APPENDIX A. RIVER REACH DEMARCATION, DELINEATION AND SUITABILITY

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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[1] following a hierarchical approach according to the following considerations:

Broad natural physical reaches that constitute the river from its source downstream. These reaches are the result of the various drivers of the system under reference conditions, *viz*. Hydrology, Geomorphology and Physico-chemical attributes. It follows that the biota responded and adapted to these reference conditions (i.e., the broad natural habitat template) in a dynamic way depending on natural climatic variation. The boundaries between different broad natural reaches are not necessarily crisp and clear. However, where marked and rapid changes occur due to geology (e.g. geomorphology and physico-chemical changes) and hydrology (e.g. large tributaries or a change in climate) these boundaries may be easy to identify.

Smaller natural reaches may be distinguished within these large reaches. Depending on the characteristics of the biological group and taxa considered, the distribution of biota will broadly coincide with the demarcation of the natural reaches. However, depending on the attributes (e.g. preferences and intolerances) of the biota they may be limited to smaller natural reaches within the broad natural physical reaches. These will result in so-called biological habitat segments (e.g. fish habitat segments, Kleynhans 1999). Depending on the life-history requirements of the biota and the dynamic nature of the ecosystems, the boundaries of the habitat segments can vary temporally and spatially. Some biota may be limited to particular smaller reaches within the broad natural reach; others may be present throughout the broad natural reach while others may be present across two or more broad natural reaches. This must be considered when defining the reference biological assemblage for a particular river reach.

Superimposed on these natural reaches are the changes brought about by anthropogenic activities. These activities may result in a homogenous impact throughout the length of a broad natural reach or their impact may be heterogeneous and result in smaller distinguishable sub-reaches. Physical driver changes as well as biological change agents (e.g. alien biota) may be involved.

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

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.

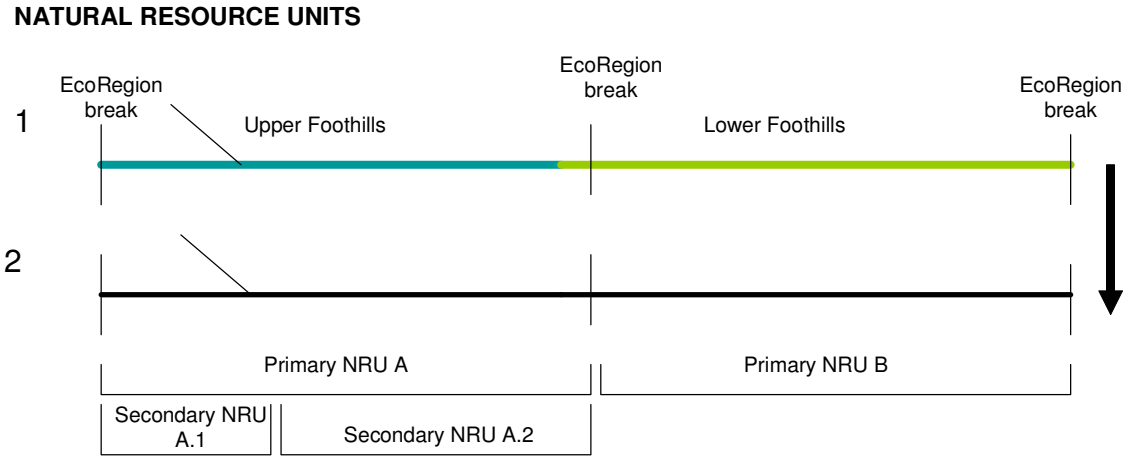

Figure A. 1 Delineation of National Resource Units

Table A. 1 Description of the rationale for the delination 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.

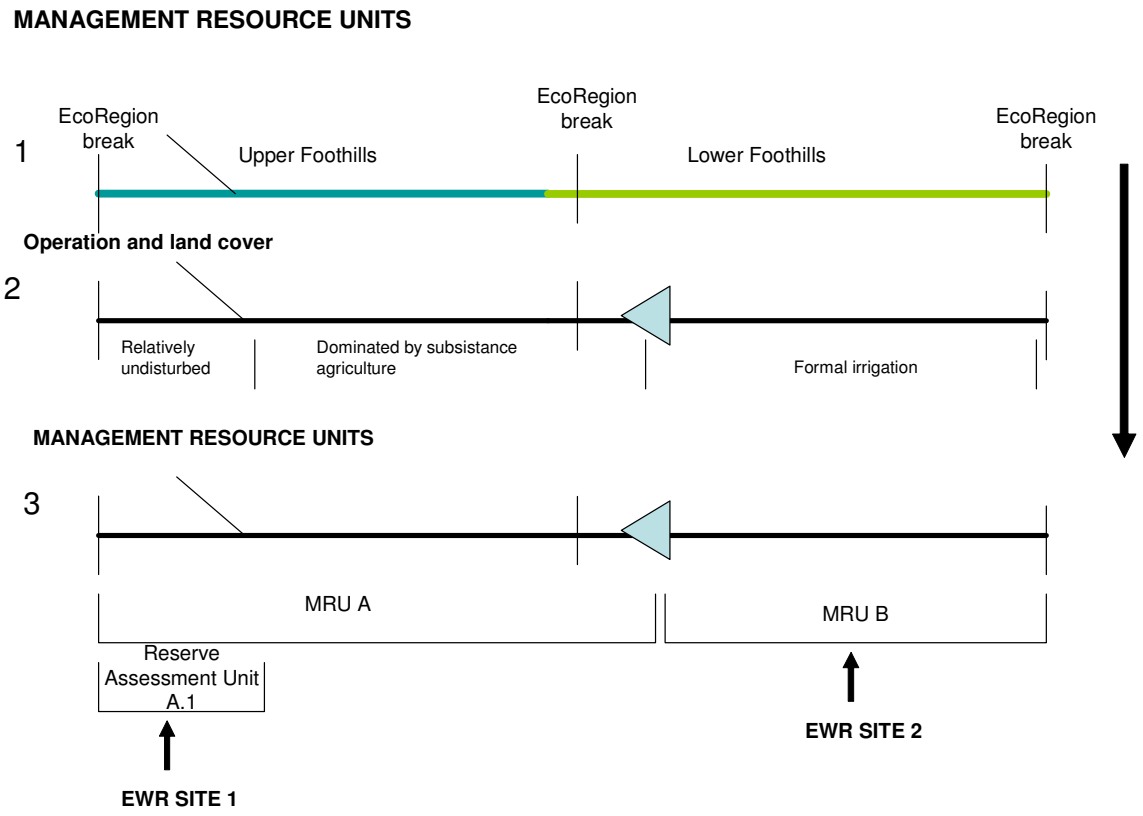

Figure A. 2 Delineation of Management Resource Units

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). Linked to this is the concept of "locality" which refers to the geographic area in which a collecting event occurs (porites.geology.uiowa.edu/entity.htm).

Ecological Water Requirement (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[2] (about >20 cm in length) rheophilics are present and abundant enough, they would usually be preferable to small rheophilics due to the larger amount of flowing habitat required which would indicate higher discharges. In cases where small rheophilics and large semi-rheophilics occur there may be a requirement for rheophilics during the dry season, but another requirement for large semi-rheophilics during the periods in the wet season when they breed.

The presence of semi-rheophilics. If rheophilics are absent, semi-rheophilics should be used as the subject to determine flow requirements. Semi-rheophilics require flowing water (usually fast) during the breeding season. However, flowing water do not necessarily have to be present during the whole duration of the wet season. Duration of flow for rheophilics during the wet season will be determined by the length of time required for successful spawning, hatching and growth of larvae to juveniles. The size of the semi-rheophilics considered is also important as this will have an influence on the dimensions of the habitat requirements.

The presence of limnophilics. If rheophilics and semi-rheophilics are absent, the requirements of limnophilics can be considered. This group do not require flowing water during any stage of their life-cycle. However, they do respond positively to improved habitat conditions (e.g. cover and feeding areas) caused by increased flows. In particular circumstances, the requirements of some limnophilics need to be considered where a drop in the water level in pools may result in a loss for example, of overhanging vegetation which may form an essential cover feature for some species to survive.

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

The following Tables provide a simple framework to interpret the suitability of a site in terms of the habitats available, velocity-depth fish guilds present and their size at the site compared to the RAU[3]:

Table A. 3 Comparison of velocity-depth ratings for RAU and the 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		
	SITE	RAU		SITE	RAU		SITE	RAU		SITE	RAU	
UB			UB			UB			UB			
OV			OV			OV			OV			
SUB			SUB			SUB			SUB			
AM			AM			AM			AM			
WC			WC			WC			WC			
BRAY - CURTIS SIMILARITY			BRAY - CURTIS SIMILARITY			BRAY - CURTIS SIMILARITY			BRAY - CURTIS SIMILARITY			

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

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

	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: 5	2	1	SCORE	
Representivity of the site for the reach				3.8	*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.*
How well does the *morphology* of the site represent that of the reach?	Very well	Don't know	Poorly	4.0	
To what extent is the *condition* of the site representative of the general condition of the reach?	Representative	Don't know	Very different	3.5	
Morphological Cues				3.5	*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.*
Is the site a bedrock or alluvial dominated section?	Alluvial	Mixed	Bedrock	3.0	
Are there good morphological clues that can be related to flood levels?	Very good	Don't know	Bad	4.0	
If these are present, are the terraces paired?	Yes	Don't know	No	3.5	
Sediment Transport Modelling				4.0	*Site is bedload dominated, and PBMT could be undertaken if an EFR determination was desired.*
Is the river a bedload dominated system (i.e. is potential bed material tranpsort modelling suitable)	Yes	Don't know	No	4.0	
Is potential bed material transport modelling going to be undertaken at this site?	Yes	Don't know	No	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: 5	2	1	SCORE	
Representivity of the site for the reach				4.0	*Morphology and condition of the site is generally consistent with the reach.*
How well does the *morphology* of the site represent that of the reach?	Very well	Don't know	Poorly	4.0	
To what extent is the *condition* of the site representative of the general condition of the reach?	Representative	Don't know	Very different	4.0	
Morphological Cues				2.2	*Gross morphology is bedrock controlled, but the bed is mioxed with bedrock, mobile cobbles, gravels and sands. Morphological cues are very poor.*
Is the site a bedrock or alluvial dominated section?	Alluvial	Mixed	Bedrock	2.0	
Are there good morphological clues that can be related to flood levels?	Very good	Don't know	Bad	2.0	
If these are present, are the terraces paired?	Yes	Don't know	No	2.5	
Sediment Transport Modelling				3.7	*Site is characterised by bedload transport, and PBMT is to be undertaken if an EFR determination was desired.*
Is the river a bedload dominated system (i.e. is potential bed material tranpsort modelling suitable)	Yes	Don't know	No	4.0	
Is potential bed material transport modelling going to be undertaken at this site?	Yes	Don't know	No	3.5	
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	
How well does the *morphology* of the site represent that of the reach?	Very well	Don't know	Poorly	4.0	*Morphology and condition of the site is generally consistent with the reach.*
To what extent is the *condition* of the site representative of the general condition of the reach?	Representative	Don't know	Very different	4.0	
Morphological Cues				3.0	
Is the site a bedrock or alluvial dominated section?	Alluvial	Mixed	Bedrock	4.0	*Although some bedrock, gross is alluvial with cobbles, gravels and sands. Morphological cues are very poor.*
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	
Is the river a bedload dominated system (i.e. is potential bed material tranpsort modelling suitable)	Yes	Don't know	No	4.0	*Site is characterised by bedload transport, and PBMT is to be undertaken if an EFR determination was desired.*
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: 5	2	1	SCORE	
Representivity of the site for the reach				3.8	
How well does the *morphology* of the site represent that of the reach?	Very well	Don't know	Poorly	3.5	*Morphology and condition of the site are generally consistent with the reach.*
To what extent is the *condition* of the site representative of the general condition of the reach?	Representative	Don't know	Very different	4.0	
Morphological Cues				2.3	*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 enginering (canal construction) and any cues have been lost here.*
Is the site a bedrock or alluvial dominated section?	Alluvial	Mixed	Bedrock	3.0	
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	*Site is characterised by bedload transport, and PBMT is to be undertaken if an EFR determination was desired.*
Is the river a bedload dominated system (i.e. is potential bed material tranpsort modelling suitable)	Yes	Don't know	No	4.0	
Is potential bed material transport modelling going to be undertaken at this site?	Yes	Don't know	No	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: 5	2	1	SCORE	
Representivity of the site for the reach				2.0	*The morphology and condition of the site generally represent the reach.*
How well does the *morphology* of the site represent that of the reach?	Very well	Don't know	Poorly	4.0	
To what extent is the *condition* of the site representative of the general condition of the reach?	Representative	Don't know	Very different		
Morphological Cues				3.2	*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.*
Is the site a bedrock or alluvial dominated section?	Alluvial	Mixed	Bedrock	4.5	
Are there good morphological clues that can be related to flood levels?	Very good	Don't know	Bad	2.0	
If these are present, are the terraces paired?	Yes	Don't know	No	3.0	
Sediment Transport Modelling				3.8	*The site is largely bedload dominated, but expect that suspended load is high in the wet season.*
Is the river a bedload dominated system (i.e. is potential bed material tranpsort modelling suitable)	Yes	Don't know	No	3.5	
Is potential bed material transport modelling going to be undertaken at this site?	Yes	Don't know	No	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: 5	2	1	SCORE	
Representivity of the site for the reach				3.3	*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.*
How well does the *morphology* of the site represent that of the reach?	Very well	Don't know	Poorly	3.0	
To what extent is the *condition* of the site representative of the general condition of the reach?	Representative	Don't know	Very different	3.5	
Morphological Cues				2.7	*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.*
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	*Site is dominated by bedload and suspended load. PBMT modelling will be undertaken.*
Is the river a bedload dominated system (i.e. is potential bed material tranpsort 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: 5	2	1	SCORE	
Representivity of the site for the reach				4.5	*Morphology and condition of the site appear to represent the reach extremely well.*
How well does the *morphology* of the site represent that of the reach?	Very well	Don't know	Poorly	4.5	
To what extent is the *condition* of the site representative of the general condition of the reach?	Representative	Don't know	Very different	4.5	
Morphological Cues				3.7	*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.*
Is the site a bedrock or alluvial dominated section?	Alluvial	Mixed	Bedrock	4.0	
Are there good morphological clues that can be related to flood levels?	Very good	Don't know	Bad	3.5	
If these are present, are the terraces paired?	Yes	Don't know	No	3.5	
Sediment Transport Modelling				5.0	*River is bedload dominated (cobbles and sands predominantly). PBMT will be undertaken for this site.*
Is the river a bedload dominated system (i.e. is potential bed material tranpsort modelling suitable)	Yes	Don't know	No	5.0	
Is potential bed material transport modelling going to be undertaken at this site?	Yes	Don't know	No	5.0	
OVERALL SCORE:				4.2	

Site Name:	Kraai River
Site number:	EFR K7
Date of assessment:	24th June 2010
Name of assesor:	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 O4 - 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

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 vegetated bars
Rocky riparian habitats available for sampling	2	open bedrock present in lower zone and avaialble for sampling
	2	
Channel morphology		
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
	1	
Vegetation		
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 identifyable i.e. leaves or flowers present at time of site visit	0	all key species identifiable
	2	
Hydraulic control		
unnatural up/downstream control affecting site	0	not observed in immediate vacinity
	0	
Overall Site Suitability Rating	**1.3**	**Site suitable**

where:

0 - suite 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

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	entire marginal zone included in sampling
Alluvial riparian habitats available for sampling	2	alluvial habitats underrepresented at the site due to extensive cobble bars and exposed bedrock in marginal and lower zones
Rocky riparian habitats available for sampling	0	site includes cobble beds and exposed bedrock especially in marginal and lower zones
	2	
Channel morphology		
Channel bank stabilization	0	less than 10% undercutting, and stabilized by vegetation
Channel manipulation	1	LB with some clearing, levelling and with a road in upper zone
Profile distance too long to effectively conduct VEGRAI	1	complete profile sampled, with exception of extreme elevation in the upper zone
	1	
Vegetation		
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 bend, differences appesr 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 *Gomphostigma vigatum*
Plant species easily identifyable i.e. leaves or flowers present at time of site visit	0	all key species identifiable
	2	
Hydraulic control		
unnatural up/downstream control affecting site	1	Boegoeberg dam nearby upstream
	1	
Overall Site Suitability Rating	**1.5**	**Site suitable**

where:

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

EFR 3

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	0	cobble beds present and avaialble for sampling
	1	
Channel morphology		
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 vinyards
Profile distance too long to effectively conduct VEGRAI	0	profile completely sampled
	3	
Vegetation		
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 *Gomphostigma vigatum*
Plant species easily identifyable i.e. leaves or flowers present at time of site visit	0	all key species identifiable
	2	
Hydraulic control		
unnatural up/downstream control affecting site	0	not observed in immediate vacinity
	0	
Overall Site Suitability Rating	**1.5**	**Site suitable**

where:

0 - suite 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 avaialble 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 triutaries
	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 identifyable i.e. leaves or flowers present at time of site visit	0	all key species identifiable
	2	
Hydraulic control		
unnatural up/downstream control affecting site	0	not observed in immediate vacinity
	0	
Overall Site Suitability Rating	1.8	Site moderately suitable

where:

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

*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	*Potamogeton* 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:	SLOW-DEEP			SLOW-SHALLOW			FAST-DEEP			FAST-SHALLOW		
SUB-SITE:	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 *large semi-rheophilic* 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			
SUB-SITE:	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**			
SUB-SITE:	**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	

*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 *large semi-rheophilic* 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: Vioolsdrift.

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: Vioolsdrift

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: Vioolsdrift**

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			
SUB-SITE:	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			
SUB-SITE:	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: Vioolsdrift**

	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 *large semi-rheophilic* 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 *large semi-rheophilic* 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 phragmytes 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 *large semi-rheophilic* 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 vegetation from dead grass and trees.	8 min EW
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, cobles. High level of siltation.	7 min EW
Sub-site 5	FS & FD over bedrock & cobles. 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				
SUB-SITE:	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				
SUB-SITE:	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				
SUB-SITE:	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 *large semi-rheophilic* 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 *large semi-rheophilic* 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 *large semi-rheophilic* 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 *large semi-rheophilic* 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 *large semi-rheophilic* 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 *large semi-rheophilic* 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 *large semi-rheophilic* 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 (*Labeobarbus kimberleyensis* – Largemoth 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 (*Labeobarbus aeneus* – 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 (*Labeo capensis* – 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 (*Labeo umbratus* – 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 (*Clarias gariepinus* – 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 (*Austroglanis sclateri* – 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.