



# Support to Phase 2 of the ORASECOM Basin-wide Integrated Water Resources Management Plan



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## DELINEATION OF MANAGEMENT RESOURCE UNITS

### REPORT

### Assessment of Environmental Flow Requirements

Prepared by:



in association with





# SUPPORT TO PHASE 2 OF THE ORASECOM BASIN-WIDE INTEGRATED WATER RESOURCES MANAGEMENT PLAN

## REPORT 5: ASSESSMENT OF ENVIRONMENTAL FLOW REQUIREMENTS

### DELINEATION OF MANAGEMENT RESOURCE UNITS

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# TERMINOLOGY AND ACRONYMS

AM	Aquatic Macrophytes
BBM	Building Block Methodology
CD: RDM	Chief Directorate: Resource Directed Measures
CMA	Catchment Management Agency
D:RQS	Directorate: Resource Quality Services
DRIFT	Downstream Response to Imposed Flow Transformation
DTM	Digital Terrain Model
DWA	Department of Water Affairs
DWAF	Department of Water Affairs and Forestry
EC	Ecological Category
EcoSpecs	Ecological Specifications
EFR	Environmental Flow Requirements
EIS	Ecological Importance and Sensitivity
EPA	Environmental Protection Agency
EWR	Ecological Water Requirements
FD	Fast Deep
FRAI	Fish Response Assessment Index
FS	Fast shallow
GAI	Geomorphological Driver Assessment Index
GDP	Gross Domestic Product
geozone	Geomorphological zone
GIS	Geographic Information System
GGP	Gross Geographic Product
ha	hectare
HAI	Hydrological Driver Assessment Index
HFSR	Habitat Flow Stressor Response
IFR	Instream Flow Requirements
IHI	Index of Habitat Integrity
LB	Left bank
MAP	Mean Annual Precipitation
MIRAI	Macroinvertebrate Response Assessment Index
MRU	Management Resource Units
NGO	Non Governmental Organization
NRU	Natural Resource Units
NWA	National Water Act
NWRS	National Water Resource Strategy
OV	Overhanging Vegetation
PAI	Physico Chemical Driver Assessment Index
PES	Present Ecological State
PMT	Project Management Team
PSP	Professional Service Provider

quat	Quaternary catchment
RB	Right Bank
RAU	Reserve Assessment Units
REC	Recommended Ecological Category
RQO	Resource Quality Objectives
RQS	Resource Quality Services
RU	Resource Unit
SANBI	South African National Biodiversity Institute
SCI	Socio Cultural Importance
SD	Slow Deep
SPATSIM	Spatial and Time Series Information Modelling
SS	Slow Shallow
SUB	Substrate
ToR	Terms of Reference
TPC	Threshold of Potential Concern
UB	Undercut banks and root wads
VEGRAI	Riparian Vegetation Response Assessment Index
WC	Water Column
WHI	Wetland Health Index
WMA	Water Management Area
WRYM	Water Resource Yield Model

## **1 RIVER REACH DEMARCATION AND DELINEATION**

### **1.1 STUDY AREA**

The study area for the Environmental Flow requirements is the Orange River Catchment which traverses four countries, i.e. South Africa, Lesotho, Botswana and Namibia. The focus of the Resource Unit delineation is only for the rivers in which EFR sites will be selected, i.e. the Caledon River, Orange River downstream of Gariiep Dam, the Kraai River and the Molopo River from its source to the Ramabatlama confluence.

### **1.2 APPROACH**

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

RUs are required as it would not be appropriate to set the same numerical EFR for the headwaters of a river as for the lowland reaches. These sections of a river frequently have different natural flow patterns, react differently to stress according to their sensitivity, and therefore require individual specifications of the EFR appropriate for that reach. The breakdown of a catchment into RUs for the purpose of determining the EFR for rivers is therefore done primarily on a biophysical basis within the catchment and called Natural Resource Units (NRU). The more detailed approach is described in Appendix A.

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

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

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

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

- An EFR site is selected within the MRU and represents a critical site within the relevant river section. Results generated at the EFR site will then be relevant for the MRU as a whole.

- No EFR site is selected within the MRU and extrapolated results from adjacent MRU with EFR sites are used. The reasons for an EFR 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 EFR sites.

Due to the number of MRUs within the study area, it is not practical and/or cost-effective to address an EFR site within each RU.

No estimations will be made for MRUs without EFR sites in as part of this study.

### **1.3 RESOURCE UNIT CONSIDERATIONS**

#### **1.3.1 EcoRegions (Level II)**

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

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

#### **1.3.2 Geomorphological zonation**

Rowntree and Wadeson (1999) have developed a zonal classification system for Southern African Rivers modified from Noble and Hemens (1978). In their classification an attempt was made to give each zone a geomorphological definition in terms of distinctive channel morphological units and reach types. After working in a number of different rivers around the country it has become clear that channel gradient is a good indicator of channel characteristics and that probable or expected difference can be identified from an analysis of gradients (Table 1.1).

**Table 1-1 Geomorphological Zonation of River Channels (adapted Rowntree and Wadeson, 1999)**

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

### 1.3.3 Land cover

The land cover per 500 m strip on both sides of the river was provided electronically ([ftp://uranus.esrin.esa.int/pub/globcover\\_v2](ftp://uranus.esrin.esa.int/pub/globcover_v2)) as maps as well as associated Excel spreadsheets. These spreadsheets provide a total summary of the hectares (ha) per quaternary catchments. This information is used to determine homogeneity of impacts and used in the decision-making regarding the MRUs. The data source (IWQS 500k rivers, Globecover regional land cover map) does not provide the same detail as that which DWA, RQS normally provides. One therefore also had to rely heavily on Google Earth, observations and local knowledge.

### 1.3.4 System operation

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

#### **Orange River: Gariep Dam to Van der Kloof Dam**

This section is dominated by hydro-electric releases from Gariep Dam.

#### **Orange River: Van der Kloof Dam to Prieska**

This section is still dominated by hydro-electric releases, abstractions and return flows.

#### **Orange River: Prieska to Boegoeberg Dam**

Mostly an inaccessible reach with little irrigation and developments.

### **Orange River: Boegoeberg Dam to Upington**

Canal system, extensive irrigation for crops such as grapes.

### **Orange River: Upington to Vioolsdrift**

Extensive irrigation in the reach to the Augrabies National Park. Extensive irrigation at Blouputs in a riparian section 'within' the Augrabies National Park. Downstream of Augrabies National Park, the irrigation areas are less due to the river not being accessible. Irrigation occurs again at Onseepkans. between Onseepkans and Vioolsdrift. there is very little to no irrigation.

### **Orange River: Vioolsdrift to the Orange River Mouth**

Canal system and extensive irrigation to 'Piece of Paradise'. From here, no irrigation on the South African side to downstream of the Richtersveld National Park. On the Namibian side outside of the cross-border Park, there are sections of mines and irrigation.

### **Caledon River: Source to Welbedacht Dam**

Most of the area has Lesotho on the left bank (LB) with associated sedimentation problems due to landuse protection. On the right bank (RB), formal irrigation and dry land irrigation take place. Many farm dams occur in the tributaries.

### **Caledon River: Welbedacht Dam to Orange River (Gariiep Dam)**

The only water flowing down the river is spills from the dam, inflows from tributaries and compensation water releases.

### **Molopo River (Upper)**

The Molopo River originates at the Molopo Eye and water is directly abstracted to Mafikeng. The flow that is released in the river is used for agriculture. Further eyes occur lower down the river and this water is diverted into canal systems supplying Slurry as well as further agriculture. Within Mafikeng, the sewage systems are not functioning properly and the river (which usually does not flow at this stage), receives sewage discharge of bad quality. Various small dams in Mafikeng occur with the Modimola Dam just downstream of Mafikeng and the Dinoseng Dam further down. The river seldom flows in these reaches.

## 2 DELINEATION RESULTS: ORANGE RIVER

### 2.1 NATURAL RESOURCE UNITS

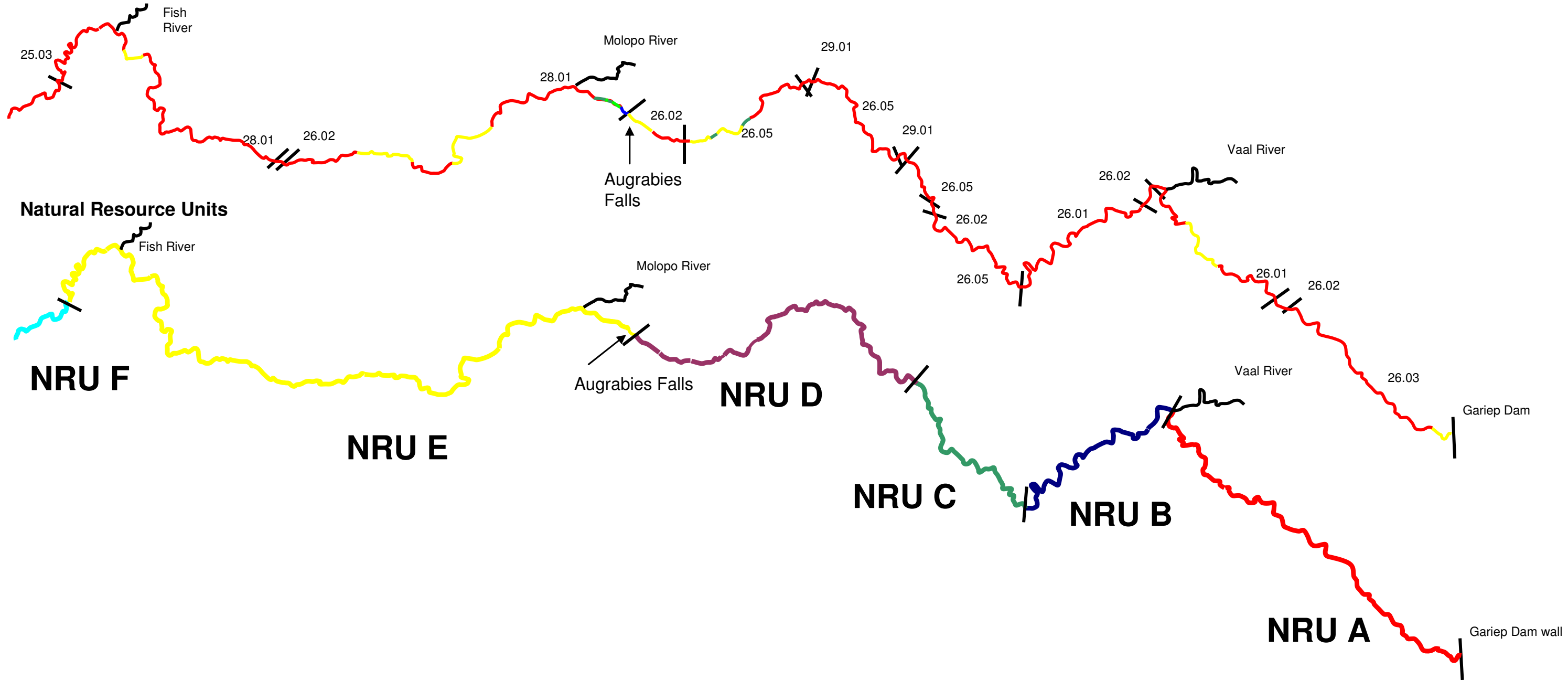
The EcoRegions and geomorphic zones are described in the map (Fig 2.1). The Natural Resource Units are derived from the EcoRegions and the geozones. The rationale for the delineation is provided in Table 2.1.

**Table 2-1 Description and rationale for the Orange River Natural Resource Units**

NRU	EcoRegion Level 2	Geozone	Rationale	Delineation
NRU Orange A	26.03 (65%) 26.01 (32%) 26.02 (3%)	Lowland (80%) Lower Foothills (20%)	The Vaal River forms a major natural hydrological break. Mostly consists of Lowland and all within one Level 1 EcoRegion, i.e. 26.	Gariep Dam wall to the Vaal confluence. -30.6248; 25.5058 -28.991; 23.8864
NRU Orange B	26.01 (90%) 26.02 (10%)	Lowland (100%)	As it all falls within one geomorph zone the EcoRegion provides a logical break (26.01).	Vaal confluence to end of 26.01. -28.991; 23.8864 -29.6658; 22.7861
NRU Orange C	26.05 (90%) 26.02 (10%)	Lowland (100%)	As it all falls within one geomorph zone the EcoRegion provides a logical break (26.05).	End of 26.01 to end of 26.05. -29.6658; 22.7861 -288574; 22.0857
NRU Orange D	26.05 (75%) 26.02 (23%) 29.01 (2%)	Lowland (80%) Lower foothills (17%) Upper foothills (3%)	Mostly falls within Lowland and EcoRegion 26.05. The Augrabies Falls form a natural barrier and therefore a logical break for the NRU.	End of 26.01 to Augrabies Falls. -288574; 22.0857 -28.5974; 20.3369
NRU Orange E	28.01 (99%) 26.02 (1%)	Lowland (75%) Lower foothills (23%) Upper foothills (2%)	The EcoRegion 28.01 provides the logical break for this NRU and coincides the change from river to estuary.	Augrabies Falls to end of 28.01 (estuary). -28.5974; 20.3369 -28.3904; 16.7772
NRU Orange F	25.03 (100%)	Lowland (100%)	Consists of the estuary.	End of 28.01 (estuary) to sea. -28.3904; 16.7772 -28.6324; 16.4572

**EcoRegions & Geomorph zones**

Dark Blue – Mountain Stream;  
 Dark Green – Upper Foothills;  
 Red - Lowland  
 Light Green – Transitional  
 Yellow – Lower Foothills



**Figure 2-1 Natural Resource Units: Orange River**



## 2.2 MANAGEMENT RESOURCE UNITS

The river is divided into MRUs and illustrated in Figure 2.2. The description of the MRUs and the rationale for selection is provided in Table 2.2.

**Table 2-2 Description and rationale of the Orange River Management Resource Units**

MRU	EcoRegion Level 2	Geozone	Land cover 500m both banks	Rationale	Delineation	Quat
MRU Orange A	26.03 (100%)	Lowland (90%) Lower Foothills (10%)	Dominated by hydro-electric releases	The section between the two dams is an isolated section. Van der Kloof Dam is a logical operational endpoint due to the operation and the barrier effect of the Dam. EFR site will be problematic in this reach due to the constraint of ESCOM operational rules	Gariep Dam wall to Van der Kloof Dam -30.6248; 25.5058. -30.2898; 25.0075	D34A D34E D34G
MRU Orange B	26.01 (90%) 26.02 (8%) 26.03 (2%)	Lowland (90%) Lower Foothills (10%)	Influenced by the hydro-electric releases from the dam. Irrigation	Prieska town forms a logical endpoint as the water level fluctuation is less significant at this point and irrigation decreases afterwards. As the Vaal River is operated not to contribute significantly to the Orange River, it was not selected as an endpoint as it was for NRU B. EFR site will be problematic in this reach due to the constraint of ESCOM operational rules	Van der Kloof Dam wall to Prieska (end of 26.01). -29.9983; 24.7917 -29.6658; 22.7861	D33A, D, E, F, G, H, K. D71A, C, D. D72A
MRU Orange C	26.05 (96%) 26.02 (2%) 29.01 (2%)	Lowland (100%)	Mostly an inaccessible gorge with limited farming activities.	Boegoeberg Dam forms a logical endpoint to this reach due to the barrier effect, the similar operation US of Boegoeberg and the increase in irrigation downstream of the dam. As most of this reach is influenced by back-up from Boegoeberg or is inaccessible, an EFR site is not advised.	Prieska (end of 26.01) to Boegoeberg Dam. -29.6658; 22.7861 -29.0426; 22.2008	D72A D72B D72C
MRU Orange D	26.05 (80%) 26.02 (18%) 29.01 (2%)	Lowland (80%) Lower foothills (18%) Upper foothills (2%)	2 reaches differentiated by the nature of the channel (multi-channel versus single) and Upington. Mostly irrigation, levees in the riparian zone and weirs.	Landuse is similar to the Augrabies National Park. The actual falls is selected as the end of the MRU due to its role as a natural barrier.	Boegoeberg Dam to Augrabies Falls. -29.6658; 22.7861 -28.5974; 20.3369	D72C D73B, C, D, E, F. D81A
RAU Orange D1	26.05 (100%)	Lowland (100%)	No farming in riparian zone, only canal on LB	Selected as a RUA as this short reach is less disturbed than rest of section. EFR site should be selected in this reach.	Boegoeberg Dam to start of irrigated lands in riparian zone. -29.6658; 22.7861 -28.9680; 22.1742	D72C D73B

MRU	EcoRegion Level 2	Geozone	Land cover 500m both banks	Rationale	Delineation	Quat
MRU Orange E	28.01 (98%) 26.02 (2%)	Lowland (80%) Lower foothills (17%) Upper foothills (3%)	Mixture of natural areas, National Park and irrigation	Same delineation as for the NRU. Irrigation limited and constrained by accessibility. EFR site preferably in an undisturbed section, but must be accessible.	Augrabies Falls to Violsdrift Weir . -28.3904; 16.7772 -28.7606; 17.7292	D81A, B, D, E, F. D82A, D, E, F.
MRU Orange F	25.03 (100%)	Lowland (97%) Lower foothills (3%)	Extensive canals and irrigation in the floodplain zone on the LB. Section of National Parks (both banks and wilderness areas.	Fish River end of study area for EFR determination, i.e. end point of this MRU	Violsdrif Weir to Fish confluence. -28.3904; 16.7772 -28.71001; 17.1753	D82F D82G D82H D82J
RAU Orange F.1	25.03 (100%)	Lowland (60%) Lower foothills (40%)	National Parks and wilderness area with some limited irrigation on RB	No access on LB after Piece of Paradise, therefore inaccessible and in better condition than the rest of the reach. EFR site should be situation in this section, however due to inaccessibility, this was not an option.	Piece of Paradise (end of irrigation) to Fish confluence. -28.3904; 16.7772 -28.7041; 17.4681	D82J

All the MRUs are illustrated on Figures 6.1.

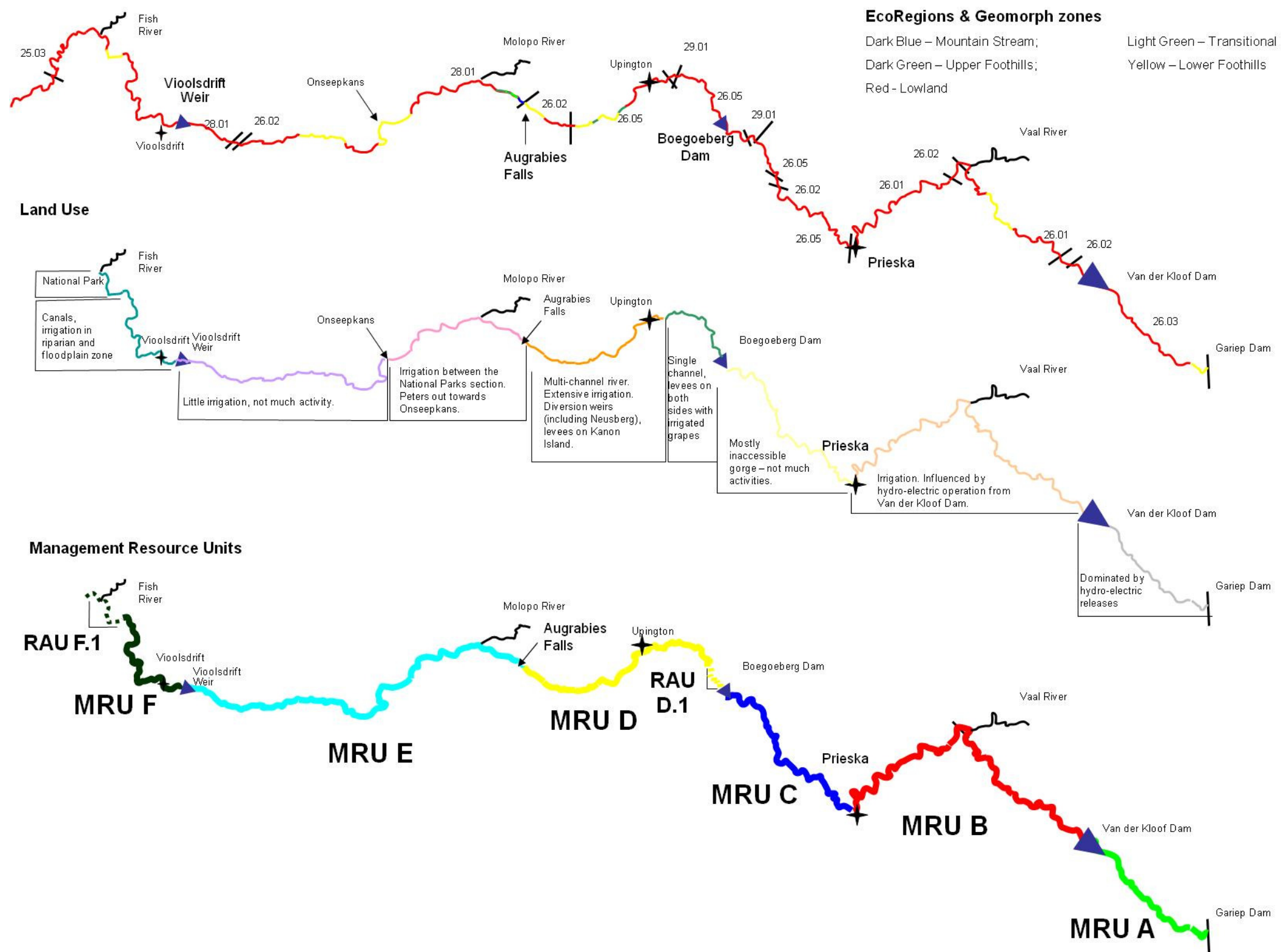


Figure 2-2 Management Resource Units

### 3 DELINEATION RESULTS: CALEDON RIVER

#### 3.1 NATURAL RESOURCE UNITS

The EcoRegions and geozones are described in Fig 3.1. The Natural Resource Units are derived from the EcoRegions and the geozones. The rationale for the delineation is provided in Table 3.1.

**Table 3-1 Description and rationale for the Caledon River Natural Resource Units**

NRU	EcoRegion Level 2	Geozone	Rationale	Delineation
NRU Caledon A	15.03 (100%)	Lowland (7%) Lower Foothills (40%) Upper Foothills (40%) Mountain stream (3%)	.The EcoRegion 15.03 as well as the change to Lowland and the inflow of the Little Caledon makes a logical break at the little Caledon.	Source to Klein Caledon confluence. -28.6172; 28.7047 -28.6946; 28.2340
NRU Caledon B	15.01 (96%) 11.03 (4%)	Lowland (100%)	.The next section falls 96% in the 15.01 EcoRegion and 100% in Lowland. The break to the 11.03 EcoRegion where a large stretch falls into that forms the end of NRUB.	Klein Caledon confluence to end of 15.01. -28.6946; 28.2340 -29.5654; 27.2085
NRU Caledon C	11.03 (100%)	Lowland (95%) Lower Foothills (5%)	The 11.03 EcoRegion defines the NRU. Only a very small section of Upper Foothills fall into the NRU.	End of 15.01 to end of 11.03. -29.5654; 27.2085 -29.9637; 26.8758
NRU Caledon D	11.01 (98%) 26.03 (2%)	Lowland (80%) Lower Foothills (20%)	The 11.01 EcoRegion defines the NRU.	End of 11.03 to end 26.03. -29.9637; 26.8758 -30.3754; 26.6552
NRU Caledon E	26.03(98%) 11.01 (2%)	Lowland (100%)	The 26.03 EcoRegion defines the NRU.	End 26.03. -29.9637; 26.8758 -30.5186; 26.0824

#### 3.2 MANAGEMENT RESOURCE UNITS

The river is divided into MRUs and illustrated in Figure 3.2 and 6.1. The description of the MRUs and the rationale for selection is provided in Table 3.2.

**Table 3-2 Description and rationale for the Caledon River Management Resource Units**

MRU	EcoRegion Level 2	Geozone	Land cover 500 m both banks	Rationale	Delineation	Quat
MRU Caledon A	15.03 (100%)	Lower Foothills (20%) Upper Foothills (60%) Mountain stream (2%)	RB: Mostly inaccessible which includes the border of Golden Gate. LB: Small inaccessible area and then the typical subsistence farming and erosion associated with Lesotho.	The inaccessible area on the RB defines the MRU. Also falls within one EcoRegion and is therefore ecologically similar.	Source to end of inaccessible area -28.6172; 28.7047. -28.5519; 28.4050	D21A
MRU Caledon B	15.01 (80%) 11.03 (12%) 15.03 (8%)	Lowland (90%) Lower Foothills (10%)	RB: Upper section indicates more erosion and than lower section which consists mostly of dryland farming LB: Subsistence farming, erosion and urban.	The section all falls within one geomorphic zone and with the same landuse on the LB. The border of the RU is defined by the change of operation – the pumping of Caledon water into Knelspoort and Welbedacht Dam immediately downstream.	End of inaccessible area to Rietspruit confluence -28.5519; 28.4050 -29.7930; 26.9210	D21A D21C D21H D22C D22D D22F D22H D22L D23A D23E D23F D23J
MRU Caledon C	11.01 (80%) 26.03 (18%) 11.03 (2%)	Lowland (80%) Lower Foothills (20%)	Extensive irrigation on both sides.	The border of the Tussen Die Riviere forms an operational break between irrigation and natural.	Welbedacht Dam to start of Tussen-Die-Riviere Game Reserve -29.9095; 26.8606 -30.4257; 26.3290	D24C D24D D24E D24F D24G D24J
MRU Caledon D	26.03(100%)	Lowland (100%)	Game managed area. Potentially influenced by back-up from Gariep Dam.	Tussen die Riviere Game Reserve.	Tussen-Die-Riviere Game Reserve to backup of Gariep Dam -30.4257; 26.3290 -30.5240; 26.065	D24J

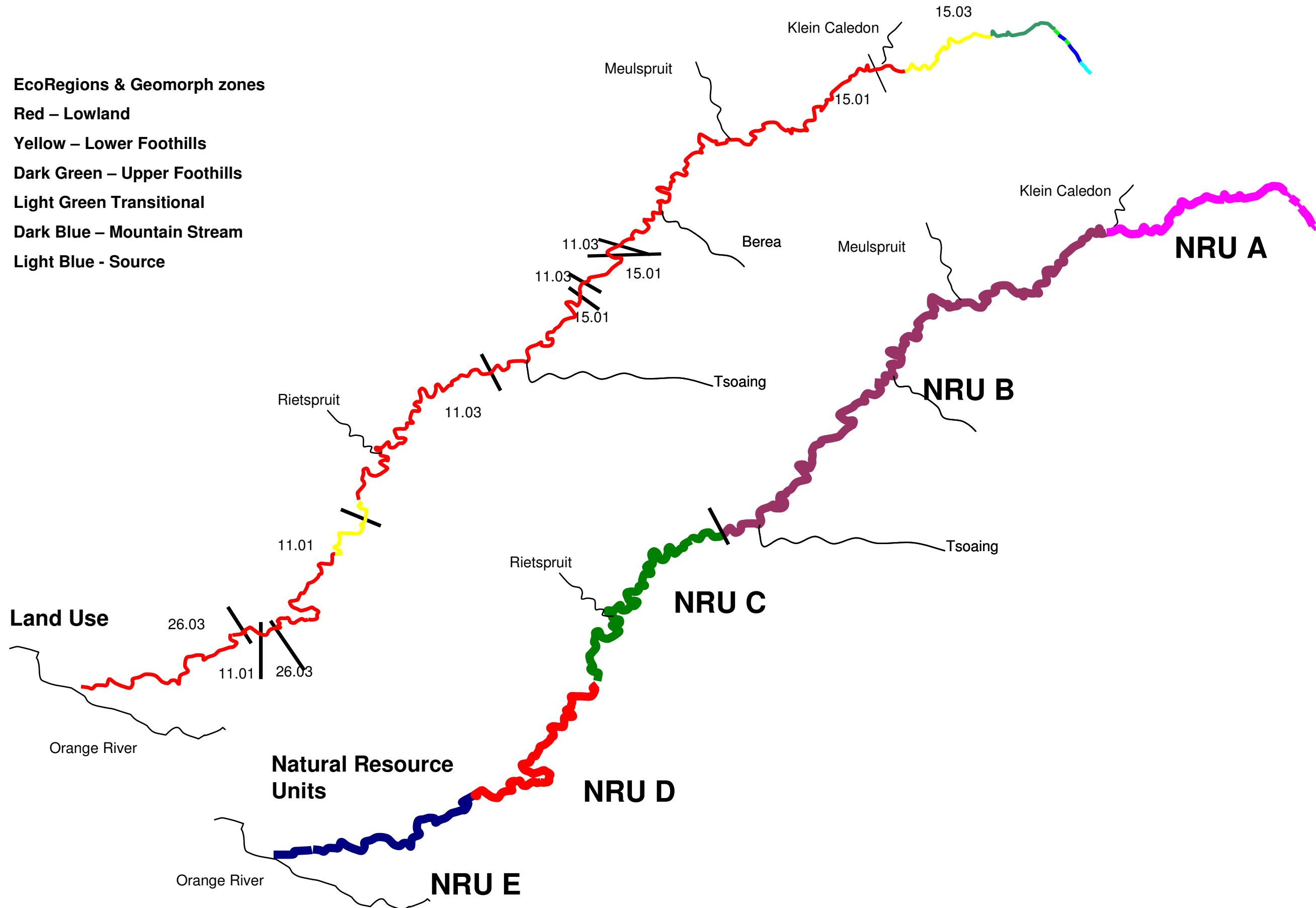


Figure 3-1 Natural Resource Units: Caledon River

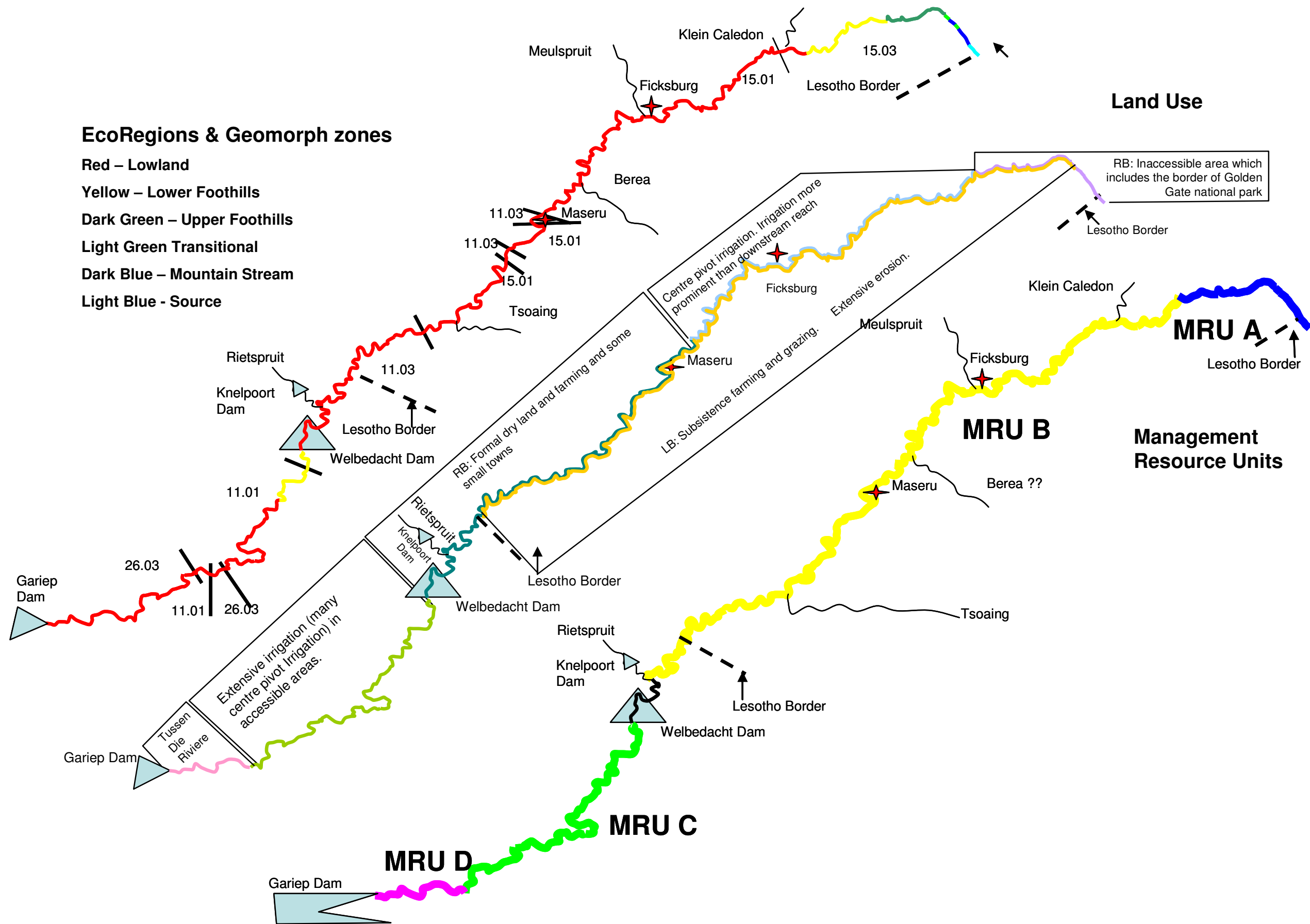


Figure 3-2 Management Resource Units: Caledon River

## 4 DELINEATION RESULTS: KRAAI RIVER

### 4.1 NATURAL RESOURCE UNITS

The EcoRegions and geozones are described in the map below (Fig 4.1). The Natural Resource Units are derived from the EcoRegions and the geozones. The rationale for the delineation is provided in Table 4.1.

**Table 4-1 Description and rationale for the Natural Resource Units**

NRU	EcoRegion Level 2	Geozone	Rationale	Delineation
NRU Kraai A	15.06 (100%)	Lower Foothills (87%) Upper Foothills (8%) Mountain Stream (2%) Lowland (3%)	The EcoRegion 15.06 and the very similar geomorph zone describes this long NRU A. The bottom section is defined by the change to Lowland River	Source to end of Lower Foothills in 15.06 -31.1997; 27.9637 -30.9013; 27.1092
NRU Kraai B	26.03 (60%) 18.04 (35%) 15.06 (5%)	Lowland (100%)	100% Lowland River consisting of two EcoRegions.	End of Lower Foothills in 15.06 to Orange River -30.9013; 27.1092; -30.6648; 26.7503

### 4.2 MANAGEMENT RESOURCE UNITS

The river is divided into MRUs and illustrated in Figure 4.2. The description of the MRUs and the rationale for selection is provided in Table 4.2.

**Table 4-2 Description and rationale for Management Resource Units**

MRU	EcoRegion Level 2	Geozone	Land cover 500 m both banks	Rationale	Delineation	Quat
MRU Kraai A	15.06 (100%)	Lower Foothills (90%) Upper Foothills (8%) Mountain Stream (2%)	Inaccessible areas mixed with irrigation in floodplain . Small towns and rural areas.	Landuse defines the MRU with the Joggemspruit confluence forming a logical end point. One EcoRegion and mostly one geozone	Source to end of irrigation in floodplain (ds of Joggemspruit)--- 31.1997; 27.9637 -30.8506; 27.7001	D13C D13E
MRU Kraai B	15.06 (100%)	Lower Foothills (100%)	Mostly inaccessible. Areas where possible, irrigated lands next to the rivers	Landuse defines the MRU and the logical break of a change in landuse coincides with the NRU break, I.E, end of 15.06.	End of irrigation in floodplain (ds of Joggemspruit) to end inaccessible area -30.8506; 27.7001 -30.9056; 27.1111	D13E D13F



MRU	EcoRegion Level 2	Geozone	Land cover 500 m both banks	Rationale	Delineation	Quat
MRU Kraai C	26.03 (60%) 18.04 (39%) 15.06 (1%)	Lowland (100%)	Extensive agriculture and irrigation.	The same as the NRU as the same landuse, probably due to the change in geozone that will result in the river being more accessible.	End inaccessible area to Orange confluence -30.9056; 27.1111- -30.8506; 27.7001	D13F D13G

All the MRUs are illustrated on maps in Figure 6.1

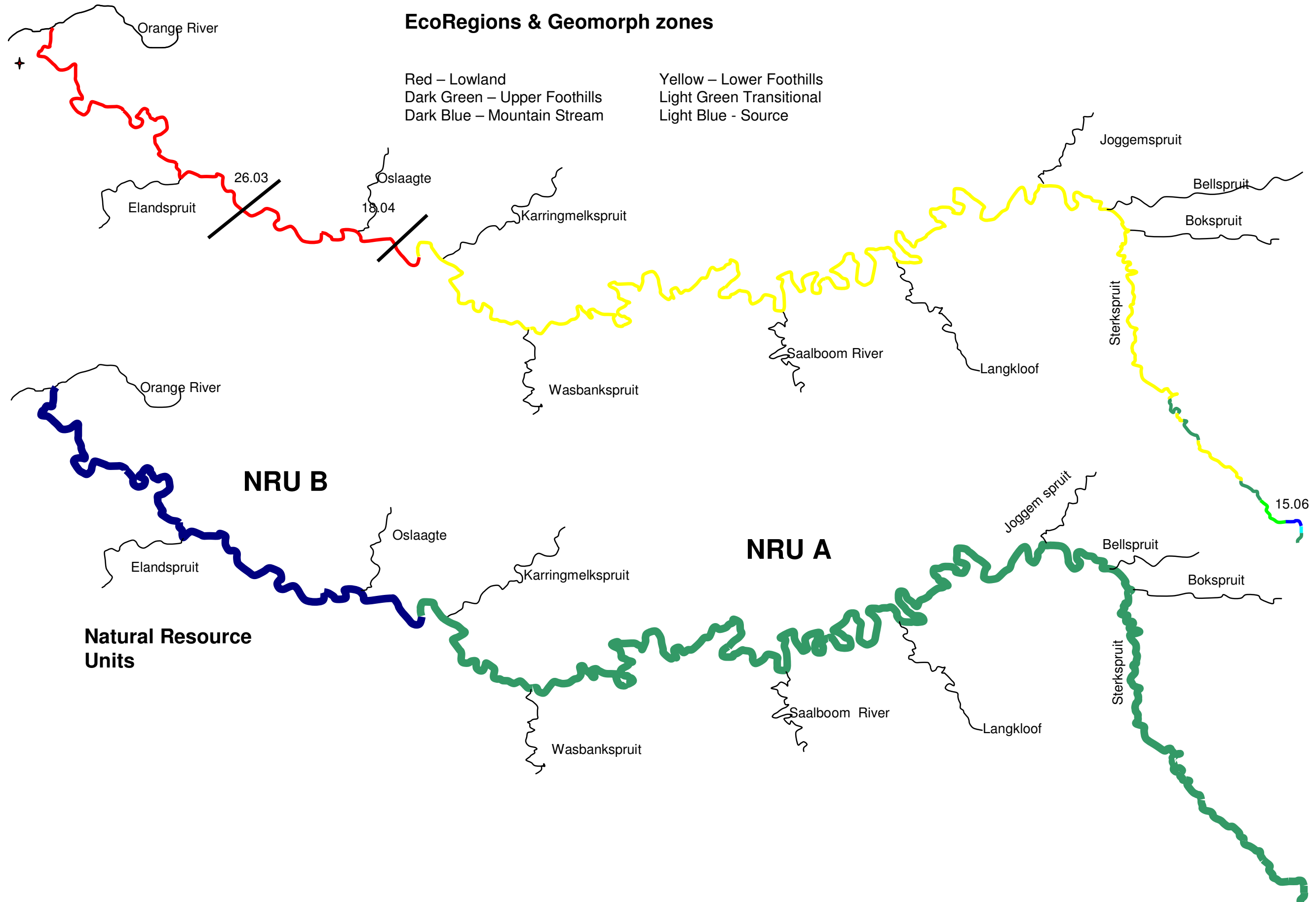


Figure 4-1 Natural Resource Units: Kraai River

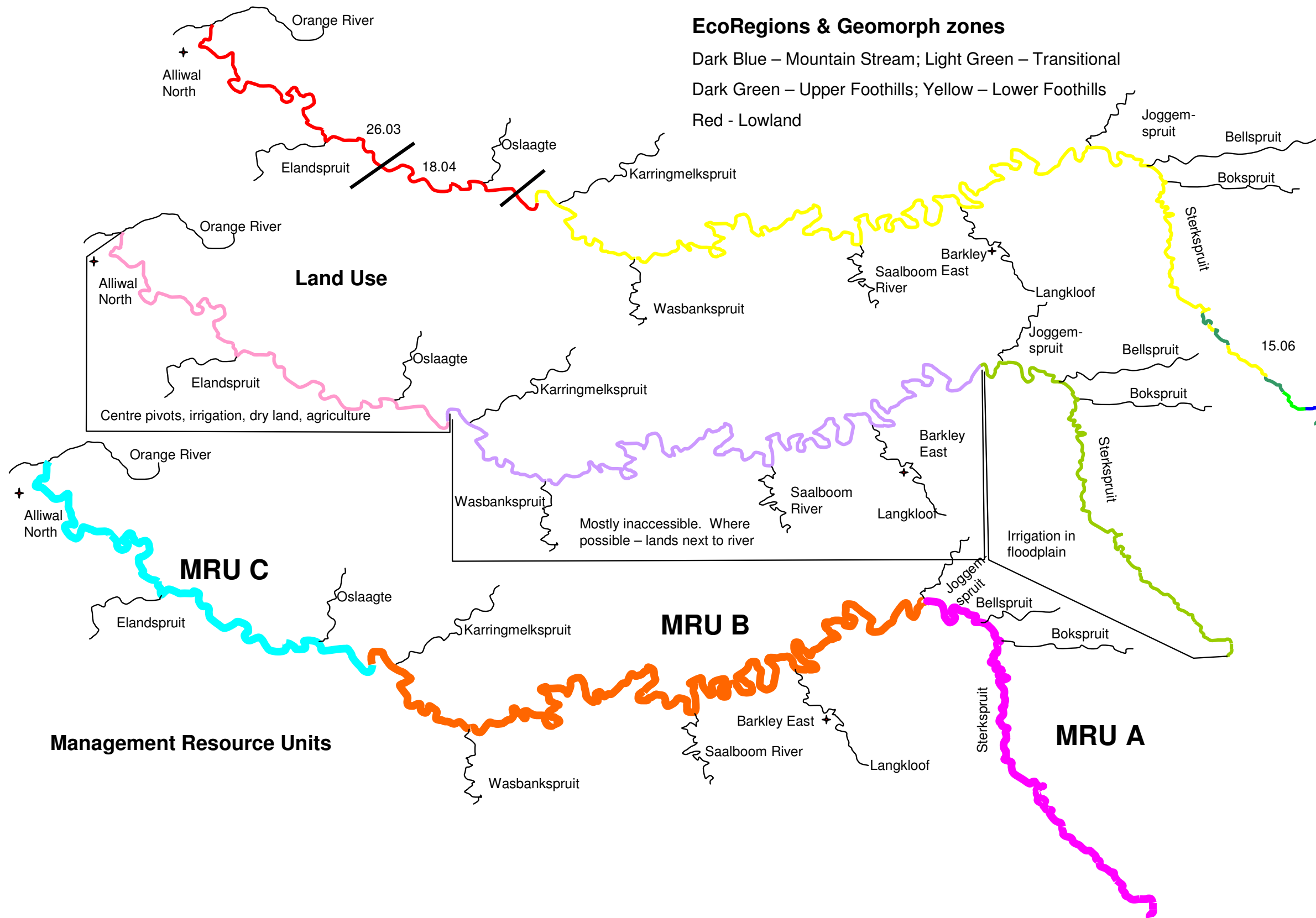


Figure 4-2 Management Resource Unit: Kraai River

## 5 DELINEATION RESULTS: UPPER MOLOPO RIVER

### 5.1 Natural Resource Units

The EcoRegions and geozones are described in the map below (Fig 5.1). The Natural Resource Units are derived from the EcoRegions and the geozones. The rationale for the delineation is provided in Table 5.1.

**Table 5-1 Description and rationale for Natural Resource Units**

NRU	EcoRegion Level 2	Geozone	Rationale	Delineation
NRU UMolopo A	11.01 (100%)	Lower Foothills (100%)	Represents the EcoRegion and includes the Lower Foothill portion.	Source to end of 11.01 -25.8889; 26.0258 -25.8609; 25.9797
NRU UMolopo B	11.01 (90%) 29.01 (10%)	Upper Foothills (70%) Lower Foothills (30%)	Includes all of 11.01 which consists of alternating Upper and Lower Foothills. The logical end was the end of the last section of Upper Foothills which was close to the end of the 11.01 EcoRegion.	End of 11.01 to end of Upper Foothills -25.8609; 25.9797 -25.8737; 25.6139
NRU UMolopo c	29.01 (100%)	Lowland (2%) Lower Foothills (98%)	Rest of the river which consists all of 29.01 and 98% Lowland. End of reach is the confluence with the Ramabatlama.	End of Upper Foothills to the Ramatlabama confluence -25.8737; 25.6139 -25.7641; 25.2174

### 5.2 MANAGEMENT RESOURCE UNITS

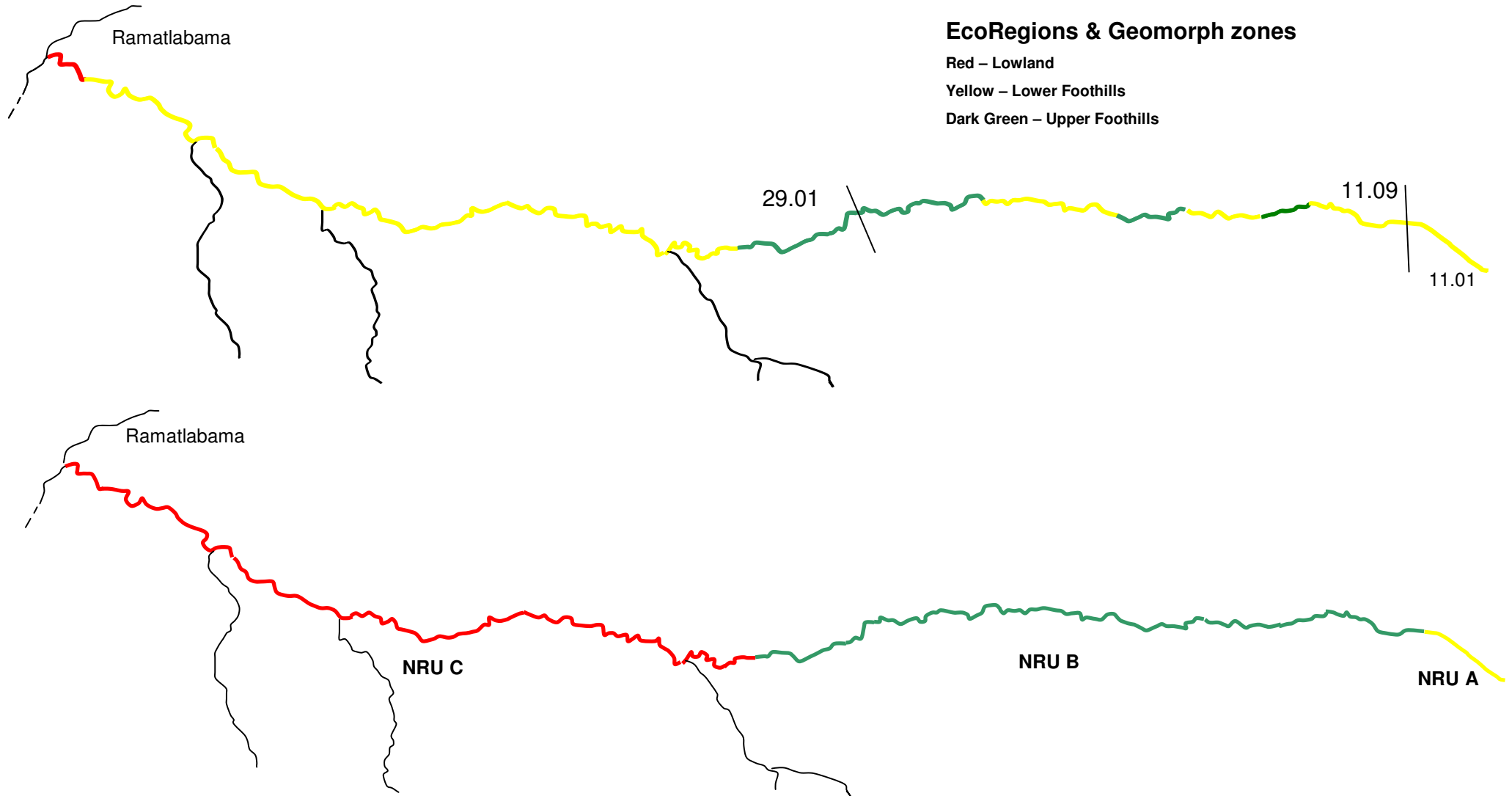
The river is divided into MRUs and illustrated in Figure 5.2. The description of the MRUs and the rationale for selection is provided in Table 5.2.

**Table 5-2 Description and rationale for Management Resource Units**

MRU	EcoRegion Level 2	Geozone	Land cover 500m both banks	Rationale	Delineation	Quat
MRU UMolopo A	11.01 (98%) 11.09 (2%)	Lower Foothills (100%)	Mostly wetland, recreation around the eye, farming, old barriers	Coincides with landuse. Represents the wetter portion of the wetland under present conditions.	Source to end wetted wetland section -25.8609; 25.9797 -25.8548; 25.9530	D41A
MRU UMolopo B	11.01 (100%)	Upper Foothills (45%) Lower Foothills (55%)	Intensive farming. Presence of Slurry. Includes gauge where all flows are diverted into two canal systems. Large sections of no flow.	Coincides with landuse. Mostly wetland although almost all flow diverted for most of the time.	End wetted wetland section to end of intensive farming US of Mafikeng -25.8548; 25.9530 -25.8558; 25.8638	D41A

MRU	EcoRegion Level 2	Geozone	Land cover 500m both banks	Rationale	Delineation	Quat
MRU UMolopo C	29.01 (100%)	Upper Foothills (100%)	Includes Mafikeng and all its small dams, Bad water quality from, amongst others, inadequate sewage works	Coincides with the land use. Logical endpoint is the Modimola Dam.	End of intensive farming US of Mafikeng to the Modimola Dam -25.8558; 25.8638 -25.8738; 25.5576	D41A
NRU UMolopo D	29.01 (100%)	Lower Foothills (98%)	Large rural areas, overgrazing, trampling, bad water quality and flow mostly consisting a trickle which is from return flows.	The section between the dams is isolated, has a specific landuse and operation, and therefore consists of one MRU.	Modimola Dam wall to the Disaneng Dam -25.8576; 25.5087 -25.8516 ; 25.3785	D41A
NRU UMolopo E	29.01 (100%)	Lower Foothills (90%) Lowland (10%)	Much less activities and settlements. Minimal flow in river.	Landuse and all other criteria similar to the Botswana border and the Ramabatlama confluence.	Disaneng Dam wall to the Ramabatlama confluence -25.8237; 25.3129 -25.7641; 25.2174	D41A

All the MRUs are illustrated on maps in Figure 6.1.



**Figure 5-1 Natural Resource Units: D41A**

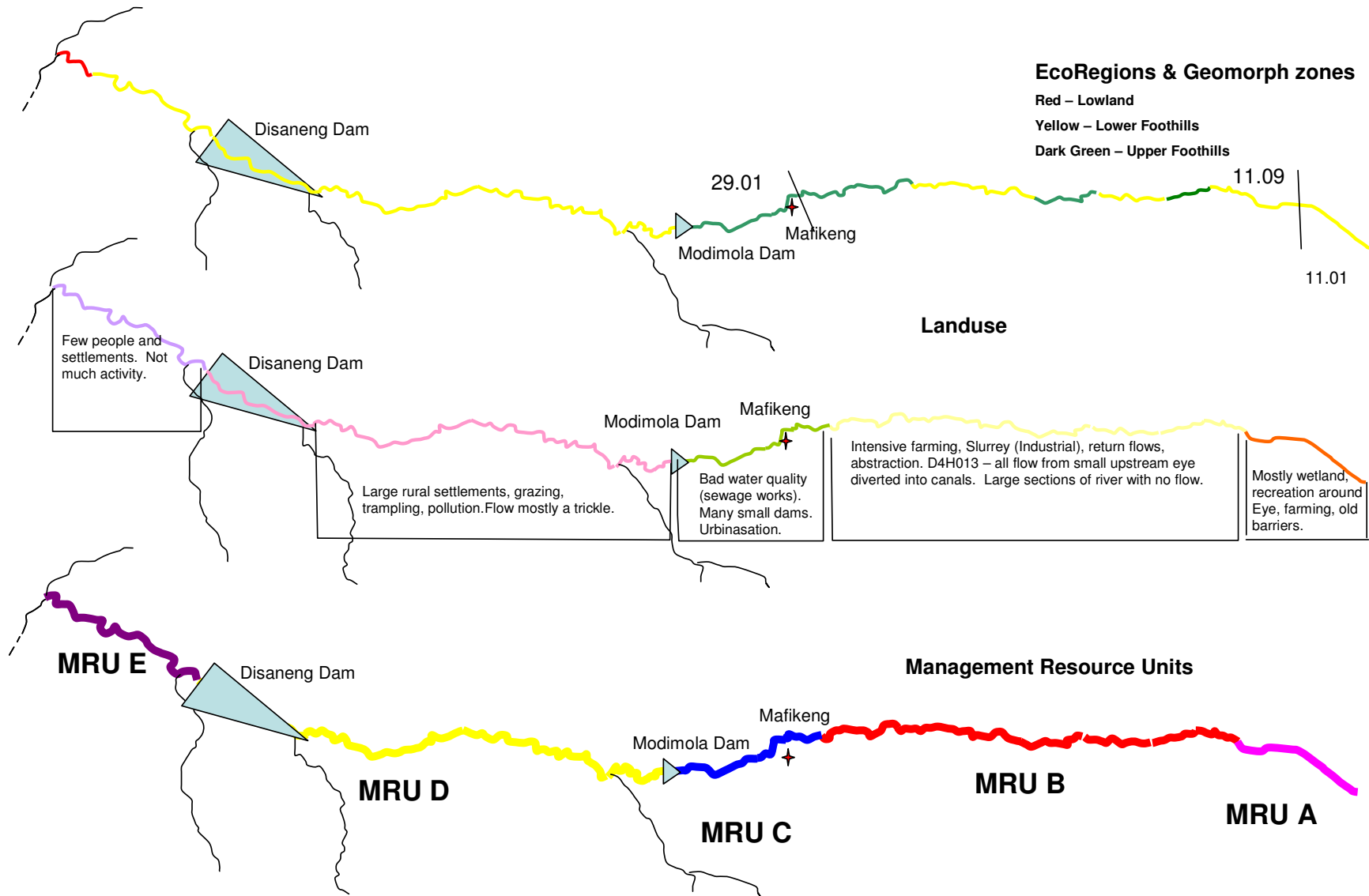


Figure 5-2 Management Resource Units: D41A

## 6 EFR SITE SELECTION

### 6.1 CRITERIA FOR SITE SELECTION

EFR sites (previously called IFR sites and referred to as EFR sites in South Africa) 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 EFR site consists of a length of river which includes one or various cross-sections for both hydraulic and ecological purposes (modified from Louw *et al.*, 1999).

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

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

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

- The locality of gauging weirs with good quality hydrological data.
- The locality of the proposed and existing developments.
- The locality and characteristics of tributaries.
- The habitat integrity or PES of the different river reaches.
- The boundaries of Level II EcoRegions within the study area.
- The reaches where people depend directly on a healthy river ecosystem.
- The suitability of the sites for follow-up monitoring.
- The locality of geomorphologically representative sites.
- The habitat diversity for aquatic organisms, marginal and riparian vegetation.
- The suitability of the sites for accurate hydraulic modelling throughout the range of possible flows, especially low flows.
- Accessibility of the sites.
- An area or site that could be critical for ecosystem functioning. These are often represented by riffle units, where low flow conditions or the cessation of flow constitutes a break in the functioning of the river, and consequently, the biota dependant on this habitat and/or perennial flow are adversely affected. Pools are not considered critical habitats in perennial system since they are still able to function or at least maintain life during periods of no flow.



The criteria in bold are the most important and therefore overrides the other criteria.

## 6.2 LOCALITY AND DESCRIPTION OF SITES




The locality of the EFR sites within the MRUs as identified during this study is provided in Table 6.1 and 6.2 and in Figure 6.1.





**Table 6-1 Locality and characteristics of EFR sites**


<b>EFR site number</b>	<b>EFR site name</b>	<b>River</b>	<b>Decimal degrees S</b>	<b>Decimal degrees E</b>	<b>EcoRegion (Level II)</b>	<b>Geozone</b>	<b>Altitude (m)</b>	<b>MRU</b>	<b>Quat</b>	<b>Gauge</b>
EFR O1	Hopetown	Orange	-29.516	24.00927	26.01	Lowland	1060	MRU Orange B	D33G	
EFR O2	Boegoeberg	Orange	-29.0055	22.16225	26.05	Lowland	871	MRU Orange D, RAU D.1	D73C	D7H008
EFR O3	Augrabies	Orange	-28.4287	19.9983	28.01	Lowland		MRU Orange E	D81B	D7H014
EFR O4	Violsdrif	Orange	-28.7553	17.71696	28.01	Lowland	167	MRU Orange F	D82F	D8H003 D8H013
EFR C5	Upper Caledon	Caledon	-28.6508	28.3875	15.03	Lower Foothills	1640	MRU Caledon A/B	D21A	
EFR C6	Lower Caledon	Caledon	-30.4523	26.27088	26.03	Lowland	1270	MRU Caledon D	D24J	
EFR K7	Lower Kraai	Kraai	-30.8306	26.92056	26.03	Lowland	1327	MRU Kraai C	D31M	D1H011
EFR M8	Molopo Wetland	Molopo	-25.8812	26.01592	11.01	Lower Foothills	1459	MRU UM C	D41A	D4H030 D4H014

The locality and characteristics of the EFR sites are provided in Table 6.1.

**Table 6-2** Locality, characteristics and view of the EFR sites.

Site information	EFR sites	Illustration
<i>EFR nr &amp; name</i> <i>River</i> <i>Previous IFR site</i> <i>National RHP site</i> <i>Decimal Degrees</i> <i>EcoRegion (Level II)</i> <i>Geozone</i> <i>Altitude (m)</i> <i>RU</i> <i>Quaternary</i> <i>Farm name</i> <i>Hydrological gauge</i>	EFR O1 Hopetown Orange - - -29.51594, 24.00927 26.01 Lowland 1060 MRU Orange B D33G Zuurgat 82 -	
<i>EFR nr &amp; name</i> <i>River</i> <i>Previous IFR site</i> <i>National RHP site</i> <i>Decimal Degrees</i> <i>EcoRegion (Level II)</i> <i>Geozone</i> <i>Altitude (m)</i> <i>RU</i> <i>Quaternary</i> <i>Farm name</i> <i>Hydrological gauge</i>	EFR O2 Boegoeberg Orange - - -29.0055, 22.16225 26.05 Lowland 871 MRU Orange D, RAU D.1 D73C Blinkfontein 10 D7H008	
<i>EFR nr &amp; name</i> <i>River</i> <i>Previous IFR site</i> <i>National RHP site</i> <i>Decimal Degrees</i> <i>EcoRegion (Level II)</i> <i>Geozone</i> <i>Altitude (m)</i> <i>RU</i> <i>Quaternary</i> <i>Farm name</i> <i>Hydrological gauge</i>	EFR O3 Augrabies Orange - - -28.42867, 19.9983 28.01 Lowland 434 MRU Orange E D81B Oranjestroom 386 D7H014	

Site information	EFR sites	Illustration
<i>EFR nr &amp; name</i> <i>River</i> <i>Previous IFR site</i> <i>National RHP site</i> <i>Decimal Degrees</i> <i>EcoRegion (Level II)</i> <i>Geozone</i> <i>Altitude (m)</i> <i>RU</i> <i>Quaternary</i> <i>Farm name</i> <i>Hydrological gauge</i>	EFR O4 Vioolsdrift Orange - - -28.75525, 17.71696 28.01 Lowland 167 MRU Orange F D82F - D8H013	
<i>EFR nr &amp; name</i> <i>River</i> <i>Previous IFR site</i> <i>National RHP site</i> <i>Decimal Degrees</i> <i>EcoRegion (Level II)</i> <i>Geozone</i> <i>Altitude (m)</i> <i>RU</i> <i>Quaternary</i> <i>Farm name</i> <i>Hydrological gauge</i>	EFR C5 Caledon Rapid III - -28.65078, 28.3875 15.03 Lower Foothills 1640 MRU Caledon B D21A Kromdraai 106 -	
<i>EFR nr &amp; name</i> <i>River</i> <i>Previous IFR site</i> <i>National RHP site</i> <i>Decimal Degrees</i> <i>EcoRegion (Level II)</i> <i>Geozone</i> <i>Altitude (m)</i> <i>RU</i> <i>Quaternary</i> <i>Farm name</i> <i>Hydrological gauge</i>	EFR C6 Lower Caledon Caledon - D2Cale_Tusse -30.4523, 26.27088 26.03 Lowland 1270 MRU CaledonD D24J Inhoek 336 -	
<i>EFR nr &amp; name</i> <i>River</i> <i>Previous IFR site</i> <i>National RHP site</i> <i>Decimal Degrees</i> <i>EcoRegion (Level II)</i> <i>Geozone</i> <i>Altitude (m)</i> <i>RU</i> <i>Quaternary</i>	EFR K7 Kraai Kraai - - -30.8306, 26.92056 26.03 Lowland 1327 MRU Kraai C D31M Witkoppies 96/2	

Site information	EFR sites	Illustration
<i>Farm name</i> <i>Hydrological gauge</i>	D1H011	
<i>EFR nr &amp; name</i> <i>River</i> <i>Previous IFR site</i> <i>National RHP site</i> <i>Decimal Degrees</i> <i>EcoRegion (Level II)</i> <i>Geozone</i> <i>Altitude (m)</i> <i>RU</i> <i>Quaternary</i> <i>Farm name</i> <i>Hydrological gauge</i>	EFR M8 Molopo Wetland Molopo - - -25.8812, 26.01592 11.01 Lower Foothills 1459 MRU UM C D41A Trekdrift 360.29 D4H030, D4H014	

The locality of sites is illustrated in Figure 6.1.

### 6.2.1 Site suitability

The site suitability of each site was assessed and is provided in Table 6.3 and 6.4. The detail assessment per component is provided in Appendix B. All scores are out of 5 with 5 referring to very high suitability (see below).

Very High: 4.1 – 5

High: 3.1 – 4

Moderate: 2.1 – 3

Low: 1.1 – 2

Very Low: 0 – 1

**Table 6-3 Biophysical Site suitability for the Crocodile system**

EFR sites	Geomorph	Riparian veg	Fish	Inverts	Average	Median	Max	Min	Comments
EFR 1	3.7	3.7			3.7	3.7	3.7	3.7	High suitability for EcoClassification from geomorph and riparian vegetation perspective.
EFR 2	3.0	3.5	3.5	4.2	3.6	3.5	4.2	3	High overall suitability with only geomorph at top range of moderate.
EFR 3	3.5	3.5	2.8	3.8	3.4	3.5	3.8	2.8	High overall suitability with only fish at top range of moderate. Fish habitat suitability is however very high and that will override the moderate suitability which is due to the (natural) lack of good indicator species.
EFR 4	3.1	3.2	2.8	2.9	3.0	3.0	3.2	2.8	Moderate suitability with geomorph and riparian vegetation falling just within the High range.
EFR 5	3.0	4.0	2.2	3.0	3.1	3.0	4.0	2.2	High overall suitability. However, only riparian vegetation falls in the top end of high, the other components are in the moderate range.
EFR 6	3.0	3.5	2.5	3.0	3.0	3.0	3.5	2.5	Moderate suitability from all perspectives for setting of EFR requirements.
EFR 7	4.2	2.5	2.8	4.1	3.4	3.5	4.2	2.5	High overall suitability. Geomorph and invertebrates fall in the Very High range.

The above table illustrates the site suitability from a biophysical point of view. Any comments regarding outliers are also provided. From a biophysical point of view, the sites all fell into the High suitability apart from EFR 4 and EFR 6. The fish suitability is mostly the lowest for EFR 3, 5 and 6. This is mostly related to the natural lack of diversity of species for setting flow requirements. This is not necessarily applicable in systems where they do not naturally occur, and the evaluation process will require to be revised in future.

At this stage, only hydraulic site suitability is evaluated as the other information is only generated later during the project. As this does provide an indication of the complexity of the hydraulic modelling, it can be used as an initial estimate of confidence. For the purposes of determining flow requirements, the low flows and high flows are evaluated separately. Geomorphology and vegetation usually are the most crucial components for high flows and fish and invertebrate for low flows.

The suitability of the sites is therefore evaluated for both low and high flows and compared to the corresponding suitability for low and high flow hydraulics. Due to the importance of the hydraulics, the hydraulic site suitability usually overrides the biophysical site suitability.

**Table 6.4 Integrated Site suitability for the Crocodile system**

EFR SITES	Bio-physical		Hydraulics		Hydraulic comments	Suitability		Comment
	Low flows	High flows	Low flows	High flows		Low flows	High flows	
EFR 2	3.9	3.3	2.0	2.0	<p><b>Positive</b> Reasonably uniform flow conditions =&gt; medium flows. Gauging weir for determining discharges at real time.</p> <p><b>Negative</b> Bedrock morphology with rapidly varied flow conditions at low flows. Multiple channels at medium/high-flows. Large and irregular nature of the bed substrate (cobbles, boulders &amp; bedrock). Influence of vegetation on flow resistance at high flows. Non-horizontal water surface across the inundated channel width at low-flows. Possibility of pooled water at the cessation of flow.</p>	2.0	3.3	<p>Low flow suitability of hydraulics overrides the biophysical high suitability.</p> <p>A long record of daily flows is more important than the hydraulics with the setting of floods. In this case therefore the biophysical rating of moderate represents the overall rating.</p>
EFR 3	3.3	3.5	3.0	4.0	<p><b>Positive</b> Reasonably uniform flow conditions at medium flows and above. Gauge with real time data (Neusberg) although some distance away.</p> <p><b>Negative</b> Large and irregular nature of the bed substrate (cobbles, boulders &amp; bedrock). Possibility of pooled water at the cessation of flow.</p>	3.0	4	<p>Low flow suitability of hydraulics and biophysical components are similar.</p> <p>A long record of daily flows is more important than the hydraulics with the setting of floods. In this case however, the hydraulics have a high suitability, and a gauge is present. The hydraulic rating therefore represents the overall rating</p>

EFR 4	2.9	3.2	2.0	4.0	<p><b>Positive</b> Reasonably uniform flow conditions at medium flows and above. Location of real time gauging weir for determining discharges.</p> <p><b>Negative attributes</b> Location of site in bedrock morphology with rapidly varied flow conditions at low flows. Large and irregular nature of the bed substrate (cobbles, boulders &amp; bedrock). Non-horizontal water surface across the inundated channel width at low-flows. Possibility of pooled water at the cessation of flow.</p>	2.0	4	<p>Low flow suitability of hydraulics overrides the biophysical high suitability.</p> <p>A long record of daily flows is more important than the hydraulics with the setting of floods. In this case however, the hydraulics have a high suitability, and a gauge is present. The hydraulic rating therefore represents the overall rating.</p>
EFR 5	2.6	3.5	2.0	4.0	<p><b>Negative</b> Location of site in bedrock morphology with rapidly varied flow conditions at low and medium flows. Large and irregular nature of the bed substrate (cobbles, boulders &amp; bedrock). Non-horizontal water surface across the inundated channel width at low-flows. Possibility of pooled water at the cessation of flow.</p>	2.0	3.5	<p>No gauge is present. The lowest rating between hydraulics and the biophysical components therefore represent the overall rating.</p>
EFR 6	2.8	3.3	2.0	4.0	<p><b>Positive</b> Reasonably uniform flow conditions at medium flows and above.</p> <p><b>Negative</b> Location of site in bedrock morphology with rapidly varied flow conditions at low flows. Large and irregular nature of the bed substrate (cobbles, boulders &amp; bedrock). Non-horizontal water surface across the inundated channel width at low-flows. Possibility of pooled water at the cessation of flow.</p>	2.0	3.3	<p>No gauge is present. The lowest rating between hydraulics and the biophysical components therefore represent the overall rating.</p>
EFR 7	3.5	3.4	3.0	4.0	<p><b>Positive</b> Reasonably uniform flow conditions at medium flows and above. Location of real time gauging weir for determining discharges.</p> <p><b>Negative</b> Possibility of divided and two-dimensional flow patterns at low flows. Possibility of non-horizontal water surface across the inundated channel width at low-flows. Possibility of pooled water at the cessation of flow.</p>	3.0	4	<p>Moderate flow suitability of hydraulics overrides slightly higher biophysical suitability.</p> <p>A long record of daily flows is more important than the hydraulics with the setting of floods. In this case however, the hydraulics have a high suitability, and a gauge is present. The hydraulic rating therefore represents the overall rating</p>

In conclusions, the overall suitability for low flows range from low (2) to moderate (3). This is mostly due to the complex sites in terms of hydraulics. The sites where low is shaded orange in Table 6.4 is however potentially not a problem as a logger was installed at these sites to obtain a wide range of calibrations. As no gauge and no logger is present at EFR 5 and 6, it is likely that the hydraulic confidence in the modelling will ultimately also be low.

The confidence of high flow EFR determination increases proportionately more if a gauge with a long record of daily flows is sufficiently close to the site. The presence of such a gauge weighs higher than the hydraulic confidence. Apart from the EFR sites in the Caledon River (EFR 5 and 6), all the sites are sufficiently close to a gauge and this, combined with the mostly high suitability for the hydraulic suitability, results in a high confidence.



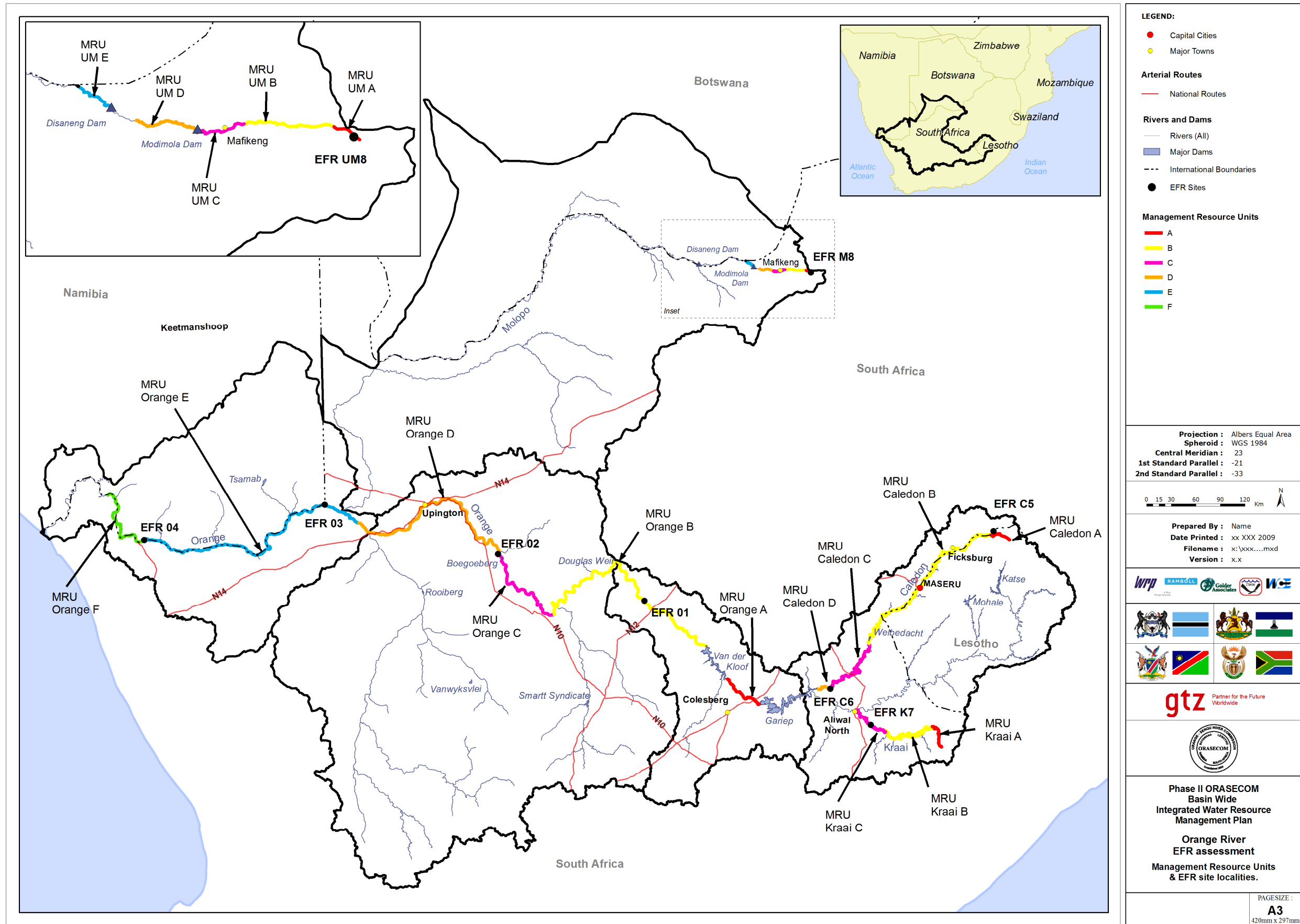


Figure 6-1 Management Resource Units and EFR sites

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**APPENDIX A. RIVER REACH  
DEMARICATION,  
DELINEATION AND  
SUITABILITY**

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**CJ Kleynhans & DM Louw****September 2007****A.1 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<sup>1</sup> 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.

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<sup>1</sup> 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](http://www.wwnorton.com/college/geo/earth2/glossary/r.htm)).

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

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 (EFR Site)

The EFR 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 EFR within this system context. This is described in the following sections and the process is diagrammatically illustrated in Figure A.1 and A.2.

## **A.2 NATURAL RESOURCE UNIT (NRU)**

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

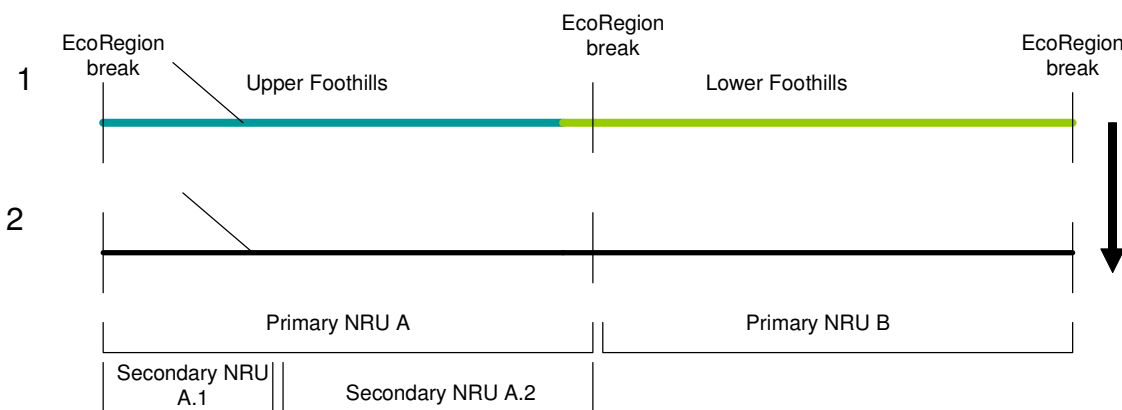
Two levels can be distinguished:

- 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:
  - Geozones (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 table form (Table A.1) is also provided.

**NATURAL RESOURCE UNITS**



**Figure A. 1 Delineation of National Resource Units**

**Table A. 1 Description of the rationale for the delineation of the National Resource Unit for the Figure A.1**

UNIT	RATIONALE	DELINEATION
Primary NRU A	EcoRegions main determinant. As most of the EcoRegion also consists of one geozone, 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

**A.3 MANAGEMENT RESOURCE UNIT (MRU)**

The purpose of distinguishing MRUs is to identify a management unit within which the EFR 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 EFR assessment being undertaken (Louw & Hughes, 2002). This means that an EFR set in the MRU, according to the EFR 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).

#### **A.4 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 EFR 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.

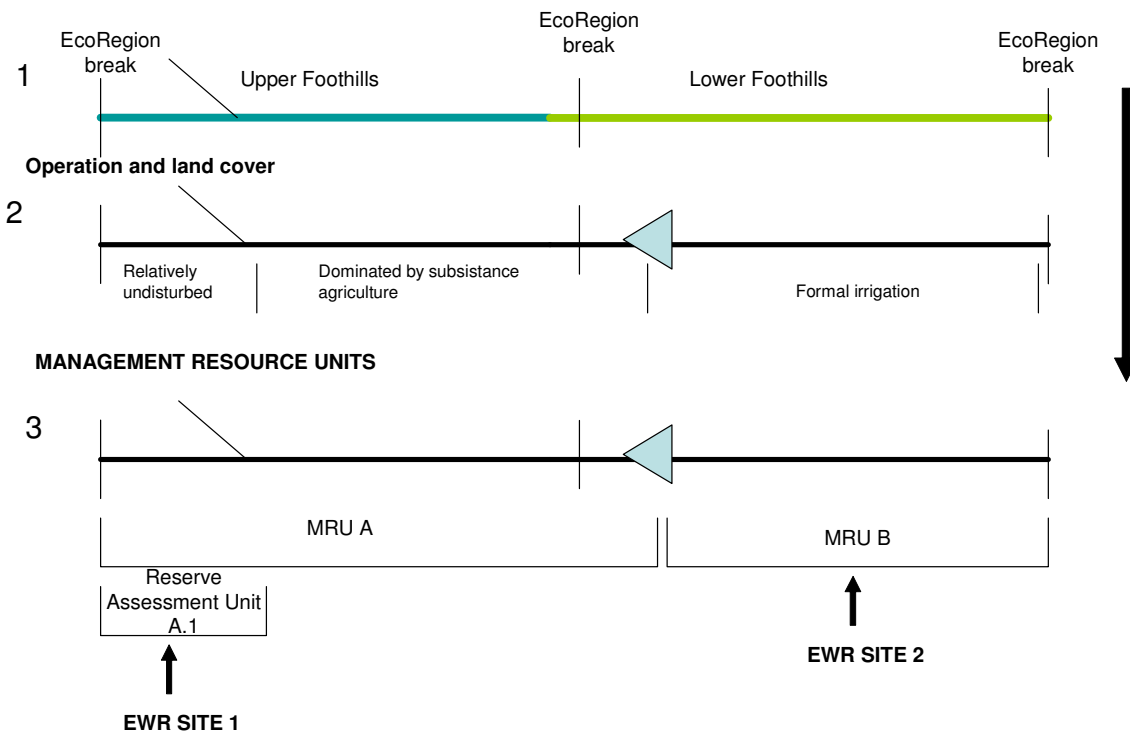


To provide for an eventual management monitoring context, the RAU can be defined in terms of biological habitat segments that represent the presence of a homogenous biological assemblage. This is important when reference conditions are formulated.

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

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

**MANAGEMENT RESOURCE UNITS**



**Figure A. 2 Delineation of Management Resource Units**

**Table A. 2 Description of the rationale for the delineation of the Management Resource Unit for the Figure A.2**

UNIT	RATIONALE	DECISION	DELINEATION
MRU A	Consists of mostly one EcoRegion Consists mostly one Geozone	MRU larger than NRU to include	Start of EcoRegion to Dam

	Land use dominated by subsistence agriculture Dam provides an operational break.	short section to the dam.	
RAU A.1	RAU provides critical habitat for species that prefer colder temperatures as the tributary brings in warmer water. As area is isolated, critical vegetation habitat such as marginal and overhanging vegetation present to provide cover. In area downstream from the tributary, this habitat has been removed by grazing and bush clearing.	Assessment of RAU for EcoClassification and EFR assessment important as forms the critical section in the MRU	Start of EcoRegion to confluence of tributary (coincides with NRU A.1)
Recommendation: RAU A.1: EcoClassification + EFR assessment therefore EFR 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 Geozone 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 + EFR assessment As no RAU identified within the MRU, the EFR 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 EFR be placed within that.			

#### A.5 ECOLOGICAL WATER REQUIREMENT SITE (EFR 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](http://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](http://porites.geology.uiowa.edu/entity.htm)).

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

The selection of EFR 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 EFR 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 EFR site and the accuracy of the hydraulics model.

In addition to an ideal EFR 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 EFR 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 EFR 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<sup>2</sup> (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.

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<sup>2</sup> 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<sup>3</sup>:

**Table A. 3 Comparison of velocity-depth ratings for RAU and the EFR 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 EFR 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	
	SIT E	RA U		SIT E	RA U		SIT E	RA U		SIT E	RA U
UB			UB			UB			UB		
OV			OV			OV			OV		
SUB			SUB			SUB			SUB		
AM			AM			AM			AM		
WC			WC			WC			WC		
BRAY - CURTIS SIMILARITY			BRAY - CURTIS SIMILARITY			BRAY - CURTIS SIMILARITY			BRAY - CURTIS SIMILARITY		

**Table A. 5 Comparison between sizes of various velocity-depth guilds at a EFR site. Large>20 cm; Small <20 cm**

VELOCITY-DEPTH GUILDS (Indicate number for flow guild per size)			
SD	SS	FD	FS

<sup>3</sup> 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

	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 EFR 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 EFR 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. AQUATIC  
INVERTEBRATES SITE  
SUITABILITY**

EFR site	River	Geomorph site suitability (/5)
1	Orange	3.7
2	Orange	3.0
3	Orange	3.5
4	Orange	3.1
5	Caledon	3.0
6	Caledon	3.0
7	Kraai	4.2
8	Molopo	4 (below dam) 1 (within the dam).

The Molopo EFR site is a wetland and was not evaluated using the Geomorphological Site Suitability tool as with the other EFR sites. The site which passes through the unchannelled valley bottom wetland (below the dam) is morphologically representative of the reach. It is likely that the vegetation and soil cues located here will provide good estimates of the EFR requirements. The cross-section located within the dam site is unsuitable for wetland EFR determination and is akin to setting flows for a river based on a cross-section through a dam. The cues from this site would only be able to inform the required level of the dam for the (now artificial) vegetation zonation and fishes which have established there.

This provides an assessment of the suitability of the site for EFR determination studies					Notes
	SCORES:			SCORE	
	5	2	1		
Representivity of the site for the reach					3.8
How well does the <i>morphology</i> of the site represent that of the reach?	Very well	Don't know	Poorly	4.0	<i>Morphology of the site is generally consistent with the reach; but the condition (especially of the banks and riparian vegetation) is in far better condition.</i>
To what extent is the <i>condition</i> of the site representative of the general condition of the reach?	Representative	Don't know	Very different	3.5	
Morphological Cues					3.5
Is the site a bedrock or alluvial dominated section?	Alluvial	Mixed	Bedrock	3.0	<i>Gross morphology is bedrock controlled, but the bed is primarily composed of mobile cobbles, gravels and sands. The site is within a relatively narrow gorge/valley. There are good cues, although no EFR determination is being undertaken at this site.</i>
Are there good morphological clues that can be related to flood levels?	Very good	Don't know	Bad	4.0	
If these are present, are the terraces paired?	Yes	Don't know	No	3.5	
Sediment Transport Modelling					4.0
Is the river a bedload dominated system (i.e. is potential bed material transport modelling suitable)	Yes	Don't know	No	4.0	<i>Site is bedload dominated, and PBMT could be undertaken if an EFR determination was desired.</i>
Is potential bed material transport modelling going to be undertaken at this site?	Yes	Don't know	No	4.0	
OVERALL SCORE:					3.7

Site Name:	ORANGE RIVER
Site number:	EFR 1
Date of assessment:	2nd June 2010
Name of assessor:	Mark Rountree



This provides an assessment of the suitability of the site for EFR determination studies					Notes
	SCORES:			SCORE	
	5	2	1		
Representivity of the site for the reach					4.0
How well does the <i>morphology</i> of the site represent that of the reach?	Very well	Don't know	Poorly	4.0	<i>Morphology and condition of the site is generally consistent with the reach.</i>
To what extent is the <i>condition</i> of the site representative of the general condition of the reach?	Representative	Don't know	Very different	4.0	
Morphological Cues					2.2
Is the site a bedrock or alluvial dominated section?	Alluvial	Mixed	Bedrock	2.0	<i>Gross morphology is bedrock controlled, but the bed is mixed with bedrock, mobile cobbles, gravels and sands. Morphological cues are very poor.</i>
Are there good morphological clues that can be related to flood levels?	Very good	Don't know	Bad	2.0	
If these are present, are the terraces paired?	Yes	Don't know	No	2.5	
Sediment Transport Modelling					3.7
Is the river a bedload dominated system (i.e. is potential bed material transport modelling suitable)	Yes	Don't know	No	4.0	<i>Site is characterised by bedload transport, and PBMT is to be undertaken if an EFR determination was desired.</i>
Is potential bed material transport modelling going to be undertaken at this site?	Yes	Don't know	No	3.5	
OVERALL SCORE:					3.0

Site Name:	ORANGE RIVER
Site number:	EFR 2
Date of assessment:	31st May 2010
Name of assessor:	Mark Rountree

Representivity of the site for the reach					4.0	<i>Morphology and condition of the site is generally consistent with the reach.</i>
How well does the <i>morphology</i> of the site represent that of the reach?	Very well	Don't know	Poorly	4.0		
To what extent is the <i>condition</i> of the site representative of the general condition of the reach?	Representative	Don't know	Very different	4.0		
Morphological Cues					3.0	<i>Although some bedrock, gross is alluvial with cobbles, gravels and sands. Morphological cues are very poor.</i>
Is the site a bedrock or alluvial dominated section?	Alluvial	Mixed	Bedrock	4.0		
Are there good morphological clues that can be related to flood levels?	Very good	Don't know	Bad	2.5		
If these are present, are the terraces paired?	Yes	Don't know	No	2.5		
Sediment Transport Modelling					4.0	<i>Site is characterised by bedload transport, and PBMT is to be undertaken if an EFR determination was desired.</i>
Is the river a bedload dominated system (i.e. is potential bed material transport modelling suitable)	Yes	Don't know	No	4.0		
Is potential bed material transport modelling going to be undertaken at this site?	Yes	Don't know	No	4.0		
OVERALL SCORE:					3.5	

Site Name:	ORANGE RIVER
Site number:	EFR 3
Date of assessment:	29th May 2010
Name of assessor:	Mark Rountree

This provides an assessment of the suitability of the site for EFR determination studies					Notes
	SCORES:			SCORE	
	5	2	1		
Representivity of the site for the reach					3.8
How well does the <i>morphology</i> of the site represent that of the reach?	Very well	Don't know	Poorly	3.5	<i>Morphology and condition of the site are generally consistent with the reach.</i>
To what extent is the <i>condition</i> of the site representative of the general condition of the reach?	Representative	Don't know	Very different	4.0	
Morphological Cues					2.3
Is the site a bedrock or alluvial dominated section?	Alluvial	Mixed	Bedrock	3.0	<i>There is some bedrock exposed at the site, but angular boulders, cobbles and sands are present. Morphological cues are limited and the one bank has been disturbed by engineering (canal construction) and any cues have been lost here.</i>
Are there good morphological clues that can be related to flood levels?	Very good	Don't know	Bad	2.0	
If these are present, are the terraces paired?	Yes	Don't know	No	2.0	
Sediment Transport Modelling					4.0
Is the river a bedload dominated system (i.e. is potential bed material transport modelling suitable)	Yes	Don't know	No	4.0	<i>Site is characterised by bedload transport, and PBMT is to be undertaken if an EFR determination was desired.</i>
Is potential bed material transport modelling going to be undertaken at this site?	Yes	Don't know	No	4.0	
OVERALL SCORE:					3.1

Site Name:	ORANGE RIVER
Site number:	EFR 4
Date of assessment:	26th May 2010
Name of assessor:	Mark Rountree

This provides an assessment of the suitability of the site for EFR determination studies					Notes
	SCORES:			SCORE	
	5	2	1		
Representivity of the site for the reach					2.0
How well does the <i>morphology</i> of the site represent that of the reach?	Very well	Don't know	Poorly	4.0	<i>The morphology and condition of the site generally represent the reach.</i>
To what extent is the <i>condition</i> of the site representative of the general condition of the reach?	Representative	Don't know	Very different		
Morphological Cues					3.2
Is the site a bedrock or alluvial dominated section?	Alluvial	Mixed	Bedrock	4.5	<i>The site is alluvial, although some bedrock is exposed on the lower bank. Morphological cues are extremely poor - the morphology of the site is dominated by the deposition of sediment slugs and does not relate to long term flood patterns.</i>
Are there good morphological clues that can be related to flood levels?	Very good	Don't know	Bad	2.0	
If these are present, are the terraces paired?	Yes	Don't know	No	3.0	
Sediment Transport Modelling					3.8
Is the river a bedload dominated system (i.e. is potential bed material transport modelling suitable)	Yes	Don't know	No	3.5	<i>The site is largely bedload dominated, but expect that suspended load is high in the wet season.</i>
Is potential bed material transport modelling going to be undertaken at this site?	Yes	Don't know	No	4.0	
OVERALL SCORE:					3.0

Site Name:	Caledon River
Site number:	EFR C5
Date of assessment:	22nd June 2010
Name of assessor:	Mark Rountree

This provides an assessment of the suitability of the site for EFR determination studies					Notes	
	SCORES:			SCORE		
	5	2	1			
Representivity of the site for the reach					3.3	<i>The morphology of the site is generally representative of the reach, although such large bedrock riffles are not common. The condition of the site is probably slightly better than the reach due to location within nature reserve.</i>
How well does the <i>morphology</i> of the site represent that of the reach?	Very well	Don't know	Poorly	3.0		
To what extent is the <i>condition</i> of the site representative of the general condition of the reach?	Representative	Don't know	Very different	3.5		
Morphological Cues					2.7	<i>The site is mix of bedrock and alluvium. Morphological cues are poorly defined - this site is possibly within the backup of the dam and thus cues are masked by extensive silt drapes/deposits. Paired terraces exist high up the banks, but lower "terraces" are related to single flow events and do not reflect long term flooding patterns.</i>
Is the site a bedrock or alluvial dominated section?	Alluvial	Mixed	Bedrock	3.5		
Are there good morphological clues that can be related to flood levels?	Very good	Don't know	Bad	2.0		
If these are present, are the terraces paired?	Yes	Don't know	No	2.5		
Sediment Transport Modelling					3.5	<i>Site is dominated by bedload and suspended load. PBMT modelling will be undertaken.</i>
Is the river a bedload dominated system (i.e. is potential bed material transport modelling suitable)	Yes	Don't know	No	2.5		
Is potential bed material transport modelling going to be undertaken at this site?	Yes	Don't know	No	4.0		
OVERALL SCORE:					3.0	

Site Name:	Caledon River
Site number:	EFR C6
Date of assessment:	23rd June 2010
Name of assessor:	Mark Rountree

This provides an assessment of the suitability of the site for EFR determination studies					Notes
	SCORES:			SCORE	
	5	2	1		
Representivity of the site for the reach					4.5
How well does the <i>morphology</i> of the site represent that of the reach?	Very well	Don't know	Poorly	4.5	<i>Morphology and condition of the site appear to represent the reach extremely well.</i>
To what extent is the <i>condition</i> of the site representative of the general condition of the reach?	Representative	Don't know	Very different	4.5	
Morphological Cues					3.7
Is the site a bedrock or alluvial dominated section?	Alluvial	Mixed	Bedrock	4.0	<i>Upper terrace appears to be paired. The site is alluvial, but many of the lower benches and terraces have been scoured away as a result of recent very large floods.</i>
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	3.5	
Sediment Transport Modelling					5.0
Is the river a bedload dominated system (i.e. is potential bed material transport modelling suitable)	Yes	Don't know	No	5.0	<i>River is bedload dominated (cobbles and sands predominantly). PBMT will be undertaken for this site.</i>
Is potential bed material transport modelling going to be undertaken at this site?	Yes	Don't know	No	5.0	
OVERALL SCORE:					4.2

Site Name:	Kraai River
Site number:	EFR K7
Date of assessment:	24th June 2010
Name of assessor:	Mark Rountree

**APPENDIX C. AQUATIC  
INVERTEBRATES SITE  
SUITABILITY**

## Key

Rating (0-5)	Description
>4.0	Very Good
>3.5	Good
>3.0	Moderate
>2.5	Poor
<2.5	Very Poor

## Key

Suitability (%)	Description
>80	Very Good
>70	Good
>60	Moderate
>50	Poor
<50	Very Poor

Site: EFR O2 - Boegoeberg			
Site Suitability: Aquatic Invertebrates	Weight	Rating of Site	Weighted Rating
BIOTOPE	(0-10)	(0-5)	
Stones In Current (SIC)	9	4	0.8
Stones Out Of Current (SOOC)	6	4	0.5
Bedrock	1	4	0.1
Aquatic Veg	1	0	-
MargVeg In Current	6	4	0.5
MargVeg Out Of Current	5	5	0.6
Gravel	4	4	0.4
Sand	2	4	0.2
Mud	1	4	0.1
Terraces and bars	10	5	1.1
Overall Suitability (%)	45	85%	
Category		Very Good	



Site: EFR 03 - Blouputs			
Site Suitability: Aquatic Invertebrates	Weight	Rating of Site	Weighted Rating
BIOTOPE	(0-10)	(0-5)	
Stones In Current (SIC)	9	4	0.8
Stones Out Of Current (SOOC)	6	4	0.5
Bedrock	1	0	-
Aquatic Veg	1	4	0.1
MargVeg In Current	6	4	0.5
MargVeg Out Of Current	5	4	0.4
Gravel	4	3	0.3
Sand	2	3	0.1
Mud	1	3	0.1
Terraces and bars	10	4	0.9
Overall Suitability (%)	45	75%	
Category		Good	3.8
Site: EFR 04 - Vioolsdrift			
Site Suitability: Aquatic Invertebrates	Weight	Rating of Site	Weighted Rating
BIOTOPE	(0-10)	(0-5)	
Stones In Current (SIC)	9	3	0.6
Stones Out Of Current (SOOC)	6	2	0.3
Bedrock	1	4	0.1
Aquatic Veg	1	0	-
MargVeg In Current	6	3	0.4
MargVeg Out Of Current	5	3	0.3
Gravel	4	4	0.4
Sand	2	4	0.2
Mud	1	2	0.0
Terraces and bars	10	3	0.7
Overall Suitability (%)	45	59%	
Category		Poor	2.9

Site C5: Caledon Upper			
Site Suitability: Aquatic Invertebrates	Weight	Rating of Site	Weighted Rating
BIOTOPE	(0-10)	(0-5)	
Stones In Current (SIC)	9	4	0.7
Stones Out Of Current (SOOC)	6	2	0.2
Bedrock	3	5	0.3
Aquatic Veg	0	0	-
MargVeg In Current	6	1	0.1
MargVeg Out Of Current	5	3	0.3
Gravel	6	3	0.4
Sand	4	4	0.3
Mud	1	4	0.1
Terraces and bars	10	3	0.6
Overall Suitability (%)	50	61%	
Category		Moderate	3.0

Site C6: Caledon Lower			
Site Suitability: Aquatic Invertebrates	Weight	Rating of Site	Weighted Rating
BIOTOPE	(0-10)	(0-5)	
Stones In Current (SIC)	9	4	0.8
Stones Out Of Current (SOOC)	6	3	0.4
Bedrock	1	4	0.1
Aquatic Veg	0	0	-
MargVeg In Current	6	2	0.3
MargVeg Out Of Current	5	1	0.1
Gravel	4	3	0.3
Sand	2	3	0.1
Mud	1	1	0.0
Terraces and bars	10	4	0.9
Overall Suitability (%)	44	61%	
Category		Moderate	3.0

Site 7: Kraai			
Site Suitability: Aquatic Invertebrates	Weight	Rating of Site	Weighted Rating
BIOTOPE	(0-10)	(0-5)	
Stones In Current (SIC)	9	4	0.8
Stones Out Of Current (SOOC)	6	5	0.7
Bedrock	1	5	0.1
Aquatic Veg	0	0	-
MargVeg In Current	6	3	0.4
MargVeg Out Of Current	5	4	0.5
Gravel	4	5	0.5
Sand	2	4	0.2
Mud	1	2	0.0
Terraces and bars	10	4	0.9
Overall Suitability (%)	44	81%	
Category		Very Good	4.1

**APPENDIX D. RIPARIAN  
VEGETATION SITE  
SUITABILITY**

**EFR 1**

**Site Suitability for the Assessment of Environmental Flows**

<b>Habitat availability</b>	<b>Rate</b>	<b>Motivation where applicable</b>
Presence / absence of the marginal zone	1	marginal zone scoured but >80% present for sampling
Proportion of marginal zone that is able to be sampled	0	> 80% available for sampling
Alluvial riparian habitats available for sampling	0	alluvial bars abundant as vegetated bars
Rocky riparian habitats available for sampling	2	open bedrock present in lower zone and available for sampling
	<b>2</b>	
<b>Channel morphology</b>		
Channel bank stabilization	0	less than 10% undercutting, and stabilized by vegetation
Channel manipulation	1	Road along upper zone is incised, site better than reach where agricultural clearing is high
Profile distance too long to effectively conduct VEGRAI	1	profile assessed
	<b>1</b>	
<b>Vegetation</b>		
Occurrence of obligate, marginal zone riparian species	2	some species reduced or absent due to flow regulation
Occurrence of obligate, non-marginal zone riparian species	0	woody and non-woody obligates common
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	2	LB with more rocky habitats than RB which is more alluvial
Able to obtain sufficient survey points of indicator species for flow requirements		survey not conducted
Riparian vegetation representative of the reach	0	site represents reach and is in better condition than majority of reach
Plant species easily identifiable i.e. leaves or flowers present at time of site visit	0	all key species identifiable
	<b>2</b>	
<b>Hydraulic control</b>		
unnatural up/downstream control affecting site	0	not observed in immediate vicinity
	<b>0</b>	
<b>Overall Site Suitability Rating</b>	<b>1.3</b>	<b>Site suitable</b>

where:

- 0 - site highly suitable
- 1 - site suitable
- 2 - site moderately suitable
- 3 - site unsuitable
- 4 - site extremely unsuitable
- 5 - site not to be used

**EFR 2**

**Site Suitability for the Assessment of Environmental Flows**

<b>Habitat availability</b>	<b>Rate</b>	<b>Motivation where applicable</b>
Presence / absence of the marginal zone	1	marginal zone scoured but >80% present for sampling entire marginal zone included in sampling alluvial habitats underrepresented at the site due to extensive cobble bars and exposed bedrock in marginal and lower zones site includes cobble beds and exposed bedrock especially in marginal and lower zones
Proportion of marginal zone that is able to be sampled	0	
Alluvial riparian habitats available for sampling	2	
Rocky riparian habitats available for sampling	0	
	<b>2</b>	
<b>Channel morphology</b>		
Channel bank stabilization	0	less than 10% undercutting, and stabilized by vegetation LB with some clearing, levelling and with a road in upper zone complete profile sampled, with exception of extreme elevation in the upper zone
Channel manipulation	1	
Profile distance too long to effectively conduct VEGRAI	1	
	<b>1</b>	
<b>Vegetation</b>		
Occurrence of obligate, marginal zone riparian species	0	woody and non-woody obligates common
Occurrence of obligate, non-marginal zone riparian species	0	
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	2	banks differ due to bend, differences appear natural
Able to obtain sufficient survey points of indicator species for flow requirements	0	sufficient both banks
Riparian vegetation representative of the reach	1	cobble beds additionally present with <i>Gomphostigma vigatum</i>
Plant species easily identifiable i.e. leaves or flowers present at time of site visit	0	all key species identifiable
	<b>2</b>	
<b>Hydraulic control</b>		
unnatural up/downstream control affecting site	1	Boegoeberg dam nearby upstream
	<b>1</b>	
<b>Overall Site Suitability Rating</b>	<b>1.5</b>	<b>Site suitable</b>

where:

- 0 - site highly suitable
- 1 - site suitable
- 2 - site moderately suitable
- 3 - site unsuitable
- 4 - site extremely unsuitable
- 5 - site not to be used

**EFR 3**

<b>Site Suitability for the Assessment of Environmental Flows</b>		
<b>Habitat availability</b>	<b>Rate</b>	<b>Motivation where applicable</b>
Presence / absence of the marginal zone	1	marginal zone scoured but >80% present for sampling
Proportion of marginal zone that is able to be sampled	0	> 80% available for sampling
Alluvial riparian habitats available for sampling	0	alluvial bars abundant as open bars and vegetated bars
Rocky riparian habitats available for sampling	0	cobble beds present and available for sampling
	<b>1</b>	
<b>Channel morphology</b>		
Channel bank stabilization	0	less than 10% undercutting, and stabilized by vegetation
Channel manipulation	3	Macro channel manipulated by artificially elevated levees and clearing and levelling for vineyards
Profile distance too long to effectively conduct VEGRAI	0	profile completely sampled
	<b>3</b>	
<b>Vegetation</b>		
Occurrence of obligate, marginal zone riparian species	0	woody and non-woody obligates common
Occurrence of obligate, non-marginal zone riparian species	0	woody and non-woody obligates common
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	2	banks differ due to cobble beds on LB
Able to obtain sufficient survey points of indicator species for flow requirements	0	sufficient both banks
Riparian vegetation representative of the reach	1	cobble beds additionally present with <i>Gomphostigma vigatum</i>
Plant species easily identifiable i.e. leaves or flowers present at time of site visit	0	all key species identifiable
	<b>2</b>	
<b>Hydraulic control</b>		
unnatural up/downstream control affecting site	0	not observed in immediate vicinity
	<b>0</b>	
<b>Overall Site Suitability Rating</b>	<b>1.5</b>	<b>Site suitable</b>

where:

- 0 - site highly suitable
- 1 - site suitable
- 2 - site moderately suitable
- 3 - site unsuitable
- 4 - site extremely unsuitable
- 5 - site not to be used

**EFR 4**

Site Suitability for the Assessment of Environmental Flows

Habitat availability	Rate	Motivation where applicable
Presence / absence of the marginal zone	1	marginal zone scoured but >80% present for sampling
Proportion of marginal zone that is able to be sampled	0	> 80% available for sampling
Alluvial riparian habitats available for sampling	0	alluvial bars abundant as open bars and vegetated bars
Rocky riparian habitats available for sampling	2	cobble beds present and available for sampling
	2	
Channel morphology		
Channel bank stabilization	0	less than 10% undercutting, and stabilized by vegetation
Channel manipulation	3	LB completely artificial to facilitate canal and road
Profile distance too long to effectively conduct VEGRAI	1	RB confounded by drainage tributaries
	3	
Vegetation		
Occurrence of obligate, marginal zone riparian species	1	marginal zone riparian obligates present and common at site:
Occurrence of obligate, non-marginal zone riparian species	1	sufficient obligate riparian species in non-marginal zone
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 20% exotic species at the site
Left and right-hand banks have riparian vegetation in similar condition	2	land use differs and so does veg types
Able to obtain sufficient survey points of indicator species for flow requirements	0	sufficient both banks
Riparian vegetation representative of the reach	0	represents reach
Plant species easily identifiable 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 vicinity
	0	
<b>Overall Site Suitability Rating</b>	<b>1.8</b>	<b>Site moderately suitable</b>

where:

- 0 - site highly suitable
- 1 - site suitable
- 2 - site moderately suitable
- 3 - site unsuitable
- 4 - site extremely unsuitable
- 5 - site not to be used



**APPENDIX E. FISH SITE  
SUITABILITY**

**ABBREVIATIONS**

EFR –	Ecological Water Requirements
FD –	Fast Deep
FS –	Fast Shallow
FRAI –	Fish Response Assessment Index
NRU –	Natural Resource Unit
MRU -	Management Resource Unit
RAU –	Resource Assessment Unit
SD –	Slow Deep
SS –	Slow Shallow

***Fish Species Abbreviations:***

ABBREVIATION	SCIENTIFIC NAMES
ASCL	<i>AUSTROGLANIS SCLATERI</i> (BOULENGER, 1901)
BANO	<i>BARBUS ANOPLUS</i> (WEBER, 1897)
BAEN	<i>LABEOBARBUS AENEUS</i> (BURCHELL, 1822)
BHOS	<i>BARBUS HOSPES</i> (BARNARD, 1938)
BKIM	<i>LABEOBARBUS KIMBERLEYENSIS</i> (GILCHRIST & THOMPSON, 1913)
BPAU	<i>BARBUS PALUDINOSUS</i> (PETERS, 1852)
BTRI	<i>BARBUS TRIMACULATUS</i> (PETERS, 1852)
CCAR*	<i>CYPRINUS CARPIO</i> LINNAEUS, 1758
CGAR	<i>CLARIAS GARIEPINUS</i> (BURCHELL, 1822)
CIDE*	<i>CTENOPHARYNGODON IDELLA</i> (VALENCIENNES, 1844)
GAFF*	<i>GAMBUSIA AFFINIS</i> (BAIRD & GIRARD, 1853)
LCAP	<i>LABEO CAPENSIS</i> (SMITH, 1841)
LUMB	<i>LABEO UMBRATUS</i> (SMITH, 1841)
MBRE	<i>MESOBOLA BREVIANALIS</i> (BOULENGER, 1908)
OMOS	<i>OREOCHROMIS MOSSAMBICUS</i>
PPHI	<i>PSEUDOCRENILABRUS PHILANDER</i> (WEBER, 1897)
TSPA	<i>TILAPIA SPARRMANII</i> SMITH, 1840
MSAL*	<i>MICROPTERUS SALMOIDES</i>

\*Alien fish species

## E.1 BACKGROUND

This report deals with the preliminary results of a fish survey conducted during May and June 2010 at selected sites in the Orange River Catchment.

## E.2 METHODOLOGY

Sites were selected within the Orange River, to be representative of the current habitats available for biota in this river section. The sites were subdivided in sub-sites for the purpose of fish sampling, based on differences in habitats, impacts, etc. At each sub-site, all applicable fishing methods were applied to determine the fish assemblage of the sub-site. The most applicable sampling method was generally found to be electro-fishing (applied using a SAMUS battery operated system) through wading in shallow areas or from a boat in deeper areas. Other methods applied included seine netting (using small seine net) and gill netting (range of mesh sizes). All fish collected were identified to species level and those not required for further analyses/identification were returned unharmed to the river.

## E.3 PRELIMINARY RESULTS

### E.3.1 Study Sites

Five sites were selected in the Lower Orange River and two sites were selected in the Caledon River and one in the Kraai River for the purpose of the baseline fish survey for the purpose of the baseline fish survey (Table E.1).

**Table E. 1: Primary EFR sites of the used for fish assessment (additional sites or stretches of river were sampled up/downstream of EFR sites).**

EFR site number	EFR site name	River	Decimal degrees S	Decimal degrees E	EcoRegion (Level II)	Geozone
EFR O1	Hopetown	Orange			26.01	Lowland
EFR O2	Boegoeberg	Orange	-29.0055	22.16225	26.05	Lowland
EFR O3	Augrabies	Orange	-28.4287	19.9983	28.01	Lowland
EFR O4	Vioolsdrif	Orange	-28.7553	17.71696	28.01	Lowland
EFR C5	Upper Caledon	Caledon	-28.6508	28.3875	15.03	Lower Foothills
EFR C6	Lower Caledon	Caledon	-30.4523	26.27088	26.03	Lowland
EFR K7	Lower Kraai	Kraai	-30.8306	26.92056	26.03	Lowland

### E.3.2 Site Suitability & preliminary fish results

#### **Site EFR 01: Hopetown**

Various sub-sites were sampled at the EFR site or within the reach using most applicable sampling techniques (Table E.2). The habitat of each sub-site is described and the sampling effort provided in Table E.2. Habitat Cover ratings are also provided for each sub-site in Table E.3. The river at this site has a wide flow channel with rapids and riffles over bedrock, side channels, and at the time of sampling vegetated pools were present in some of the non-flowing side channels.

**Table E. 2: Description of fish sub-sites sampled in reach EFR 01: Hopetown.**

SUB-SITE	DESCRIPTION	SAMPLING EFFORT
Sub-site 1	FS & FD over bedrock (covered by algae) and reeds as overhanging and instream vegetation along sides. Limited SS & SD along edge.	40min EW
Sub-site 2	FS & FD over bedrock (covered by algae) and reeds as overhanging and instream vegetation along sides.	30 min EW
Sub-site 3	<i>Potamogeton</i> spp. stand on sand in mainstream along reeds.	8 min EW
Sub-site 4	Side/secondary channel with trickle at time of sampling (will be connected with more flow during peak of release). SS & SD with bedrock (often covered with silt), abundant aquatic vegetation and overhanging vegetation. Filamentous algae abundant.	12 min EW

EW: Electrofishing through wading.

**Table E. 3: Fish habitat assessment (sampled) at each sub-site.**

Velocity-Depth Category: SUB-SITE:	SLOW-DEEP			SLOW-SHALLOW			FAST-DEEP			FAST-SHALLOW		
	1&2	3	4	1&2	3	4	1&2	3	4	1&2	3	4
ABUNDANCE:	1	0	3	1	0	3	4	0	0	2	0	0
Overhanging vegetation:	3	0	3	2	0	3	1	0	0	0	0	0
Undercut banks & root wads:	1	0	0	1	0	0	0	0	0	0	0	0
Substrate:	4	0	2	4	0	2	5	0	0	5	0	0
Instream vegetation:	2	0	3	2	0	3	0	0	0	0	0	0
Water Column:	3	0	3	1	0	1	3	0	0	1	0	0

0 – absent; 1 – rare; 2 – sparse; 3 – common; 4 - abundant; 5 – very abundant

Six indigenous fish species were sampled at the different sub-sites (Table E.4). A habitat profile of where each species was sampled or observed for this reach is provided in Table E.5, indicating general habitat preferences of fish species at the site/in reach.

**Table E. 4: Presence in number of individuals (and size range in mm) of different fish species sampled at the different sub sites (May/June 2010) and their relative size-flow guild.**

Species	Size Flow-guild classification	Sub-site 1	Sub-site 2	Sub-site 3	Sub-site 4
ASCL	Large semi-rheophilic	5 (50-250)			
BAEN	Large semi-rheophilic	8 (100-600)	1 (100)		
BTRI	Small semi-rheophilic			2 (50,80)	
LCAP	Large semi-rheophilic	6 (150-450) (2 with anomalies)	3 (70-100)		
PPHI	Small limnophilic	12 (40-80)		4 (30-50)	2 (30, 70) (1 with anomaly)
TSPA	Intermediate limnophilic				1 (40)

**Table E. 5: Fish habitat profile based on habitats where different fish species were observed or sampled at the site EFR O1.**

	SLOW-DEEP	SLOW-SHALLOW	FAST-DEEP	FAST-SHALLOW
Overhanging vegetation:	PPHI, TSPA	PPHI, TSPA		
Undercut banks & root wads:				
Substrate:			BAEN (A), LCAP (A), ASC (A&J) (more in FI)	LCAP (A), ASCL (A&J)
Instream vegetation:	PPHI (A&J), TSPA	TSPA, BTRI		BTRI
Water Column:				

\*Alien species; J- juvenile; A - adult

Suitability of the site to be utilised in ecological water requirement study in terms of fish is provided in Table E.6.

**Table E. 6: Suitability scores of site in terms of EFR application.**

SUITABILITY SCORES		Comments
EFR SUITABILITY	n/a	Only eco-classification 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.		

**General comments:**

*FRAI application:* Site atypical of reach especially due to presence of rapids (FS & FD) over bedrock and secondary channels (therefore most probably higher habitat variability than most of reach). Reach most probably dominated by FD habitats. Site however provided best diversity of habitats (i.e. rapids, riffles, side channels, and pools in side channels) and therefore highest possibility of sampling fish species present in this reach.

Daily water level fluctuations at site/reach will have negative impact on fish (in terms of habitat suitability and availability, water quality - especially temperature regime, etc.). Daily water fluctuations will also have a negative impact on nesting fish species (Cichlidae).

Extensive substrate algae on rocks (possible indication of nutrient enrichment).

Water had a relatively high turbidity, with almost a milky colour. Could especially have negative influence on predatory species (adult BKIM).

Adequate spawning habitats occur in the area if inundated during higher flows (i.e. sand, gravel and cobble beds (yellowfish) and grassy vegetated areas (catfish) for semi-rheophilics).

### **Site EFR 02: Boegoeberg**

Various sub-sites were sampled at the EFR site or within the reach using most applicable sampling techniques (Table E.7). The habitat of each sub-site is described and the sampling effort provided in Table E.7. Habitat Cover ratings are also provided for each sub-site in Table E.8.

**Table E. 7: Description of fish sub-sites sampled in reach EFR 02: Boegoeberg**

SUB-SITE	DESCRIPTION	SAMPLING EFFORT
Sub-site 1a	FD & FS with overhanging vegetation, instream vegetation and substrate (bedrock & boulders), reeds and grass.	60min EW (total for 2 samplers)
Sub-site 1b	FD & FS over bedrock & boulders (white water)	
Sub-site 1c	SS (below FS) with rocks and vegetation	
Sub-site 1d	SS over bedrock	
Sub-site 1e	FD & SD with overhanging vegetation (reeds), logs over bedrock and boulders.	
Sub-site 2a	SS & SVS over rocks (silted) and with instream vegetation as cover	75min EW (total for 2 samplers)
Sub-site 2b	FS & FD over rocks (bedrock & boulders)	
Sub-site 2c	SS, SD & FD with instream and overhanging vegetation over rocks (bedrock)	
Sub-site 3	FD & FS over rocks	15 min EW
Sub-site 4	SD, SS in and upstream of weir, with abundant reeds as cover, sand banks and rocky habitats (bedrock, cobble and boulders)	40min EB
Sub-site 5	FS & FD (rapid) over rocks (boulder, cobble and bedrock)	12min EB Angling

EW: Electrofishing through wading.

**Table E. 8:** Fish habitat assessment (sampled) at each sub-site.

Velocity-Depth Category:	SLOW-DEEP					SLOW-SHALLOW				
SUB-SITE:	1	2	3	4	5	1	2	3	4	5
ABUNDANCE:	1	3	0	4	0	2	3	0	1	1
Overhanging vegetation:	3	3	0	3	0	3	2	0	1	1
Undercut banks & root wads:	2	1	0	2	0	2	1	0	0	0
Substrate:	3	3	0	2	0	3	3	0	1	3
Instream vegetation:	2	3	0	2	0	2	2	0	1	0
Water Column:	3	3	0	5	0	1	1	0	1	1

Velocity-Depth Category:	FAST-DEEP					FAST-SHALLOW				
SUB-SITE:	1	2	3	4	5	1	2	3	4	5
ABUNDANCE:	3	2	4	2	4	2	2	2	0	2
Overhanging vegetation:	3	2	1	2	1	3	3	1	0	0
Undercut banks & root wads:	1	2	1	0	0	1	1	1	0	0
Substrate:	3	4	5	2	4	3	4	5	0	4
Instream vegetation:	1	2	2	2	0	1	2	2	0	0
Water Column:	3	3	3	3	3	1	1	1	0	1

0 – absent; 1 – rare; 2 – sparse; 3 – common; 4 - abundant; 5 – very abundant

Eight indigenous and another 3 alien fish species were sampled at the different sub-sites (Table E.9). A habitat profile of where each species was sampled or observed for this reach is provided in Table E.10, indicating general habitat preferences of fish species at the site/in reach.

**Table E. 9: Presence in number of individuals (and size range in mm) of different fish species sampled at the different sub sites (May/June 2010) and their relative size-flow guild.**

Species	Size Flow – Guild classification	Sub-site 1a	Sub-site 1b	Sub-site 1c	Sub-site 1d	Sub-site 1e	Sub-site 2a	Sub-site 2b	Sub-site 2c	Sub-site 3	Sub-site 4	Sub-site 5
ASCL	Large semi-rheophilic		1 (100)				No fish					
BAEN	Large semi-rheophilic		2 (150)					n.c.			n.c.	n.c.
BPAU	Small semi-rheophilic								n.c.			
BTRI	Small semi-rheophilic	40 (40 – 90)	20 (40 – 90)	4		15		n.c.	n.c.	n.c.		
CCAR*	n/a			1 (50)								
CGAR	Large semi-rheophilic				1 (150)	1 (anomaly)			n.c.			

Species	Size Flow – Guild classification	Sub-site 1a	Sub-site 1b	Sub-site 1c	Sub-site 1d	Sub-site 1e	Sub-site 2a	Sub-site 2b	Sub-site 2c	Sub-site 3	Sub-site 4	Sub-site 5
CIDE*	n/a								n.c.			
GAFF*	n/a								n.c.			
LCAP	Large semi-rheophilic	20 (40 – 150)	15 (40 – 150)	5	3	5		n.c.	n.c.	n.c.	n.c.	n.c.
PPHI	Small limnophilic	2 (40)							n.c.			
TSPA	Intermediate limnophilic	5 (40 – 50)							n.c.			

n/a – not applicable (alien species)

n.c. – Not counted

**Table E. 10: Fish habitat profile based on habitats where different fish species were observed or sampled at the site EFR O2: Boegoeberg.**

	SLOW-DEEP	SLOW-SHALLOW	FAST-DEEP	FAST-SHALLOW
Overhanging vegetation (reeds & trees):	BTRI, LCAP			
Undercut banks & root wads:		Roots: TSPA, PPHI, BTRI		
Substrate:	LCAP (J&A), BTRI (J&A), CGAR (J), CIDE* (J)	CCAR* (J), PPHI, TSPA (with veg. & rocks), BPAU (veg. & sand)	BAEN (J&A), LCAP (J&A), BTRI (A), ASCL (A)	BTRI (A&J), LCAP (J)
Instream vegetation:	PPHI (J&A), TSPA (J&A), BPAU (A), GAFF*	Sand & veg.: GAFF*, TSPA, BPAU		Sand & veg.: TSPA, BTRI
Water Column:	BAEN, CGAR, BTRI, LCAP			

\*Alien species; J- juvenile; A - adult

Suitability of the site to be utilised in setting flows (ecological water requirement) in terms of fish is provided in Table E.11.



**Table E. 11: Suitability scores of site in terms of EFR and FRAI application.**

SUITABILITY SCORES		Comments
EFR SITE SUITABILITY	3.5	Flow sensitive habitats for fish (FS & FD) very well represented at site. High habitat diversity with various secondary canals at site. In the absence of rheophilic species in the Orange River system, next best guild expected to be large semi-rheophilic. Various <i>large semi-rheophilic</i> species expected and sampled at site and will be important indicator group for fast-flowing habitats. Representatives of small-rheophilic and limnophilic guild also present 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.		

**General comments:**

FRAI APPLICATION: Most of the available habitats (velocity-depth and cover classes) were sampled adequately at the site as well as additional site upstream of EFR site (FD sampling generally difficult, but adequately sampled using electrofishing from boat). Although habitats at the site may be atypical of reach (higher habitat diversity related to secondary channel), it should provide an indication of the “best case scenario” in terms of fish diversity.

NB: Overall fish abundance very low (much lower than observed at downstream sites EFR3 & 4), especially for BAEN & LCAP. Most abundant species BTRI.

As observed at other sites, very few to no fish utilize SD with reeds (instream and overhang) along edge of channel (marginal zone).

Right bank of EFR site had abundant gravel-cobble beds that would be suitable yellowfish spawning site.

Good spawning habitat for most of fish species in side channel.

Sediment regime altered (upstream weir and dam)

Temperature regime altered by inundation of dam and weir.

Dam and even weir a definite migration barrier to fish during low flows (and possibly high flows as well).

**Site EFR 03: Augrabies**

Various sub-sites were sampled at the EFR site or within the reach using most applicable sampling techniques (Table E.12). The habitat of each sub-site is described and the sampling effort provided in Table E.12. Habitat Cover ratings is also provided for each sub-site in Table E.13.

**Table E. 12: Description of fish sub-sites sampled in reach EFR 03: Augrabies**

SUB-SITE	DESCRIPTION	SAMPLING EFFORT
Sub-site 1	FD, FS, SD & SS. Abundant bedrock and boulder (esp. in FD & FS), reeds as overhang and instream veg. along edge, inundated grass on sand banks (grazed)	EB 65min
Sub-site 2	SS with inundated grass, FS & FD over rocks (boulders & cobbles), SD with sand, grass and silt.	EW 55 min (2 samplers). 2 x small (30m) anchovy seine net.
Sub-site 3	SD along reeds.	3 hours
Sub-site 4a	FS & FD over rocks	EB: 13 km of reach covered in boat. Approximately 60min in total.
Sub-site 4b	SS with inundated vegetation and stones (out of current)	
Sub-site 4c	SD (along edge) with reeds as instream and overhanging vegetation.	

EW: Electrofishing through wading.

EB: Electrofishing from boat.

**Table E. 13: Fish habitat assessment (sampled) at each sub-site.**

Velocity-Depth Category:	SLOW-DEEP				SLOW-SHALLOW			
	1	2	3	4	1	2	3	4
ABUNDANCE:	3	1	5	3	2	3	0	1
Overhanging vegetation:	3	0	2	3	1	0	0	2
Undercut banks & root wads:	1	0	1	2	0	0	0	0
Substrate:	3	1	0	3	2	1	0	2
Instream vegetation:	2	2	3	2	3	2	0	2
Water Column:	5	5	5	5	1	1	0	1
Velocity-Depth Category:	FAST-DEEP				FAST-SHALLOW			
	1	2	3	4	1	2	3	4
ABUNDANCE:	3	2	1	2	2	2	0	1
Overhanging vegetation:	3	0	1	3	1	0	0	1
Undercut banks & root wads:	1	0	0	1	0	0	0	0
Substrate:	4	3	0	3	4	4	0	4
Instream vegetation:	0	0	3	2	1	0	0	0
Water Column:	5	5	5	5	1	1	0	1

0 – absent; 1 – rare; 2 – sparse; 3 – common; 4 - abundant; 5 – very abundant

Ten indigenous and another 2 alien fish species were sampled at the different sub-sites (Table E.14). A habitat profile of where each species was sampled or observed for this reach is provided in Table E.15, indicating general habitat preferences of fish species at the site/in reach.

**Table E. 14: Presence in number of individuals (and size range in mm) of different fish species sampled at the different sub sites (May/June 2010) and their relative size-flow guild.**

Species	Size Flow-guild classification	Sub-site 1	Sub-site 2	Sub-site 3	Sub-site 4a	Sub-site 4b	Sub-site 4c
BAEN	Large semi-rheophilic	8 (100-350)	3 (50-150)		n.c. (50-500)		
BKIM	Large semi-rheophilic	1 (450)					
BPAU	Small semi-rheophilic		1 (60)				
BTRI	Small semi-rheophilic	2 (40-60)	29 (40-80)				
CCAR*	n/a						1 (400)
CGAR	Large semi-rheophilic	1 (800)		1 (700)			
GAFF*	n/a		2				
LCAP	Large semi-rheophilic	20 (250-400)	6 (60-100)		n.c.		
MBRE	Small semi-rheophilic	10 (20-45)	13 (30-60)				50 (30-50)
OMOS	Large limnophilic	3 (140-150)	9 (30-40)			12 (30-80)	
PPHI	Small limnophilic		3 (25-40)				
TSPA	Intermediate limnophilic					2 (40-70)	

n/a – not applicable (\*alien species)

n.c. – Not counted

**Table E. 15: Fish habitat profile based on habitats where different fish species were observed or sampled at the site EFR O3: Augrabies**

	SLOW-DEEP	SLOW-SHALLOW	FAST-DEEP	FAST-SHALLOW
Overhanging vegetation (mostly reeds)	No fish	No fish	No fish	No fish
Undercut banks & root wads:	Not sampled/available	Not sampled/available	Not sampled/available	Not sampled/available
Substrate:	LCAP, BAEN, BKIM, BTRI, MBRE	MBRE	LCAP, BAEN, BKIM, BTRI	LCAP (J), BTRI (A&J)
Instream vegetation:	CGAR (A), MBRE, BPAU, PPHI	OMOS (A&J), MBRE, BPAU, PPHI		

Water Column:	CGAR (A), BAEN, BKIM, LCAP		CGAR (A), BAEN, BKIM, LCAP	
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\*Alien species; J- juvenile; A - adult

Suitability of the site to be utilised in setting flows (ecological water requirement) in terms of fish is provided in Table E.16.

**Table E. 16: Suitability score of site in terms of EFR.**

SUITABILITY SCORES		Comments
EFR SITE SUITABILITY	2.8	Flow sensitive habitats for fish (FS & FD) well represented at site. Moderate habitat diversity at site. In the absence of rheophilic species in the Orange River system, next best indicator guild (in terms of setting flows) expected to be large semi-rheophilic. Various <i>large semi-rheophilic</i> species expected and sampled at site and will be important indicator group for fast-flowing habitats. Representatives of small-rheophilic and limnophilic guild also present 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.		

**General comments:**

*FRAI APPLICATION:* Most of the available habitats (velocity-depth and cover classes) were sampled adequately at the site as well as in additional 13km river section sampled upstream of EFR site.

LCAP seems to be less abundant than at site EFR04: Violsdrift.

Mostly deep wide channels/long pools with intermittent rapids/runs. Wide deep channel with dense reeds as marginal vegetation.

Gravel and cobble beds on bends for spawning habitat.

Sandy gravel beds also present on bends with vegetation for fish species with preference for this habitat type.

Consider the maintenance of sand/gravel and even mud banks/bars required for establishment of vegetation.

Riparian zone seems close to natural and very dense.

Reeds along edges (mostly SD) again observed to be a “dead zone” at time of sampling with very limited fish sampled/observed in these areas.

Side channels occur at the site (dry during sampling), with vegetation (grasses), rocks and gravel beds, which would provide good spawning and nursery habitat at higher flows when inundated.

At the time of sampling a good riffle area existed at the cross section – good for larger semi-rheophilics i.t.o. habitat and feeding.

Density or abundance of fish seemed to be low at the time of sampling, with most fish sampled in FD.

In the reach - FS vegetated habitats with sandy and/or gravel substrate (on bends or at in-stream islands) also seemed to be more productive i.t.o. fish sampling.

#### **Site EFR 04: Violsdrift**

Various sub-sites were sampled at the EFR site or within the reach using most applicable sampling techniques (Table E.17). The habitat of each sub-site is described and the sampling effort provided in Table E.17. Habitat Cover ratings are also provided for each sub-site in Table E.18.

**Table E. 17: Description of fish sub-sites sampled in reach EFR 04: Violsdrift**

SUB-SITE	DESCRIPTION	SAMPLING EFFORT
Sub-site 1	FS, FD, SS & SD. Rocks, reeds along edges as overhanging and instream vegetation.	EB: 45 min
Sub-site 2	SS & SD with reeds, logs & roodwads	EB: 30 min
Sub-site 3	Below weir: FS, SS & FD over rocks, reeds provide instream vegetation and overhang.	EW: 28 min
Sub-site 4	13km stretch of river: mostly SD & FD with limited FS & SS. Reeds along edges and rocky areas and substrates provide cover. Also overhang from trees.	EB: 13 km stretch covered. In total approximately 80 min electrofishing.

EW: Electrofishing through wading.

EB: Electrofishing from boat.

**Table E. 18: Fish habitat assessment (sampled) at each sub-site.**

Velocity-Depth Category:	SLOW-DEEP				SLOW-SHALLOW			
	1	2	3	4	1	2	3	4
ABUNDANCE:	2	5	0	4	2	1	2	1
Overhanging vegetation:	0	2	0	2	0	0	1	1
Undercut banks & root wads:	0	1	0	1	0	2	0	0
Substrate:	4	2	0	3	4	3	4	2
Instream vegetation:	1	4	0	3	1	2	2	1
Water Column:	5	5	0	5	1	0	1	1
Velocity-Depth Category:	FAST-DEEP				FAST-SHALLOW			
	1	2	3	4	1	2	3	4
ABUNDANCE:	4	1	2	2	2	0	4	1
Overhanging vegetation:	0	1	1	1	0	0	1	1
Undercut banks & root wads:	0	2	0	2	0	0	0	0
Substrate:	5	4	4	4	5	0	4	4

Instream vegetation:	1	2	1	2	1	0	1	1
Water Column:	5	5	3	5	1	0	1	1

0 – absent; 1 – rare; 2 – sparse; 3 – common; 4 - abundant; 5 – very abundant

Eleven indigenous and 1 alien fish species were sampled at the different sub-sites (Table E.19). A habitat profile of where each species was sampled or observed for this reach is provided in Table E.20, indicating general habitat preferences of fish species at the site/in reach.

**Table E. 19: Presence in number of individuals (and size range in mm) of different fish species sampled at the different sub sites (May/June 2010) and their relative size-flow guild.**

Species	Size Flow-guild classification	Sub-site 1	Sub-site 2	Sub-site 3	Sub-site 4
BAEN	Large semi-rheophilic	7 (50-450) 2 anomalies		13 (20-450)	n.c.
BHOS	Small semi-rheophilic			47 (70-90)	n.c.
BKIM	Large semi-rheophilic	1 (400)			
BPAU	Small semi-rheophilic	1 (50)		1 (70)	n.c.
BTRI	Small semi-rheophilic	7 (35-75)		38	
CCAR*	n/a		2 (400-600)		
CGAR	Large semi-rheophilic		1 (1200)	1 (300) anomaly	
LCAP	Large semi-rheophilic	48 (35-400)	15 (50-400)	37 (100-200)	n.c.
MBRE	Small semi-rheophilic	60 (35-80)	8 (35-80)	38	n.c.
OMOS	Large limnophilic	9 (50-140)		14 (50-100)	
PPHI	Small limnophilic	1 (45)	1 (50)		
TSPA	Intermediate limnophilic	1 (50)		24 (40-45)	n.c.

n/a – not applicable (alien species)

n.c. – Not counted

**Table E. 20: Fish habitat profile based on habitats where different fish species were observed or sampled at the site EFR O4: Violdsdrift**

	SLOW-DEEP	SLOW-SHALLOW	FAST-DEEP	FAST-SHALLOW
Overhanging vegetation	CGAR (A)			
Undercut banks & root wads:				

Substrate:	LCAP (A&J), MBRE (A&J), BTRI, BKIM (A)	LCAP (J), MBRE (A&J), BAEN (J)	LCAP (A), MBRE (A&J), BKIM (A), BAEN (A&J), BHOS	LCAP (J&A), MBRE (A&J), BAEN (J), BTRI, BHOS
Instream vegetation:	CGAR (A)	OMOS (J), TSPA (A), PPHI, BPAU	MBRE	MBRE
Water Column:	LCAP (A&J), MBRE (A), CCAR*	TSPA (A), OMOS (J), PPHI	LCAP (A)	

\*Alien species; J- juvenile; A – adult

Suitability of the site to be utilised in setting flows (ecological water requirement) in terms of fish is provided in Table E.21.

**Table E. 21: Suitability score of site in terms of EFR.**

SUITABILITY SCORES		Comments
EFR SITE SUITABILITY	2.8	Flow sensitive habitats for fish (FS & FD) well represented at site. Moderate habitat diversity at site. In the absence of rheophilic species in the Orange River system, next best indicator guild (in terms of setting flows) expected to be large semi-rheophilic. Various <i>large semi-rheophilic</i> species (including BKIM) expected and sampled at site and will be important indicator group for fast-flowing habitats. Representatives of small-rheophilic and limnophilic guild also present 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.

### General comments:

FRAI APPLICATION: Most of the available habitats (velocity-depth and cover classes) were sampled adequately at the site as well as in additional 13km river section sampled downstream of EFR site. Site also sampled directly below weir upstream of EFR site.

Reeds along edges (mostly SD) observed to be a “dead zone” at time of sampling with very limited fish sampled/observed in this habitat.

Most potadromous fish species should be able to successfully negotiate upstream weir (limited migration barrier to small species or juveniles)

LCAP very abundant at site, with yellowfish also being abundant (especially in rapid-run habitats)

BHOS sampled in relatively fast flowing water (below weir).

Good rapid and riffle habitat at site. FD dominant. Instream aquatic vegetation not abundant (little or few vegetated areas) at site.

OMOS, PPHI, and CGAR sampled in *Phragmites*.

In-stream aquatic vegetation species identified, of importance for fish, at site and reach are *Cyperus marginatus* (water reed), *Persicaria serrulata* (snake roots and knot weeds), and *Cynodon*

*dactylon* (water grass). These plants provide cover and habitat for fish and need sediment (including pebbles, gravel, sand, and mud) to establish.

The *Phragmites* does not seem to provide adequate or preferred habitat for fish (cover, feeding etc.). The other vegetation species as mentioned above seem to be the preferred vegetation types by fish for habitat as indicated by the fish sampled.

### **Site EFR C5: Upper Caledon**

Representative sections of all available habitat were sampled at the EFR site or within the reach using most applicable sampling techniques (Table E.23). The habitat sampled is described and the sampling effort provided in Table E.23. Habitat Cover ratings is also provided for each sub-site in Table E.24.

**Table E. 22: Description of fish sub-sites sampled in reach EFR 01: Hopetown.**

SUB-SITE	DESCRIPTION	SAMPLING EFFORT
Sub-site 1	FS, SS & SD over bedrock, boulders, cobbles. Substrate covered with algae and sediment. Very limited sedges (inundated), some overhanging vegetation provided by grass, shrubs and poplars. Limited undercut banks.	45min EW

EW: Electrofishing through wading.

**Table E. 23: Fish habitat assessment (sampled) at the site (June 2010).**

Velocity-Depth Category:	SLOW-DEEP	SLOW-SHALLOW	FAST-DEEP	FAST-SHALLOW
ABUNDANCE:	1	3	0	3
Overhanging vegetation:	2	2		1
Undercut banks & root wads:	2	1		1
Substrate:	2	3		3
Instream vegetation:	1	2		1
Water Column:	3	1		1

0 – absent; 1 – rare; 2 – sparse; 3 – common; 4 - abundant; 5 – very abundant

Only one indigenous fish species, namely the Small-mouth yellowfish (*Labeobarbus aeneus*) was sampled at the site during June 2010 (Table E.25). A habitat profile of where the species was sampled or observed for this reach is provided in Table E.26, indicating general habitat preferences of fish species.



**Table E. 24: Presence in number of individuals (and size range in mm) of different fish species sampled at the different sub sites (June 2010) and their relative size-flow guild.**

Species	Size Flow-guild classification	Sub-site 1
BAEN	Large semi-rheophilic	1 (85)

**Table E. 25: Fish habitat profile based on habitats where different fish species were observed or sampled at the site EFR C5.**

	SLOW-DEEP	SLOW-SHALLOW	FAST-DEEP	FAST-SHALLOW
Overhanging vegetation:				
Undercut banks & root wads:				
Substrate:		BAEN (J) over sand/silt.		
Instream vegetation:				
Water Column:				

\*Alien species; J- juvenile; A - adult

Suitability of the site to be utilised in ecological water requirement study in terms of fish is provided in Table E.27.

**Table E. 26: Suitability scores of site in terms of EFR application.**

SUITABILITY SCORES		Comments
EFR SITE SUITABILITY	2.2	Flow sensitive habitats for fish (FS & FD) very well represented at site. Habitat diversity at site representative of those expected under natural conditions (potentially some loss of deep areas due to sedimentation). In the absence of rheophilic species in the area (none expected under natural conditions), next best guild for determining flow requirements should be the large semi-rheophilic guild. One <i>large semi-rheophilic</i> species sampled at site during survey, which may be an important indicator group for fast-flowing habitats. The low fish species diversity (natural and present) however reduced the applicability of fish in setting flows for the site, resulting in overall moderate site suitability.
0: Not suitable, 1 - 1.9: very low suitability, 2 - 2.9: Moderate suitability,		
3 - 3.9: High suitability, 4 - 5: Very high suitability.		

**General comments:**

*FRAI application:* Site typical of reach and should be representative of fish assemblage present in the reach. Relatively high habitat diversity (flow-depth and cover features) at site.

Due to survey conducted in mid-winter, fish results of low confidence. During these very cold periods (water temperature was 5° at time of sampling), the fish tend to move into deep pools and dams to avoid extreme temperature fluctuations. Their metabolism furthermore becomes very low and they hardly move around. Sampling success, even in these deep refuge areas, are therefore very low.

Extensive sedimentation (catchment and bank erosion) as well as substrate algae on rocks (possible indication of nutrient enrichment).

Other potential impact on fish may be related to presence of predatory alien fish species (known presence of trout and bass in the area).

**Site EFR C6: Lower Caledon**

Representative sections of all available habitat were sampled at the EFR site or within the reach using most applicable sampling techniques (Table E.28). The habitat sampled is described and the sampling effort provided in Table E.28. Habitat Cover ratings is also provided for each sub-site in Table 29.

**Table E. 27: Description of fish sub-sites sampled in reach EFR 01: Hopetown.**

SUB-SITE	DESCRIPTION	SAMPLING EFFORT
Sub-site 1	FS, FD, SS & SD over bedrock / boulders. No vegetation. Sand/silt. Very high turbidity.	40 min EW
Sub-site 2	SD & SS along edge over sand with phragmites stems in water (IV)	10 min EW
Sub-site 3	SS & SD along edge over sand/silt. Some bedrock/cobbles. No vegetation. Downstream of rapid.	28min EW
Sub-site 4	SS, SD & FS over gravel, sand & silt. In main stream (include some SVS & FVS)	8 min EW
Sub-site 5	SS, SD with flow over sand, gravel, cobbles along edge of river.	8 min EW
Sub-site 6	SD along reeds (some rootwads)	8 min EB
Sub-site 7	SD in middle of river.	5 min EB
Sub-site 8	SD, SS over bedrock	5 min EB
Sub-site 9	FS & FD	5 min EB
Sub-site 10	SS & SD along edge over gravel/sand/silt/cobbles.	3 small seine nets.

EW: Electrofishing through wading

EB – Electrofishing from boat

IV – instream vegetation

**Table E. 28: Fish habitat assessment (sampled) at the sub-sites (June 2010).**

Velocity-Depth Category:	SLOW-DEEP					SLOW-SHALLOW				
SUB-SITE:	1	2	3	4	5	1	2	3	4	5
ABUNDANCE:	1	3	3	2	3	2	3	3	3	3
Overhanging vegetation:	0	1	0	0	0	0	1	0	0	0
Undercut banks & root wads:	0	2	0	0	0	0	2	0	0	0
Substrate:	3	1	2	2	2	3	1	2	2	2
Instream vegetation:	0	1	0	0	0	0	1	0	0	0
Water Column:	3	3	3	3		1	1	1	1	1

Velocity-Depth Category:	SLOW-DEEP					SLOW-SHALLOW				
SUB-SITE:	6	7	8	9	10	6	7	8	9	10
ABUNDANCE:	4	5	3	1	3	1	0	2	2	3
Overhanging vegetation:	2	0	0	0	0	2	0	0	0	0
Undercut banks & root wads:	3	0	0	0	0	3	0	0	0	0
Substrate:	1	3	4	3	2	1	0	4	3	2
Instream vegetation:	1	0	0	0	0	1	0	0	0	0
Water Column:	4	5	0	3	3	1	0	0	1	1

Velocity-Depth Category:	FAST-DEEP					FAST-SHALLOW				
SUB-SITE:	1	2	3	4	5	1	2	3	4	5
ABUNDANCE:	2	0	0	0	0	3	0	0	3	0
Overhanging vegetation:	0	0	0	0	0	0	0	0	0	0
Undercut banks & root wads:	0	0	0	0	0	0	0	0	0	0
Substrate:	3	0	0	0	0	3	0	0	2	0
Instream vegetation:	0	0	0	0	0	0	0	0	0	0
Water Column:	3	0	0	0	0	1	0	0	1	0

Velocity-Depth Category:	FAST-DEEP					FAST-SHALLOW				
SUB-SITE:	6	7	8	9	10	6	7	8	9	10
ABUNDANCE:	0	0	0	2	0	0	0	0	3	0
Overhanging vegetation:	0	0	0	0	0	0	0	0	0	0
Undercut banks & root wads:	0	0	0	0	0	0	0	0	0	0
Substrate:	0	0	0	3	0	0	0	0	3	0
Instream vegetation:	0	0	0	0	0	0	0	0	0	0
Water Column:	0	0	0	3	0	0	0	0	1	0

0 – absent; 1 – rare; 2 – sparse; 3 – common; 4 - abundant; 5 – very abundant

Two indigenous fish species, namely the Small-mouth yellowfish (*Labeobarbus aeneus*) and Orange-Vaal labeo (*Labeo capensis*) were sampled at the site during June 2010 (Table E.30).

Another indigenous species, the Sharptooth catfish (*Clarias gariepinus*) was observed. A habitat profile of where the species was sampled or observed for this reach is provided in Table E.31, indicating general habitat preferences of fish species.

**Table E. 29: Presence in number of individuals (and size range in mm) of different fish species sampled at the different sub sites (June 2010) and their relative size-flow guild.**

Species	Size Flow-guild classification	Sub-site 1	Sub-site 2	Sub-site 3	Sub-site 4	Sub-site 5	Sub-site 6	Sub-site 7	Sub-site 8	Sub-site 9	Sub-site 10
BAEN	Large semi-rheophilic		No fish	9 (30-60)	No fish			1 (250)	3 (150 - 300)	No fish	6 (40-60)
CGAR	n/a	1 observed									
LCAP	Large semi-rheophilic	2 (40-60)		8 (50-90)		31 (40-70)	1 (60)	2 (100 - 120)	3 (150 - 200)		18 (20 - 70)

**Table E. 30: Fish habitat profile based on habitats where different fish species were observed or sampled at the site EFR C5.**

	SLOW-DEEP	SLOW-SHALLOW	FAST-DEEP	FAST-SHALLOW
Overhanging vegetation:	Sampled, no fish.	Sampled, no fish.	None available	None available
Undercut banks & root wads:	Sampled, no fish.	Sampled, no fish.	None available	None available
Substrate:	LCAP(A & J) & BAEN (A&J) over bedrock. LCAP (J) & BAEN (J) over sand/silt.	LCAP (J) & BAEN (J) over bedrock. LCAP (J) & BAEN (J) over sand/silt.	Sampled, no fish.	Sampled, no fish.
Instream vegetation:	Sampled, no fish.	Sampled, no fish.	None available	None available
Water Column:	BAEN (A) & LCAP (A)			

J- juvenile; A - adult

Suitability of the site to be utilised in ecological water requirement study in terms of fish is provided in Table E.32.

**Table E. 31: Suitability scores of site in terms of EFR application**

SUITABILITY SCORES		Comments
EFR SITE SUITABILITY	2.5	Flow sensitive habitats for fish (FS & FD) well represented at site. Moderate habitat diversity at site. Overall habitat diversity at site moderate with most flow-depth categories well represented. In the absence of rheophilic species in the area (none expected under natural conditions), next best guild for determining flow requirements should be the large semi-rheophilic guild. Two <i>large semi-rheophilic</i> species sampled at site during survey, which should be useful indicators for setting flows (due to their requirement for flowing habitats in some-life stages). The low fish species diversity (natural and present) however reduced the applicability and value of fish as a biotic group in setting flows for the site, resulting in overall moderate site suitability.

0: Not suitable, 1 - 1.9: very low suitability, 2 - 2.9: Moderate suitability, 3 - 3.9: High suitability, 4 - 5: Very high suitability.

### General comments:

*FRAI application:* Site have highest habitat diversity of average site in reach, therefore provides highest possibility of sampling any fish species that may be present in the reach.

Due to survey conducted in mid-winter, fish results of low confidence. During these very cold periods (water temperature was 5° at time of sampling), the fish tend to move into deep pools and dams to avoid extreme temperature fluctuations. Their metabolism furthermore becomes very low and they hardly move around. Sampling success, even in these deep refuge areas, are therefore very low.

Extremely high turbidity at time of sampling could be limiting factor for fish. Atypical for this time of year according to locals. Flow also higher than normal for this season.

Extensive sedimentation/siltation

Other potential impact on fish may be related to presence of predatory alien fish species.

### Site EFR K7: Lower Kraai

Representative sections of all available habitat were sampled at the EFR site or within the reach using most applicable sampling techniques (Table E.33). The habitat sampled is described and the sampling effort provided in Table E.33. Habitat Cover ratings is also provided for each sub-site in Table E.34.

**Table E. 32: Description of fish sub-sites sampled in reach EFR 01: Hopetown.**

SUB-SITE	DESCRIPTION	SAMPLING EFFORT
Sub-site 1	Secondary channel on LB. FVS, FS, SS, SVS, SD over boulders, cobbles, gravel. Some sedimentation and overhanging	8 min EW

	vegetation from dead grass and trees.	
Sub-site 2	FS & FD over cobbles, boulders, gravel.	19 min EW
Sub-site 3	SS & SD over cobbles and boulders (some siltation).	12 min EW
Sub-site 4	SS, SD & FD mostly over bedrock, with some boulders, cobbles. High level of siltation.	7 min EW
Sub-site 5	FS & FD over bedrock & cobbles. Some algae and siltation.	5 min EW
Sub-site 6	FD & SD over rocks.	10 min EW
Sub-site 7	SD & SS. Margin with overhang (Willows, sedges and rootwads)	8 min EW
Sub-site 8	SS & SD. Large bedrock overhanging and into water.	12 min EW

EW: Electrofishing through wading

EB – Electrofishing from boat

IV – instream vegetation

**Table E. 33: Fish habitat assessment (sampled) at the sub-sites (June 2010).**

Velocity-Depth Category:	SLOW-DEEP					SLOW-SHALLOW				
	1	2	3	4	5	1	2	3	4	5
ABUNDANCE:	2	0	3	1	0	4	0	3	3	0
Overhanging vegetation:	2	0	0	0	0	2	0	0	0	0
Undercut banks & root wads:	3	0	0	0	0	2	0	0	0	0
Substrate:	3	0	4	2	0	3	0	4	3	0
Instream vegetation:	1	0	0	0	0	1	0	0	0	0
Water Column:	3	0	3	2	0	1	0	1	1	0

Velocity-Depth Category:	SLOW-DEEP					SLOW-SHALLOW				
	6	7	8			6	7	8		
ABUNDANCE:	3	4	4			0	1	2		
Overhanging vegetation:	0	3	0			0	2	0		
Undercut banks & root wads:	0	3	0			0	3	1		
Substrate:	4	1	4			0	1	3		
Instream vegetation:	0	0	0			0	0	0		
Water Column:	5	3	5			0	1	1		

Velocity-Depth Category:	FAST-DEEP					FAST-SHALLOW				
	1	2	3	4	5	1	2	3	4	5
ABUNDANCE:	0	4	0	0	0	1	3	0	1	3
Overhanging vegetation:	0	0	0	0	0	0	0	0	0	0
Undercut banks & root wads:	0	0	0	0	0	0	0	0	0	0
Substrate:	0	4	0	0	0	3	4	0	1	4
Instream vegetation:	0	1	0	0	0	0	0	0	0	0
Water Column:	0	3	0	0	0	1	1	0	1	1

Velocity-Depth Category:	FAST-DEEP					FAST-SHALLOW				
SUB-SITE:	6	7	8			6	7	8		
ABUNDANCE:	3	0	0			0	0	0		
Overhanging vegetation:	0	0	0			0	0	0		
Undercut banks & root wads:	0	0	0			0	0	0		
Substrate:	4	0	0			0	0	0		
Instream vegetation:	0	0	0			0	0	0		
Water Column:	5	0	0			0	0	0		

0 – absent; 1 – rare; 2 – sparse; 3 – common; 4 - abundant; 5 – very abundant

Two indigenous fish species, namely the Small-mouth yellowfish (*Labeobarbus aeneus*) and Orange-Vaal labeo (*Labeo capensis*) were sampled at the site during June 2010 (Table E.35). A habitat profile of where the species was sampled or observed for this reach is provided in Table E.36, indicating general habitat preferences of fish species.

**Table E. 34: Presence in number of individuals (and size range in mm) of different fish species sampled at the different sub sites (June 2010) and their relative size-flow guild.**

Species	Size Flow-guild classification	Sub-site 1	Sub-site 2	Sub-site 3	Sub-site 4	Sub-site 5	Sub-site 6	Sub-site 7	Sub-site 8
BAEN	Large semi-rheophilic	3 (40-120)	1 (280)	39 (40-100)	12 (40-60)	No fish	No fish	3 (30-60)	
LCAP	Large semi-rheophilic			3 (50-60)	2 (40-70)			2 (50/60)	3 (30-60)

**Table E. 35: Fish habitat profile based on habitats where different fish species were observed or sampled at the site EFR C5.**

	SLOW-DEEP	SLOW-SHALLOW	FAST-DEEP	FAST-SHALLOW
Overhanging vegetation:	Limited available LCAP (J) & BAEN (J)	Limited available BAEN (J)	None available	None available
Undercut banks & root wads:	(Willows) BAEN & LCAP	None available	None available	None available
Substrate:	LCAP (J) & BAEN (J) over boulders.	LCAP (J) & BAEN (J) over bedrock & boulders.	BAEN (A)	No fish. Adequately sampled.
Instream vegetation:	None available	None available	None available	None available
Water Column:	Sampled, no fish.		Sampled, no fish.	

J- juvenile; A - adult

Suitability of the site to be utilised in ecological water requirement study in terms of fish is provided in Table E.37.

**Table E. 36: Suitability scores of site in terms of EFR application.**

SUITABILITY SCORES		Comments
EFR SITE SUITABILITY	2.8	Flow sensitive habitats for fish (FS & FD) well represented at site. Overall habitat diversity at site very good with all flow-depth categories well represented. Moderate habitat diversity at site. In the absence of rheophilic species in the area (none expected under natural conditions), next best guild for determining flow requirements should be the large semi-rheophilic guild. Two <i>large semi-rheophilic</i> species sampled at site during survey, which should be useful indicators for setting flows (due to their requirement for flowing habitats in some-life stages). The low fish species diversity (natural and present) however reduced the applicability and value of fish as a biotic group in setting flows for the site, resulting in overall moderate site suitability.

0: Not suitable, 1 - 1.9: very low suitability, 2 - 2.9: Moderate suitability, 3 - 3.9: High suitability, 4 - 5: Very high suitability.

**General comments:**

- FRAI application: Site have highest habitat diversity of average site in reach, therefore provides highest possibility of sampling any fish species that may be present in the reach.
- Due to survey conducted in mid-winter, fish results of low confidence. During these very cold periods, the fish tend to move into deep pools and dams to avoid extreme temperature fluctuations. Their metabolism furthermore becomes very low and they hardly move around. Sampling success, even in these deep refuge areas, are therefore very low.
- Fast waters in general dead zones with very few individuals. Most probably related to seasonal variation in distribution at site (colder periods move into slower water).
- Although fish did not utilise fast habitats, important to maintain flow to ensure adequate water quality in slow habitats.



#### E.4 SUMMARY

A total of 11 indigenous fish species native to the Orange River, 1 translocated species (OMOS) and 3 alien fish species were sampled during the May/June 2010 survey at 4 EFR sites in the Orange River (Table E.41). These species represent all size-flow guilds present in the Orange River system, namely small and large semi-rheophilic, as well as small-and large limnophilic. A habitat profile of where each species was sampled or observed during the survey is provided in Table E.42, indicating general habitat preferences of fish species as observed during the current survey. Suitability of each site to be utilised in setting flows (ecological water requirement) in terms of fish is provided in Table E.43.

**Table E.41: Presence of different fish species sampled at the different sites (May/June 2010) and their relative size-flow guild.**

Species	Size Flow-guild classification	EFR O1	EFR O2	EFR O3	EFR O4
ASCL	Large semi-rheophilic				
BAEN	Large semi-rheophilic				
BHOS	Small semi-rheophilic				
BKIM	Large semi-rheophilic				
BPAU	Small semi-rheophilic				
BTRI	Small semi-rheophilic				
CCAR*	n/a				
CGAR	Large semi-rheophilic				
CIDE*	n/a				
GAFF*	n/a				
LCAP	Large semi-rheophilic				
MBRE	Small semi-rheophilic				
OMOS (T)	Large limnophilic				
PPHI	Small limnophilic				
TSPA	Intermediate limnophilic				

n/a – not applicable (alien species), T - translocated

**Table E.42: Summarised fish habitat profile based on habitats where different fish species were observed or sampled during the survey (all sites combined)**

	SLOW-DEEP	SLOW-SHALLOW	FAST-DEEP	FAST-SHALLOW
Overhanging vegetation	PPHI, TSPA, CGAR (A) BTRI, LCAP	PPHI, TSPA		
Undercut banks & root wads:		Roots: TSPA, PPHI, BTRI		

Substrate:	LCAP (A&J), MBRE (A&J), BKIM (A), BTRI (J&A), CGAR (J), CIDE* (J), BAEN,	LCAP (J), MBRE (A&J), BAEN (J) CCAR* (J), PPHI, TSPA (with veg. & rocks), BPAU (veg. & sand)	MBRE (A&J), BKIM (A), BAEN (A&J). BHOS, ASC (A&J) (more in FI), LCAP (J&A), BTRI (A),	LCAP (J&A), MBRE (A&J), BAEN (J), BHOS, ASCL (A&J) BTRI (A&J),
Instream vegetation:	CGAR (A), PPHI (A&J), TSPA (J&A), BPAU (A), GAFF*, MBRE, BPAU	OMOS (J), TSPA (A), PPHI, BTRI Sand & veg.: GAFF*, BPAU (A&J), MBRE		Sand & veg.: TSPA, BTRI
Water Column:	LCAP (A&J), MBRE (A), CCAR* BAEN, BTRI, CGAR (A), BKIM,	TSPA (A), OMOS (J), PPHI	LCAP (A) CGAR (A), BAEN, BKIM	

\*Alien species; J- juvenile; A - adult

**Table E.43: Summary of suitability scores of each site for setting ecological water requirements in terms of fish.**

EFR SITE	SUITABILITY SCORES	Comments
EFR02: Boegoeberg	3.5	Flow sensitive habitats for fish (FS & FD) very well represented at site. High habitat diversity with various secondary canals at site. In the absence of rheophilic species in the Orange River system, next best guild expected to be large semi-rheophilic. Various <i>large semi-rheophilic</i> species expected and sampled at site and will be important indicator group for fast-flowing habitats. Representatives of small-rheophilic and limnophilic guild also present at site.
EFR03: Augrabies	2.8	Flow sensitive habitats for fish (FS & FD) well represented at site. Moderate habitat diversity at site. In the absence of rheophilic species in the Orange River system, next best indicator guild (in terms of setting flows) expected to be large semi-rheophilic. Various <i>large semi-rheophilic</i> species expected and sampled at site and will be important indicator group for fast-flowing habitats. Representatives of small-rheophilic and limnophilic guild also present at site.
EFR04: Vioolsdrift	2.8	Flow sensitive habitats for fish (FS & FD) well represented at site. Moderate habitat diversity at site. In the absence of rheophilic species in the Orange River system, next best indicator guild (in terms of setting flows) expected to be large semi-rheophilic. Various <i>large semi-rheophilic</i> species (including BKIM) expected and sampled at site and will be important indicator group for fast-flowing habitats. Representatives of small-rheophilic and limnophilic guild also present at site.

EFR C5: Upper Caledon	2.2	Flow sensitive habitats for fish (FS & FD) very well represented at site. Habitat diversity at site representative of those expected under natural conditions (potentially some loss of deep areas due to sedimentation). In the absence of rheophilic species in the area (none expected under natural conditions), next best guild for determining flow requirements should be the large semi-rheophilic guild. One <i>large semi-rheophilic</i> species sampled at site during survey, which may be an important indicator group for fast-flowing habitats. The low fish species diversity (natural and present) however reduced the applicability of fish in setting flows for the site, resulting in overall moderate site suitability.
EFR C6: Lower Caledon	2.5	Flow sensitive habitats for fish (FS & FD) well represented at site. Moderate habitat diversity at site. Overall habitat diversity at site moderate with most flow-depth categories well represented. In the absence of rheophilic species in the area (none expected under natural conditions), next best guild for determining flow requirements should be the large semi-rheophilic guild. Two <i>large semi-rheophilic</i> species sampled at site during survey, which should be useful indicators for setting flows (due to their requirement for flowing habitats in some-life stages). The low fish species diversity (natural and present) however reduced the applicability and value of fish as a biotic group in setting flows for the site, resulting in overall moderate site suitability.
EFR K7: Lower Kraai	2.8	Flow sensitive habitats for fish (FS & FD) well represented at site. Overall habitat diversity at site very good with all flow-depth categories well represented. Moderate habitat diversity at site. In the absence of rheophilic species in the area (none expected under natural conditions), next best guild for determining flow requirements should be the large semi-rheophilic guild. Two <i>large semi-rheophilic</i> species sampled at site during survey, which should be useful indicators for setting flows (due to their requirement for flowing habitats in some-life stages). The low fish species diversity (natural and present) however reduced the applicability and value of fish as a biotic group in setting flows for the site, resulting in overall moderate site suitability.

0: Not suitable, 1 - 1.9: very low suitability, 2 - 2.9: Moderate suitability,  
3 - 3.9: High suitability, 4 - 5: Very high suitability.

**Table E..44: Summary of the spawning and migration specifications for the larger semi-rheophilic fish species (Skelton, 1993).**

Species	Flow and habitat needed
BKIM ( <i>Labeobarbus kimberleyensis</i> – Largemouth yellowfish)	Need gravel beds for spawning – mid to late summer. Eggs hatch within 2-3 days. Feed and free swimming 3-4 days later. Total flow duration needed for spawning – 5-7 days.
BAEN ( <i>Labeobarbus aeneus</i> – Smallmouth – yellowfish)	Need gravel beds for spawning – mid to late summer. Eggs hatch within 2-8 days. Feed and free swimming 4-6 days later. Total flow duration needed for spawning – 6-14 days.
LCAP ( <i>Labeo capensis</i> – Orange River Mudfish)	Need rocky rapids for spawning – summer. Eggs hatch within 3-4 days. Feed and free swimming 4-5 days later. Total flow duration needed for spawning – 7-9 days.

	Rapid growth.
LUMB ( <i>Labeo umbratus</i> – moggel)	Need shallow rocky areas or flooded grass banks for spawning – summer. Eggs hatch within 2 days. Feed and free swimming 2-4 days later. Total flow duration needed for spawning – 4-6 days. Rapid growth.
CGAR ( <i>Clarias gariepinus</i> – Sharptooth catfish)	Need vegetation – shallow grassy verges for spawning – summer. Eggs hatch within 1-2 days. Feed and free swimming 2-3 days later. Total flow duration needed for spawning – 3-5 days. Rapid growth. Known to migrate up to 60km upstream in fish river catchment.
ASCL ( <i>Austroglanis sclateri</i> – Rock catfish)	Not much known about this species. Lives in rocky habitat with flowing water, favouring rapids, where it most probably spawns.

**APPENDIX F. HYDRAULIC  
SITE SUITABILITY**

**F.1 ORANGE RIVER SITE 2 - BOEGEBERG****F.1.1 Positive attributes**

Reasonably uniform flow conditions at medium flows and above.

Location of gauging weir for determining discharges.

The data for the gauge (D7H008 - Zeekoebaart) is available at near real-time on the DWAF hydrology web site, making it useful for the collection of hydraulic data over the duration of the study.

**F.1.2 Negative attributes**

Location of site in bedrock morphology with rapidly varied flow conditions at low flows.

Multiple channels at medium/high-flows making it difficult to predict stage-discharge relationships in the absence of detailed topographical survey and two-dimensional hydraulic modelling.

Large and irregular nature of the bed substrate (cobbles, boulders & bedrock). Influence of vegetation on flow resistance at high flows. This makes resistance and energy slope predictions difficult for all flows, compromising the accuracy of the stage-discharge relationship.

Non-horizontal water surface across the inundated channel width at low-flows.

Possibility of pooled water at the cessation of flow.

**F.2 ORANGE RIVER SITE 3 - AUGRABIES****F.2.1 Positive attributes**

Reasonably uniform flow conditions at medium flows and above.

Location of gauging weir for determining discharges (though some distance upstream at Neusberg).

The data for the gauge (D7H014 -Neusberg) is available at near real-time on the DWAF hydrology web site, making it useful for the collection of hydraulic data over the duration of the study.

**F.2.2 Negative attributes**

Large and irregular nature of the bed substrate (cobbles, boulders & bedrock). This makes resistance and energy slope predictions difficult at low flows, compromising the accuracy of the stage-discharge relationship.

Possibility of pooled water at the cessation of flow.

**F.3 ORANGE RIVER SITE 4 - VIOOLSDRIF****F.3.1 Positive attributes**

Reasonably uniform flow conditions at medium flows and above.

Location of gauging weir for determining discharges.

The data for the gauge (D8H003 - Vioolsdrif) is available at near real-time on the DWAF hydrology web site, making it useful for the collection of hydraulic data over the duration of the study.

**F.3.2 Negative attributes**

Location of site in bedrock morphology with rapidly varied flow conditions at low flows.

Large and irregular nature of the bed substrate (cobbles, boulders & bedrock). This makes resistance and energy slope predictions difficult for all flows, compromising the accuracy of the stage-discharge relationship.

Non-horizontal water surface across the inundated channel width at low-flows.

Possibility of pooled water at the cessation of flow.

**F.4 CALEDON RIVER SITE 5****F.4.1 Positive attributes**

None.

**F.4.2 Negative attributes**

Location of site in bedrock morphology with rapidly varied flow conditions at low and medium flows.

Large and irregular nature of the bed substrate (cobbles, boulders & bedrock). This makes resistance and energy slope predictions difficult for all flows, compromising the accuracy of the stage-discharge relationship.

Non-horizontal water surface across the inundated channel width at low-flows.

Possibility of pooled water at the cessation of flow.

**F.5 CALEDON RIVER SITE 6****F.5.1 Positive attributes**

Reasonably uniform flow conditions at medium flows and above.

**F.5.2 Negative attributes**

Location of site in bedrock morphology with rapidly varied flow conditions at low flows.

Large and irregular nature of the bed substrate (cobbles, boulders & bedrock). This makes resistance and energy slope predictions difficult for all flows, compromising the accuracy of the stage-discharge relationship.

Non-horizontal water surface across the inundated channel width at low-flows.

Possibility of pooled water at the cessation of flow.

## **F.6 KRAAI RIVER SITE 7**

### **F.6.1 Positive attributes**

Reasonably uniform flow conditions at medium flows and above.

Location of gauging weir for determining discharges.

The data for the gauge (D1H001) is available at near real-time on the DWAf hydrology web site, making it useful for the collection of hydraulic data over the duration of the study.

### **F.6.2 Negative attributes**

Possibility of divided and two-dimensional flow patterns at low flows.

Possibility of non-horizontal water surface across the inundated channel width at low-flows.

Possibility of pooled water at the cessation of flow.

For these reasons (ie. negative attributes), an additional low-flow cross-section was positioned downstream of the "main" cross-section.