Report No. ORASECOM: 010/2011

ORANGE - SENQU RIVER COMMISSION
BOTSWANA LESOTHO
ORASECOM
NAMIBIA SOUTH AFRICA
Established 2000

Commissioned by: Federal Ministry for Economic Cooperation and Development

In Delegated Cooperation with: UKaid from the Department for International Development; Australian Government Aid Program

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

Updated: December 2010

ENVIRONMENTAL FLOW REQUIREMENTS - VOLUME 1

REPORT

Assessment of Environmental Flow Requirements

Prepared by:

wrp
A Miya Group Company

in association with

DMM, Golder Associates, PIK, RAMBØLL, WCE

Report No. ORASECOM: 010/2010

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

WORK PACKAGE 5: ASSESSMENT OF ENVIRONMENTAL FLOW REQUIREMENTS - VOLUME 1

ENVIRONMENTAL FLOW REQUIREMENTS

Compiled by: Delana Louw and Johan Koekemoer (Editors)

Updated:
December 2010

Prepared for:

A Miya Group Company

WRP (Pty)Ltd
Physical address:
Block 5 Green Park Estate
27 George Storrar Drive
Groenkloof
South Africa, 0181

Postal address:
P O Box 1522
Brooklyn Square, 0075
Pretoria
South Africa

Tel: +27 12 346-3496
Fax: +27 12 346-9956
E Fax: 086 625 7218
E-mail: wrp@wrp.co.za
Internet: www.wrp.co.za

by:

Rivers4

Rivers for Africa eFlows Consulting (Pty) Ltd
Postal address:
P.O. Box 1684
Derdepark
South Africa, 0035

Cell: +27 82 461 1289
Fax: +27 86 656 6799
E-mail: iwre@icon.co.za

REFERENCES

This report is to be cited in bibliographies as:

Louw MD and S Koekemoer (editors); Deliverable 12: Volume 1: Environmental Flow Requirements Produced for WRP as part of Support to Phase II ORASECOM Basin Wide Integrated Water Resources Management Plan.

ACKNOWLEDGEMENTS

- Pule, Rapule (ORASECOM Secretariat)
- Thamae, Lenka (ORASECOM Secretariat)

Authors of the report are:

- Louw, Delana (Rivers for Africa)
- Dr Andrew Birkhead (Streamflow Solutions)
- Dr Pieter Kotze (Clean Stream Biological Services)
- Dr Rob Palmer (Nepid Consulting)
- Dr Patsy Scherman (Scherman, Colloty & Associates Environmental & Aquatic Management Consulting)
- Dr Andrew Deacon (SANPARKS)
- Dr Hugo Bezuidenhout (SANPARKS)
- Prof. Denis Hughes (IWR, Rhodes University)
- Koekmoer, Shael (Koekemoer Aquatic Services)
- Mackenzie, James (Mackenzie Ecological & Development Services)
- Rountree, Mark (Fluvius Environmental Consultants
- Koekemoer, Johan (Koekemoer Aquatic Services)
- Mallory, Heather (editing)
- Roux, Hermien (North West DACERD: Biodiversity – Scientific support)

DELIVERABLE 12

Consists of three volumes as follows:

VOLUME 1: ENVIRONMENTAL FLOW REQUIREMENTS
This is the main report and contains the EcoClassification and EFR results.

VOLUME 2: SUPPORT TO VOLUME 1 IN TERMS OF MONITORING: ECOSPECS AND THRESHOLDS OF POTENTIAL CONCERN
This document contains the monitoring component of the Work Package 5. The emphasis is on technical data in the form of tables which summarises EcoSpecs and Thresholds of Potential Concern.

VOLUME 3: SPECIALIST APPENDICES: SUPPORTING INFORMATION TO VOLUME 1 (ENVIRONMENT FLOW REQUIREMENTS) and VOLUME 2 (MONITORING: ECOSPECS AND THRESHOLDS OF POTENTIAL CONCERN)
Information is generated in most specialist fields that are used to support the determination of EFRs, EcoSpecs and TPCs. This information is available in Volume 3.

EXECUTIVE SUMMARY

BACKGROUND

This work forms part of the following study: Support to Phase II ORASECOM basin wide integrated water resources management plan.The main objective of the Work Package 5 (Environmental Flow requirements (EFR)), is to assess EFRs at selected key areas of the Orange River Basin at an Intermediate Level (DWA RSA criteria).

This report focuses on the results of the EFRs at the EFR sites.

The scoping study (Louw *et al*, 2010) provides the 'hotspots' which indicate the areas where detailed information, i.e. in this case, detailed EFR studies will be required. The main rivers within these areas are then selected and delineated into Management Resource Units (Resource Unit Report). These Resource Units indicate an area for which an EFR will be relevant. This means that theoretically, each Resource Unit will require an EFR site where EFRs are determined. The number of EFR sites is however constrained by time, budget and suitability of sites for EFR determination (Resource Unit Report). Once this information is available, field information is collated at the EFR sites and hydrology is produced for the sites. This leads to the determination of the EcoClassification of the EFR sites and the setting of flow regimes to maintain different ecological states.

STUDY AREA AND LOCATION OF EFR SITES

The locality of the EFR sites within the MRUs as identified during this study is provided in the table below.

Locality and characteristics of EFR sites

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

APPROACHES AND METHOD

As indicated in the Terms of Reference, EFRs were determined applying the Intermediate Ecological Reserve Methodology (IERM) (DWAF, 1999).The methodology consists of two different steps:

- EcoClassification
- EFR quantification for different ecological states

The EcoClassification process was followed according to the methods of Kleynhans and Louw (2007)

EcoClassification refers to the determination and categorisation of the PES (health or integrity) of various biophysical attributes of rivers compared to the natural (or close to natural) reference condition. The state of the river is expressed in terms of biophysical components:

- Drivers (physico-chemical, geomorphology, hydrology), which provide a particular habitat template; and
- Biological responses (fish, riparian vegetation and aquatic invertebrates).

Different processes are followed to assign a category (A→F; A = Natural, and F = critically modified) to each component. Ecological evaluation in terms of expected reference conditions, followed by integration of these components, represents the Ecological Status or EcoStatus of a river.

The Habitat Flow Stressor Response method (HFSR) (IWR S2S, 2004; O'Keeffe *et al.*, 2002), a modification of the Building Block Methodology (BBM; King and Louw, 1998) was used to determine the low (base) flow EFRs. This method is one of the methods used to determine EFRs at the intermediate level.

The approach to set high flows is a combination of the Downstream Response to Imposed Flow Transformation (DRIFT; Brown and King, 2001) approach and BBM.

ECOCLASSIFICATION RESULTS

The results are summarised in the table below.

EcoClassification Results summary

EFR O1 (HOPETOWN)

EIS: MODERATE
The highest scoring metrics are instream and riparian rare and endangered biota, unique riparian biota, instream biota intolerant to flow, taxon richness of riparian biota, critical riparian habitat and refugia and riparian migration corridor.

PES: C
The major issues that have caused the change from reference conditions are the releases for hydropower, barrier effects of the dams, water quality problems and the destruction of and removal of vegetation on floodplains for agriculture. The dominant factor seems to be the hydro-electric releases.

Driver Components	PES	TREND
IHI HYDROLOGY	E	
WATER QUALITY	D	
GEOMORPHOLOGY	C/D	-
INSTREAM IHI	D/E	
RIPARIAN IHI	C	
Response Components	**PES**	**TREND**
FISH	C/D	0
MACRO INVERTEBRATES	C	0
INSTREAM	C	0
RIPARIAN VEGETATION	B/C	0
RIVERINE FAUNA	C	0
ECOSTATUS	C	0
EIS	MODERATE	

EFR O2 (BOEGOEBERG)

EIS: HIGH
Highest scoring metrics are instream and riparian rare /endangered biota, unique riparian biota, instream biota intolerant to flow, taxon richness of riparian biota, diversity of riparian habitat types, critical riparian habitat, refugia, and migration corridor.

PES: C
Loss of frequency of large floods, agricultural return flows, higher low flows than natural in the dry season, drought and dry periods, decreased low flows at other times, release of sediment, presence of alien fish species and barrier effects of dams.

REC: B/C
Instream improvement was not possible due to constraints and no EFR will be set for REC.

AEC D (instream)
Decreased low flows in the wet and dry season. Decreased floods, decreased dilution resulting in worse water quality. Reduced low flows will result in less light penetration which will result in algal and benthic growth.

Driver Components	PES	TREND	REC	AEC↓
IHI HYDROLOGY	E			
WATER QUALITY	C		C	D
GEOMORPHOLOGY	C	0	C	C
INSTREAM IHI	C/D			
RIPARIAN IHI	B/C			
Response Components	**PES**	**TREND**	**REC**	**AEC↓**
FISH	C	0	C	D
MACRO INVERTEBRATES	C	0	C	D
INSTREAM	C	0	C	D
RIPARIAN VEGETATION	B	0	A/B	B/C
RIVERINE FAUNA	C	0	B	C
ECOSTATUS	C	0	B/C	C
EIS	HIGH			

EFR O3 (AUGRABIES)

EIS: HIGH
Highest scoring metrics are instream and riparian rare /endangered biota, unique instream and riparian biota, taxon richness of riparian biota, diversity of riparian habitat types, critical riparian habitat, refugia, migration corridor, National Park.

PES: C
Decreased frequency of large floods. Agricultural return flows, agricultural activities and associated water quality impacts. Higher low flows than natural in the dry season, drought and dry periods. Decreased low flows at other times. Presence of alien fish species and barrier effects of dams and alien vegetation. Decreased sedimentation.

REC: B
Reinstate droughts (i.e., lower flows than present during the drought season).Improved (higher) wet season base flows. Clear vegetation. Improved agricultural practices.

AEC: D
Increased agriculture with associated impacts on water quality and decreased wet season base flows. Decreased floods. Increased vegetation aliens.

Driver Components	PES	TREND	REC	AEC↓
IHI HYDROLOGY	E			
WATER QUALITY	C		C	D
GEOMORPHOLOGY	C	0	C	C-
INSTREAM IHI	D			
RIPARIAN IHI	C/D			
Response Components	**PES**	**TREND**	**REC**	**AEC↓**
FISH	C	0	B	D
MACRO INVERTEBRATES	C	0	B	D
INSTREAM	C	0	B	D
RIPARIAN VEGETATION	B/C	-	B	C
RIVERINE FAUNA	C	0	B	C
ECOSTATUS	C	0	B	C*
EIS	HIGH			

* The focus for setting EFRs will be on the instream EC of a D

EFR O4 (VIOOLSDRIF)

EIS: HIGH
Highest scoring metrics are instream and riparian rare /endangered biota, unique instream and riparian biota, migration corridor, National Park.

PES: B/C
Decreased frequency of large floods. Agricultural return flows and mining activities – water quality problems. Higher low flows than natural in the dry season, drought and dry periods. Decreased low flows at other times. Presence of alien fish species and barrier effects of dams. Decreased sedimentation due to lack of large floods and upstream dams. Alien vegetation.
REC:
Improved (higher) wet season base flows. Clear vegetation aliens. Control grazing and trampling.
AEC:
Increased mining with associated impacts on water quality and decreased wet season base flows. Decreased floods. Increased vegetation aliens (esp *Prosopis sp.*).Habitat loss for a large percentage of time due to decreased flows. Vegetation: Increased sedges due to increased sedimentation.

Driver Components	PES	Trend	REC	AEC↓
IHI HYDROLOGY	D			
WATER QUALITY	C/D		C/D	D
GEOMORPHOLOGY	C	0	C	C
INSTREAM IHI	D			
RIPARIAN IHI	D			
Response Components	**PES**	**Trend**	**REC**	**AEC↓**
FISH	C	0	B/C	D
MACRO INVERTEBRATES	C	0	B/C	D
INSTREAM	C	0	B/C	D
RIPARIAN VEGETATION	C	-	B	C/D
RIVERINE FAUNA	C	-	B/C	C/D
ECOSTATUS	C	-	B/C	D
EIS	HIGH			

EFR C5 (UPPER CALEDON)

EIS: LOW.
Highest scoring metrices are rare and endangered riparian species, instream biota taxon richness, and sensitive instream habitat (to flow changes).

PES: C/D
Grazing and trampling, bank erosion, sedimentation, exotic vegetation and fish species.

REC:C/D
EIS is low - provides no motivation for improvement. The problems are also all non-flow related.

AEC ↓: D
Decreased flows due to increased abstraction. Reduced dilatation - impact temperature and oxygen. Increased sedimentation (continued erosion). Habitat loss for a large percentage of time. Vegetation – increased sedges due to increased sedimentation.

Driver Components	PES	Trend	AEC↓
IHI HYDROLOGY	A/B		
WATER QUALITY	B/C		C
GEOMORPHOLOGY	C	-	C/D
INSTREAM IHI	B/C		
RIPARIAN IHI	C		
Response Components	**PES**	**Trend**	**AEC↓**
FISH	D	0	E
MACRO INVERTEBRATES	C	0	C/D
INSTREAM	D	0	D
RIPARIAN VEGETATION	C	0	C
ECOSTATUS	C/D		D
EIS	LOW		

EFR C6 (LOWER CALEDON)

EIS: LOW
The highest scoring matrices are rare and endangered riparian species.

PES:C
Sedimentation (bank erosion), significantly reduced base flows, alien fish species.

REC:C
EIS is low - provides no motivation for improvement.

AEC ↑: B/C
Bottom releases must take place during the wet season and not during low flow conditions. Low flows must be improved. No zero flows or limited duration.

Driver Components	PES	Trend	AEC↑
IHI HYDROLOGY	E		
WATER QUALITY	C		C(+)
GEOMORPHOLOGY	C/D	0	C
INSTREAM IHI	E		
RIPARIAN IHI	B/C		
Response Components	**PES**	**Trend**	**AEC↑**
FISH	D	0	C
MACRO INVERTEBRATES	D	0	C
INSTREAM	D	0	C
RIPARIAN VEGETATION	B	0	B
ECOSTATUS	C		B/C
EIS	LOW		

EFR K7 (LOWER KRAAI)

EIS: MODERATE
The highest scoring matrix was unique riparian biota.

PES: C
Reduced base flows, exotic vegetation and fish species, grazing and trampling, bank erosion.

REC: C
The EIS is moderate which does not provide motivation for improvement.

AEC↓: C
Increased abstraction; more frequent zero flows. Negative impact on water quality. Decrease in small floods (e.g. by an increase of dams in the tributaries).Slightly higher sedimentation in areas.

AEC↑: B
Decreased abstraction (higher base flows) and no zero flows. Improved water quality. Alien vegetation should be cleared.

Driver Components	PES	Trend	AEC↓	AEC↑
IHI HYDROLOGY	A/B			
WATER QUALITY	B/C		C	A/B
GEOMORPHOLOGY	A/B	0	B/C	A/B
INSTREAM IHI	B/C			
RIPARIAN IHI	C			
Response Components	**PES**	**Trend**	**AEC↓**	**AEC↑**
FISH	C	0	D	B
MACRO INVERTEBRATES	C	0	D	B
INSTREAM	C	0	D	B
RIPARIAN VEGETATION	C	-	C-	B/C
ECOSTATUS	C		C	B
EIS	MODERATE			

EFR M8 (MOLOPO WETLANDS)

EIS: HIGH
Wetland is a unique habitat in this dry region. Highest scoring matrix were Rare and endangered vegetation types. Unique fish and macroinvertebrate species. Critical habitat and refuge and a Proclaimed area.

PES: C
Pesticide spraying. Backup effect from poorly designed road crossings. Burning of reeds. Alien fish species.

REC: B
As the EIS is HIGH, the REC is an improvement of the PES.

Driver Components	PES	REC
IHI HYDROLOGY	D/E	
WATER QUALITY	B	B
GEOMORPHOLOGY	B	B
Response Components	**PES**	**REC**
FISH	C	B
MACRO INVERTEBRATES	C	B
INSTREAM	C	B
RIPARIAN VEGETATION	C/D	B/C
ECOSTATUS	C/D	B
WETLAND IHI	D	C
LARGER WETLAND / MRU ECOSTATUS	C	B

The confidence in EcoClassification is provided in the Table and is based on data availability and EcoClassification where:

- Data availability: Evaluation based on the adequacy of any available data for interpretation of the Ecological Category and AEC.
- EcoClassification: Evaluation based on the confidence in the accuracy of the Ecological Category.

The confidence score is based on a scale of 0 – 5 and colour coded where:

0 – 1.9: Low 2 – 3.4: Moderate 3.5 – 5: High

These confidence ratings are applicable to scoring provided in this report.

Confidence in EcoClassification

	Data availability									EcoClassification								
EFR site	Hydrology	Physico-chemical	Geomorph	IHI	Fish	Macro-invertebrates	Vegetation	Average	Median	Hydrology	Physico-chemical	Geomorp	IHI	Fish	Macro-invertebrates	Vegetation	Average	Median
O1	2.5	3.3	2	3	3	2	4.5	2.9	3.00	4	3	2.5	2.6	3	3	4	3.2	3
O2	2.5	3.3	4	3.5	3	4	4.5	3.5	3.5	3	3.5	3.5	2.6	3	4	4	3.4	3.5
O3	2	3	3	3.5	3	4	4.5	3.3	3	3	3.5	3	3	3.5	4	3.8	3.4	3.5
O4	2	2.25	3.5	3.5	3	4	4.5	3.3	3.5	3	2.5	3	3	3.5	4	3.8	3.3	3
C5	2.5	3.5	2.5	3.5	3	2	4.5	3.1	3	2.5	3.5	3.5	3.5	4	3	3.3	3.3	3.5
C6	2	3.8	3	3.5	3	2	4.5	3.1	3	3	4	3.5	3.2	3	3	3.7	3.3	3.2
K7	4	3.8	3	3	3	2	4.5	3.3	3.	3	3	4	3.5	3.5	2	4	3.3	3.5
M8	4	0.5	1.5	3.5	3	4	4.5	3.4	3.8	2	1.9	3	3.3	2	3	3.4	2.7	3

The results indicate an overall moderate to high confidence. Considering that only one biophysical survey was undertaken, the confidence is higher than expected. This is probably due to the moderate to high confidence in the data availability. The only low confidence is linked to the lack of physico-chemical data at EFR M8 and the lack of available geomorphological data.

ENVIRONMENTAL FLOW REQUIREMENTS

A summary of the final flow results are provided below as a percentage of the natural MAR and the volumes.

Summary of results as a percentage of the natural MAR

EFR site	EC	Maintenance low flows		Drought low flows		High flows		Long term mean	
		(%nMAR)	MCM	(%nMAR)	MCM	(%nMAR)	MCM	(% nMAR)	MCM
Virgin MARs									
EFR O2	PES/REC	11.6	1226.55	4.4	465.24	5.4	570.98	15.2	1607.20
	AEC↓: D	5.8	613.27	3.1	327.78	5	528.69	11.3	1194.83
EFR O3	PES: C	8.4	883.10	2.6	273.34	4.7	494.12	11.9	1251.06
	REC: B	17.6	1850.31	3.4	157.37	4.7	494.12	19.2	2018.52
	AEC↓: D	4.1	431.04	2.2	231.29	4.4	462.58	9	946.18
EFR O4	PES: C	6.3	651.11	0.9	35.16	4.2	434.07	8.9	919.82
	REC: B/C	10.1	1043.85	1.3	134.36	4.2	434.07	12.2	1260.88

EFR site	EC	Maintenance low flows		Drought low flows		High flows		Long term mean	
		(%nMAR)	MCM	(%nMAR)	MCM	(%nMAR)	MCM	(% nMAR)	MCM
	AEC↓: D	3.1	320.39	0.8	31.25	3.8	392.73	6.9	713.12
EFR C5	PES/REC: C/D	13.8	7.85	5.8	3.30	11.4	6.49	26	14.80
EFR C6	PES/REC: D	8.8	118.62	0.3	3.40	10.5	141.54	20.1	270.94
	AEC↑: C	15.5	208.93	2.2	29.66	13.1	176.58	26.1	351.82
EFR K7	PES/REC: C	11.4	77.81	0	0.00	8.4	57.33	18.1	123.53
	AEC↑: B	16.5	112.61	1.2	7.70	8.4	57.33	21.8	148.79
	AEC↓: D	5.1	34.81	0	0.00	7.1	48.46	12.9	88.04

The overall confidence in the results are linked to the confidence in the hydrology and hydraulics as the hydrology provides the check and balance of the results and the hydraulics convert the requirements in terms of hydraulic parameters to flow. Therefore, the following rationale is applied when determining the overall confidence:

- If the hydraulics confidence is lower than the biological responses column, the hydraulics confidence becomes the overall confidence. Hydrology confidence is also considered, especially if used to guide the requirements.
- If the biological confidence is lower than the hydraulics confidence, the biological confidence becomes the overall confidence. Hydrology confidence is also considered. If hydrology is used to guide requirements, than that confidence will be overriding.

Overall Confidence in EFR results

Site	Hydrology	Biological responses Low flows	Hydraulic: Low Flows	OVERALL: LOW FLOWS	COMMENT	Biophysical responses: High flows	Hydraulics: High Flows	OVERALL: HIGH FLOWS	COMMENT
EFR O2	3.5	2.7	2.5	**2.5**	Hydraulic confidence is not high as the measured flows were all higher than the flows required.	3.3	5	**3.3**	Even though the hydraulics confidence was high, the biophysical responses was moderate and that became the overall confidence.
EFR O3	2	3	2	**2**	See above for hydraulic confidence. As the hydraulic confidence was lower than the biological responses, this became the overall confidence.	3.5	5	**3.5**	Even though the hydraulics confidence was high, the biophysical responses was lower (although still high) and that became the overall confidence.
EFR O4	2.6	3	2.5	**2.5**	See above.	2.8	5	**2.8**	Even though the hydraulics confidence was high, the biophysical responses were moderate and that became the overall confidence.
EFR C5	1.6	3.5	3.5	**3.5**	The hydraulic and biological confidences are both high.	3	3	**3**	The hydraulic and biolophysical confidence are both moderate.
EFR C6	2.4	3	2	**2**	See above for hydraulic confidence. As the hydraulic confidence was lower than the biological responses, this became the overall confidence.	3	4	**3**	Even though the hydraulics confidence was high, the biophysical responses were moderate and that became the overall confidence.
EFR K7	2.6	3	3	**3**	The hydraulic and biological confidences are both moderate.	3	3	**3**	The hydraulic and biolophysical confidence are both moderate.

ANALYSIS OF FLOW REQUIREMENTS AT EFR M8

The EcoClassification results indicated that Ecological Importance and Sensitivity (EIS) were HIGH and therefore an improvement was required.

- Mafikeng presently has water shortages and it is highly unlikely that there is any scope to decrease abstractions in order to increase flow to the wetland.
- The Bosbokpark crossing causes back-up and is a mjor impact on the wetland. Increased water to the wetland will probably not have the desired effect without addressing the back-up problems.

Setting flow requirements within such a modified system will serve no purpose as increased flow on its own will not improve the system due to the back-up effect of the lower crossing (Bosbokpark). In order to improve the wetland the main objectives set for EFR 8 were to revert back to a functioning wetland which can be achieved by:
- Improved *Phragmites* cover.
- Reinstatement of shallow areas with constant depth.
- Cease spraying of toxic pesticides for control of *Quelea quelea* and reeds.

An additional aim would be to achieve a greater area of wetted wetland, i.e. that some flows and dampness increased in the wetland downstream of the Bosbokpark crossing.

Various hydraulic-related management scenarios were devised and were assessed to determine whether the current state of the wetland could be improved.
- Scenario1: Drop crossing by 1.2m.
- Scenario 2: Drop crossing by 2.2m.
- Scenario 3: Drop crossing to original bed level.
- Scenario 4: Present day flow with no spraying to kill reeds.
- Scenario 5: Reduce present day flow by 50 %.

The figure below summarises the consequences of each scenario indicating the change from PES in the Ecological Category. Based on the results in the table section of the figure, the scenarios are ranked in terms of the achievement of the REC, and if the REC is not met ranking is based on the degree to which the REC is not achieved. The ranking is depicted by means of a traffic diagram where good indicates the achievement of the REC and red indicates non-achievement. One could also view this ranking in terms of the changes from PES which is pegged in the middle of the traffic diagram.

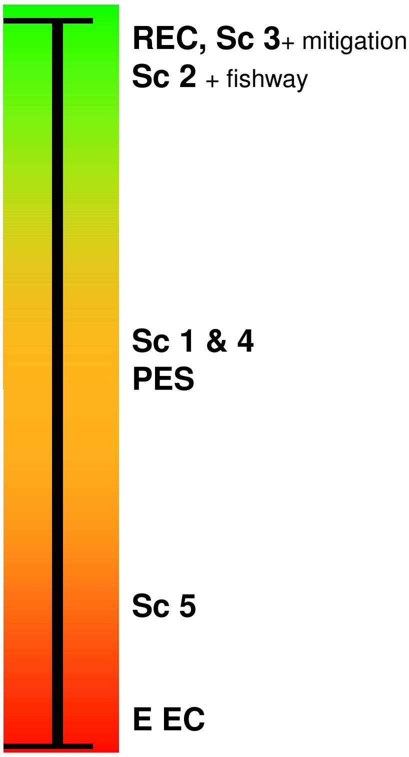
None of the scenarios achieve the REC of a B for all components. Both Sc 2 and 3 achieve an improvement to a B/C and it is felt that with the following appropriate additional measures, the REC can be achieved.
- Sc 2: The construction of a fishway to connect the wetland to the upstream Molopo Eye.
- Sc 3: Would require mitigation measures to address erosion and incision. The construction of a fishway to connect the wetland to the upstream Molopo Eye.

Scenario 2 and 3 are similar apart from riparian vegetation which improves more under Sc 2. It is therefore ranked marginally higher than Sc 3 (Figure 23.3). Scenario 1 and 4 result in marginal improvements of the PES.

Scenario 5, i.e. a decrease of flow to the wetland, will significantly drop the EC to a D/C and is therefore ranked close to the bottom of the traffic diagram.

Consequences of scenarios and ranking

Driver Components	PES	REC	Sc1	Sc 2	Sc 3	Sc 4	Sc 5
IHI HYDROLOGY	D/E		D/E	D/E	D/E	D/E	E/F
WATER QUALITY	B	B	B	B	B	B	B
Response Components	**PES**	**REC**	**Sc1**	**Sc 2**	**Sc 3**	**Sc 4**	**Sc 5**
FISH	C	B	C	B	B	C	D
MACRO-INVERTEBRATES	C	B	C+	B/C	B/C	C+	C/D
INSTREAM	C	B	C	B/C	B/C	C	D
RIPARIAN VEGETATION	C/D	B/C	C	B/C	C	C	C/D
ECOSTATUS	C	B	C+	B/C	B/C	C+	C/D
WETLAND IHI	D	C	C/D	C	C		D
LARGER WETLAND / MRU	C	B	C	B	B	C	D/E



The conclusion is that either Scenario 2 or 3 can be implemented and considering the requirement of crossing by landowners, Scenario 2 (which will require dropping, but not removing the crossing) will probably be the preferred option.

RECOMMENDATIONS

The low flow confidences range from MODERATE to HIGH with only EFR C5 rated as high. This is due to high confidence hydraulics and biological response information. Even though the hydrology is low, this does not play a significant role, as flow is not the driver at this site.

Hydraulics confidences range from 2 - 2.5 for EFR O2, O3, O4 and C6. The confidence can only be improved by obtaining additional low flow calibration data that at lower flows than measured during the study.

The confidence in biological information is mostly moderate as only one survey was undertaken. Additional surveys in different seasons should be undertaken to refine the baseline.

The high flow confidences range from MODERATE to HIGH with only EFR O3 rated as high due to high confidence hydraulics and biological response information. The hydraulic confidence at EFR C5 and K7 were moderate as flood conditions were absent at these sites during hydraulic calibration. However an improvement in hydraulic confidence alone will not improve the overall confidence and therefore the confidence in biophysical responses should also be improved by undertaking monitoring.

It is strongly recommended that an Ecological Water Resources Monitoring (EWRM) programme is initiated as soon as possible. The information gathered during this study is suitable for the baseline, but if too much time relapses between the baseline and monitoring, new surveys and EcoClassification process will have to be undertaken.

The table below provides a summary of the recommendations.

Summary of recommendations required to improve confidences

EFR sites	Low flow confidence	High flow confidence	Recommendations
O2	2.5	3.3	Initiate EWRM programme. Obtain hydraulic low flow calibrations.
O3	2	3.5	Initiate EWRM programme.Obtain hydraulic low flow calibrations.
O4	2.5	2.8	Initiate EWRM programme.Obtain hydraulic low flow calibrations.
C5	3.5	3	Initiate EWRM programme. Obtain hydraulic high flow calibrations.
C6	2	3	Initiate EWRM programme. Obtain hydraulic low flow calibrations.
K7	3	3	Initiate EWRM programme. Obtain hydraulic low and high flow calibrations.
M8			Hydraulic confidence in the areas of the wetland that does not receive backup from the crossing was moderate (3). It is however not recommended that more hydraulic calibrations are done as it would be more cost-effective to implement the recommendation (Sc 2 - lowering the Bosbokpark crossing by 2.2 m) and monitoring the biological responses. Monitoring should include the impact on the lower wetland to determine whether the required improvements in these sections are achieved.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

TERMINOLOGY AND ACRONYMS

AEC	Alternative ecological category
AMOS	Anguilla mossambica (peters 1852)
ASCL	*Austroglanis sclateri*
BAEN	*Labeobarbus aeneus*
BANO	Barbus anoplus (weber, 1897)
BBM	Building Block Methodology
BBRI(cf.)	Barbus brevipinnis (jubb, 1966)
BHOS	Barbus hospes (barnard, 1938)
BKIM	*Barbus kimberleyensis*
BPAL	Barbus pallidus (smith, 1841)
BPAU	Barbus paludinosus (peters, 1852)
BTRI	Barbus trimaculatus (peters, 1852)
CAUR*	Carassius auratus (linnaeus, 1758)
CCAR*	Cyprinus carpio linnaeus, 1758
CGAR	Clarias gariepinus (burchell, 1822)
CIDE*	Ctenopharyngodon idella (valenciennes, 1844)
DRIFT	Downstream Response to Imposed Flow Transformation
DRM	Desktop reserve model
DWA	Department of Water Affairs
DWAF	Department of Water Affairs and Forestry
EC	Ecological Category
EcoSpecs	Ecological Specifications
EFR	Environmental Flow Requirements
EIS	Ecological Importance and Sensitivity
EFR	Ecological Flow Requirements
FD	Fast Deep
FDI	Flow dependent invertebrates
FRAI	Fish Response Assessment Index
FROC	Fish frequency of occurrence
FS	Fast shallow
GAFF*	Gambusia affinis (baird & girard, 1853)
GAI	Geomorphological Driver Assessment Index
geom	geomorphology
geozone	Geomorphological zone
G&S	Goods & Services
HFSR	Habitat Flow Stressor Response
IERM	Intermediate Ecological Reserve Methodology
IFR	Instream Flow Requirements
IHI	Index of Habitat Integrity
IUCN	International Union for Conservation of Nature
LCAP	*Labeo capensis*
LB	Left bank
LMAC*	Lepomis macrochirus (rafinesque, 1819)
LSR	Large semi-rheophilic
LUMB	Labeo umbratus (smith, 1841)

MAR	Mean Annual Runoff
MAP	Mean Annual Precipitation
MBRE	Mesobola brevianalis (boulenger, 1908)
MCB	Macro channel bank
MIRAI	Macroinvertebrate Response Assessment Index
MRU	Management Resource Units
MSAL*	Micropterus salmoides
nMAR	Natural mean annual runoff
OMOS	Oreochromis mossambicus
OMYK*	Oncorhynchus mykiss (walbaum, 1792)
ORASECOM	Orange-Senqu River Commission
PAI	Physico Chemicalical Driver Assessment Index
PES	Present Ecological State
PPHI	Pseudocrenilabrus philander (weber, 1897)
PQUA	Pseudobarbus quathlambae (barnard, 1938)
Q	Discharge
quat	quaternary catchment
RB	right bank
REC	Recommended Ecological Category
Rip Veg	Riparian vegetation
RU	Resource Unit
SANBI	South African National Biodiversity Institute
SD	Slow Deep
SPATSIM	Spatial and Time Series Information Modelling
sp	species
SS	Slow Shallow
STRU*	Salmo trutta
TPC	Threshold of Potential Concern
TSPA	Tilapia sparrmanii smith, 1840
VEGRAI	Riparian Vegetation Response Assessment Index
WMA	Water Management Area

1 INTRODUCTION

1.1 BACKGROUND AND OBJECTIVES OF THE STUDY

This work forms part of the following study: Support to Phase II ORASECOM basin wide integrated water resources management plan.The main objective of the Work Package 5 (Environmental Flow requirements (EFR)), according to the TOR, is to assess EFRs at selected key areas of the Orange River Basin at an Intermediate Level (DWA RSA criteria). An intermediate level implies specific steps, of which the following are relevant for this study:

- A scoping (Desktop) level assessment of ecological and socio-cultural condition and importance across the basin.
- Delineation into Management Resource Units and selection of EFR sites.
- One biophysical survey to collect the relevant data at each EFR site.
- Two measurements at a low and a high flow to calibrate the hydraulic model.
- Assessment of the Present Ecological State and other scenarios in terms of ecological state.
- Assessment of flow requirements following a holistic approach, preferably those developed specifically for Southern African conditions for each ecological state.
- Assessment of the ecosystem services, also referred to as Goods and Services (G&S)
- Monitoring aspects.

This report focuses on the results of the study associated with the bold bullets above.

The scoping study (Louw *et al*, 2010) provides the 'hotspots' which indicate the areas where detailed information, i.e. in this case, detailed EFR studies will be required. The main rivers within these areas are then selected and delineated into Management Resource Units (Resource Unit Report). These Resource Units indicate an area for which an EFR will be relevant. This means that theoretically, each Resource Unit will require an EFR site where EFRs are determined. The number of EFR sites is however constrained by time, budget and suitability of sites for EFR determination (Resource Unit Report). Once this information is available, field information is collated at the EFR sites and hydrology is produced for the sites. This leads to the determination of the EcoClassification of the EFR sites and the setting of flow regimes to maintain different ecological states.

1.2 STUDY AREA AND LOCATION OF EFR SITES

The focus on the EFR determination was on the following rivers:

- Orange River downstream of Vanderkloof Dam
- Caledon River
- Kraai River
- Upper Molopo River

The locality of the EFR sites within the MRUs as identified during this study is provided in Table 1.1 and 1.2 and in Figure 1.1.

Table 1.1 Locality and characteristics of EFR sites

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

Table 1.2 Locality, characteristics and view of EFR sites

Site information	EFR sites	Illustration
EFR nr & name *River* *Previous IFR site* *National RHP site* *Decimal Degrees* *EcoRegion (Level II)* *Geozone* *Altitude (m)* *RU* *Quaternary* *Farm name* *Hydrological gauge*	EFR O1 Hopetown Orange - - -29.51594, 24.00927 26.01 Lowland 1060 MRU Orange B D33G Zuurgat 82 -	
EFR nr & name *River* *Previous IFR site* *National RHP site* *Decimal Degrees* *EcoRegion (Level II)* *Geozone* *Altitude (m)* *RU* *Quaternary* *Farm name* *Hydrological gauge*	EFR O2 Boegoeberg Orange - - -29.0055, 22.16225 26.05 Lowland 871 MRU Orange D, RAU D.1 D73C Blinkfontein 10 D7H008	

Site information	EFR sites	Illustration
EFR nr & name *River* *Previous IFR site* *National RHP site* *Decimal Degrees* *EcoRegion (Level II)* *Geozone* *Altitude (m)* *RU* *Quaternary* *Farm name* *Hydrological gauge*	EFR O3 Augrabies Orange - - -28.42867, 19.9983 28.01 Lowland 434 MRU Orange E D81B Oranjestroom 386 D7H014	
EFR nr & name *River* *Previous IFR site* *National RHP site* *Decimal Degrees* *EcoRegion (Level II)* *Geozone* *Altitude (m)* *RU* *Quaternary* *Farm name* *Hydrological gauge*	EFR O4 Vioolsdrift Orange - - -28.75525, 17.71696 28.01 Lowland 167 MRU Orange F D82F - D8H013	
EFR nr & name *River* *Previous IFR site* *National RHP site* *Decimal Degrees* *EcoRegion (Level II)* *Geozone* *Altitude (m)* *RU* *Quaternary* *Farm name* *Hydrological gauge*	EFR C5 Caledon Rapid III - -28.65078, 28.3875 15.03 Lower Foothills 1640 MRU Caledon B D21A Kromdraai 106 -	
EFR nr & name *River* *Previous IFR site* *National RHP site* *Decimal Degrees* *EcoRegion (Level II)* *Geozone* *Altitude (m)* *RU* *Quaternary* *Farm name* *Hydrological gauge*	EFR C6 Lower Caledon Caledon - D2Cale_Tusse -30.4523, 26.27088 26.03 Lowland 1270 MRU CaledonD D24J Inhoek 336 -	

Site information	EFR sites	Illustration
EFR nr & name *River* *Previous IFR site* *National RHP site* *Decimal Degrees* *EcoRegion (Level II)* *Geozone* *Altitude (m)* *RU* *Quaternary* *Farm name* *Hydrological gauge*	EFR K7 Kraai Kraai - - -30.8306, 26.92056 26.03 Lowland 1327 MRU Kraai C D31M Witkoppies 96/2 D1H011	
EFR nr & name *River* *Previous IFR site* *National RHP site* *Decimal Degrees* *EcoRegion (Level II)* *Geozone* *Altitude (m)* *RU* *Quaternary* *Farm name* *Hydrological gauge*	EFR M8 Molopo Wetland Molopo - - -25.8812, 26.01592 11.01 Lower Foothills 1459 MRU UM C D41A Trekdrift 360.29 D4H030, D4H014	

The locality of sites is illustrated in Figure 1.1.

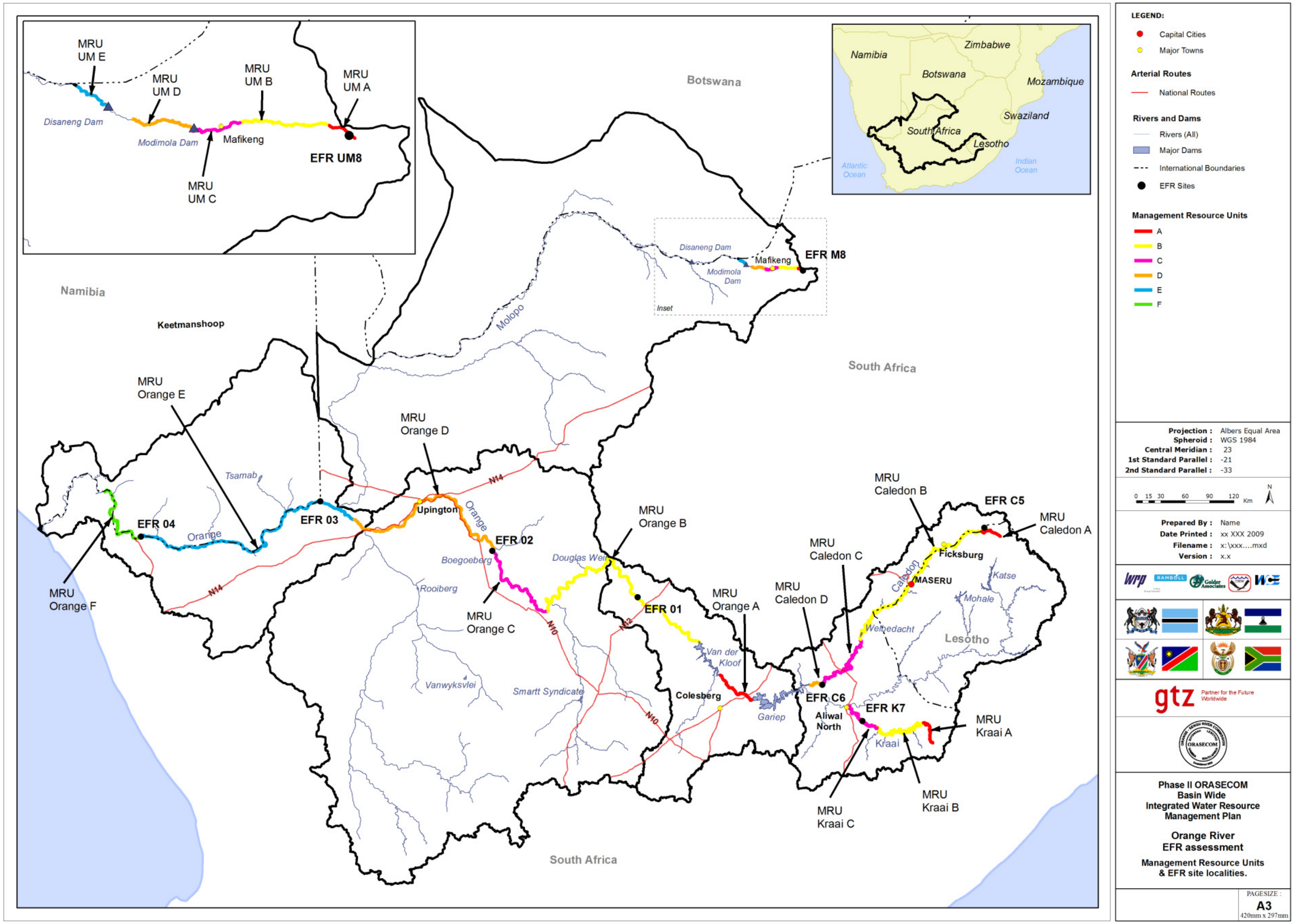


Figure 1.1 Management Resource Units and EFR sites

1.3 OBJECTIVES OF THE EFR STUDY

The objectives of the study are to determine the EFR for different ecological state at each EFR site.

1.4 DATA AVAILABILITY

Information collated during physical surveys was used to provide the results in this report. This data availability is summarised in Table 1.1.

Table 1.3 Availability of data for each EFR site

Component	Data Availability	Confidence
O1 HOPETOWN		
Hydrology	Hydrology provided by WRP	2.5
Diatoms	No data were available for the EFR site specifically except one sample taken during 2010 EFR site visit. Diatom sample collection during 2008 and 2009 US and DS of site was available along with *in situ* water quality data.	3
Water Quality	RC: Orange River @ Marksdrift (D33K; ecoregion II: 26.01) D3H008Q01 (1966 – 1978; n=51) PES: 1) Orange River @ Marksdrift (D33K; ecoregion II: 26.01) D3H008Q01 (2000 – 2010; n=414-427) 2) Data from diatom sample collection in 2008 (n=2)	RC: 3 PES: 3.5
Geomorphology	A historical aerial photographic record dating back to the 1950's, and coarse scale map from 1905, was available for this site and these data were used to assess the Reference conditions of the site. The nearest gauge is 70km downstream, but this is broadly representative of the flows at the site. Confidence in the site assessment is low because site visit was rapid, and hydrological data are not clear (sub-daily data needed to assess the impact of peaking at the site, and this is not available).	2
Fish	Single site visits and fish sampling during June 2010. Various previous fish surveys in region. Atlas of Southern African Freshwater fishes (Scott *et al.*, 2006). SAIAB Data base (2006). Reference Fish Frequency of Occurrence Report (Kleynhans *et al.,* 2007)	*3*
Macroinvertebrates	Low. One SASS5 survey was used to determine PES: 2010/06/02	2
Riparian Vegetation	Satellite images (Google earth) of the respective reach and aerial photos (1906 (map), 1955, 1959, 1968, 1974, 1976, 1978, 1988, 2008). Hydrology specialist questionnaire Ecoregion class and associated information Geomorphic Zone classification and GAI IHI segments / impacts Biomes and vegetation types of South Africa: (Rutherford & Westfall, 1986; van Wyk & van Wyk, 1997; Mucina & Rutherford, 2006) SANBI Plant of Southern Africa online database (based on several herbaria collections). Data collected during field visit (June 2010).	4.5
Riverine Fauna	1 site visit Terrestrial habitat survey (rapid) Site photos	2
O2 BOEGOEBERG		
Hydrology	Hydrology provided by WRP Observed data from D7H008	3.5
Diatoms	Site specific diatom data were available from sample collection during 2005, 2008 – 2009 as well as data from sample collected during EFR site visit. Diatoms were taken during 2005, 2008 - 2009 across the reach, along with measured *in situ* water quality measurements.	3.5
Water Quality	RC: Orange River @ Boegoeberg Reserve (D73B; ecoregion II: 26.05) D7H008Q01 (1966 – 1979; n=43 - 57) PES: 1) Orange River @ Boegoeberg Reserve (D73B; ecoregion II: 26.05) D7H008Q01 (2000 – 2009; n=348)	RC: 3 PES: 3.5

Component	Data Availability	Confidence
	2) Data from diatom sample collection in 2005, 2008, 2009, 2010	
Geomorphology	Historical aerial photographic record dating back to the 1930's was available for this site and these data were used to assess the Reference conditions of the site. The nearest gauge is at the nearby Boegoeberg Dam and has a very long record from the 1930's. Confidence in the site assessment is thus high because the hydrological data and aerial photography have very long records.	4
Fish	Single site visits and fish sampling during June 2010. Various previous fish surveys in region. Atlas of Southern African Freshwater fishes (Scott *et al.*, 2006). SAIAB Data base (2006). Reference Fish Frequency of Occurrence Report (Kleynhans *et al.,* 2007)	*3*
Macroinvertebrates	Good. One SASS5 survey was collected during the present study (2010-05-31), but additional data were collected by the Onderstepoort Veterinary Institute as part of the Orange River Blackfly Control Programme between 1991 and 1996 (Palmer 1996, 1997a, b).	4
Riparian vegetation	Satellite images (Google earth) of the respective reach and aerial photos (1964, 1974, 1984, 2004, 2010). Hydraulic cross-section (profile) at the site together with surveyed key vegetation points Hydrology specialist questionnaire Ecoregion class and associated information Geomorphic Zone classification and GAI IHI segments / impacts Biomes and vegetation types of South Africa: (Rutherford & Westfall, 1986; van Wyk & van Wyk, 1997; Mucina & Rutherford, 2006) SANBI Plant of Southern Africa online database (based on several herbaria collections). Data collected during field visit (June 2010).	4.5
Riverine Fauna	1 site visit Terrestrial habitat survey (rapid) Site photos	2
	O3 AUGRABIES	
Hydrology	Hydrology provided by WRP	2
Diatoms	No data were available for EFR site specifically except one sample taken during 2010 EFR site visit. Diatom sample collection during 2008 and 2009 US and DS of site was available along with *in situ* water quality data.	3
Water Quality	RC: Orange River @ Kakamas (D73F; ecoregion II: 26.05) D7H003Q01 (1965 – 1980; n=68) PES: 1) Orange River @ Neusberg (D73F; ecoregion II: 26.05) D7H014Q01 (1995 – 2010; n=94) 2) Data from diatom sample collection in 2008 (n=7)	RC: 2.5 PES: 3.5
Geomorphology	A historical aerial photographic record dating back to the 1940's was available for this site. This documents gross morphological changes to the site and aids in the Reference State and PES determinations and assessments. The nearest discharge gauge (D7H014) is 80kms upstream of the site, but this has a relatively short record (starting in 1993). The D8H004 gauge is approximately 85kms downstream and this record starts in 1971 and runs to 2010. This latter gauge was utilised to represent flows at the site since there are few significant tributaries and the record is much longer and therefore better able to represent long term flow conditions.	3
Fish	Single site visits and fish sampling during June 2010. Various previous fish surveys in region. Atlas of Southern African Freshwater fishes (Scott et al., 2006). SAIAB Data base (2006). Reference Fish Frequency of Occurrence Report (Kleynhans et al., 2007)	3
Macroinvertebrates	Good. One SASS5 survey was collected during the present study (2010.05.29), but additional data were collected by the Onderstepoort Veterinary Institute as part of the Orange River Blackfly Control Programme between 1991 and 1996 (Palmer 1996, 1997a, b).	4
Riparian vegetation	Satellite images (Google earth) of the respective reach and aerial photos (1941, 1962, 1967, 1969, 1976, 2008). Hydraulic cross-section (profile) at the site together with surveyed key vegetation points Hydrology specialist questionnaire	4.5

Component	Data Availability	Confidence
	Ecoregion class and associated information Geomorphic Zone classification and GAI IHI segments / impacts Biomes and vegetation types of South Africa: (Rutherford & Westfall, 1986; van Wyk & van Wyk, 1997; Mucina & Rutherford, 2006) SANBI Plant of Southern Africa online database (based on several herbaria collections). Data collected during field visit (June 2010).	
Riverine Fauna	1 site visit Terrestrial habitat survey (rapid) Site photos	2
O4 VIOOLSDRIFT		
Hydrology	Hydrology provided by WRP Observed data from D8H003/13	3
Diatoms	Site specific diatom data were available from sample collection during 2008 – 2009 as well as data from sample collected during EFR site visit. Three diatom samples were taken during 2005, 2008 - 2009 across the reach, along with measured *in situ* water quality measurements.	3.5
Water Quality	RC: Orange River @ Korridor Brand Kaross (D82L; ecoregion II: 25.03) D8H007Q01 (1980; n=35) PES: 1) Orange River @ Oppenheimer Bridge, Alexander Bay (D82L; ecoregion II: 25.03) D8H012Q01 (1995 – 2003; n=263) 2) Data from diatom sample collection in 2008 (n=9)	2 2.5
Geomorphology	A historical aerial photographic record dating back to the 1930's was available for this site, as well as anecdotal descriptions of the river reach from the Orange River Reconnaissance Study that was conducted in the early 1900's. These data document gross morphological changes to the site and reach and aid in the Reference State and PES determinations and assessments. The D8H003 gauge was used to represent flows at the site, since this gauge provides a long discharge record beginning in 1935.	3.5
Fish	Single site visits and fish sampling during June 2010. Various previous fish surveys in region. Atlas of Southern African Freshwater fishes (Scott et al., 2006). SAIAB Data base (2006). Reference Fish Frequency of Occurrence Report (Kleynhans et al., 2007)	3
Macroinvertebrates	Good. One SASS5 survey was collected during the present study (2010.05.26), but additional data were collected by the Onderstepoort Veterinary Institute as part of the Orange River Blackfly Control Programme between 1991 and 1996 (Palmer 1996, 1997a, b). Reference conditions were based on professional judgment and data collected in the catchment by Niehaus and Kotze (2003), and Marie Watson (unpublished data	4
Riparian vegetation	Satellite images (Google earth) of the respective reach and aerial photos (1937, 1961, 1964, 1969, 1976, 1978, 1989, 2006). Hydraulic cross-section (profile) at the site together with surveyed key vegetation points Hydrology specialist questionnaire Ecoregion class and associated information Geomorphic Zone classification and GAI IHI segments / impacts Biomes and vegetation types of South Africa: (Rutherford & Westfall, 1986; van Wyk & van Wyk, 1997; Mucina & Rutherford, 2006) SANBI Plant of Southern Africa online database (based on several herbaria collections).	4.5
Riverine Fauna	1 site visit Terrestrial habitat survey (rapid) Site photos	2
C5 UPPER CAELDON		
Hydrology	Hydrology provided by WRP	2.5
Diatoms	No data were available for the EFR site specifically except one sample taken during 2010 EFR site visit. Good information available from diatom sample collection during 2008 and 2009 across the reach and tributaries, along with *in situ* water quality measurements.	3.5
Water Quality	RC: Little Caledon River @ Caledonspoort (D21C; ecoregion II: 15.03). D2H012Q01 (1975 – 1977; n=84)	RC: 4

Component	Data Availability	Confidence
	PES: 1) Little Caledon River @ Caledonspoort (D21C; ecoregion II: 15.03). D2H012Q01 (2002 – 2010; n=47/48). 2) Data from diatom sample collection in 2008 + 2009	PES: 3
Geomorphology	A historical aerial photographic record dating back to the 1960's was available for this site, and exposed cut banks at the site document Reference and subsequent sediment characteristics of the site. The nearest gauge is 60km downstream – too far to represent flows at the site (more than 5 times the size of the catchment at the EFR site).	2.5
Fish	Single site visits and fish sampling during June 2010. Limited fish surveys in region (for Rapid Reserve Determinations and EIA's). Atlas of Southern African Freshwater fishes (Scott et al., 2006). SAIAB Data base (2006). Reference Fish Frequency of Occurrence Report (Kleynhans *et al.,* 2007)	*3*
Macroinvertebrates	Low. One SASS5 survey was used to determine PES: 2010/06/22	2
Riparian Vegetation	Satellite images (Google earth) of the respective reach and aerial photos (1964, 1974, 1984, 2004, 2010). Hydraulic cross-section (profile) at the site together with surveyed key vegetation points Hydrology specialist questionnaire Ecoregion class and associated information Geomorphic Zone classification and GAI IHI segments / impacts Biomes and vegetation types of South Africa: (Rutherford & Westfall, 1986; van Wyk & van Wyk, 1997; Mucina & Rutherford, 2006) SANBI Plant of Southern Africa online database (based on several herbaria collections). Data collected during field visit (June 2010).	4.5
C6 LOWER CALEDON		
Hydrology	Hydrology provided by WRP	2
Diatoms	No data were available for the EFR site specifically except one sample taken during 2010 EFR site visit. Fewer samples taken during 2008 – 2009 across the reach than EFR C5.	3
Water Quality	RC: Caledon River @ Jammerdrift (D23G; ecoregion II: 11.03) D2H001Q01 (1976 – 1979; n=92). PES: 1) Caledon River @ Kommissiedrift (D24G; ecoregion II: 11.10). D2H036Q01 (2000 – 2010; n=90-96). 2) Weldam Raw (Bloem Water intake: labelled BW on Table 5.3) (D23J; ecoregion II: 11.03). (2001 – 2010; n=230. 3) Data from Slabbert (2007).	RC: 3.5 PES: 4
Geomorphology	A long historical aerial photographic record dating back to the 1940's was available for this site. The nearest gauge upstream at Welbedacht Dam – too far to represent flows directly at the site.	3
Fish	Single site visits and fish sampling during June 2010. Limited fish surveys in region (for Rapid Reserve Determinations and EIA's). Atlas of Southern African Freshwater fishes (Scott et al., 2006). SAIAB Data base (2006). Reference Fish Frequency of Occurrence Report (Kleynhans *et al.,* 2007)	*3*
Macroinvertebrates	Low. One SASS5 survey was used to determine PES: 2010/06/23 Reference conditions were based on professional judgment and data collected in the catchment by Niehaus and Kotze (2003), and Marie Watson (unpublished data).	2
Riparian vegetation	Satellite images (Google earth) of the respective reach and aerial photos (1944, 1951, 1969, 1974, 2008). Hydraulic cross-section (profile) at the site together with surveyed key vegetation points Hydrology specialist questionnaire Ecoregion class and associated information Geomorphic Zone classification and GAI IHI segments / impacts Biomes and vegetation types of South Africa: (Rutherford & Westfall, 1986; van Wyk & van Wyk, 1997; Mucina & Rutherford, 2006) SANBI Plant of Southern Africa online database (based on several herbaria collections). Data collected during field visit (June 2010).	4.5
K7 KRAAI		

Component	Data Availability	Confidence
Hydrology	Hydrology provided by WRP Observed data from D1H011	5
Diatoms	No data were available for the EFR site specifically except one sample taken during 2010 EFR site visit. Diatom sample collection during 2008 and 2009 US and DS of site was available along with *in situ* water quality data.	3
Water Quality	RC: Kraai River @ Roodewal (D13L; ecoregion II: 26.03). D1H011Q01 (1974 – 1977; n=80). PES: 1) Kraai River @ Roodewal (D13L; ecoregion II: 26.03). D1H011Q01 (2000 – 2010; n=64-66). 2) Data from diatom sample collection in 2008 + 2009.	RC: 3.5 PES: 4
Geomorphology	A historical aerial photographic record dating back to the 1960's was available for this site. A good and relatively reliable, long hydrological record is available from a gauge at the site.	3
Fish	Single site visits and fish sampling during June 2010. Limited fish surveys in region. Atlas of Southern African Freshwater fishes (Scott *et al*., 2006). SAIAB Data base (2006). Reference Fish Frequency of Occurrence Report (Kleynhans *et al.,* 2007)	*3*
Macroinvertebrates	Low. One SASS5 survey was used to determine PES: 2010/06/24	2
Riparian vegetation	Satellite images (Google earth) of the respective reach and aerial photos (1969, 1974, 1987, 2008). Hydraulic cross-section (profile) at the site together with surveyed key vegetation points Hydrology specialist questionnaire Ecoregion class and associated information Geomorphic Zone classification and GAI IHI segments / impacts Biomes and vegetation types of South Africa: (Rutherford & Westfall, 1986; van Wyk & van Wyk, 1997; Mucina & Rutherford, 2006) SANBI Plant of Southern Africa online database (based on several herbaria collections). Data collected during field visit (June 2010).	4.5
M8 MOLOPO WETLAND		
Hydrology	Hydrology provided by WRP Observed data from D4H030/14	5
Diatoms	Diatom data collected during 2005 as part of a PhD study (De la Rey, 2008). Diatoms at four RHP sites were sampled during May, July and September 2005. The EFR site was sampled during April 2010.	2
Water Quality	No data available.	n/a
Wetland Condition	A historical aerial photographic record dating back to the 1940's was available for this site, and previous work on the Molopo close to Mafikeng had confirmed the historic extent of seasonal to permanent wetland areas. Hydraulics and hydrological behaviour of the wetland system is complex, and this reduces confidence in the assessment.	1.5
Fish	Single site visits and fish sampling during June 2010. Limited fish surveys in region. Atlas of Southern African Freshwater fishes (Scott et al., 2006). SAIAB Data base (2006). Reference Fish Frequency of Occurrence Report (Kleynhans et al., 2007)	*3*
Macroinvertebrates	Moderate. Detailed study focussing on mayflies and caddisflies, conducted by the Albany Museum (Barber and de Moor 1993). Invertebrate data also collected from the area on 20 and 21 April 2010; plus SASS data collected further downstream by Hermien Roux (river health database).	4
Riparian vegetation	Satellite images (Google earth) of the respective reach and aerial photos (1943, 1975, 1985, 2008). 4x Hydraulic cross-sections (profile) at the site together with surveyed key vegetation points Hydrology info Ecoregion class and associated information IHI segments / impacts Biomes and vegetation types of South Africa: (Rutherford & Westfall, 1986; van Wyk & van Wyk, 1997; Mucina & Rutherford, 2006)	4.5

Component	Data Availability	Confidence
	SANBI Plant of Southern Africa online database (based on several herbaria collections). Data collected during field visit (June 2010)	

1.5 THIS REPORT

The report consists of the main report (this report, Volume 1) which is outlined below. Specialist appendices are provided separate (Volume 3). All component assessment models and EcoStatus models applied to this study is provided in electronic format.

Chapter 1: Introduction

This chapter provides an overview of the study area, objectives of the study area and data availability.

Chapter 2: Approaches and Methods

This chapter outlines the methods followed for the Ecological Reserve process. Summarised methods are provided for the EcoClassification and EWR scenario determination.

Chapter 3, 4, 7, 10, 13, 16, 19 and 22: EcoClassification

The EcoClassification results are provided for each EFR site.

Chapter 5-6, 8-9, 11-12, 14-15, 17-18 and 20-21: Determination of stress indices and EFR scenarios

The stress indices for all physical and biological components at each EWR site are provided. These chapters provide results of different EWR scenarios with respect to low and high flows for the respective EFR sites except EFR M8. Aspects covered in these chapters are component and integrated/stress curves, generating stress requirements, general approach to high flows and final results.

Chapter 23: Evaluation of Operational scenarios

Operational scenarios at EFR M8 were developed with the aim ofinproving wetland functionality. The scenarios and the ecological consequences of these scenarios are discussed.

Chapter 24: Conclusions and Recommendations

The EcoClassification and EWR scenario results are summarised and recommendations are made.

Chapter 25: References

2 APPROACHES AND METHOD

As indicated in the Terms of Reference, EFRs were determined applying the Intermediate Ecological Reserve Methodology (IERM) (DWAF, 1999). The methodology consists of two different steps:

- EcoClassification
- EFR quantification for different ecological states

2.1 ECOCLASSIFICATION

The EcoClassification process was followed according to the methods of Kleynhans and Louw (2007). Information shown below is a summary of the EcoClassification approach. For more detailed information on the approach and suite of EcoStatus methods and models, refer to:

- Physico-chemical Driver Assessment Index (PAI): Kleynhans et al. (2005).
- Geomorphological Driver Assessment Index (GAI): Rountree and du Preez (in prep).
- Fish Response Assessment Index (FRAI): Kleynhans (2007).
- Macroinvertebrate Response Assessment Index (MIRAI): Thirion (2007).
- Riparian Vegetation Response Assessment Index (VEGRAI): Kleynhans et al. (2007a).
- Instream Habitat Integrity (IHI): Kleynhans *et al*. (2009).

EcoClassification refers to the determination and categorisation of the PES (health or integrity) of various biophysical attributes of rivers compared to the natural (or close to natural) reference condition. The purpose of EcoClassification is to gain insight into the causes and sources of the deviation of the PES of biophysical attributes from the reference condition. This provides the information needed to derive desirable and attainable future ecological objectives for the river. The EcoClassification process also supports a scenario-based approach where a range of ecological endpoints has to be considered.

The state of the river is expressed in terms of biophysical components:

- Drivers (physico-chemical, geomorphology, hydrology), which provide a particular habitat template; and
- Biological responses (fish, riparian vegetation and aquatic invertebrates).

Different processes are followed to assign a category (A→F; A = Natural, and F = critically modified) to each component. Ecological evaluation in terms of expected reference conditions, followed by integration of these components, represents the Ecological Status or EcoStatus of a river. The EcoStatus can therefore be defined as the totality of the features and characteristics of the river and its riparian areas that bear upon its ability to support an appropriate natural flora and fauna (modified from: Iversen *et al*., 2000). This ability relates directly to the capacity of the system to provide a variety of goods and services.

2.1.1 Process

The steps followed in EcoClassification are as follows:

- Determine reference conditions for each component.
- Determine the PES for each component, as well as for the integrated EcoStatus.
- Determine the trend for each component, as well as for the EcoStatus.
- Determine the reasons for the PES and whether these are flow or non-flow related.

- Determine the EIS for the biota and habitat.
- Considering the PES and the Ecological Importance and Sensitivity (EIS), suggest a realistic Recommended Ecological Category (REC) for each component, as well as for the EcoStatus.
- Determine alternative Ecological Categories (ECs) for each component, as well as for the EcoStatus.

Note: The Alternative Ecological Categories (AECs) are designed by using a combination of the most likely impacts or changes that could result in a decrease or improvement of the present state. This could include both flow and non flow-related changes depending on the issues governing conditions at the site.

The flow diagram (Kleynhans and Louw, 2007) (Figure2.1) illustrates the process.

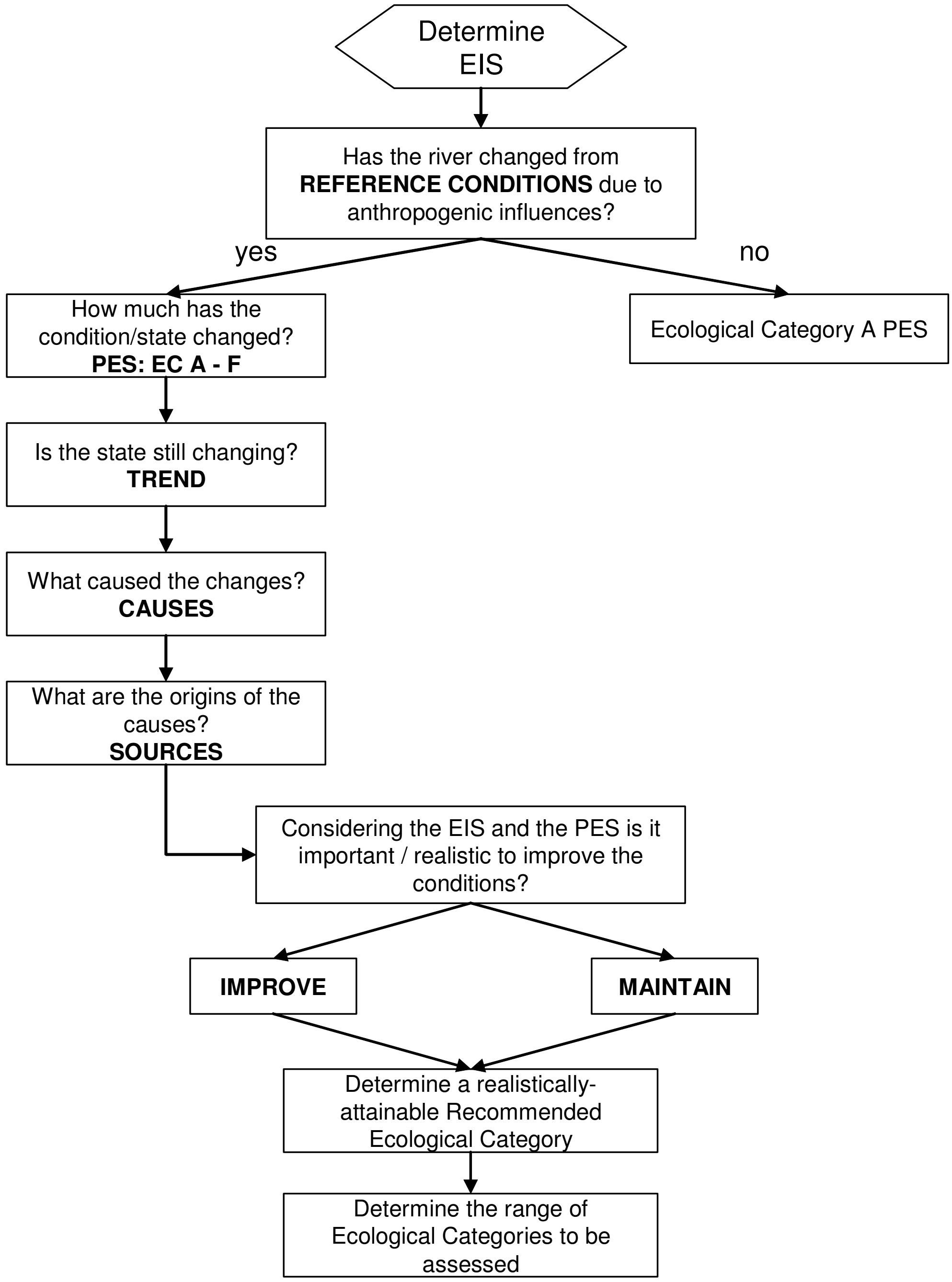


Figure 2.1 Flow diagram illustrating the information generated to determine the range of ECs for which the EFR will be determined

2.1.2 General Approach

The Level 4 EcoStatus assessment has been applied according to standard methods. The minimum tools required for this assessment are shown in Figure 2.2.

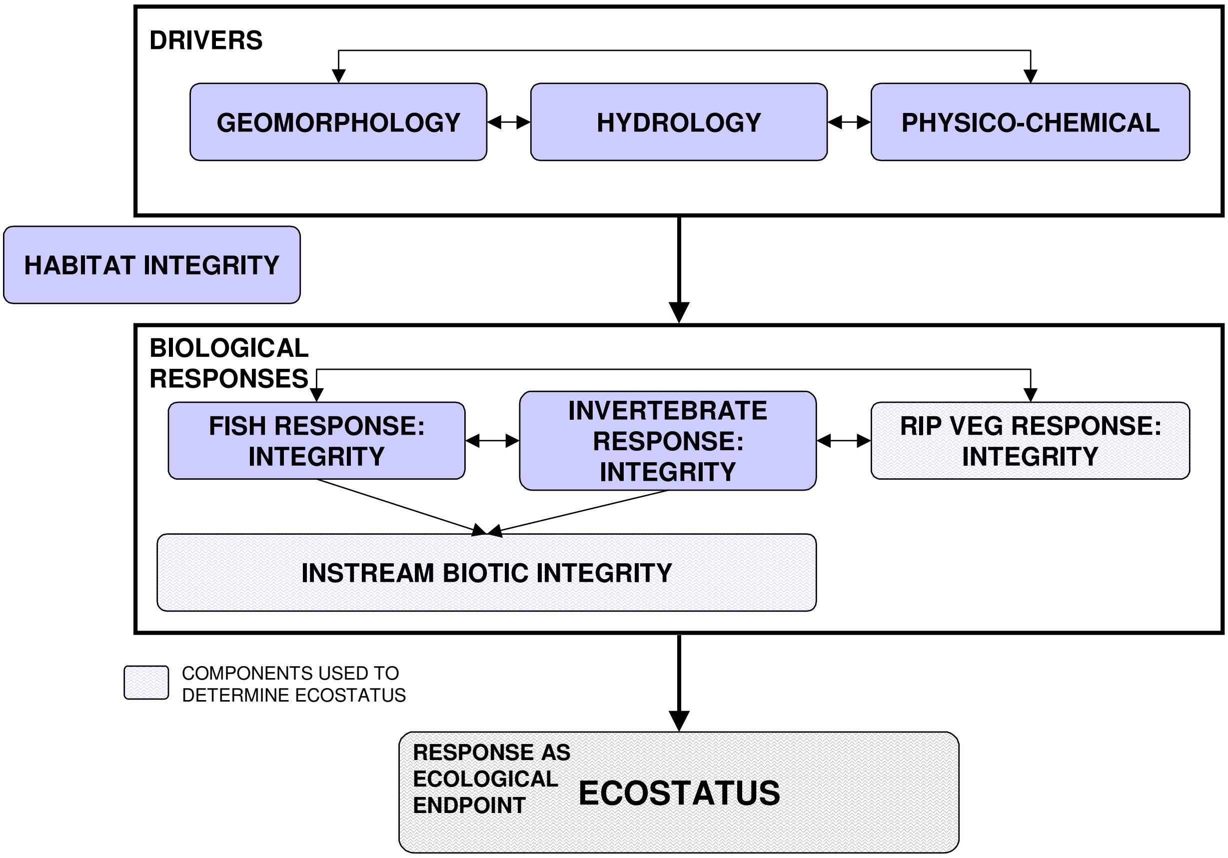


Figure 2.2 EcoStatus Level 4 determination

The role of the EcoClassification process is, amongst others, to define the various ECs for which Ecological Flow Requirements (EFR) will be set. It is therefore an essential step in the EFR process. The EFR process is essentially a scenario-based approach and the EFRs determined for a range of ECs are referred to as EFR scenarios. This range of ECs would include the PES, REC (if different from the PES) and the AECs. When designing a scenario that could decrease the PES, flow changes are first evaluated. If this, and the response of other drivers, are deemed to be insufficient on its own to change the category, then the current non-flow related impacts are 'increased', or new non-flow related impacts are included. It is attempted to create a realistic scenario, however, it must be acknowledged that there are many scenarios that could result in a changed EC.

2.1.3 Ecological Importance and Sensitivity (EIS)

The EIS model, developed by Dr CJ Kleynhans (DWAF, 1999) was used for this study. This approach estimates and classifies the EIS of the streams in a catchment by considering a number of components surmised to be indicative of these characteristics.

The following ecological aspects were considered as the basis for the estimation of EIS:

- The presence of rare and endangered species, unique species (i.e., endemic or isolated populations) and communities, intolerant species and species diversity were taken into account for both the instream and riparian components of the river.
- Habitat diversity was also considered. This included specific habitat types such as reaches with a high diversity of habitat types, i.e., pools, riffles, runs, rapids, waterfalls, riparian forests, etc.

With reference to the bullets above, biodiversity in its general form (i.e. Noss, 1990) was taken into account as far as the available information allowed:

- The importance of a particular river or stretch of river in providing connectivity between different sections of the river, i.e., whether it provided a migration route or corridor for species, was considered.
- The presence of conservation or relatively natural areas along the river section also served as an indication of ecological importance and sensitivity.
- The sensitivity (or fragility) of the system and its resilience (i.e., the ability to recover following disturbance) of the system to environmental changes was also considered. Consideration of both the biotic and abiotic components was included here.

The EIS results are summarised in this report and the models are provided electronically. EIS categories are summarised in Table 2.3.

Table 2.1 EIS categories (Modified from DWAF, 1999)

EIS Categories	General Description
Very high	Quaternaries/delineations that are considered to be unique on a national or even international level based on unique biodiversity (habitat diversity, species diversity, unique species, rare and endangered species). These rivers (in terms of biota and habitat) are usually very sensitive to flow modifications and have no or only a small capacity for use.
High	Quaternaries/delineations that are considered to be unique on a national scale due to biodiversity (habitat diversity, species diversity, unique species, rare and endangered species). These rivers (in terms of biota and habitat) may be sensitive to flow modifications but in some cases, may have a substantial capacity for use.
Moderate	Quaternaries/delineations that are considered to be unique on a provincial or local scale due to biodiversity (habitat diversity, species diversity, unique species, rare and endangered species). These rivers (in terms of biota and habitat) are usually not very sensitive to flow modifications and often have a substantial capacity for use.
Low/Marginal	Quaternaries/delineations that are not unique at any scale. These rivers (in terms of biota and habitat) are generally not very sensitive to flow modifications and usually have a substantial capacity for use.

2.2 EFR DETERMINATION

The Habitat Flow Stressor Response method (HFSR) (IWR S2S, 2004; O'Keeffe *et al.*, 2002), a modification of the Building Block Methodology (BBM; King and Louw, 1998) was used to determine the low (base) flow EFRs. This method is one of the methods used to determine EFRs at the intermediate level. A short summary of the approach is provided below.

The basic approach is to set stress indices for fish and macroinvertebrates. The stress index describes the consequences of flow reduction on flow dependant biota and is determined by first assessing the response of habitat to a flow reduction. The habitat flow index is described separately for fish and macroinvertebrates as an instantaneous response of habitat to flow in terms of a 0 – 10 index relevant for the specific site. The zero stress (best habitat) and 10 stress (worst habitat) is fixed as follows to ensure that the range for fish and macroinvertebrates are the same:
0: Optimum habitat represented by the maximum natural base flow. Note that without adequate hydrological data, this is difficult to identify.
10: No flow.

The second step is to determine the biota stress index which describes the instantaneous response of biota to change in habitat (and therefore flow) in terms of a 0 – 10 stress index. The description of the changes of habitat at each stress level (as described in the habitat stress index) is then related to the response of the fish and macroinvertebrates indicators. The biota stress index is described separately for fish and macroinvertebrates. The zero stress, representing optimum habitat, would therefore represent a situation of zero stress to biota with the maximum abundance of species present under these conditions.

The stress index therefore describes the habitat conditions and biota response for fish and macroinvertebrates at a range of low flows. The fish and macroinvertebrate stress-flow relationship will not be the same as the responses to the same flow will/can result in different stress for fish and macroinvertebrates.

The fish and macroinvertebrate stress indices are then used to convert separate natural and present day flow time series to a stress time series. The stress time series is converted to a stress duration graph for the highest and lowest flow months. This then provides the specialist with the information of how much the stress has changed from natural under present conditions due to changes in flow. It would follow that if flow has decreased from natural, stress would increase and vice versa. If specialists do not agree with the levels of stress under natural conditions based on their knowledge of the species, the stress indices were refined.

Tools used to determine the stress indices are specialist knowledge and information about the indicator species' habitat requirements, the hydraulics in the specific format required, and the natural hydrology.

At this stage only the instantaneous response of habitat and biota to flow reduction has been assessed. This means that the actual stress requirements AT SPECIFIC DURATIONS AND DURING SPECIFIC SEASONS to maintain the biota in a certain ecological state has not yet been assessed. The information used to determine the Ecological Category for the instream biota is considered when determining the stress required to maintain or achieve this ecological state. The stress requirement is set for drought and maintenance conditions. Drought stress is set at 5% exceedance. The maintenance stress is set at a percentage which is determined based on the low flow hydrological variability of the specific river being assessed. The more variable the river, the higher the percentage at which maintenance stress is set. Any stress requirements for other percentage points can also be provided.

The requirements are still provided in terms of the separate fish and macroinvertebrate indices. Obviously one can only deal with one stress-flow relationship, and an integrated stress index is required for this. The integrated stress curve is comprised by the highest stress of either the fish or macroinvertebrate component at any one flow. This forms the integrated stress curve and the results for fish and macroinvertebrates must therefore be converted to integrated stress in order to be comparable.

Figure 2.4 illustrates an example of the interpolated individual component stresses as well as the integrated curve. The black line represents the integrated curve and while the other lines represent the stress flow relationships for the various components. The integrated line in this case consists of the flow dependant macroinvertebrates (FDI) (purple line) for the stress range 0 to 5, and fish (blue line) for the stress range 5 to 10.

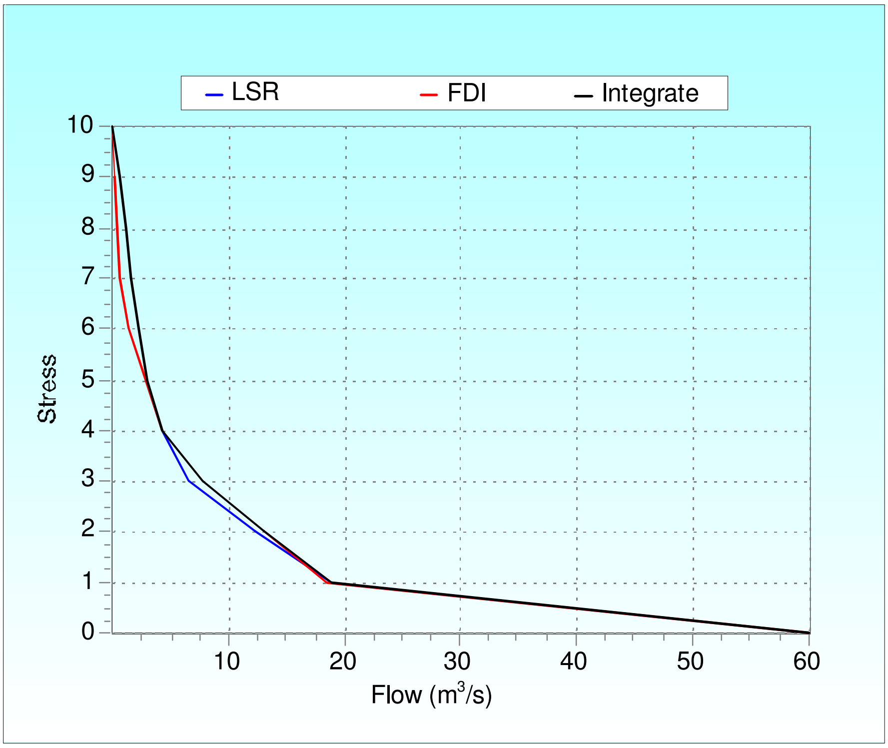


Figure 2.3 Component and integrated stress curves

Specialists determine the required stress (based on the habitat and biota response) for different durations and for different ecological categories. The complexity here, as with all flow requirement methods, is to interpret an instantaneous response in terms of duration and seasonal requirements. The required stress is therefore converted to integrated stress and plotted on a graph which also shows the natural and present day flow converted to integrated stress. This therefore supplies the 'hydrological check' to ensure that the requirements are realistic in terms of the natural hydrology and present day hydrology (only used when realistic and of reasonable confidence). The low flow stress requirement for an EC consists of the component requirement with the lowest stress requirement (highest flow requirements). For example, if fish has a requirement at 5% duration of a stress of 6 to achieve a C EC, and macroinvertebrates has a requirement for a C EC of 8, the final requirement will be a stress of 6 as the 6 stress would cater for the macroinvertebrates, whereas the 8 stress could not cater for the fish and would result in the fish being in a lower EC. These final requirements are therefore connected manually (a 'hand drawn line' as the required stress duration) and illustrated as a stress duration graph.

Figure 2.5 is an example of a stress duration graph and illustrates the stress requirements and stress points required for a B PES and REC (purple arrowed line), and C AEC (green arrowed line).The different coloured circles indicate the requirements of the instream biota for the specific EC. Each circle is labeled as follows and indicates a different biotic component:

- LSR – Large semi-rheophilic fish guild.
- FDI – Flow dependent macroinvertebrates.
- MVI – marginal vegetation macroinvertebrates.

In this example the drought flows (5%) of the different biotic components are the same for all ECs.

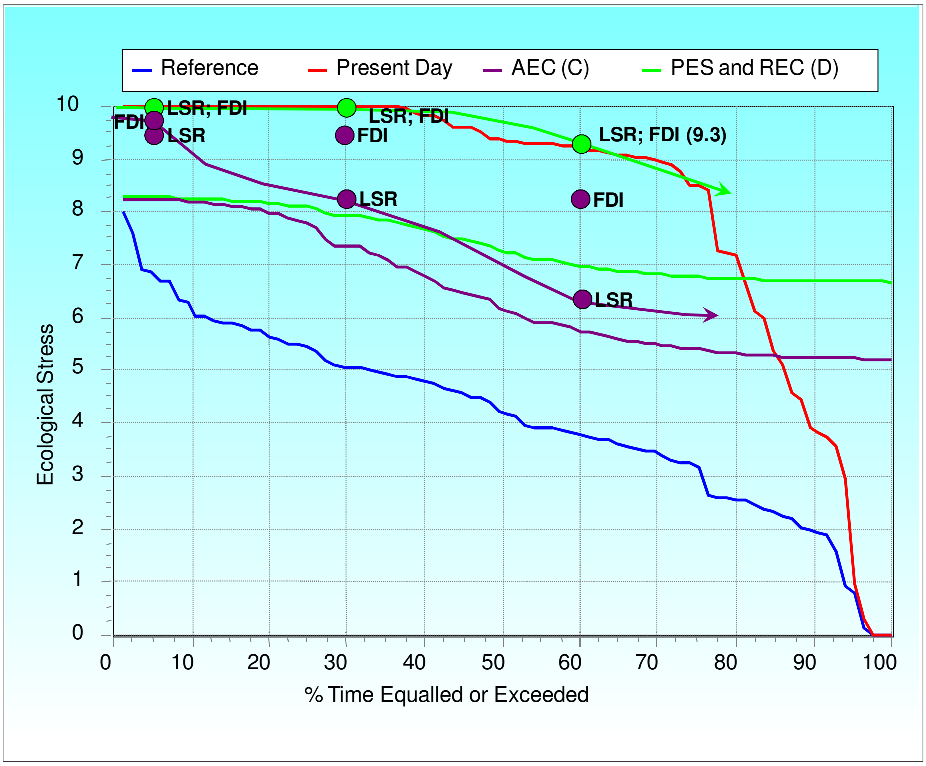


Figure 2.4 Stress duration curve for a D PES and REC, and C AEC up - DRY season

These stress requirements (provided for two key months or the high and low flow season), must now be manipulated to provide a complete low flow regime as follows:

- The Desktop estimates for the same ECs as being assessed are converted to stress and also provided on the above graph. The hydrologist then uses the Desktop estimate and modifies it to fit the specialist requirements. This is done using the Desktop Reserve Model and the Flow Stressor Response model within SPATSIM[1] (Spatial and Time Series Modelling) (Hughes and Forsythe, 2006).The process is specifically designed this way as the seasonal characteristics of the hydrology and the rules for the different ECs are built into the Desktop estimate[2]. This would therefore ensure that the requirements set by specialists do not deviate significantly from the natural seasonal variability.
- There are a range of options that one can use to make these modifications to the Desktop Reserve Model (DRM), such as changing the total volume required for the year, changing specific monthly volumes, changing durations of either drought or maintenance flows, changing the seasonal distribution and changing the category rules and shape factors.
- The DRM will then extrapolate the requirements to the other months or seasons and specialists can check these other months.
- The changes made to the DRM to fit the specialist requirements are documented.

The graphs for the final low flow stress requirements are documented.

[1]SPATSIM is an integrated data management and modelling software package developed in Delphi using the spatial data handling functions of Map Objects. It has been designed to allow the efficient management, processing and modelling of the type of data associated with a range of water resource assessment approaches used in South Africa including streamflow and other time series data display and analysis, rainfall-runoff models (including the Pitman monthly model) and a variety of Ecological Reserve determination models.
[2]The desktop estimates for specific ECs include rules for these ECs based on long-term data records and expert information.

2.2.1 High flows

The approach to set high flows is a combination of the Downstream Response to Imposed Flow Transformation (DRIFT; Brown and King, 2001) approach and BBM. The high flows are determined as follows:

- Flood ranges for each flood class and the geomorphology and riparian vegetation functions are identified and tabled by the relevant specialists.
- These are provided to the instream specialists who indicate:
  - which instream function these floods cater for,
  - whether additional instream functions apart are required,
  - Whether they require any additional flood classes to the ones identified.
- The number of floods for each flood class is identified as well as where (early, mid, late) in the season they should occur.
- These numbers of floods are then adjusted for the different Ecological Categories.
- The floods are evaluated by the hydrologist to determine whether they are realistic. A nearby gauge with daily data is used for this assessment. Without this information it is difficult to judge whether floods are realistic.
- The hydrologist then determines the daily average and documents the months in which the floods are spaced.
- The floods are then entered into the DRM to provide the final .rul and .tab files.

2.2.2 Final flow requirements

The low and high flows are combined to produce the final flow requirements for each EC as:

- An EFR table, which shows the results of high flows and low flows for each month separately. Floods with a frequency higher than 1:1 are often not included as they cannot be managed.
- An EFR rule table which provides the recommended EFR flows as a duration table, showing flows which should be provided when linked to a natural trigger (natural modelled hydrology in this case). EFR rules are supplied for total flows as well as for low flows only.

The low flow EFR rule table is useful for operating the system, whereas the EFR table must be used for operation of high flows.

3 ECOCLASSIFICATION: EFR O1 (HOPETOWN)

3.1 EIS RESULTS

The EIS evaluation results in a **MODERATE** importance. The highest scoring matrices are:

- Presence of aquatic instream rare and endangered fish species (BKIM);
- Presence of rare and endangered riparian biota such as the clawless otter, black stork, African marsh harrier, Namaqua stream frog, Straw-coloured fruit bat, *Crinum bulbispermum;*
- Unique riparian biota: Orange River white-eye, Upper Gariep Alluvial Vegetation classified as vulnerable (2.3% under protection), 5 endemic riparian obligates;
- Aquatic instream biota that is intolerant to zero flow situations: Semi-rheophillics, and rheophillic invertebrates;
- Riparian wetland biota – taxon richness: 59 species of riverine fauna present (61% of expected spp);
- Critical riparian habitat and refugia: The riparian (large tree) habitat is a refuge for 17 true riparian spp and 7 semi-aquatic spp. for nesting, roosting and shelter;
- Riparian migration corridor.
-

3.2 REFERENCE CONDITIONS

The reference conditions (RC) for the components in EFR O1 are summarised in Table 3.1

Table 3.1 EFR O1: Reference conditions

Component	Reference conditions	Conf
Hydrology	6738 nMAR	2.5
Physico-chemical	See the description of RC per variable in Table 3.2	3
Geomorphology	Braided reach (as indicated in the 1950's and 1960's aerial photos), with multiple channels of gravel, cobbles and sand. The banks would have been well-vegetated.	3
Riparian vegetation	Vaalbos Rocky Shrubland vegetation type, which occurs within the Savanna Biome and the Eastern Kalahari Bushveld Bioregion. Distinct from the terrestrial zone, and is categorised at an azonal vegetation type: the Upper Gariep Alluvial Vegetation. Expect a mix of open alluvia or cobble/boulder and vegetated areas in the marginal zone. Vegetation, similarly, should be a mix of woody (*Gomphostigma virgatum, Salix mucronata subs. mucronata*) and non-woody (*Phragmites australis, Cyperus marginatus*) vegetation. In the lower zone one would expect the same as the marginal zone, with the addition of lower zone alluvial-loving woody species such as *Combretum erythrophyllum* and *Searsia pendulina*. Terraces or bars should be well vegetated with some open areas. Vegetation on the upper zone should be dominated by woody species (*Acacia karoo, Ziziphus mucronata, Searsia pendulina* mainly) with some savanna species occurring. Banks should be well vegetated and dominated by woody riparian thickets, with dominant species as outlined above and a small proportion of terrestrial woody species.	3
Fish	Based on the available fish distribution data and expected habitat composition, 11 indigenous fish species have a high to definite probability of occurrence. The indigenous AMOS is also mentioned as having peripheral occurrence, but was excluded from reference conditions as this species is not expected to occur naturally in the Orange River and can probably not complete its life-cycle successfully. The expected habitat composition at the site also met the requirements of all expected fish species. The expected FROC provided in Kleynhans *et al.* (2007) for site D3ORAN-HOPET was broadly used to determine the reference FROC, with changes made based on additional information.	3

Component	Reference conditions	Conf
Macroinvertebrates	Reference conditions were based on professional judgment and data collected in the area by Agnew (1965), Pitchford and Visser (1975), de Kock *et al* (1974), Pretorius *et al* (1974) and Palmer (1996). The reference SASS5 Score is 188 and the ASPT is 6.5. The expected number of SASS5 taxa is 29.	3
Riverine Fauna	Cover has increased (Mackenzie, *pers com*). Original fauna consisted of 95 riverine vertebrate species which includes aquatic and semi-aquatic species, marginal habitat species, and riparian species.	3

3.3 PRESENT ECOLOGICAL STATE

The PES reflects the changes in terms of the Ecological Category (EC) – Table 3.2) from reference conditions. The summarised information is provided in Table 3.2.

Table 3.2 EFR O1: Present Ecological State

Component	PES Description	EC	Conf
Hydrology	3678.65 present day MAR (54.6% of nMAR)	E	2
Physico-chemical	See table 3.3	D	3
Geomorphology	Reasons for the PES are: Present Day flows in this section are about half of the MAR. A peaking hydro-power dam operates about 100km upstream of the site with twice-daily floods. Despite these daily floods, large flood sizes and frequencies are highly reduced; accounting for the increased area of bars and islands in the reach (observed over the historical record), and especially the progressive stabilisation of the sedimentary features by vegetation. Scouring events across these bars are too infrequent and small to keep sedimentary and vegetation encroachment in check. Although there are increased sediment loads from the upper catchment, much of this is trapped in the upstream dams, but tributaries and flushing of fines and suspended load through the dams compensates for some of the reduced sediment supply downstream. Additionally, large floods are reduced, so the reduced sediment is somewhat offset by a reduced frequency of large scour events. Moderate floods now occur as twice-daily flows due to peaking hydropower generation, and this has likely armoured sections of the channel, but may be responsible for the increased vegetation in the lower riparian zones due to more frequent wetting.	C/D	2.5
Riparian vegetation	Marginal Zone: Dominated by dense stands of *Phragmitesaustralis* with a distinct lack of woody marginal zone species such as *Gomphostigmavirgatum* and *Salix mucronata*, although these species occur with very low abundance. The frequency of inundation disturbance is likely to prohibit recruitment of these species while reeds are able to withstand and even benefit. Lower Zone: The zone is frequently flooded, which is clearly shown by scour and also species composition. Marginal zone woody species are common in this zone, as well as many sedge and wetland species. Woody species have attained high densities and stature and have likely benefited from frequent wetting that is not extreme enough to be an impact as it is in the marginal zone. Upper zone and even terrestrial woody species (such as *Acacia karoo* and *Ziziphus mucronata*) are also commonly recruiting in this zone, but seem to fail to reach full maturity (due to flooding disturbance). Upper Zone: Terrace or bar vegetation component is absent and represents the expected for the lower zone. Macro Channel Bank: Dominated by woody riparian and terrestrial savanna species with a mix of open areas that are either sandy or colonised by grasses.	B/C	4

Component	PES Description	EC	Conf
Fish	All the expected fish species should still be present in this river reach albeit in a moderately to highly reduced FROC. Species that are thought to have been impacted the most include LUMB, BANO, BKIM and CGAR. The primary changes responsible for deterioration in the fish assemblage is primarily associated with altered hydrology / flow modifications related to fluctuating water releases for hydro-electric power generation. This results in loss of marginal vegetation as cover, flushing of substrates (critical impact during spawning of substrate breeders) and laying dry of marginal zone (especially significant during breeding season for vegetation spawners). The impacts of migration barriers on the natural movement of fish are furthermore expected to impact the fish assemblage negatively in this river reach. Other impacts are related to water quality deterioration (especially impacts from dams on temperature and oxygen, as well as presence of toxics). The presence of alien fish species (both predacious and habitat modifying) furthermore impact on the natural fish populations of this reach.	C/D	3
Macroinvertebrates	A total of 21 SASS5 taxa was observed at the site, out of 27 expected (i.e. 78%). The observed SASS5 Score was 128 (72%), and the ASPT was 6.1 (92%). Key taxa expected but not observed were mainly taxa that prefer slow-flowing water, such as shrimps (*Atyidae), Coroxidae, Notonectidae, Ceratopogonidae,* and *Lymnaeidae*. The fauna was dominated by baetid mayflies. No other taxa were abundant. *Leptophlebiid* mayflies and *gomphid* dragonflies were less abundant than expected. A number of sensitive taxa were recorded, including *Leptoceridae (Leptoceridae (Parasetodes* and Oecetis *sp*), flat-headed mayflies (*Heptageniidae) Tricoryhtidae* and *Leptophliidae.*	C	3
Riverine Fauna	82% of expected fauna species (78 from 95 animals) can occur in this segment. This comprises 84% aquatic and semi-aquatic species, 71% marginal habitat species, and 90% riparian species. Thus, the deep channel with some instream pools, shallower edges and associated marginal vegetation dominates the riverine habitat of this reach. The utilization of the terrain behind or in the riparian band (floodplain areas) in stretches of the river reach is utilized by organized agriculture, eliminating most of the backwater habitats that would have been there originally. The band of riparian vegetation on the higher terraces or floodplains consists of large tree and thicket components which forms favourable upper riparian habitats. In some places the thickets are irregular and patchy, discontinuing the migration corridor. There are little shallow marginal areas such as sandbanks and mudflats with hygrophilous vegetation on the river margins, as reeds encroach in these habitats.	C	4

Table 3.3 EFR O1: Present Ecological State: Physico-Chemical

RIVER	Orange River	**WATER QUALITY MONITORING POINTS**		
		RC	Orange River @ Marksdrift (D33K; ecoregion II: 26.01) D3H008Q01 (1966 – 1978; n=51)	
EFR SITE	EFR O1 (D33G; ecoregion II: 26.01)	**PES**	1) Orange River @ Marksdrift (D33K; ecoregion II: 26.01) D3H008Q01 (2000 – 2010; n=414-427) 2) Data from diatom sample collection in 2008 (n=2)	
Confidence assessment	Moderate - High confidence. Although sufficient data, particularly for the present state, data gaps exist, e.g. metal ions, pesticides, herbicides. Water quality and EFR site in the same EcoRegion level II.			
Water Quality Constituents		**RC Value**	**PES Value**	**Category/Comment**
Inorganic salts (mg/L)	TEACHA was not used for data assessment, as salinity levels not significantly elevated.			
Salt ions (mg/L)	Ca	29.75	24.74	Concentrations similar for the PES, except for sulphate, sodium and chloride which show increases from
	Cl	9.96	12.98	
	K	1.80	1.79	

	Mg	11.00	10.24	the RC.
	Na	10.80	13.75	
	SO_4	11.00	19.94	
Nutrients (mg/L)	SRP	0.014 *	0.020	A category
	TIN	0.15	0.38	B category
Physical Variables	pH (5^{th} + 95^{th} %ile)	6.93 + 8.02	7.64 + 8.34	A/B category
	Temperature	-	Two upstream dams result in large fluctuations in Temperature + DO.	No data. C – D category (qualitative assessment)
	Dissolved oxygen	-		
	Turbidity (NTU)	-	**WMS data:** Avg: 17.62 95^{th} %ile: 51.2 **Koekemoer (2010):** 21.85 (avg)	No RC data. Turbidity from system that naturally carries sediments, although trapped in dams. A/B category (qualitative assessment).
	Electrical conductivity (mS/m)	28.36 (n=79)	28.88	A category
Response variables	Chl a: periphyton (mg/m^2)	-	-	-
	Chl a: phytoplankton (µg/L)	-	Avg: 17.5 (n=2) (Koekemoer, 2010)	C category
	Macroinvertebrates	ASPT:6.6 SASS: 179	ASPT: 6.1 SASS: 128 MIRAI: 72.8%	C category
	Fish community score		FRAI: 57.6%	C/D category
	Diatoms	-	EFR O1: 15.7. Marksdrift: 14.4 (avg SPI)	B category
Toxics	Fluoride (mg/L)	1.5 **	0.31	A category
	Aluminium (mg/L)	0.02 **	0.221 (n=2) (Koekemoer, 2010)	E category
	Iron (mg/L)	-	0.143 (n=2) (Koekemoer, 2010)	No guideline + insufficient data
	Ammonia (mg/L)	0.002	0.01	A category
	Other	-	-	Impacts expected due to farming-related pesticides and fertilizer use.
OVERALL SITE CLASSIFICATION		**D – final category based on output of PAI model, expert judgement and hydrology category (E)**		

** boundary value for the A category recalibrated* *- no data* *** benchmark value, as no data*

3.3.1 EFR O1: Trend

The trend was also assessed. Trend refers to the situation where the responses have not yet stabilised in reaction to catchment changes. The evaluation is therefore based on the existing catchment condition. Geomorphology only indicated a long term negative trend and this was due to sediment which is still moving through the system. This however did not affect the other components which were all stable (See Figure 3.6).

3.3.2 EFR O1: PES causes and sources

The reasons for changes from reference conditions must be identified and understood. These are referred to as causes and sources ((http://cfpub.epa.gov/caddis/)). The PES for the components at EFR O1 as well as the causes and sources for the PES are summarised in Table 3.4.

Table 3.4 EFR O1: PES causes and sources

	PES	Conf	Causes	Sources	F[1]/NF[2]	Conf
Hydro[3]	E	2	Increase in unseasonal releases of small floods, decrease of moderate and large floods.	Twice daily flood releases from Vanderkloof dam for hydro power, upstream dams	F	5
Physico -chemical	D	3	Elevated nutrients and potential toxicant loads due to fertilizer and pesticide use	Land-use is agricultural, resulting in some toxicant and nutrient loading expected, although data only reflects a small increase in salts and nutrients.	NF	4
			Temperature fluctuations result in a change in water quality category from a C to D category.	The location of the upstream dam and twice daily peaks in flow impact on temperature and levels.	F	2
Geomorphology	C/D	2.5	Reduced frequency and size of large floods	Large dams upstream trap big floods and reduce the magnitude and frequency downstream	F	2.5
			Reduced sediment load	Upstream dams trap sediment and reduce supply to downstream reaches. These impacts have been ameliorated somewhat by reduced flows, and flushing of suspended loads through the dams.	NF	
			Peaking power generation – daily stage fluctuations	Daily stage fluctuations are reworking sediments in the marginal and lower riparian zones, and probably armouring the bed.	F	
Riparian vegetation	B/C	4	Increased reed cover in the marginal zone	Reduced and regulated flows	F	3
			Increased woody cover and density especially on lower zone and mid-channel bars	Bi-daily fluctuations and reduced moderate floods	F	
			Altered species composition	Small percentage of exotic annuals	NF	
Fish	C/D	3	Decreased overhanging vegetation as cover for fish resulted in decreased FROC of species with preference for these habitats. Loss of habitat (cover) also resulted in increased exposure to predators.	Continuous fluctuation in water levels due to hydro power releases. Increased bank erosion, flow modification and inundation. Farming: removal or change in riverine vegetation.	F	*3.5*
			Decrease in FROC and abundance of fish species with preference for fast habitats.	Loss in abundance and diversity of especially fast habitats as result of decreased base flows.	F	
			Decreased water quality affect species with requirement for good water quality.	Presence of toxins, altered temperature and oxygen due to dams and other human activities. Farming: water abstraction, reduced flows, pollutants. Farming: mineralization and eutrophication (fertilizers) due to irrigation run-off. Farming: Potential presence of pesticides and herbicide. Dams trapping silt altering water clarity, altered temperature and O2 regimes.	NF	
			Decreased species diversity and abundance as result of presence of predacious alien species (MSAL) feeding on indigenous fish.	Presence of alien predatory species. Dams create further suitable habitat for undesirable species.	NF	
			Bio-turbation from CCAR. Increased turbidity and disturbed bottom substrates reduce bottom substrate quality and water quality for indigenous fish (especially impact on LUMB breeding habitats)	Presence of alien CCAR. Dams create habitat for undesirable species.	NF	

	PES	Conf	Causes	Sources	F[1]/NF[2]	Conf
			Decreased abundance, and therefore FROC related to over utilization of fish resource for human consumption.	Poaching and over-fishing of fish using nets (gill and seine nets, often home-made).	NF	
			Reduced spawning success resulting in decreased FROC of many species.	Flushing away of eggs or laying dry of marginal zone breeding areas (rocky/cobbles and vegetated). Flow modification: Absence or lag effect on spring flushes, reduced habitat suitability and stimuli, modified flow pattern disrupt normal breeding cycle of fish species.	F	
			Presence of migration barriers reduces migration success (breeding, feeding and dispersal) of some species.	Large dams and some weirs.	NF	
Macroinvertebrates	C	3	Flow fluctuations (bi-daily)	Generation of peak demand hydro-power	F	4
			Elevated low flows	Discharges to meet demands for winter power generation and irrigation demands	F	4
			Increased photic depth	Upstream impoundments trapping silt	NF	4
			Altered water temperature (warmer winters, colder summers)	Thermal inertia of upstream impoundment	NF	3
			Increased Phytoplankton	Upstream impoundments	NF	4
			Toxic algal blooms, such as *Microcystis*	Annual overturn	NF	3
Riverine Fauna	C	4	Discontinued riparian corridor that originally acted as migration corridor Loss of riparian trees for perching, nesting and feeding by riverine fauna	Removal of riparian vegetation for agriculture	NF	3
			Increase in reeds in marginal zone, replacing mudflats and sandy alluvial habitats for waders (birds) Slow habitats for fish and invertebrates impacted – thus impacting on *piscivorous* and *invertivorous* fauna Daily inundation of lower marginal zone deter semi-aquatic fauna to settle in the zone	Daily elevated flows due to dam releases	F	
			Less variability in the fluvial system (lower high flows, higher low flows) jeopardize faunal diversity and integrity	Unnatural flow regimes (high and low flows)	F	
			Loss of habitat for wetland faunal species that utilized these habitats	Destruction of floodplain habitats by agriculture	NF	

1 Flow related 2 Non Flow related 3 Hydrology

The major issues that have caused the change from reference conditions are the releases for hydropower, barrier effects of the dams, water quality problems and the destruction of and removal of vegetation on floodplains for agriculture. The dominant factor seems to be the hydro-electric releases.

3.3.3 EFR O1: PES EcoStatus

To determine the EcoStatus, the macroinvertebrates and fish must first be combined to determine an instream EC. The instream and riparian categories are integrated to determine the EcoStatus. Confidence is used to determine the weight that the EC should carry when integrating into an EcoStatus (riparian, instream and overall). The EC percentages are provided (Table 3.5) as well as the portion of those percentages used in calculating the EcoStatus.

Table 3.5 MRU: EFR O1: Instream

INSTREAM BIOTA	Importance Score	Weight
FISH		
1.What is the natural diversity of **fish** species with different flow requirements	3	80
2.What is the natural diversity of **fish** species with a preference for different cover types	4	100
3.What is the natural diversity of **fish** species with a preference for different flow depth classes	3.5	90
4. What is the natural diversity of **fish** species with various tolerances to modified water quality	2.5	70
MACROINVERTEBRATES		
1. What is the natural diversity of **invertebrate** biotopes	3.5	80
2. What is the natural diversity of **invertebrate** taxa with different velocity requirements	4	100
3. What is the natural diversity of **invertebrate** taxa with different tolerances to modified water quality	2	50
Fish	**3**	
Macroinvertebrates	**3**	
Confidence rating for instream biological information	**3**	
INSTREAM ECOLOGICAL CATEOGORY	**C**	
Riparian vegetation	**B/C**	
Confidence rating for riparian vegetation zone information	3.2	
ECOSTATUS	**C**	

3.4 RECOMMENDED ECOLOGICAL CATEGORY (REC):

The REC is determined based on ecological criteria only and considers the EIS, the restoration potential and attainability there-of. The EIS is MODERATE, therefore the REC is to maintain the PES in a C.

3.5 SUMMARY OF ECOCLASSIFICATION RESULTS

Table 3.6 EFR O1: Summary of EcoClassification results

Driver Components	PES	TREND
IHI HYDROLOGY	E	
WATER QUALITY	D	
GEOMORPHOLOGY	C/D	-
INSTREAM IHI	D/E	
RIPARIAN IHI	C	
Response Components	**PES**	**TREND**
FISH	C/D	0
MACRO INVERTEBRATES	C	0
INSTREAM	C	0
RIPARIAN VEGETATION	B/C	0
RIVERINE FAUNA	C	0
ECOSTATUS	C	0
EIS	MODERATE	

3.6 FLOW REQUIREMENTS

Due to the unlikely situation that the present operation of the dam will change and the strategic use (ESCOM) that results in this operation, the setting of flow requirements were not going to be undertaken. This was confirmed with the EcoClassification assessment. There are also no non-flow related mitigation measures that can be taken to improve the system.

As the EIS is MODERATE, the aim is to maintain the EIS. The current operation of the system and the present day hydrology will therefore maintain the EFR for this site. Any changes to operation of the system, or new developments that could further decrease the spills of the dams will have to be assessed as part of the scenario evaluation phase.

4 ECOCLASSIFICATION: EFR O2 (BOEGOEBERG)

4.1 EIS RESULTS

The EIS evaluation results in a **HIGH** importance. The highest scoring matrices are:

- Riparian rare and endangered species such as clawless otter, black stork, African marsh harrier, Namaqua stream frog, straw-coloured fruit bat. Riparian vegetation: 2 spp listed as declining, *Acacia aerioloba, Crinum bulbispernum;*
- Unique riparian biota: Orange river white-eye and 6 endemic riparian vegetation species;
- Riparian biota – taxon richness: 75 species of riverine fauna present (79% of expected spp). Riparian vegetation: Occurs in Griqualand West centre of plant endemism;
- High diversity of riparian habitat types and features such as the abundance of riparian and marginal habitat available for riverine fauna;
- Critical riparian habitat and refugia: The lush riparian (large tree) habitat is a refuge for 19 true riparian spp and 7 semi-aquatic spp. for nesting, roosting and shelter;
- Riparian habitat which is sensitive to flow changes: Rheophytes sensitive to flow changes. Need fast flowing shallow water;
- Riparian migration corridor: A riparian band in the area annually inundated by high floods remains intact. This intact band forms a very important migration corridor for most of the riverine faunal species present in the area.
-

4.2 REFERENCE CONDITIONS

The reference conditions for the components in EFR O2 are summarised below in Table 3.1

Table 4.1 EFR O2: Reference conditions

Component	Reference conditions	Conf
Hydrology	10573.7 nMAR	3.5
Physico-chemical	See the description of RC per variable in Table 4.3.	3
Geomorphology	The gross morphology of the site is close to reference conditions. The site was a bedrock anatomising reach, characterised by multiple distributaries separated by very stable, vegetated bedrock core bars. Within the active channels, local slopes are steep and sediment deposition would be inhibited such that sandy sedimentary features would be limited to lee areas and low-energy marginal zones. Backwaters would be common.	4
Riparian vegetation	Occurs within the Lower Gariep Broken Veld type, which occurs within the Nama-Karoo Biome and the Bushmanland Bioregion. The riparian zone is distinct from the terrestrial zone however, and is catagorised at an azonal vegetation type: the Lower Gariep Alluvial Vegetation. Alluvial terraces and banks are dominated by woody riparian thickets (mainly *Acacia karoo, Ziziphus mucronata, Rhus pendulina)* or stands of *Tamarix usneoides* or reeds (*Phragmites australis*). Cobble or boulder features are characterised by a mix of woody species (*T. usneoides*, *Gomphostigma virgatum*) and sedges (*Cyperus spp)*. Frequently flooded alluvia are open or grassed (*Cynodon dactylon* mainly) and *Salix mucronata* is also common on frequently inundated alluvia. *Crinum bulbispermum* is common. Marginal Zone: Expect a mix of open alluvia or cobble/boulder and vegetated areas. Vegetation, similarly, should be a mix of woody (*Gomphostigma virgatum, Salix mucronata subs. mucronata* and *subs. capensis*) and non-woody (*Phragmites australis, Cyperus marginatus*) vegetation. Lower Zone: Expect the same as the marginal zone, with *Tamarix usneoides* on low lying bars. Upper Zone: Terraces should be well vegetated with small percentage of open areas. Vegetation will be a mix of reed beds (*P. australis*) or woody thickets (*Acacia karoo, Ziziphus mucronata, Rhus pendulina* and *Combretum erythrophyllum* mainly).	3

Component	Reference conditions	Conf
	Macro Channel Bank: Banks should be well vegetated and dominated by woody riparian thickets, with dominant species as outlined above. Floodplain: Should be similar to the macro channel bank with *Acacia erioloba* as a landmark species. Expect woody thickets with some open alluvial areas that are variously grassed.	
Fish	Eleven indigenous fish species (ASCL,BANO, BAEN, BKIM, BPAU, BTRI, CGAR, LCAP, LUMB, PPHI & TSPA) have a high to definite probability of occurrence. The expected habitat composition at the site also met the requirements of the expected fish species. The indigenous *AMOS* is also mentioned as having peripheral occurrence, but was excluded from reference conditions as this species is not expected to occur naturally in the Orange River and can probably not complete its life-cycle successfully. The expected FROC provided in Kleynhans *et al.* (2007) for site D7ORAN-SEEKO, located within the fish reach under investigation was broadly used to determine the reference FROC for reach EFR O2, with alterations made based on all available current information.	3
Macroinvertebrates	Reference conditions were based on professional judgment and data collected in the area by Agnew (1965), de Kock *et al* (1974), Pretorius *et al* (1974) and Palmer (1996). The reference SASS5 Score is 179 and the ASPT is 6.6. The expected number of SASS5 taxa is 27.	4
Riverine Fauna	Potentially 95 animal species inhabited the riverine habitats. Open alluvia in marginal zone utilized by waders. Variety of tree zones (from lower to macro channel bank) with different structural compositions act as refuge, shelter, breeding and feeding habitats, while the intact riparian corridor being used as a migration route for riverine fauna. Mudflats and alluvial soils in lower riparian zone used by burrowing and tunnelling fauna. Reeds and shrubs also utilized as shelter, breeding and feeding habitats.	3

4.3 PRESENT ECOLOGICAL STATE

The PES reflects the changes in terms of the Ecological Category (EC – Table 4.8) from reference conditions. The summarised information is provided in Table 4.2.

Table 4.2 EFR O2: Present Ecological State

Component	PES Description	EC	Conf
Hydrology	4629.6 nMAR (44% of nMAR)	E	3
Physico-chemical	See Table 4.3	C	3.5
Geomorphology	Although the flows are critically reduced at the site, this has been in some ways compensated for by the reduced sediment loads (since much is trapped in upstream dams). The site is generally not very sensitive to the impacts of base flow and small flood changes, nor to small changes in sediment load. The key issue for this site is the loss of large floods that scour and maintain the distributary channels and beds. The very large dams now in place in the upstream catchment will probably prevent any sufficiently large scour events to occur in future, and thus stabilisation and increasing vegetation on the lower banks and bars will occur in the future. Rthe historical aerial photographs show slight encroachment of vegetation in to the channels.	C	3.5
Riparian vegetation	Marginal: Cobble and bedrock areas have a vibrant population of *G. virgatum*. Other dominants however are *S. mucronata, P. australis Cyperus marginatus, Persicaria decipiens, P. lapathifolia* and *Cynodon dactylon*. Lower: Well wooded in places with *G. virgatum*, and *S. mucronata* mainly, but also with *Acacia karoo* recruits. Areas which are open (mainly cobble/boulder) or dominated by non-woody vegetation (*P. australis, Crinum bulbispermum, Cyperus marginatus, Persicaria x2* and *C. dactylon* mainly) make up the mosaic. Upper: RB has extensive open areas (cobble or boulder) with *T. usneoides* mainly. Otherwise the zone is predominantly woody with common species on both banks but LB mainly being *T. usneoides, A. karoo, R. pendulina, Z. mucronata. D. lycioides, Lycium hirsutum A. erioloba, Prosopis glandulosa*, and *P. velutina*). A single specimen of *Combretum erythrophyllum* was found. Macro Channel Bank: similar to upper zone, but without the cobble/boulder beds Floodplain: similar to Macro channel bank, with terrestrial species and	B	3.6

Component	PES Description	EC	Conf
	dominated by woody thickets		
Fish	All the expected fish species are still present in this river reach albeit in a slightly to moderately reduced FROC (LUMB, BANO and BKIM). Some loss of marginal zone overhanging vegetation due to altered hydrological regime also impact fish assemblage negatively. The negative impacts associated with the alien species – CIDE, GAFF, CCAR – include: loss of vegetation and habitat, bio-turbation and habitat loss, wq alteration, and predation on native fish eggs and larvae.	C	3
Macroinvertebrates	A total of 20 SASS5 taxa was observed at the site, out of 27 expected (i.e. 74%). The observed SASS5 Score was 116 (65%), and the ASPT was 5.8 (87%). The most obvious change from natural has been outbreaks of pest blackflies (mainly *Simulium chutteri*) following impoundment. The bivalve *Corbicula fluminalis* was noticeably absent during the site-visit. This bivalve is particularly sensitive to elevated sediments, and its absence is probably associated with the periodic emptying of Boegoeberg Dam, which releases high concentrations of sediment. Other taxa that were expected but not observed included *Heptageniidae, Ecnomidae, Hirudinea, Sisyridae, Corixidae* and *Ceratopogonidae*. The most sensitive taxa recorded at the site were *Atyidae, Tricorythidae and Leptophlebiidae*. Elevated nutrients lead to excessive growth of epilithic algae, particularly during low-flow periods, and this reduces the suitability of substrates for colonisation of benthic invertebrates. The Chironomid *Cardiocladius africana* thrive under these conditions. Monthly data on aquatic invertebrates were collected at Gifkloof, near Upington, between 1991 and 1996 (Palmer 1997b). These data provide a reliable indication of the key ecological drivers that affect the diversity and abundance of benthic macroinvertebrates in the middle and lower Orange River. *Very Low Flows:* During very low flow (<16 m^3/s) the river was characterised by clear water (Secchi depth > 47cm) and low concentrations of planktonic algae. The average number of macroinvertebrate taxa (29), the average number of SASS4 taxa (18), highest during these flow conditions. Taxa typically associated with very low flow included the filter-feeding midge *Rheotanytarsus fuscus*, the sponge *Ephydatia fluviatilis* and the blackflies *Simulium adersi* and *S. ruficorne*. *Low Flows:* During low flow (16 to 59 m^3/s) the river was characterised by moderate clarity (Secchi depth 25 to 47 cm) and moderate concentrations of planktonic algae. Numerous taxa were associated with low flows, including the mayflies *Afronurus peringueyi, Baetis glaucus* and *Euthraulus elegans*, and the blackflies Simulium damnosum s.l. and *S. mcmahoni.* *Moderate Flows:* During moderate flow (60 to 142 m^3/s) the probability of planktonic algal blooms was high. Taxa typically associated with moderate flows were the caddisfly *Amphipsyche scottae* and the blackflies *Simulium chutteri* and *S. gariepense.* The Average SASS4 Score per Taxon (ASPT) was highest under moderate flow conditions. *Very High Flows:* Dramatic changes in species composition and abundance were recorded after a flood in January 1996. Species whose abundance increased after the flood included the blackfly *S. chutteri*, the mayfly *Tricorythus discolor*, and the caddisflies Cheumatopsyche thomasseti and *Aethaloptera maxima*. Species that disappeared after the flood included the mayfly *A. peringueyi,* the caddisfly *Ecnomus thomasseti,* the sponge *E. fluviatilis,* the blackfly *S. mcmahoni* and the midge *R. fuscus*. *Fluctuating Flows:* Many invertebrates in the Orange River have life-history characteristics that buffer against unfavourable conditions. These include desiccation-resistant stages and rapid rates of development. Such characteristics are likely to promote the coexistence of species in fluctuating environments. This highlights the importance of disturbance in maintaining a diverse river ecosystem. Taxa whose abundance increased when flows fluctuated were the leech *Salifa perspicax,* the mayflies *T. discolor* and *B. glaucus*, the caddisflies A. scottae and *A. maxima* and the blackfly *S. chutteri*. The number of SASS4 families and total SASS4 scores were unaffected by flow variation, but invertebrate abundance dropped as flow variation increased. The lowest SASS4 score (indicating poor conditions) was recorded in June 1994, following a mid-winter period of unseasonally high flow. Taxa present during low flow were found throughout southern Africa, and were of little conservation importance. Taxa present during high flow, by contrast, included unusual species, endemic to large, turbid rivers. The	C	4

Component	PES Description	EC	Conf
	maintenance of a healthy invertebrate fauna in the middle Orange River therefore depends on maintaining, or at least simulating, natural flow fluctuations. Simulating natural flow fluctuations would also help to conserve threatened species, such as the blackfly *S. gariepense*, and help reduce population outbreaks of the pest *S. chutteri.* *Stable Flows:* Stable flows caused by impoundment are detrimental to taxa adapted to either low or high flow. However, unseasonally high flows were shown to be detrimental to aquatic invertebrates. The pest blackfly *S. damnosum* became abundant during a long period of stable, low-flow conditions in 1993. Other taxa whose abundance increased during stable flow conditions were the stonefly *Neoperla spio,* Turbellaria and the midges *Cardiocladius africanus* and *R. fuscus*, the muscid fly *Xenomyiasp*. and the sponge *E. fluviatilis*. The overall abundance of caddisflies and predators started declining after 20 days of constant flow, whereas the abundance of gatherers started declining after 15 days of constant flow. *Water Temperature:* Water temperature had a significant impact on invertebrates. Of particular interest was an inverse relation between the abundance of blackflies and caddisflies as water temperatures changed: blackflies were more abundant than caddisflies during cold conditions, whereas caddisflies were more abundant than blackflies during warm conditions. *Benthic Algae:* Benthic algae were usually abundant in late winter to early spring (July to September). They were most abundant when the water was moderately clear (Secchi depth >18 cm) or when the flow was less than 130 m^3/s. There was a corresponding increase in the abundance of scrapers (mostly the midge *Cardiocladius africanus*) between August and October in most years. The ASPT was usually highest during low algal cover (<10 %). The middle and lower Orange River is mostly wide and the rapids are shallow. This means that primary production in most rapids in the Orange River is not limited at flows less than 130 m^3/s. *Planktonic Algae:* The abundance of planktonic algae was highly seasonal, with lowest values in winter (June to August), and highest values in autumn (March to May). The abundance of invertebrates increased as the abundance of planktonic algae increased. These changes had no significant influence on the SASS4 scores or the ASPT. However, in some years blooms of the blue-green algae *Microcystissp*. developed in Lake Vanderkloof, particularly in autumn. There was a slight decline in the total number of invertebrate taxa as the abundance of *Microcytissp*. increased, but these changes did not greatly affect SASS4 scores or the ASPT. Highest numbers of the pest blackfly *S. damnosum* were recorded in June 1995 following a *Microcystissp*. bloom in the previous month. By contrast, the abundance of *S. chutteri* consistently declined during *Microcystis* blooms.		
Riverine Fauna	75 of the expected 95 animal species (79%) potentially can occur in this segment. This comprises 45 aquatic and semi-aquatic species, 11 marginal habitat species, and 19 riparian species. The riparian vegetation habitats have not changed much, as most of the riparian trees of diverse structures are still intact to act as refuge, shelter, breeding and feeding habitats, and a migration route. However, the changes in flows (removal of higher flows) resulted in the marginal zone being vegetated with reeds and hygrophilous shrubs, eliminating mudflats and alluvial sandbars.	C	3.6

Table 4.3 EFR O2: Present Ecological State: Physico-Chemical

RIVER	Orange River	**WATER QUALITY MONITORING POINTS**	
		RC	Orange River @ Boegoeberg Reserve (D73B; ecoregion II: 26.05) D7H008Q01 (1966 – 1979; n=43 - 57)
EFR SITE	O2 (D81B; ecoregion II: 28.01)	**PES**	1) Orange River @ Boegoeberg Reserve (D73B; ecoregion II: 26.05) D7H008Q01 (2000 – 2009; n=348) 2) Data from diatom sample collection in 2005, 2008, 2009, 2010
Confidence assessment	Moderate confidence. Although sufficient data for most variables, data gaps exist, particularly in the case of herbicides, pesticides and metal ions. Note that water quality and EFR sites are <u>not</u> in the same EcoRegion level II.		

Water Quality Constituents	RC Value	PES Value	Category/Comment
Inorganic salts (mg/L)	TEACHA was not used for data assessment, as salinity levels not elevated.		

Salt ions (mg/L)	Ca	37.40	34.06	Concentrations similar for the PES, except for sulphate, sodium and chloride which show increases from the RC, particularly sulphate and chloride.
	Cl	20.36	46.28	
	K	3.70	3.99	
	Mg	15.10	18.00	
	Na	23.70	35.36	
	SO_4	48.10	63.99	
Nutrients (mg/L)	SRP	0.014 *	0.022	A category
	TIN	0.14	0.22	A category
Physical Variables	pH (5^{th} + 95^{th} %ile)	7.05 + 7.91	7.71 + 8.60	A/B category
	Temperature	-	-	Site downstream of numerous dams upstream, with significant changes expected from natural.
	Dissolved oxygen	-	-	
	Turbidity (NTU)	-	Avg: 7.92 95^{th} %ile: 30.67	Levels not very significant. A/B category (qualitative assessment)
	Electrical conductivity (mS/m)	35.68 *	50.80	A/B category. RC shows slightly elevated natural salt levels.
Response variables	Chl a: periphyton (mg/m^2)	-	-	-
	Chl a: phytoplankton (µg/L)	-	46.5 (n=2; 2008) (Koekemoer, 2010)	E category
	Macroinvertebrates	ASPT: 6.6 SASS: 165	ASPT: 5.8 SASS: 116 MIRAI: 63.7%	C category (Palmer, 2010)
	Fish community score		FRAI: 66.9%	C category (Kotzé, 2010)
	Diatoms	-	SPI: avg – 12.9 (n=4; Boegoeberg + EFR O2)	B/C category (Koekemoer, 2010)
Toxics	Fluoride (mg/L)	0.452	0.260	A category
	Ammonia (mg/L)	0.002	0.011	A category
	Aluminium (mg/L)	0.02 **	0.166 (n=2; 2008) (Koekemoer, 2010)	D category
	Iron (mg/L)	-	0.110 (n=2; 2008) (Koekemoer, 2010)	No guideline + insufficient data
	Arsenic (mg/L)	0.02 **	297 (n=2; 2008) (Koekemoer, 2010)	E category
	Cadmium (mg/L)	0.000 3 **	0.005 (n=2; 2008) (Koekemoer, 2010)	E category
	Lead (mg/L)	0.002 **	0.011 (n=2; 2008) (Koekemoer, 2010)	E category
	Other	-	-	Impacts expected due to farming-related pesticides and fertilizer use.
OVERALL SITE CLASSIFICATION		**C: 69.34%** (from PAI model)		

** boundary value for the A category recalibrated* *- no data* *** benchmark value, as no data*

4.3.1 EFR O2: Trend

The trend was also assessed. Trend refers to the situation where the responses have not yet stabilised in reaction to catchment changes. The evaluation is therefore based on the existing catchment condition. The trend at all components is stable (See Figure 4.8).

4.3.2 EFR O2: PES Causes and Sources

The reasons for changes from reference conditions must be identified and understood. These are referred to as causes and sources ((http://cfpub.epa.gov/caddis/)). The PES for the components at EFR O2 as well as the causes and sources for the PES are summarised in Table 4.4.

Table 4.4 EFR O2: PES Causes and Sources

	PES	Conf	Causes	Sources	F[1]/NF[2]	Conf
Hydro[3]	E	3	Increase in unseasonal releases of small floods, decrease of moderate and large floods.	Twice daily flood releases from Vanderkloof dam for hydro power, upstream dams	F	5
			Increased base flows during drought and dry seasons and decreased base flows during the wet season	Operation for irrigation and other users	F	
Physico-chemical	C	3.5	Elevated nutrients and potential toxicant loads due to fertilizer and pesticide use	Agriculture, resulting in some toxicant and nutrient loading expected.	NF	4
Geomorphology	C	3.5	Reduced frequency and size of large floods	Large dams	F	4
			Reduced sediment load	Although upstream dams have reduced the sediment load, annual flushing of the upstream dam reintroduces some sediments	F	2.5
Riparian vegetation	B	3.6	Increased vegetation cover	Reduced base flows especially in summer and reduced moderate and large floods	F	2.5
			Altered species composition	Small percentage of perennial exotic species	NF	4
Fish	C	3	Decreased overhanging vegetation as cover for fish result in decreased FROC of species with preference for these habitats. Loss of habitat (cover) also results in increased exposure to predators.	Increased bank erosion, flow modification and inundation. Farming: removal or change in riverine vegetation.	F NF	3.5
			Decrease in FROC and abundance of fish species with preference for fast habitats.	Decreased base flows.	F	
			Decreased water quality.	Presence of toxics, agriculture, dams trapping silt altering water clarity, stratification in dams	NF	
			Decreased species diversity and abundance	Presence of alien predatory species (GAFF) feeding on indigenous fish eggs and larvae.	NF	
			Increased turbidity and disturbed bottom substrates reduce bottom substrate quality and water quality for indigenous fish (especially impact on LUMB breeding habitats)	Presence of alien CCAR which cause bio-turbation. Dams create habitat for undesirable species.	NF	
			Decreased native species diversity and abundance as result of presence of alien species.	Alien species will have negative impact on native species - CCAR – bio-turbation; GAFF - predation on eggs and fry; CIDE - loss of aquatic vegetation and habitat.	NF	
			Decreased abundance, and therefore FROC related to over utilization for human consumption.	Poaching and over-fishing of fish using nets (gill and seine nets, often home-made).	NF	
			Reduced spawning success resulting in decreased FROC of many species.	Flow modification: Absence of spring flushes, reduced habitat suitability and stimuli, flow pattern disrupts normal breeding cycle.	F	
			Presence of migration barriers reduces migration success (breeding, feeding and dispersal) of some species.	Some dams/weirs (incl. Boegoeberg Dam)	NF	

Macroinvertebrates[7]	C	4	Elevated low flows	Discharges to meet demands for winter power generation and irrigation demands	F	4
			Water quality deterioration	Agricultural return flows	F	3
			Aseasonal releases	Operation of Vanderkloof Dam	F	4
			Pesticides	Blackfly Control Programme	NF/F	4
			Elevated sediment	Periodic emptying of Boegoeberg Dam for maintenance, usually during winter (i.e. low flow)	NF	4
			Toxic algal blooms, such as *Microcystis*	Annual overturn of vanderkloof Dam, plus inputs from Harts River (Spitzkop Dam)	NF	2
Riverine Fauna	C	3.6	Reduced abundance. Loss of habitat diversity due to reduced flow volumes Reduced abundance in piscivorous species - Reduction in fish abundance (due to reduction of habitat) as a food base for piscivorous species	Operation of the system.	F	3
			Impact adversely on instream biota that acts as food source for piscivores and invertivores	Operation of the system	F	
			Marginal zone invaded by reeds and shrubs, removing mudflat and alluvial sandbank habitats –habitat for waders	Loss of frequency and magnitude of larger floods	F	

1 Flow related 2 Non Flow related 3 Hydrology

The major issues that have caused the change from reference conditions are increased

- Loss of frequency of large floods;
- Agricultural return flows;
- Higher low flows than natural in the dry season, drought and dry periods;
- Decreased low flows at other times;
- Annual release of sediment;
- Present of alien fish species and barrier effects of dams.

4.3.3 EFR O2: PES EcoStatus

To determine the EcoStatus, the macroinvertebrates and fish must first be combined to determine an instream EC. The instream and riparian categories are integrated to determine the EcoStatus. Confidence is used to determine the weight that the EC should carry when integrating into an EcoStatus (riparian, instream and overall). The EC percentages are provided (Table 4.5) as well as the portion of those percentages used in calculating the EcoStatus.

Table 4.5 MRU: EFR O2: Instream

INSTREAM BIOTA	Importance Score	Weight
FISH		
1.What is the natural diversity of **fish** species with different flow requirements	3	80
2.What is the natural diversity of **fish** species with a preference for different cover types	4	100
3.What is the natural diversity of **fish** species with a preference for different flow depth classes	3.5	90
4. What is the natural diversity of **fish** species with various tolerances to modified water quality	2.5	70
MACROINVERTEBRATES		
1. What is the natural diversity of **invertebrate** biotopes	3.5	80

2. What is the natural diversity of **invertebrate** taxa with different velocity requirements	4	100
3. What is the natural diversity of **invertebrate** taxa with different tolerances to modified water quality	2	50
Fish	**3**	
Macroinvertebrates	**4**	
Confidence rating for instream biological information	**3.6**	
INSTREAM ECOLOGICAL CATEOGORY	**C**	
Riparian vegetation	**B**	
Confidence rating for riparian vegetation zone information	3.6	
ECOSTATUS	**C**	

4.4 RECOMMENDED ECOLOGICAL CATEGORY (REC):

The REC is determined based on ecological criteria only and considers the EIS, the restoration potential and attainability there-of. The EIS is HIGH; therefore the REC should be set to improve the PES.

The scenario to improve the PES includes the following:

- Lower flows (70 – 100 % duration) which should not be more than natural flows as is presently the case. The seasonality ration between wet and dry season should also be improved. This situation will improve the black fly problems as well as a general improvement in the instream biota.
- Higher low flows in the wet season.
- Geomorphology will require improved large floods however that will not happen as there is no way to operate and provide the large floods.
- Dredging of the dam should happen during the wet season.
- Alien vegetation should be cleared (especially *Prosopis*).

The water quality and geomorphology will not improve under this scenario (table 4.6). The FRAI, MIRAI and VEGRAI were run to determine the level of improvement that will be achieved. The fish and invertebrates will only improve within the C category. Another option that was investigated was that the releases from Vanderkloof should be well mixed and this will improve the water quality and the instream biota. It was however confirmed (Mane Maree *pers com*) that there is only one bottom outlet and that this is not a physical possibility. It was therefore not possible to provide flows to improve the situation to the REC.

Table 4.6 EFR O2: REC

	PES	REC	Comments	Conf
Physico-Chemical	C	C	This cannot be achieved with the changes recommended, as the reasons for the water quality state is non flow-related.	n/a
Geom	C	C	To improve the PES, it is necessary to reinstate the large floods that have been removed due to upstream dams. This is not possible, so the scenario was not considered further.	n/a
Riparian vegetation	B	A/B	Removal of exotic woody species improves the PES from 85% to 85.6%. Improving seasonality and wet season base flows in the marginal zone (rating from 2 to 1) results in a further improvement to 86.6%. This is mainly facilitated by reduced cover in woody vegetation (mainly *Salix mucronata*) and grasses, with an associated increase in open bedrock and alluvium. Similarly, these hydrological changes in the lower zone further improve the PES to 88.3% (an EC of A/B). Vegetation response is a reduction in reed cover with an associated increase in open areas.	2.7

	PES	REC	Comments	Conf
Fish	C	C	Due to the hydrological change being so extreme at present, it is highly unlikely that conditions can be returned to a "largely natural" (Category B) condition, based on improved flows. The present ecological status is furthermore impacted by various non-flow related impacts (especially the presence of alien fish species and migration barriers), and without improvement of these impacts, conditions will not improve adequately to achieve a category B. The lack of water quality improvement associated with the recommended flow improvement to achieve the REC furthermore limits the fish assemblage to improve adequately to achieve a largely natural (B) conditions.	2.5
Macroinvertebrates	C	C	Lower base flows during the dry season and a wider seasonal range of base flows is expected to increase habitat variability and thereby increase biodiversity, and also reduce the incidence of outbreaks of the pest blackfly *Simulium chutteri*. Taxa expected to appear under a more natural flow regime include *Corixidae, Ceratopogonidae* and *Hirudinae.* Improved operation of Boegoeberg, by not draining during the dry season, is likely to create conditions suitable for colonisation by *Corbiculiidae* and *Ancylidae*. The total number of SASS5 taxa is expected to increase to 26. The overall SASS Score is expected to be 156, and the ASPT 6.0. The category is likely to remain in Category C mainly because of water quality issues.	3
Riverine Fauna	C	B	Improving seasonality and wet season base flows in the marginal zone results in an improvement in open area habitats: a) reduced cover in woody vegetation and grasses, with an associated increase in open bedrock and alluvium b) reduction in reed cover. The increase in open areas results in the reclamation of mudflat and alluvial sandbar habitats which provide good foraging habitat for waders.	3

4.5 ALTERNATIVE ECOLOGICAL CATEGORY (AEC)↓:

The hypothetical scenario includes:

- Decreased low flows in the wet and dry season.
- Decreased flows
- Decreased dilution resulting in worse water quality.
- Reduced low flows will result in less light penetration which will result in algal and benthic growth.

Each component is adjusted to indicate the metrics that will react to the scenarios. The rule based models are available electronically and summarised in Table 4.7.

Table 4.7 EFR O2: AEC↓

	PES	AEC↓	Comments	Conf
Physico-chemical	C	D	Increased abstractions result in lower low flows in the wet and dry seasons. This will result in higher temperatures, lower oxygen levels, and a small increase in turbidity, and elevations in nutrients, toxicants and salts. Fewer floods, resulting in decreased dilution of agricultural return-flows will exacerbate the situation. Lower (base) flows result in less light penetration, with a resulting increasing in algal and benthic growth.	3
Geom	C	C	Further reduced floods and reduced low flows will cause a decline in the PES of the geomorphology, but within the category. This is because bedrock anatomising planforms – the reach type within which this site is situated – is extremely resilient to changes in both flow and also relatively resilient to changes in sediment. The expected change would thus be from a high C to a lower C.	2

Rip veg	B	B/C	A further reduction of base flows, especially summer, as well as floods will result in additional woody (*S. mucronata* and *G. virgatum*) and non-woody (*P.* australis) cover in the lower and marginal zones. This is due to additional available habitat and reduced flooding disturbance will facilitate higher recruitment opportunities in the marginal zone. The overall PES remains a B, but the score has decreased. The PES of the marginal and lower zones however, has reduced to B/C (81.3%) since reduction of flows mainly affects these two zones.	2.5
Fish	C	D	Decreased flows (loss of fast habitats) together with increased benthic algal growth on substrates (increased photic depth related to lower flows) will result in deterioration of riffle/rapid/run over rocky substrate habitats with a resultant negative impact on fish species with a requirement for this habitat type (esp. ASCL, BAEN, BKIM and LCAP). Further deterioration in flood regime will also negatively impact fish in terms of migratory cues , flushing of substrate to create good quality substrate for spawning, resulting in further deterioration of fish assemblage (especially BAEN and BKIM). Decreased water quality will furthermore impact some fish species (especially early life stages) negatively. Decreased flows may furthermore create more favourable conditions (slow habitats) for alien fish species (esp. CCAR & GAFF) which will result in increased impact on indigenous fish species. (marginal vegetation expected to not be impacted significantly, therefore species with a requirement for this cover feature should not be impacted significantly).	2.8
Macroinvertebrates	C	D	Lower base flows during the dry and wet seasons is likely to reduce the incidence of outbreaks of the pest blackfly *Simulium chutteri*, but increase problems associated with *Simuliumimpukane.* A reduced seasonal range of base flows will also reduce water quality and habitat variability and thereby reduce biodiversity. Taxa expected to disappear include those that are sensitive to water quality deterioration, such as *Tricorythidae, Elmidae, Chlorocyphidae, Atyidae* and *Leptophlebiidae*. The total number of SASS5 taxa is expected to drop to15. The overall SASS Score is expected to be 64, and the ASPT 4.3.	3
Riverine fauna	C	C	A further reduction of base flows, especially summer, as well as floods will result in an increase of vegetation cover in the lower and marginal zones, benefitting arboreal fauna. The mudflat and alluvial sandbar habitats will still be absent as reed and other wetland shrubs will be covering the marginal zone, keeping out waders.	3

4.6 SUMMARY OF ECOCLASSIFICATION RESULTS

Table 4.8 EFR O2: Summary of EcoClassification results

Driver Components	PES	TREND	REC	AEC↓
IHI HYDROLOGY	E			
WATER QUALITY	C		C	D
GEOMORPHOLOGY	C	0	C	C
INSTREAM IHI	C/D			
RIPARIAN IHI	B/C			
Response Components	**PES**	**TREND**	**REC**	**AEC↓**
FISH	C	0	C	D
MACRO INVERTEBRATES	C	0	C	D
INSTREAM	C	0	C	D
RIPARIAN VEGETATION	B	0	A/B	B/C
RIVERINE FAUNA	C	0	B	C
ECOSTATUS	C	0	B/C	C
EIS	HIGH			

5 EFR O2 (BOEGOEBERG) – DETERMINATION OF STRESS INDICES

Stress indices are set for fish and macroinvertebrates to aid in the determination of low flow requirements. The stress index describes the consequences of flow reduction on flow dependant biota. It therefore describes the habitat conditions for fish and macroinvertebrates indicator species for various low flows. These habitat conditions for different flows and the associated habitat conditions are rated from 10 (zero flows) to 0, which is optimum habitat for the indicator species.

5.1 INDICATOR SPECIES OR GROUP

5.1.1 Fish indicator group: Large semi - rheophilic species (BAEN)

As a result of the absence of any true rheophilic fish species in this system, the large semi-rheophilic flow guild was selected as indicator group for setting flows. This group generally requires FS, FI and FD flow-depth categories over good quality substrate (gravel and cobbles) for spawning. Egg and embryo development also takes place in these habitats, while larvae prefer SD with substrate as optimal habitats. Juvenile and adult specimens have a high preference for SD, FS, FI and FD habitats with substrate and water column as cover. Flows should furthermore remain adequate to allow migration between reaches, thus depth in riffle and rapids should remain adequate, especially during the wet season. Emphasis was placed on the requirements of the *Labeobarbus* species (BKIM & BAEN) within this group in setting flows.

Table 5.1 Summarised habitat requirements for different life stage of the large semi-rheophilic indicator group.

FISH SP	SPAWNING	EGG & EMBRYO DEVELOPMENT	LARVAE	JUVENILES	ADULTS
BAEN	**FS, FI over substrate**. Spring to midsummer (September to January). Fast (>0.3m/s) with substrate (Gravel & cobbles). flowing water, well oxygenated and low sediments loads. BAEN breeds from spring through to mid-summer after the first substantial rains of the season.	**FS with substrate (gravel/cobbles).** Flows to last long enough for eggs to hatch and embryos to develop. Sudden pulse after spawning may cause many of the eggs to be washed out of the spawning beds and die in the deeper less oxygenated pools and also be smothered by silt. Also if the flow subsides it could result in higher temperatures and lower oxygen thus killing the developing embryos or leaving them stranded. The fertilised eggs of BAEN incubate for 3 to 8 days at 18-21.5 ^{o}C, whereafter the embryos remain in the gravel for a further period.	**SD with substrate.** (October to February). Cover, flow, oxygen and low silt loads. At swim-up they require suitable flows to move them away from the spawning beds to the nursery areas usually shallow backwaters which are warmer. If the backwaters are not there due to too high or too low flows the larval fish will die out as this is a very critical stage where they have to start eating. Larvae are initially inactive and sink to the bottom, not becoming mobile until 4 to 6 days after hatching. At this stage, they begin feeding on microscopic organisms.	**FS, FI& SS with substrates. SD at night.**	**SD, FD, FI& FS with substrates and water column.**

BKIM	**FS &FD with substrates** (**gravel, cobbles)** flowing water, well oxygenated and low sediments loads. The breeding season extends from mid to late summer. The species requires gravel beds in flowing water to spawn.	**FS & FI with substrate (gravel/cobbles).** Flows to last long enough for the embryos to develop and hatch out. The incubation period is 2 to 3 days and larvae become mobile after a further 3 to 4 days at 23-25 ^{o}C.	**SD with substrate.**	**FI & SD with substrates.**	**SD, FD & FI with substrates and water column.**

5.1.2 Macroinvertebrate indicator group: *Amphipsyche scottae*

Amphipsyche scottae is a flow-dependent hydropsychid caddisfly that is common in the middle and lower Orange River. This species prefers moderate to fast currents (0.6 to 0.8 m/s), with cobble substrates. This species is sensitive to deterioration in water quality.

5.2 STRESS FLOW INDEX

A stress flow index is generated for every component, and describes the progressive consequences to the flow dependent biota of flow reduction. The stress flow index is generated in terms of habitat response and biotic response and is discussed below.

5.2.1 Habitat response

The habitat flow index is described separately for fish and macroinvertebrates as an instantaneous response of habitat to flow in terms of a 0 – 10 index relevant for the specific site where:

- 0 - Optimum habitat (fixed at the natural maximum base flow which is based on the 10% annual value using separated natural baseflows).
- 10 - Zero discharge (Note: Surface water may still be present).

The instantaneous response of fish and invertebrate breeding habitat, abundance, cover, connectivity, and water quality are derived by considering (amongst others) rated velocity depth classes (in terms of abundance) to flow changes based on a 0 - 5 scale where:
0 = Velocity - depth class is absent under the specific flow condition.
1 = Velocity - depth class is rare under the specific flow condition.
2 = Velocity - depth class is sparse under the specific flow condition.
3 = Velocity - depth class occurs moderately under the specific flow condition.
4 = Velocity - depth class occurs abundantly under the specific flow condition.
5 = Velocity - depth class is very abundant under the specific flow condition.

Fish and invertebrate habitat is then rated separately according to a 0 – 5 scale where:
0 = No habitat available.
1 = Very low occurrence
2 = Low occurrence
3 = Moderate occurrence
4 = Large/Good occurrence
5 = Optimum occurrence

5.2.2 Biota response

The biota stress index is the instantaneous response of biota to change in habitat (and therefore flow), based on a scale of 0 – 10 where:

- 0 = Optimum habitat with least amount of stress possible for the indicator groups ***at the site*** (fixed at the natural maximum baseflow in the same way as for the habitat response).
- 10 = Zero discharge. The biota response will depend on the indicator groups present, i.e. rheophilics will have left whereas semi-rheophilics will still be present and survive.

The instantaneous response of fish and invertebrate breeding habitat, abundance, cover, connectivity, and water quality are derived by considering (amongst others) rated velocity depth classes (in terms of abundance) to flow changes based on a 0 (VD class absent) - 5 (VD class very abundant).Fish and invertebrate habitat is then rated separately according to a 0 (no habitat) – 5 (optimum occurrence of habitat).

5.2.3 Integrated stress curve

The integrated stress curve represents the highest stress for either fish or macroinvertebrates at a specific flow.

The species stress discharges in Table 5.3 indicate the discharge evaluated by specialists to determine the biota stress. The highest discharge representing a specific stress is used to define the integrated stress curve (Figure 5.1).

In this specific case, the LSR fish stress index represents the integrated stress range 6 – 10, therefore the blue curve (representing the LSR stress index) is lying 'beneath' the integrated stress line (black). The FDI stress index represents the integrated stress range 0 – 6, therefore the red curve (representing the FDI stress index) is lying 'beneath' the integrated stress line (black) (Figure 5.1).

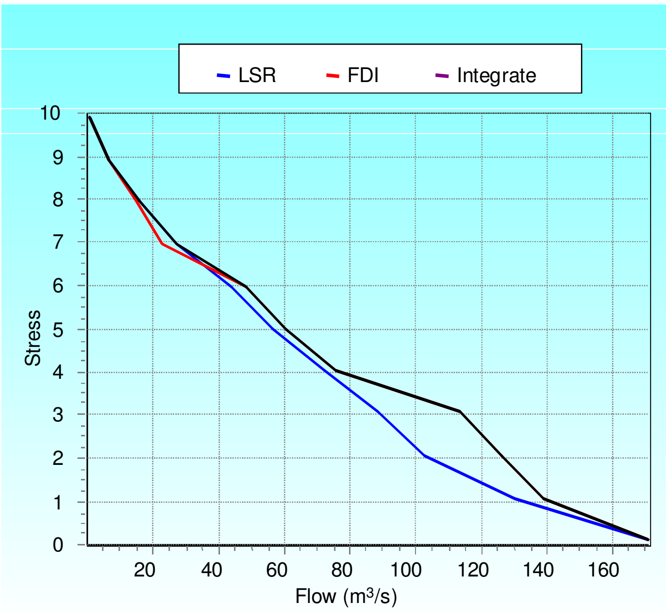


Figure 5.1 EFR O2: Species stress discharges used to determine biotic stress

Table 5.2 EFR O2: Species stress discharges used to determine biotic stress

Stress	Flow (m^3/s)		Integrated Flow (m^3/s)
	LSR	FDI	
0	171	171	171
1	130	139	139
2	103	126	126
3	88	113	113
4	72	75	75
5	56	60	60
6	43	48	48
7	27	22	27
8	15.1	14	15.1
9	6	6	6
10	0.001	0.001	0.001

Table 5.3 provides the summarised biotic response for the integrated stresses.

Table 5.3 EFR O2: Integrated stress and summarised habitat/biotic responses

Integrated stress	Flow (m^3/s)	Driver (fish/inverts/both)	Habitat and/or Biotic responses
0	171	Both	Habitat suitability for semi-rheophilic fish guild optimal for all criteria (spawning habitat, nursery habitat, abundance, cover, connectivity and water quality) evaluated. The turbidity is suitable for the threatened blackly *Simulium gariepense*.
1	139	Invertebrate	Instream biotopes plentiful and suitable for flow-sensitive species. The river bed becomes light-limited, with Secchi depth typically 8 to 17 cm. The high turbidity favours the mayflies *Tricorythus discolor* and *Baetis glaucus,* and the caddisflies *Ampipsyche scottae* and *Aethaloptera maxima.*
2	126	Invertebrate	Critical habitats sufficient for flow-sensitive taxa, except for those that prefer high turbidity.
3	113	Invertebrate	High concentration of planktonic algae provides food for filter-feeding invertebrates such as *Simulium chutteri* and *Tricorythus discolor.*
4	75	Invertebrate	The lower marginal vegetation starts to provide suitable habitat for invertebrates, such as the freshwater shrimp *Caridina nilotica*.
5	60	Invertebrate	Moderate water clarity, with Secchi depth typically about 25 cm. Critical habitats very reduced. Conditions suitable for scrapers, such as Burnupia
6	48	Invertebrate	Critical habitat residual and flow-sensitive species reduced. High water clarity, providing suitable conditions for taxa such as the midge *Cardiocladius africanus, Euthraulus elegans* and the blackfly *Simulium damnosum.*
7	27	Invertebrate	No critical habitat. Most flow-sensitive taxa disappear.
8	15.1	Fish	In terms of habitat suitability for large semi-rheophilic fish guild, spawning habitat, nursery habitat, abundance, cover, connectivity and water quality in very low condition and connectivity in low condition.
9	6	Fish	In terms of habitat suitability for large semi-rheophilic

Integrated stress	Flow (m^3/s)	Driver (fish/inverts/both)	Habitat and/or Biotic responses
			fish guild, nursery habitat, abundance, cover, connectivity and water quality are of very low suitability while no spawning habitat will be available.
10	0.001	Both	Habitat not suitable for any of the criteria assessed (spawning habitat, nursery habitat, abundance, cover, connectivity and water quality) for the large-semi-rheophilic fish guild.

6 EFR O2 (BOEGOEBERG) - DETERMINATION OF EFR SCENARIOS

6.1 ECOCLASSIFICATION SUMMARY OF EFR O2

EFRO2

EIS: HIGH
Highest scoring metrics are instream & riparian rare /endangered biota, unique riparian biota, flow intolerant instream biota, taxon richness of riparian biota, diversity of riparian habitat types, critical riparian habitat, refugia, migration corridor.

PES: C
Loss of frequency of large floods, agricultural return flows, higher low flows than natural in the dry season, drought and dry periods, decreased low flows at other times, release of sediment, presence of alien fish species &barrier effects of dams.

REC: B/C
Instream improvement was not possible due to constraints and no EFR will be set for REC.

AEC D (instream)
Decreased low flows in the wet and dry season. Decreased floods, decreased dilution resulting in worse water quality. Reduced low flows will result in less light penetration which will result in algal and benthic growth

Driver Components	PES	TREND	REC	AEC↓
IHI HYDROLOGY	E			
WATER QUALITY	C		C	D
GEOMORPHOLOGY	C	0	C	C
INSTREAM IHI	C/D			
RIPARIAN IHI	B/C			
Response Components	**PES**	**TREND**	**REC**	**AEC↓**
FISH	C	0	C	D
MACRO INVERTEBRATES	C	0	C	D
INSTREAM	C	0	C	D
RIPARIAN VEGETATION	B	0	A/B	B/C
RIVERINE FAUNA	C	0	B	C
ECOSTATUS	C	0	B/C	C
EIS	HIGH			

6.2 HYDROLOGICAL CONSIDERATIONS

The wettest and driest months were identified as March and September. Droughts are set at 95% exceedance (flow) and 5% exceedance (stress). Maintenance flows are set at 40% exceedance (flow) and at 60% exceedance (stress).

6.3 LOW FLOW REQUIREMENTS (IN TERMS OF STRESS)

The integrated stress index is used to identify required stress levels at specific durations for the wet and dry month/season.

6.3.1 Low flow (in terms of stress) requirements

The fish and macroinvertebrate flow requirements for different Ecological Categories (ECs) are provided in Table 6.1 and graphically illustrated in Figure 6.1. The results are plotted for the wet and dry season on stress duration graphs and compared to the Desktop Reserve Model (DRM) low flow estimates for the same range of ECs. The stress requirements (as a 'hand drawn line') are illustrated in Figures 6.1.

For easier reference the range of ECs are colour coded in the Tables and figures:
PES and REC **Purple** AEC↓: Green

Summarised motivations for the final requirements are provided in Table 6.2.

Table 6.1 EFR O2: Species and integrated stress requirements as well as the final integrated stress and flow requirement

Duration	LSR stress	Integrated stress	FDI stress	Integrated stress	FINAL* (Integrated stress)	FLOW (m^3/s)
PES C ECOSTATUS		**FISH: C**		**MACROINVERTEBRATES: C**		
			DRY SEASON			
5%	8.5	**8.5**	8.7	**8.7**	8.5	10.2
30%	7.3	**7.3**	7.4	**7.8**	7.3	22.7
60%	7.3	**7.3**	6.9	**6.9**	7.3*	28.8
			WET SEASON			
5%	7.2	**7.2**	6.8	**6.8**	6.8	30.8
30%	6.7	**6.8**	6.6	**6.6**	6.6	35.2
60%	5.1	**5.5**	5.4	**5.4**	5	60**
AEC↓ C ECOSTATUS		**FISH: D**		**MACROINVERTEBRATES: D**		
			DRY SEASON			
5%	9.2	9.2	9.1	9.1	9.1	5.3
30%	8.3	8.3	8.3	8.4	8.3	12.1
60%	7.6	7.6	7.3	7.7	7.6	19.2
			WET SEASON			
5%	7.6	7.6	7.5	7.8	7.6	19.2
30%	7	7	6.8	7.1	7	27
60%	5.8	6.1	6.2	6.1	6.1	48

*invertebrates requested slightly higher flows than present day therefore the final recommendation is based on the fish requirement
** this flow was recommended by riparian vegetation as the fish and invertebrate requirements are too low (54.4 m^3/s) to maintain the vegetation PES

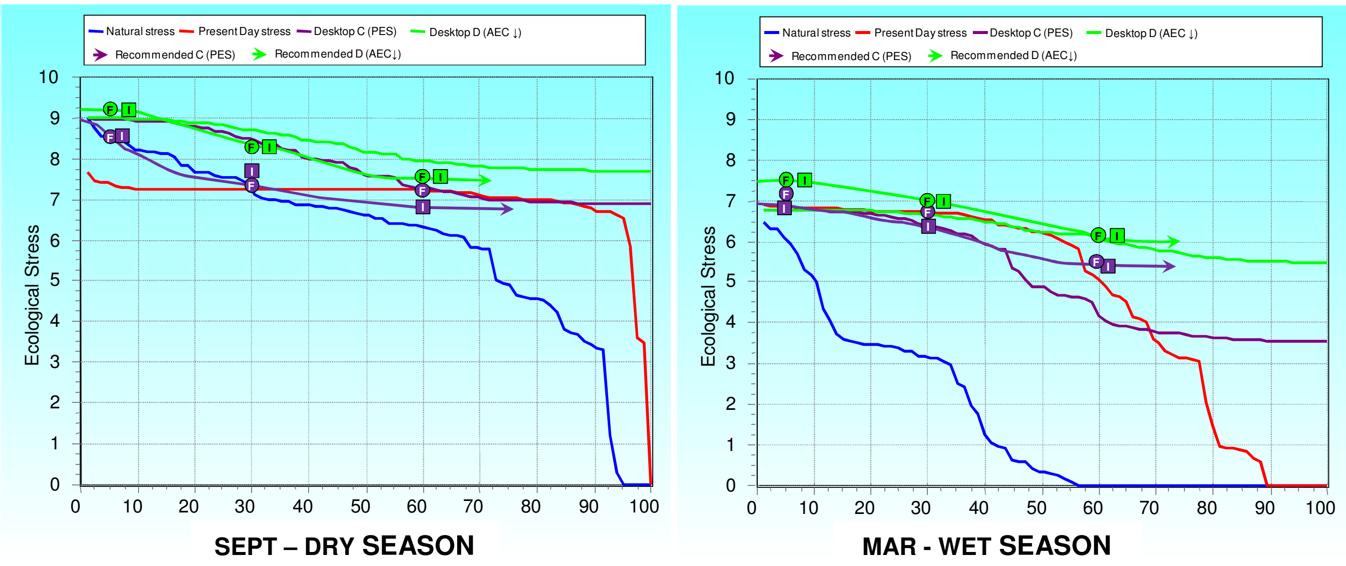


Figure 6.1 EFR O2: Stress duration curve for a PES, REC and AEC

Table 6.2 EFR O2: Summary of motivations

Month	% Stress duration	Component stress	Integrated stress	Flow m^3/s	Comment
PES:EcoStatus		**FISH: C**			**MACROINVERTEBRATES: C**
Sep	5% drought	8.5 LSR	8.5	10.2	Habitat suitability will be very low in terms of providing cover/abundance, connectivity and water quality, but adequate to allow survival and maintenance of PES during droughts.
	60% maintenance	7.3 LSR	7.3	28.8	Habitat suitability will generally be low in terms of proving cover/abundance, connectivity and water quality, but adequate to allow survival and maintenance of PES.
Mar	5% drought	6.8 FDI	6.8	30.8	This stress is slightly higher than the present-day flow, but will maintain the PES. The average current speeds at this stress are lower than that preferred by the indicator taxon, *Amphipsyche scottae*, but there is no justification for requesting more flow than present.
	60% maintenance			60	SEE TABLE 6.3
AEC↓: EcoStatus		**FISH: D**			**MACROINVERTEBRATES: D**
Sep	5% drought	9.1 FDI	9.1	5.3	Natural stress will be introduced into the system. The stress-duration is higher than the natural stress, and significantly higher than the present-day stress. Elevated low-flows at this time of the year are the main reason leading to outbreaks of pest blackflies. The requested stress will therefore reduce outbreaks of pest blackflies.
	60% maintenance	7.6 LSR	7.6	19.2	Habitat suitability will generally be very low to low in terms of providing cover/abundance, connectivity and water quality, but lower than under present scenario, resulting in deterioration in the fish assemblage.
Mar	5% drought	7.6 LSR	7.6	19.2	Habitat suitability will generally be very low to low in terms of providing cover/abundance, connectivity and water quality and very low in terms of suitable spawning and nursery habitats, but lower than under present scenario, resulting in deterioration in the fish assemblage.
	60% maintenance	5.8 LSR	6.1	48	Habitat suitability will generally be low to low in terms of providing cover/abundance, connectivity, water quality nursery habitats and very low in terms of suitable spawning habitat, but lower than under present scenario, resulting in deterioration in the fish assemblage.

6.3.2 EFR O2 Riparian vegetation verification of low flow requirements

The low flow requirements as set by the instream biota is checked (and modified if necessary) to ensure that it caters for any riparian vegetation (specifically marginal) and riverine fauna. This verification is summarised in Table 6.3.

Table 6.3 EFR O2: Verification of low flow requirements for instream biota to maintain riparian vegetation in the required EC.

PES						
Species	**Season**	**Duration**	**Q**	**Average Inundation / Height above water level (m)**		**Note**
				lower limit	**upper limit**	
G. virgatum	Dry	5%	10.2	0.52	1.51	Water stress is high and some mortality expected, especially along the upper limit of populations, but this is usual for drought, even in the dry season.
C. marginatus				0.54	1.62	
P. decipiens				0.55	1.01	
P. lapathifolia				0.65	1.49	
P. australis				0.70	1.62	
S. mucronata				0.76	1.36	
G. virgatum		60%	28.8	0.35	1.34	Water stress quite high, but normal for dry season and because plants reduce metabolic requirements, survival will be sufficient for PES to be unaltered.
C. marginatus				0.37	1.45	
P. decipiens				0.38	0.84	
P. lapathifolia				0.48	1.32	
P. australis				0.53	1.45	
S. mucronata				0.59	1.19	
G. virgatum	Wet	5%	30.8	0.33	1.33	Comparable to dry season base flows, but during the wet season these flows are likely to cause reproductive failure / abortion. Survival of existing vegetation is however likely to be high and not likely to change the PES.
C. marginatus				0.36	1.44	
P. decipiens				0.36	0.82	
P. lapathifolia				0.46	1.31	
P. australis				0.52	1.43	
S. mucronata				0.58	1.17	
G. virgatum		60%	60	0.11	1.11	On average most populations are not inundated, although up to 20 cm of inundation can occur at selected low points. These base flows are sufficient to facilitate survival and, together with small floods, reproduction. The PES is not likely to change.
C. marginatus				0.14	1.22	
P. decipiens				0.14	0.61	
P. lapathifolia				0.24	1.09	
P. australis				0.30	1.21	
S. mucronata				0.36	0.95	
Conclusion: Low flow requirements for instream fauna will maintain the PES for riparian vegetation (in a B class), provided that class I floods are provided. Riparian zone structure and functionality will remain unchanged from current.						

Table 6.4 EFR O2: Verification of low flow requirements for instream biota to maintain riverine fauna in the required EC

Season	Duration	Q	Note
Dry	5%	10.2	Some mortality expected in the riparian vegetation, especially along the upper limit of populations. This happened natural and the riverine fauna will be adapted to some loss in vegetation. Piscivorous animals will be fine since the fish population will not change much, and lowered water levels will improve the chances of obtaining fish as food.
Dry	60%	28.8	Water stress quite high, but normal for dry season and the vegetation survival will be sufficient to maintain the habitat for riverine fauna.
Wet	5%	30.8	Survival of existing vegetation is likely to be high and not likely to change the PES, and the riverine fauna will react accordingly.

Season	Duration	Q	Note
Wet	60%	60	These base flows are sufficient to facilitate survival and reproduction in the riparian vegetation, thus the PES is not likely to change and the riverine fauna will react accordingly.
Conclusion: Only during the dry season at 5% will the vegetation show a level of stress, however, the riverine fauna will not respond drastically if the changes in marginal vegetation are small.			

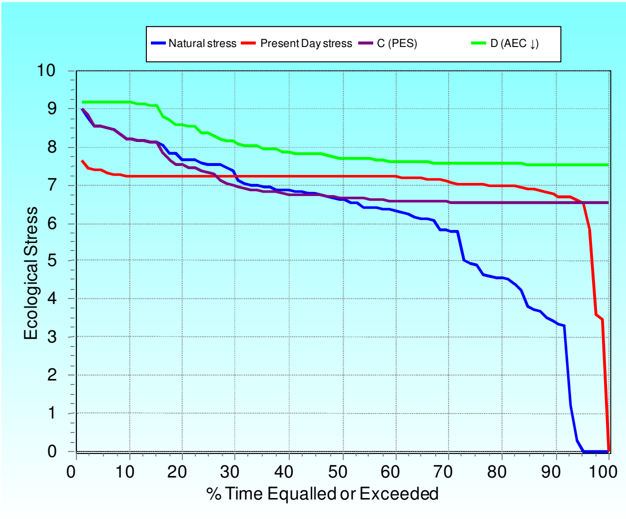
6.3.3 Final low flow requirements

To produce the final results, the DRM results for the specific category are modified according to specialists' requirements Figure 6.3. There are a range of options one can use to make these modifications, such as changing the total volume required for the year, specific monthly volumes, either drought or maintenance flow durations, seasonal distribution and changing the category rules and shape factors. To produce the final results, the DRM results for the specific category were modified according to specialists' requirements (Figure 15.2). There are a range of options one can use to make these modifications, such as changing the total volume required for the year, specific monthly volumes, either drought or maintenance flow durations, seasonal distribution and changing the category rules and shape factors. The following changes were required:

- PES: C EC.
  - Maintenance seasonal distributions set to 0.56.
  - Wet season rules:
    - Shape factor set to 8.
    - Lower shift factor set to 94; Upper shift set to 10.
    - Low flow max (%): 101.
  - Dry season rules:
    - Shape factor set to 4.
    - Lower shift factor set to 100; Upper shift set to 0.
    - Low flow max (%): 130.

- AEC down: D EC.
  - Drought and Maintenance seasonal distributions set to 1.2.
  - Wet season rules:
    - Shape factor set to 8.
    - Lower shift factor set to 94; Upper shift set to 10.
    - Low flow max (%): 101.
  - Dry season rules:
    - Shape factor set to 4.
    - Lower shift factor set to 90; Upper shift set to 0.
    - Low flow max (%): 130.
    - Small manual adjustment to dry season maintenance flows.

Dry Season (September)



Wet Season (March)

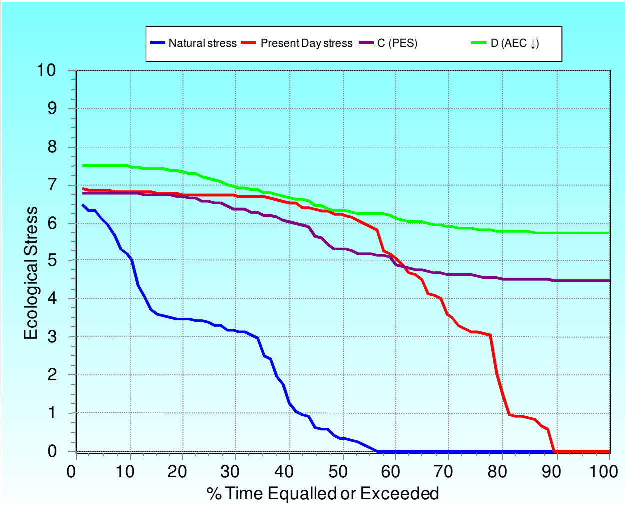


Figure 6.2 EFR O2: Final stress requirements for low flows

6.4 HIGH FLOW REQUIREMENTS

The high flow classes were identified as follows:

- The geomorphologist and riparian vegetation specialist identified the range of flood classes required and listed the functions of each flood.
- The instream specialists then indicated which of the instream flooding functions were addressed by the floods identified for geomorphology and riparian vegetation (indicated by a ✓ in Table 6.4).
- Any of the floods required by the instream biota and not addressed by the floods already identified, were then described (in terms of ranges and functions) for the instream biota.

Detailed motivations provided in Table 6.4 and final high flow results are provided in Table 6.5.

Table 6.5 EFR O2: Identification of instream functions addressed by the identified floods for geomorphology and riparian vegetation

FLOOD RANGE (m3/s) FLOOD CLASS (instantaneous peak)	Geomorphology & riparian vegetation motivation	Fish flood functions						Invertebrate flood functions				Riverine fauna		
		Migration cues & spawning	Migration habitat (depth etc)	Clean spawning substrate	Create nursery areas	Resetting water quality	Inundate vegetation for spawning	Breeding and hatching cues	Clear fines	Scour substrate	Reach or inundate specific areas	Scour lower zone habitats	Create floodplain habitats	Invigorate riparian vegetation habitats
150 - 200	Required to inundate 50 to 60% of marginal and lower zone vegetation (*Gomphostigma virgatum, Cyperusmarginatus, Persicaria decipiens, P. lapathifolia, Phragmites australis* and *Salix mucronata*). Prevents establishment of upper zone (*Acacia karoo*) & terrestrial species in the lower zone. Required to begin inundation of the *Crinum bulbispermum* population which will support reproductive demands. Required during growing season (spring to summer: Nov - Jan).	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓[1]	
300 - 400	Required to flood lower zone riparian species (*S. mucronata* and *P. australis*) and inundate about 50% of the *C. bulbispermum* population. This will flush sediment in seasonal channels and facilitate recruitment opportunities at higher levels, but create flooding disturbance at the lower limits which also maintains habitat and vegetative patchiness. These floods may cause some scour in the marginal zone, again, important for maintaining patchiness and similarly maintain seasonal channels. Required during summer (Nov - Jan).	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓[2]	
850 - 1000	Required to begin inundation of *Searsia pendulina* (which is where the tree line starts). Will facilitate recruitment &vigour of upper zone woody species, but also prevent their encroachment into the lower zone. Similarly, these floods are also useful for preventing terrestrialisation and expansion of exotic species such as *P. galndulosa.* Activation of the *Tamarix usneoides* population (i.e. no inundation, but sufficient soil moisture to facilitate recruitment and maintain reproductive outputs). Larger floods are also important to scour marginal and lower zone habitats and maintain open patches. Needed late in the growing season (Feb, Mar).	✓	✓	✓	✓	✓	✓	✓	□	□	□			✓[3]
2000 - 2500	Large and infrequent flood to inundate about 50% of the *T. usneoides* population. Important to maintain *T. usneoides* recruitment, but also to scour large sections of the macro-channel bed and maintain overall patchiness. Also creates flooding disturbance for upper zone and bank woody species such as *S.pendulina, A. karoo* and *Z. mucronata*. Useful to reduce exotic perennial species, especially *P. glandulosa*. Also activates lower limit of *A. erioloba*.	✓	✓	✓	✓	✓	✓	□	□	□	□			✓[4]
✓[1]	Inundate channels in anatomising area behind island on right hand bank. Supply a mosaic of habitats for fish and eventually for wetland fauna to forage in. Scour channels, supply embankments for nesting and tunnelling.													
✓[2]	Larger floods are important to scour marginal and lower zone habitats and maintain open patches resulting in mudflats and alluvial sandbars as habitat.													
✓[3]	Main motivation for these flows is for the riparian vegetation to be invigorated, to which the riparian fauna will react accordingly.													
✓[4]	Main motivation for these flows is for the riparian vegetation to be invigorated, to which the riparian fauna will react.													

The number of high flow events required for each EC is provided in Table 6.5. The availability of high flows was verified using the observed data at gauge D7H008.

Table 6.6 EFR O2: The recommended number of high flow events required

FLOOD RANGE (m^3/s)	INVERTEBRATES	FISH	VEGETATION	GEOMORPHOLOGY	FINAL* (No of events)	MONTHS	DAILY AVERAGE (m^3/s)	DURATION
PES and REC: C								
150-200	3	3	3	2	3	Nov, Dec, Jan	150	6
300-400	1	1	1	1:2	1	Feb	350	8
850-1000	1:3		1:3	1:5	1:3**	Mar	850	12
2000+			1:5+	1:10	1:5+	Late summer	N/S	N/S
AEC↓: D								
150-200	1	2	2	1	2	Nov, Jan	150	6
300-400	1:1	0	1:1	1:3	1	Feb	350	8
850-1000			1:3	1:5	1:3	Mar	850	12
2000+			1:5+	1:10	1:5+		N/S	N/S

* Final refers to the agreed on number of events considering the individual requirements for each component.
**Refers to frequency of occurrence, i.e. the flood will occur once in three years.
N/S Not Specified.

6.5 FINAL FLOW REQUIREMENTS

The low and high flows were combined to produce the final flow requirements for each EC as:

- An EFR table, which shows the results for each month for high flows and low flows separately (Table 6.7 – 6.8). Floods with a high frequency are not included in the modelled results as they cannot be managed.
- An EFR rule table which provides the recommended EFR flows as a duration table, linked to a natural trigger (natural modelled hydrology in this case). EFR rules are supplied for total flows as well as for low flows only (Table 6.9 – 6.10).

The low flow EFR rule table is useful for operating the system, whereas the EFR table must be used for operation of high flows.

Table 6.7 EFR O2: EFR table for PES and REC: C

Desktop version:		2	Virgin MAR (MCM)	10573.7
BFI	0.329	Distribution type		Vaal
MONTH	LOW FLOWS		HIGH FLOWS	
	Maintenance (m^3/s)	Drought (m^3/s)	Daily average (m^3/s) on top of base flow	Duration (days)
OCTOBER	28.211	0.627		
NOVEMBER	36.708	13.665	150	6
DECEMBER	39.92	19.512	150	6
JANUARY	47.269	21.408	150	6
FEBRUARY	61.393	31.478	350	8
MARCH	60.014	31.051	850	12
APRIL	53.153	11.705		
MAY	39.716	10.906		

Desktop version:		2	Virgin MAR (MCM)	10573.7
BFI	0.329	Distribution type		Vaal
MONTH	LOW FLOWS		HIGH FLOWS	
	Maintenance (m^3/s)	Drought (m^3/s)	Daily average (m^3/s) on top of base flow	Duration (days)
JUNE	30.813	11.3		
JULY	24.956	10.919		
AUGUST	23.653	10.171		
SEPTEMBER	24.231	6.115		
TOTAL MCM	1230.5	467.2	566.4	
% OF VIRGIN	11.64	4.42	5.36	
Total IFR	1797			
% of MAR	16.99			

Table 6.8 EFR O2: EFR table for AEC↓: D

Desktop version:		2	Virgin MAR (MCM)	10573.7
BFI	0.304	Distribution type		Vaal
MONTH	LOW FLOWS		HIGH FLOWS	
	Maintenance (m^3/s)	Drought (m^3/s)	Daily average (m^3/s) on top of base flow	Duration (days)
OCTOBER	11	0.627		
NOVEMBER	17	10.459	150	6
DECEMBER	20	12.055		
JANUARY	25	15.286	150	6
FEBRUARY	34	20.908	350	8
MARCH	34	20.891	850	12
APRIL	29	11.705		
MAY	20	10.906		
JUNE	13	7.867		
JULY	11	5.475		
AUGUST	10	4.902		
SEPTEMBER	9	4.973		
TOTAL MCM	609.4	329.2	532.1	
% OF VIRGIN	5.76	3.11	5.03	
Total IFR	1141.5			
% of MAR	10.8			

Table 6.9 EFR O2: Assurance rules for PES and REC: C

Desktop Version 2, Printed on 2010/11/03
Summary of IFR rule curves for: EFRO2 Natural Flows
Determination based on defined BBM Table with site specific assurance rules.
Regional Type: Vaal PES and REC = C

Data are given in m^3/s mean monthly flow

Month	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	41.794	41.290	40.355	38.693	35.879	31.408	24.876	16.404	7.318	0.886
Nov	78.886	73.772	68.755	63.201	53.796	46.506	37.174	27.231	19.120	15.301
Dec	81.831	76.003	70.433	64.246	54.201	46.139	36.811	28.390	22.927	21.077
Jan	86.915	81.014	75.267	68.727	58.092	49.246	39.134	30.201	24.623	22.993
Feb	167.673	147.682	130.734	114.213	88.708	72.594	55.999	43.593	37.338	35.992

(% Points)

Mar	212.180	209.565	202.463	186.957	160.086	123.942	87.367	60.804	48.008	41.514
Apr	61.872	61.103	59.035	54.536	46.721	36.114	25.189	17.023	12.905	12.019
May	48.843	48.166	46.652	43.699	38.752	31.794	23.840	16.814	12.427	11.144
Jun	40.975	40.456	39.304	37.064	33.308	27.997	21.852	16.304	12.705	11.486
Jul	34.839	34.425	33.615	32.153	29.748	26.210	21.682	16.858	12.923	11.070
Aug	35.162	34.856	34.289	33.280	31.571	28.857	24.892	19.749	14.233	10.328
Sep	37.215	36.958	36.513	35.750	34.456	32.304	28.403	21.748	13.353	7.494

Reserve flows without High Flows

Oct	41.794	41.290	40.355	38.693	35.879	31.408	24.876	16.404	7.318	0.886
Nov	51.211	50.561	49.289	46.994	43.219	37.667	30.560	22.988	16.810	13.902
Dec	53.136	52.548	51.243	48.705	44.449	38.431	31.468	25.182	21.104	19.723
Jan	58.221	57.564	56.095	53.229	48.428	41.677	33.959	27.141	22.883	21.639
Feb	71.576	70.962	69.309	65.713	59.466	50.988	42.256	35.728	32.437	31.729
Mar	67.585	67.014	65.465	62.082	56.221	48.336	40.357	34.563	31.771	31.280
Apr	61.872	61.103	59.035	54.536	46.721	36.114	25.189	17.023	12.905	12.019
May	48.843	48.166	46.652	43.699	38.752	31.794	23.840	16.814	12.427	11.144
Jun	40.975	40.456	39.304	37.064	33.308	27.997	21.852	16.304	12.705	11.486
Jul	34.839	34.425	33.615	32.153	29.748	26.210	21.682	16.858	12.923	11.070
Aug	35.162	34.856	34.289	33.280	31.571	28.857	24.892	19.749	14.233	10.328
Sep	37.215	36.958	36.513	35.750	34.456	32.304	28.403	21.748	13.353	7.494

Natural Duration curves

Oct	631.571	345.904	243.160	171.151	109.282	82.788	63.762	40.931	25.336	5.780
Nov	918.985	673.117	500.725	372.319	254.479	224.730	170.517	136.802	59.047	17.191
Dec	1020.120	723.973	540.834	415.502	339.382	299.522	213.527	114.475	82.269	33.774
Jan	1270.557	903.875	638.303	521.184	395.508	298.484	227.173	172.547	96.210	43.003
Feb	2052.472	1278.741	891.353	538.802	436.872	319.498	273.276	229.588	135.235	45.705
Mar	1562.280	1034.289	698.014	607.411	468.765	335.738	252.647	200.396	126.176	41.514
Apr	899.541	636.867	406.590	319.606	288.630	238.515	170.093	119.487	75.598	29.344
May	353.271	265.091	197.431	133.277	106.732	82.154	72.353	47.551	34.606	11.470
Jun	192.647	140.895	91.454	71.937	60.683	56.296	43.534	33.029	22.477	11.617
Jul	149.578	100.896	84.569	67.040	47.525	39.221	32.818	26.329	19.108	15.084
Aug	152.337	106.582	83.796	60.140	50.881	34.069	27.770	23.466	18.246	14.445
Sep	229.946	126.123	86.844	65.251	48.935	39.734	28.403	21.748	13.353	8.333

Table 6.10 EFR O2: Assurance rules for AEC↓: D

Desktop Version 2, Printed on 2010/11/03
Summary of IFR rule curves for: EFRO2 Natural Flows
Determination based on defined BBM Table with site specific assurance rules.
Regional Type: Vaal AEC DOWN = D

Data are given in m^3/s mean monthly flow

% Points

Month	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	22.801	22.479	21.853	20.697	18.696	15.507	10.986	5.642	1.168	0.767
Nov	59.802	54.879	50.194	45.190	36.677	30.819	23.717	16.949	12.561	11.995
Dec	35.148	34.698	33.665	31.625	28.223	23.566	18.534	14.519	12.429	12.200
Jan	70.158	64.401	58.946	52.944	43.228	35.820	27.693	21.023	17.373	16.805
Feb	148.597	128.716	112.039	96.084	71.588	56.976	42.191	31.453	26.280	25.369
Mar	221.525	218.605	210.676	193.365	163.364	123.010	82.176	52.518	38.233	35.716
Apr	44.741	44.225	42.824	39.766	34.465	27.335	20.120	14.880	12.356	11.912
May	33.158	32.734	31.768	29.864	26.686	22.301	17.490	13.543	11.382	11.046
Jun	22.846	22.555	21.885	20.561	18.355	15.334	12.070	9.465	8.110	7.961
Jul	20.775	20.471	19.859	18.731	16.870	14.189	10.938	7.840	5.831	5.572
Aug	20.786	20.555	20.107	19.279	17.845	15.561	12.322	8.494	5.290	5.002
Sep	20.517	20.360	20.072	19.549	18.617	17.002	14.325	10.255	5.071	5.071

Reserve flows without High Flows

Oct	22.801	22.479	21.853	20.697	18.696	15.507	10.986	5.642	1.168	0.767
Nov	32.137	31.707	30.839	29.240	26.605	22.805	18.199	13.809	10.963	10.596
Dec	35.148	34.698	33.665	31.625	28.223	23.566	18.534	14.519	12.429	12.200
Jan	41.466	40.967	39.830	37.590	33.851	28.692	23.032	18.388	15.846	15.451
Feb	52.500	52.007	50.667	47.742	42.673	35.855	28.956	23.945	21.531	21.106
Mar	51.149	50.676	49.393	46.592	41.737	35.207	28.599	23.799	21.488	21.080

Apr	44.741	44.225	42.824	39.766	34.465	27.335	20.120	14.880	12.356	11.912
May	33.158	32.734	31.768	29.864	26.686	22.301	17.490	13.543	11.382	11.046
Jun	22.846	22.555	21.885	20.561	18.355	15.334	12.070	9.465	8.110	7.961
Jul	20.775	20.471	19.859	18.731	16.870	14.189	10.938	7.840	5.831	5.572
Aug	20.786	20.555	20.107	19.279	17.845	15.561	12.322	8.494	5.290	5.002
Sep	20.517	20.360	20.072	19.549	18.617	17.002	14.325	10.255	5.071	5.071

Natural Duration curves

Oct	631.571	345.904	243.160	171.151	109.282	82.788	63.762	40.931	25.336	5.780
Nov	918.985	673.117	500.725	372.319	254.479	224.730	170.517	136.802	59.047	17.191
Dec	1020.120	723.973	540.834	415.502	339.382	299.522	213.527	114.475	82.269	33.774
Jan	1270.557	903.875	638.303	521.184	395.508	298.484	227.173	172.547	96.210	43.003
Feb	2052.472	1278.741	891.353	538.802	436.872	319.498	273.276	229.588	135.235	45.705
Mar	1562.280	1034.289	698.014	607.411	468.765	335.738	252.647	200.396	126.176	41.514
Apr	899.541	636.867	406.590	319.606	288.630	238.515	170.093	119.487	75.598	29.344
May	353.271	265.091	197.431	133.277	106.732	82.154	72.353	47.551	34.606	11.470
Jun	192.647	140.895	91.454	71.937	60.683	56.296	43.534	33.029	22.477	11.617
Jul	149.578	100.896	84.569	67.040	47.525	39.221	32.818	26.329	19.108	15.084
Aug	152.337	106.582	83.796	60.140	50.881	34.069	27.770	23.466	18.246	14.445
Sep	229.946	126.123	86.844	65.251	48.935	39.734	28.403	21.748	13.353	8.333

A comparison between the Desktop Reserve Model estimates and the EFR results in terms of percentages of natural flow are provided in Table 6.11.

Table 6.11 EFR O2: Modifications made to the DRM

Changes	PES and REC: C		AEC↓: D	
	DRM	EFR	DRM	EFR
MLIFR - Maintenance low flow	11.6%	11.6%	5.7%	5.8%
DLIFR - Drought low flow	4.4%	4.4%	4.4%	3.1%
MHIFR - Maintenance high flow	9.8%	5.4%	8.3%	5.0%
Long-term % of virgin MAR	18.8%	15.2%	14.6%	11.3%

7 ECOCLASSIFICATION: EFR O3 (AUGRABIES)

7.1 EIS RESULTS

The EIS evaluation results in a **HIGH** importance**.** The highest scoring matrices are:

- Rare and endangered instream biota: BKIM,*Simulium gariepense;*
- Rare and endangered riparian biota: Clawless otter, black stork, straw-coloured fruit bat. *A. erioloba* (IUCN[3] listed as declining). *Euclea pseudenus* (SANBI protected tree). Vegetation type = Lower Gariep Alluvial vegetation (Conservation status: Endangered);
- Unique aquatic biota: Some fish species endemic to the Orange System (ASCL, BAEN, and LCAP). BTRI in lower Orange possibly unique population. BHOS endemic to lower Orange, MBRE isolated population in Orange;
- Unique riparian biota: Orange River white-eye restricted to catchment, paradise frog (SA Endemic), 6 endemic vegetation plants;
- Riparian biota – taxon richness: 70 out of 87 riverine faunal species present (80% of expected);
- Riparian habitat: Diversity of types and features: Cobble beaches, grazing lawns, backwaters, intact riparian zone, reed beds and some mud flats;
- Riparian migration corridor: A riparian band in the area annually inundated by high floods, remains intact, despite the larger area in the floodplains being cleared a planted with agricultural crops. This intact band forms a very important migration corridor for most of the riverine faunal species present in the area;
- National parks, wilderness areas, reserves, heritage sites, natural areas: Augrabies National Park.

7.2 REFERENCE CONDITIONS

The reference conditions for the components in EFR O3 are summarised below in Table 7.1

Table 7.1 EFR O3: Reference conditions

Component	Reference conditions	Conf
Hydrology	10513.08 nMar	3.5
Physico-chemical	See the description of RC per variable in Table 7.2.	2.5
Geomorph	The historical aerial photographic record indicates the planform of this pool riffle and rapid reach is very stable. This stability is not unexpected given that much of the reach is bedrock controlled.	3.5
Riparian vegetation	The assessed area at EFR 3 occurs within the Lower Gariep Broken Veld vegetation type, which occurs within the Nama-Karoo Biome and the Bushmanland Bioregion. The riparian zone is distinct from the terrestrial zone however, and is catagorised at an azonal vegetation type: the Lower Gariep Alluvial Vegetation. Alluvial terraces and banks are dominated by woody riparian thickets (mainly *Acacia karoo, Ziziphus mucronata, Rhus pendulina*) or stands of *Tamarix usneoides* or reeds (*Phragmites australis*). Cobble or boulder features are characterised by a mix of woody species (*T. usneoides, Gomphostigma virgatum*) and sedges (*Cyperus spp*). Frequently flooded alluvia are open or grassed (*Cynodon dactylon* mainly) and *Salix mucronata* is also common on frequently inundated alluvia. Marginal Zone: Expect a mix of open alluvia or cobble/boulder and vegetated areas. Vegetation, similarly, should be a mix of woody (*Gomphostigma virgatum, Salix mucronata subs. mucronata*) and non-woody (*Phragmites australis, Cyperus marginatus*) vegetation. Lower zone: Expect the same as the marginal zone, with *Tamarix usneoides* on low lying bars.	3

[3] International Union for Conservation of Nature.

Component	Reference conditions	Conf
	Upper zone: Terraces should be well vegetated with small percentage of open areas. Vegetation will be a mix of reed beds (*P. australis*) or woody thickets (*Acacia karoo, Ziziphus mucronata, Rhus pendulina* mainly). Macro channel bank : Banks should be well vegetated and dominated by woody riparian thickets, with dominant species as outlined above. Also expect *Euclea pseudobenus*. Floodplain : Should be similar to the Macro channel bank with *Acacia erioloba* as a landmark species. Expect scattered woody / grass mix with open alluvial areas (e.g. 1941 aerial photo).	
Fish	Twelve indigenous fish species have a high to definite probability of occurrence under reference conditions in this reach (Appendix D). The expected habitat composition at the site also meets the requirements of these fish species. The indigenous AMOS is mentioned as having peripheral occurrence, but it was excluded from reference conditions as this species is not expected to occur naturally in the Orange River and can probably not complete its life-cycle successfully. The expected FROC provided in Kleynhans *et al.* (2007) for site D7ORAN-BLOUP, located within the fish reach under investigation was broadly used to determine the reference FROC for reach EFR O3, with alterations made based on all available information.	2.5
Macro-invertebrates	Reference conditions were based on professional judgment and data collected by Palmer (1996, 1997a). The reference SASS5 Score is 179 and the ASPT is 6.6. The expected number of SASS5 taxa is 27.	4
Riverine Fauna	Potentially 87 animal species inhabited the riverine habitats. Open alluvia in marginal zone utilized by waders. Backwaters in side channels with overhanging and emergent vegetation as habitat for retreating species. Variety of tree zones (from lower to Macro Channel Bank) with different structural compositions act as refuge, shelter, breeding and feeding habitats, while the intact riparian corridor being used as a migration route for riverine fauna. Mudflats and alluvial soils in lower riparian zone used by burrowing and tunnelling fauna. Reeds and shrubs also utilized as shelter, breeding and feeding habitats.	3

7.3 PRESENT ECOLOGICAL STATE

The PES reflects the changes in terms of the EC (Table 7.2) from reference conditions. The summarised information is provided in Table 7.2.

Table 7.2 EFR O3: Present Ecological State

Component	PES Description	EC	Conf
Hydrology	4228.47 present day MAR (40% of nMAR)	E	1.5
Physico-chemical	See Table 7.3	C	3.5
Geomorph	Flood sizes and frequencies are highly reduced, with even floods up to the 1:10 year possibly being attenuated upstream. These critically reduced flows at the site constrain channel maintenance. However, despite the lower flows, the PES is ameliorated by concomitant declines in sediment loads (since much is trapped in upstream dams), although some sediment replenishment occurs from tributary inputs. The site has some bedrock control and therefore is not very sensitive to the impacts of base flow and small flood changes. Cobbles, boulders and gravels in the channel and along the margins are generally not embedded, although they are slightly armoured. This suggests that scouring of the bed is occurring frequently enough that the bed is remaining mobile.	C	3

Component	PES Description	EC	Conf
Riparian vegetation	Marginal Zone: Sparse cover, with recent flood scour observed. LB mostly open *C. dactylon* and *C. marginatus*. Cobble areas have a vibrant population of *G. virgatum*. Other dominants are *S. mucronata* and *P. australis* and this features well on RB, but have almost completely been removed on LB by high grazing pressure. *C. dactylon* also shows evidence of grazing and form lawns where it occurs. Lower Zone: LB dominated by open cobble with *T. usneoides*. RB is mainly reed dominated (*P. australis*) alluvium with *S. mucronata*. Upper Zone: LB has extensive open areas (cobble or alluvium) as a result of grazing and physical removal, with vegetation mainly comprised of riparian thickets (common species are *T. usneoides*, *A. karoo, R. pendulina, Z. mucronata. D. lycioides, E. pseudobenus, Lycium bosciifolium, A. erioloba, M. linearis, Prsopis glandulosa, P. velutina*). RB mainly reeds as lower, but also with open bedrock areas and a cobble/alluvium mixed ephemeral channel. Annual and bi-annual exotic species are abundant. Macro channel bank: Same as upper zone, with *Schotia affra* on the RB. Floodplain: Only occurs on LB and has been removed and transformed into agricultural land for grapes and vegetables.	B/C	3.8
Fish	All the expected fish species are still present in this river reach albeit in a slight to moderately reduced FROC. The species that are thought to have been impacted the most are BHOS, LUMB, BAEN, BKIM, LCAP, BPAU, PPHI and TSPA. The primary changes responsible for deterioration in the fish assemblage is primarily associated with altered hydrology / flow modifications (due to large dams and flow regulation), causing habitat deterioration and loss; and water quality alterations. Other impacts are related to water quality deterioration, some loss of marginal zone overhanging vegetation which may also be associated with the fluctuating flows and altered hydrological regime. The presence of alien and introduced indigenous fish species (trans-located OMOS) furthermore have a potential negative impact on the fish assemblage of this river reach (in terms of competition for habitat, feeding, and predation pressure).	C	3.5
Macro-invertebrates	A total of 20 SASS5 taxa was observed at the site, out of 27 expected (i.e. 74%). The observed SASS5 Score was 135 (75%), and the ASPT was 6.8 (102%). Taxa that were abundant during the site-visit included the mayflies *Tricorythus discolor* and *Baetis glaucus*, and the blackfly *Simulium chutteri*. The most obvious change from natural has been outbreaks of pest blackflies (mainly *Simulium chutteri)* following impoundment. The site experienced a flood of 700 m^3/s six weeks before the site-visit. The threatened blackfly *S. gariepense* was recorded during the site-visit, reflecting the post-flood conditions suitable for this species. The invertebrate fauna at this site is similar to that expected at EFR02, so the description presented in Table 4.2 is applicable to this site.	C	4
Riverine Fauna	70 of the expected 87 animal species (80%) potentially can occur in this segment. This comprises 37 aquatic and semi-aquatic species, 14 marginal habitat species, and 19 riparian species. Aquatic and semi-aquatic species (80% of expected): The changes in flows impact on the food source (abundance of fish) of piscivorous species. Lower flows eliminate associated deep pool habitat (overhanging vegetation for kingfishers; emerging vegetation for warblers, weavers and moorhen) and slower backwater habitats (ducks, coots, storks). Marginal habitat species (64% of expected): The changes in flows (removal of higher flows) resulted in the marginal zone being vegetated with reeds and hygrophilous shrubs, reducing mudflats and alluvial sandbars. Thus less waders (sandpipers, plovers) and open habitat animals (plovers, geese) present. Also species that use sand bars and sandbanks lose digging substrate (monitors, bee-eaters, martins). Riparian species (100% of expected): The riparian vegetation habitats on the upper zones have not changed much, as most of the riparian trees of diverse structures are still intact to act as refuge, shelter, breeding and feeding habitats, and a migration route. Some trampling and grazing will affect shelter for smaller species (shrews, frogs). On the other hand the loss of the floodplains to agriculture removed a very important component of the riparian habitat. Some sensitive species and some diversity are lost by this land change. However, most of the floodplain habitat (alluvial floodplain channels and associated vegetation) is presented in the upper and lower riparian zone.	C	3.8

Table 7.3 EFR O3: Present Ecological State: Physico-Chemicalical

RIVER	Orange River	**WATER QUALITY MONITORING POINTS**	
		RC	Orange River @ Kakamas (D73F; ecoregion II: 26.05) D7H003Q01 (1965 – 1980; n=68)
EFR SITE	EFR O3 (D81B; ecoregion II: 28.01)	**PES**	1) Orange River @ Neusberg (D73F; ecoregion II: 26.05) D7H014Q01 (1995 – 2010; n=94) 2) Data from diatom sample collection in 2008 (n=7)
Confidence assessment	Moderate confidence. Although sufficient data, particularly for the present state, data gaps exist, e.g. metal ions, pesticides, herbicides. Note that the EFR site and monitoring points are not in the same EcoRegion level II. Agricultural activities were also already in place in the 1960s.		

Water Quality Constituents		**RC Value**	**PES Value**	**Category/Comment**
Inorganic salts (mg/L)	TEACHA was not used for data assessment, as salinity levels not significantly elevated.			
Salt ions (mg/L)	Ca	46.4	32.2	Concentrations similar for the PES as compared to natural levels.
	Cl	31.3	33.9	
	K	3.58	3.88	
	Mg	22.9	16.9	
	Na	34.2	33.5	
	SO_4	59.2	50.9	
Nutrients (mg/L)	SRP	0.014 *	0.029	B category
	TIN	0.11	0.09	A category
Physical Variables	pH (5^{th} + 95^{th} %ile)	6.93 + 8.01	7.81 + 8.46	A/B category
	Temperature	-		Little impact expected, although temperature less variable than natural (B category).
	Dissolved oxygen			
	Turbidity (NTU)	-	**WMS data (n=186):** Avg: 12.74 95^{th} %ile: 52.43 **Koekemoer (2010):** 5.9 (avg)	No RC data. Turbidity from system trapped in dams. A/B category (qualitative assessment).
	Electrical conductivity (mS/m)	45.4 * (n=118)	51.62 (n=129)	A category
Response variables	Chl a: periphyton (mg/m^2)	-	-	-
	Chl a: phytoplankton (µg/L)	-	Avg: 18.4 (n=7) (Koekemoer, 2010)	C category
	Macroinvertebrates	ASPT:6.6 SASS: 165	ASPT: 6.7 SASS: 133 MIRAI: 75.9%	C category (Palmer, 2010)
	Fish community score		FRAI: 76.9%	C category (Kotzé, 2010)
	Diatoms	-	Avg SPI: 12.6 (n=5)	C category (Koekemoer, 2010)
Toxics	Fluoride (mg/L)	0.44	0.51	A category
	Aluminium (mg/L)	0.02 **	0.08 (n=7) (Koekemoer, 2010)	B category
	Iron (mg/L)	-	0.073 (n=7) (Koekemoer, 2010)	No guideline + insufficient data
	Ammonia (mg/L)	0.002 (n=41)	0.006	A category
	Other	-	-	Impacts expected due to intensive farming-related pesticides and fertilizer use.
OVERALL SITE CLASSIFICATION		**C: 72.40% (from PAI model)**		

** boundary value for the A category recalibrated* *- no data* *** benchmark value, as no data*

7.3.1 EFR O3: Trend

The trend was also assessed. Trend refers to the situation where the responses have not yet stabilised in reaction to catchment changes. The evaluation is therefore based on the existing catchment condition. The trend at all components is stable (See Figure 7.8) apart from vegetation and riverine fauna. The site has a high degree of physical disturbance (vegetation removal, grazing, trampling and lighting fires) which has already and will continue to promote pioneer species, especially exotic riparian species such as *Prosopis gladulosa*. *P. glandulosa* recruitment was extensive at the site, and cover of perennial exotics will increase over time. (confidence: 4). If the structure of the riparian zone is altered, this will change the habitat from a patch mosaic to dense woodland, uncommon for these areas. The change will impact adversely on the riverine fauna composition.

7.3.2 EFR O3: PES Causes and Sources

The reasons for changes from reference conditions must be identified and understood. These are referred to as causes and sources ((http://cfpub.epa.gov/caddis/)). The PES for the components at EFR O3as well as the causes and sources for the PES are summarised in Table 7.4.

Table 7.4 EFR O3: PES Causes and Sources

	PES	Conf	Causes	Sources	F[1]/NF[2]	Conf
Hydrology	E	1.5	Decrease of floods.	Large upstream dams	F	5
			Increased base flows during drought and dry seasons and decreased base flows during the wet season	Operation for irrigation and other users	F	
Physico-chemical	C	3.5	Elevated nutrients and potential toxicant loads due to fertilizer and pesticide use from agricultural activities.	Agricultural activities	NF	3
			Less variability in temperatures than under the natural state.	Operation for irrigation and other users	F	4
Geom	C	3	Reduced sediment loads	Large dams upstream trap sediment loads, but this is in some ways ameliorated by tributary inputs downstream of the dams. The impact of reduced sediment is also ameliorated by the concomitant reduction of floods.	NF	4
Rip Veg	B/C	3.8	Altered species composition and loss of indigenous riparian cover	Invasions of alien vegetation	NF	4
			Increased reed density	Frequent fires (unnatural)	NF	4
			Altered non-woody vegetation structure (forming of lawns) and increased cover	High grazing pressure, especially LB	NF	4
			Increased reed and other non-woody cover in marginal and lower zones	Reduced base flows, especially in the wet season. Reduced small and moderate floods.	F	3
Fish	C	3.5	Decreased overhanging vegetation as cover.	Erosion, change in flow, agriculture.	F/NF	3.5
			Decrease in FROC and abundance of fish species with preference for fast habitats.	Decreased base flows.	F	
			Decreased water quality affect species with requirement for high water quality.	Presence of toxics, farming, changes hydrology, dams trapping sit.	NF	
			Decreased FROC of species with preference for substrate as preferred cover and habitat for spawning, feeding etc.	Increased algal growth on substrates (increased nutrients from farming)	F/NF	
			Decreased species diversity and abundance.	Presence of alien predatory species.	NF	
			Increased turbidity and disturbed bottom substrates (impact on LUMB breeding habitats)	Presence of alien CCAR.	NF	

	PES	Conf	Causes	Sources	F[1]/NF[2]	Conf
			Decreased abundance and FROC of detritus feeders (esp. LUMB)	Competition by introduced indigenous OMOS).	NF	
			Decreased abundance, and therefore FROC	.Poaching and over-fishing using nets (gill and seine nets, often home-made).	NF	
			Reduced spawning success resulting in decreased FROC of many species.	Flow modification: Absence or lag effect of spring flushes.	F	
			Reduced migration success (breeding, feeding and dispersal) of some species.	Some small dams/weirs.	NF	
Macroinvertebrates[7]	C	4	Elevated low flows	Discharges to meet demands for winter power generation and irrigation demands	F	4
			Water quality deterioration	Agricultural return flows	F	2
			Aseasonal releases	Operation of Vanderkloof Dam	F	4
			Toxic algal blooms, such as *Microcystis*	Annual overturn of vanderkloof Dam plus inputs from Harts River (Spitzkop Dam)	NF	2
			Pesticides	Blackfly Control Programme	NF/F	4
Riverine fauna	C	3.8	Reduced abundance due to loss of habitat diversity and food (fish) source	Hydrology changes	F	4
			Change in inundation deteriorate marginal habitats – wider reed patches smothers open habitats for waders	Loss of frequency and magnitude of larger floods	F	
			Marginal zone invaded by reeds and shrubs, removing mudflat and alluvial sandbank habitats –habitat for waders	No zero flows which did occur naturally.	F	
			Rejuvenation of riverine habitats by flooding is absent and results in less resilient and diverse system.	Small and medium floods heavily impacted – due to large dams.	F	
			Absence of floodplain reduces riparian fauna abundance.	Loss of floodplains due to agriculture.	F	

1 Flow related 2 Non Flow related

The major issues that have caused the change from reference conditions are the following:

- Decreased frequency of large floods;
- Agricultural return flows, agricultural activities and associated water quality impacts;
- Higher low flows than natural in the dry season, drought and dry periods;
- Decreased low flows at other times;
- Present of alien fish species and barrier effects of dams;
- Decreased sedimentation due to lack of large floods and upstream dams;
- Alien vegetation.

7.3.3 EFR O3: PES EcoStatus

To determine the EcoStatus, the macroinvertebrates and fish must first be combined to determine an instream EC. The instream and riparian categories are integrated to determine the EcoStatus. Confidence is used to determine the weight that the EC should carry when integrating into an EcoStatus (riparian, instream and overall). The EC percentages are provided (Table 7.5) as well as the portion of those percentages used in calculating the EcoStatus.

Table 7.5 MRU: EFR O3: Instream

INSTREAM BIOTA	Importance Score	Weight
FISH		
1.What is the natural diversity of **fish** species with different flow requirements	3	80
2.What is the natural diversity of **fish** species with a preference for different cover types	4	100
3.What is the natural diversity of **fish** species with a preference for different flow depth classes	3.5	90
4. What is the natural diversity of **fish** species with various tolerances to modified water quality	2.5	70
MACROINVERTEBRATES		
1. What is the natural diversity of **invertebrate** biotopes	3.5	80
2. What is the natural diversity of **invertebrate** taxa with different velocity requirements	4	100
3. What is the natural diversity of **invertebrate** taxa with different tolerances to modified water quality	2	50
Fish	**3.5**	
Macroinvertebrates	**4**	
Confidence rating for instream biological information	**3.8**	
INSTREAM ECOLOGICAL CATEOGORY	**C**	
Riparian vegetation	**B/C**	
Confidence rating for riparian vegetation zone information	3.8	
ECOSTATUS	**C**	

7.4 RECOMMENDED ECOLOGICAL CATEGORY (REC):

The REC is determined based on ecological criteria only and considers the EIS, the restoration potential and attainability there-of. The EIS is HIGH, therefore the REC is an improvement of the PES to a B. A B can be achieved if the following is implemented:

- Reinstate droughts (i.e., lower flows than present during the drought season);
- Improved (higher) wet season base flows;
- Above will not improve water quality; however, water quality improvement in this case will not aid in significantly improving the instream biota;
- Geomorphology cannot improve without reinstating floods;
- Clear vegetation aliens which will improve the vegetation condition in the marginal and lower zones. Improvement in the upper zone will only be possible with removal of agriculture (will not happen) and by decreased grazing and trampling;
- Improved agricultural practices: Elevated concentrations of nutrients are attributed mainly to irrigation return flows, and these are likely to be the main cause of algal blooms, some of which are toxic. Improved irrigation management, particularly with respect to the nutrient content of irrigation return flows on the larger estates, is recommended to improve the EC.

Table 7.6 EFR O3 REC

	PES	REC	Comments	Conf
Physico-chemical	C	C	This cannot be achieved with the changes recommended (e.g. improved wet season base flows), as the reasons for the water quality state is non flow-related. Even an improvement in the toxics by a category (through improved localised agricultural activities) does not move the category from a C.	n/a
Geom	C	C	To improve the PES, it is necessary to reinstate the large floods and reintroduce sediment that is trapped in upstream dams. This is not possible.	3

	PES	REC	Comments	Conf
Riparian vegetation	B/C	B	Removal of all existing perennial exotic species at the site and allocation to woody riparian and terrestrial species improves the EC from 78% to 78.8% (improve the lower zone from B to A/B). A combination of improved wet season base flows, improved small and moderate flooding, reduced fires in reed beds, and reduced grazing pressure improver the PES to 82.4% (B). Main changes are reduced woody (flow related) and reed cover (flow related and reduced fires) in the marginal and lower zones with allocation to open areas. Reduction of grazing pressure is likely to reduce open alluvial areas in the upper zone and Macro Channel Bank with additional grass cover. (see VEGRAI for specific notes and changes).	2.5
Fish	**C**	**B**	Improved hydrology (especially higher wet season base flows and lower droughts), improved habitat availability (both fast and slow habitats), and condition (flushing of sediments). This will lead to an improvement of the FROC of most species (esp. ASCL, BAEN, BKIM, and BHOS). Recommended improved agricultural practices may result in an improvement in water quality (decreased nutrients, and toxic spills - herbicides/pesticides), and should benefit some fish species (especially during early life stages).	**3**
Macroinvertebrates	C	B	Lower baseflows during the dry season and a wider seasonal range of baseflows is expected to increase habitat variability and thereby increase biodiversity, and also reduce the incidence of outbreaks of the pest blackfly *Simulium chutteri*. Taxa expected to appear under a more natural flow regime and improved management of irrigation return flows include Cordulidae, Ancylidae, Porifera and Coenagrionidae. The abundance of Muscidae is expected to decline. The total number of SASS5 taxa is expected to increase to 23. The overall SASS Score is expected to be 157, and the ASPT 6.8.	3
Riverine fauna	C	B	A combination of: ▪ improved wet season base flows, ▪ improved small and moderate flooding, ▪ reduced fires in reed beds, ▪ reduced grazing pressure will change riverine fauna habitats as follow: ▪ reduced woody and reed cover in the marginal and lower zones ▪ and more open areas with grass cover. The more open areas in the marginal and lower zone will result in the return of faunal species that prefer grassy grazing lawns (ducks, geese), mudflats (waders), alluvial sandbars (plovers) and shallow edge habitats for waders.	2.5

7.5 ALTERNATIVE ECOLOGICAL CATEGORY (AEC↓):

The hypothetical scenario includes:

- Increased agriculture with associated impacts on water quality and decreased wet season and other base flows.
- Decreased floods
- Increased vegetation aliens (especially *Prosopis* sp)

Each component is adjusted to indicate the metrics that will react to the scenarios. The rule based models are available electronically and summarised in Table 7.7.

Decrease in flow alone with the limited non-flow related recommendations will not decrease the riparian vegetation EC sufficient to drop the EcoStatus to a D. The instream is however a D and the flows will be set for a D EC as representative of an AEC down.

Table 7.7 EFR O3: AEC ↓

	PES	AEC↓	Comments	Conf
Physico-chemical	C	D	Decreased flows (wet season base flows + floods), and expanded agricultural activities (e.g. farming at Riemvasmaak) will cause a deterioration in salts, nutrients and toxics levels. THIS ASSUMES THAT FERTILIZER AND PESTICIDE USE IS INCREASED.	3
Geomorphology	C	C -	Further reduced floods and reduced low flows will cause a decline in the PES of the geomorphology, but within the class. This is because bedrock controlled reaches are resilient to changes in both flow and also relatively resilient to changes in sediment. The expected change would thus be from a high C to a lower C EC.	2
Riparian vegetation	B/C	C	*Prosopisgalndulosa* and other perennial exotic species increase by 15%, (a likely scenario if exotic invasion is left unchecked). Reducing wet season base flows and flooding disturbance will facilitate increased reed cover and density as well as more *C. dactylon* where fine sediments deposit along cobble bars. This is due to less disturbance which maintains open patches and patch dynamics, and a small amount of additional available habitat for rheophytes to colonise on the water's edge. If nutrient are increased, this trend will be further exacerbated, especially for reeds. Overall the EC reduces to 72.8% (C).	2.5
Fish	C	D	Decreased flows (loss of fast habitats) together with increased benthic algal growth on substrates (increased photic depth related to lower flows) will result in deterioration of riffle/rapid/run over rocky substrate habitats with a resultant negative impact on fish species with a requirement for this habitat type (esp. ASCL, BAEN, BKIM and LCAP). Further deterioration in flood regime will also negatively impact fish in terms of flushing of substrate to create good quality substrate for spawning, resulting in further deterioration of fish assemblage (especially BAEN and BKIM). Decreased water quality will furthermore impact some fish species (especially early life stages) negatively. Decreased flows may furthermore create more favourable conditions (slow habitats) for alien fish species (esp. CCAR & GAFF) which will result in increased impact on indigenous fish species. (marginal vegetation expected to not be impacted significantly; therefore species with a requirement for this cover feature should not be impacted significantly). Other impacts are decreased habitat quality due to a loss of fast habitats and deterioration of substrate quality due to algal growth and sedimentation (related to nutrient enrichment and reduced flushing).	3
Macroinvertebrates	C	D	Lower baseflows during the dry and wet seasons and increased agricultural development are likely to reduce the incidence of outbreaks of the pest blackfly *Simulium chutteri*, but increase problems associated with *Simulium ?impukane*. A reduced seasonal range of baseflows will also reduce water quality and habitat variability and thereby reduce biodiversity. Taxa expected to disappear include those that are sensitive to water quality deterioration, such as Perlidae, Heptageniidae, Leptoceridae, Atyidae and Ancylidae. The total number of SASS5 taxa is expected to drop to 15. The overall SASS Score is expected to be 78, and the ASPT 5.2.	3
Riverine fauna	C	C	The loss of open areas in the marginal and lower zone will result in the loss of faunal species that prefer grassy grazing lawns (ducks, geese), mudflats (waders), alluvial sandbars (plovers) and shallow edge habitats for waders. The lack of shrubbery in the upper zone where there is an increase in grazing lawns will lead to lost shelter for smaller fauna.	2.5

7.6 SUMMARY OF ECOCLASSIFICATION RESULTS

Table 7.8 EFR O3: Summary of EcoClassification results

Driver Components	PES	TREND	REC	AEC↓
IHI HYDROLOGY	E			
WATER QUALITY	C		C	D
GEOMORPHOLOGY	C	0	C	C-
INSTREAM IHI	D			
RIPARIAN IHI	C/D			
Response Components	**PES**	**TREND**	**REC**	**AEC↓**
FISH	C	0	B	D
MACRO INVERTEBRATES	C	0	B	D
INSTREAM	C	0	B	D
RIPARIAN VEGETATION	B/C	-	B	C
RIVERINE FAUNA	C	0	B	C
ECOSTATUS	C	0	B	C*
EIS	HIGH			

* The focus for setting EFRs will be on the instream EC of a D

8 EFR O3 (AUGRABIES) – DETERMINATION OF STRESS INDICES

Stress indices are set for fish and macroinvertebrates to aid in the determination of low flow requirements. The stress index describes the consequences of flow reduction on flow dependant biota. It therefore describes the habitat conditions for fish and macroinvertebrates indicator species for various low flows. These habitat conditions for different flows and the associated habitat conditions are rated from 10 (zero flows) to 0, which is optimum habitat for the indicator species.

8.1 INDICATOR SPECIES OR GROUP

8.1.1 Fish indicator group: Large semi - rheophilic species (BAEN)

See 5.1.1 and Table 5.1.

8.1.2 Macroinvertebrate indicator group: *Amphipsyche scottae*

See 5.1.2.

8.2 STRESS FLOW INDEX

A stress flow index is generated for every component, and describes the progressive consequences to the flow dependent biota of flow reduction. The stress flow index is generated in terms of habitat response and biotic response and is discussed below.

8.2.1 Habitat response

The habitat flow index is described separately for fish and macroinvertebrates as an instantaneous response of habitat to flow in terms of a 0 – 10 index relevant for the specific site where:

- 0 - Optimum habitat (fixed at the natural maximum base flow which is based on the 10% annual value using separated natural baseflows).
- 10 - Zero discharge (Note: Surface water may still be present).
-

The instantaneous response of fish and invertebrate breeding habitat, abundance, cover, connectivity, and water quality are derived by considering (amongst others) rated velocity depth classes (in terms of abundance) to flow changes based on a 0 (VD class absent) - 5 (VD class very abundant).

Fish and invertebrate habitat is then rated separately according to a 0 (no habitat) – 5 (optimum occurrence of habitat).

8.2.2 Biota response

The biota stress index is the instantaneous response of biota to change in habitat (and therefore flow), based on a scale of 0 – 10 where:

- 0 = Optimum habitat with least amount of stress possible for the indicator groups at the site (fixed at the natural maximum baseflow in the same way as for the habitat response).
- 10 = Zero discharge. The biota response will depend on the indicator groups present, i.e. rheophilics will have left whereas semi-rheophilics will still be present and survive.

The instantaneous response of fish and invertebrate breeding habitat, abundance, cover, connectivity, and water quality are derived by considering (amongst others) rated velocity depth classes (in terms of abundance) to flow changes based on a 0 (VD class absent) - 5 (VD class very abundant).Fish and invertebrate habitat is then rated separately according to a 0 (no habitat) – 5 (optimum occurrence of habitat).

8.2.3 Integrated stress curve

The integrated stress curve represents the highest stress for either fish or macroinvertebrates at a specific flow.

The species stress discharges in Table 8.1 indicate the discharge evaluated by specialists to determine the biota stress. The highest discharge representing a specific stress is used to define the integrated stress curve. Figure 8.1 illustrates this graphically.

In this specific case, the FDI stress index represents the integrated stress index (these values are the highest flow for a stress) for stress 0 – 10, therefore the red curve (representing the FDI stress index) is lying ‘beneath’ the integrated stress line (black) (Figure 8.1).

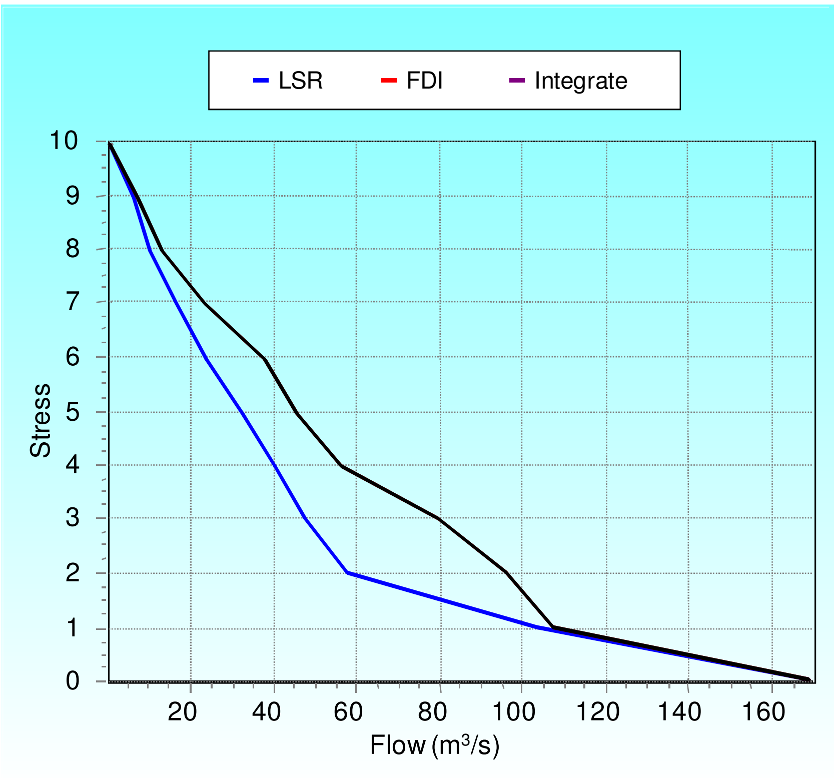


Figure 8.1 EFR O3: Species stress discharges used to determine biotic stress

Table 8.1 EFR O3: Species stress discharges used to determine biotic stress

Stress	Flow (m^3/s)		Integrated Flow (m^3/s)
	LSR	FDI	
0	170	170	170
1	104	108	108
2	56	97	97
3	44.7	80	80
4	36.4	56	56
5	26.7	46	46
6	17	38	38
7	12.3	23	23
8	8.4	13	13
9	4.8	7	7
10	0.001	0.001	0.001

Table 8.2 provides the summarised biotic response for the integrated stresses.

Table 8.2 EFR O3: Integrated stress and summarised habitat/biotic responses

Integrated stress	Flow (m^3/s)	Driver (fish/inverts/both)	Habitat and/or Biotic responses
0	170	Both	Habitat suitability for semi-rheophilic fish guild optimal for all criteria (spawning habitat, nursery habitat, abundance, cover, connectivity and water quality) evaluated. The turbidity is suitable for the threatened blackly *Simulium gariepense*.
1	108	Invertebrate	Instream biotopes plentiful and suitable for flow-sensitive species, with critical habitats (FCS and VFCS) comprising about 48% of the cross-section. The river bed becomes light-limited, with Secchi depth typically 8 to 17 cm. The high turbidity and high current speeds (average current speed 0.6 m/s) favours the mayflies *Tricorythus discolor* and *Baetis glaucus,* and the caddisflies *Amphipsyche scottae* and *Aethaloptera maxima.*
2	97	Invertebrate	Critical habitats sufficient for flow-sensitive taxa, except for those that prefer high turbidity.
3	80	Invertebrate	High concentration of planktonic algae provides food for filter-feeding invertebrates such as *Simulium chutteri* and *Tricorythus discolor.* Average current speeds 0.5 m/s, which is lower than the preferred current speeds of species such as *Simulium chutteri* and *Aethaloptera maxima.*
4	56	Invertebrate	The lower marginal vegetation, mainly *Phragmites austraulis* and some sedge, starts to provide suitable habitat for invertebrates, such as the freshwater shrimp *Caridina nilotica* and Leptoceridae. Critical habitats (FCS and VFCS) comprising about 34% of the cross-section.
5	46	Invertebrate	Moderate water clarity, with Secchi depth typically about 25 cm. Critical habitats very reduced. Conditions suitable for scrapers, such as *Burnupia.* Critical habitats (FCS and VFCS) comprising about 28% of the cross-section.
6	38	Invertebrate	Critical habitat residual (22%) and flow-sensitive species reduced. High water clarity, providing suitable conditions for taxa such as the midge *Cardiocladius africanus, Euthraulus elegans* and the blackfly *Simulium damnosum.*

Integrated stress	Flow (m^3/s)	Driver (fish/inverts/both)	Habitat and/or Biotic responses
7	23	Invertebrate	Very little critical habitat (6%). Most flow-sensitive taxa disappear. Low turbidity, slow current speeds and limited dilution leads to excessive growth of benthic algae, which limits suitability of instream habitats. With warmer temperatures, this leads to oxygen depletion at night, so invertebrates sensitive to water quality deterioration, such as stoneflies (Perlidae), disappear.
8	13	Invertebrate	No critical habitat. Water very shallow - average of 5 cm above thalweg. Water quality deteriorates.
9	7	Invertebrate	No critical habitat. Water very shallow - average of 2 cm above thalweg. Excessive growth of benthic algae, reducing quality of instream habitats.
10	0.001	Invertebrate	No flow. Macroinvertebrates diapause phase triggered. Habitat not suitable for any of the criteria assessed (spawning habitat, nursery habitat, abundance, cover, connectivity and water quality) for the large-semi-rheophilic fish guild.

9 EFR O3 (AUGRABIES) - DETERMINATION OF EFR SCENARIOS

9.1 ECOCLASSIFICATION SUMMARY OF EFR O3

EFRO3

EIS: HIGH
Highest scoring metrics are instream & riparian rare /endangered biota, unique instream and riparian biota, taxon richness of riparian biota, diversity of riparian habitat types, critical riparian habitat, refugia, migration corridor, National Park.

PES: C
Decreased frequency of large floods. Agricultural return flows, agricultural activities and associated water quality impacts. Higher low flows than natural in the dry season, drought and dry periods. Decreased low flows at other times. Presence of alien fish species and barrier effects of dams and alien vegetation. Decreased sedimentation.

REC: B
Reinstate droughts (i.e., lower flows than present during the drought season).Improved (higher) wet season base flows. Clear vegetation. Improved agricultural practices.

AEC: D
Increased agriculture with associated impacts on water quality and decreased wet season base flows. Decreased floods. Increased vegetation aliens

Driver Components	PES	TREND	REC	AEC↓
IHI HYDROLOGY	E			
WATER QUALITY	C		C	D
GEOMORPHOLOGY	C	0	C	C-
INSTREAM IHI	D			
RIPARIAN IHI	C/D			
Response Components	**PES**	**TREND**	**REC**	**AEC↓**
FISH	C	0	B	D
MACRO INVERTEBRATES	C	0	B	D
INSTREAM	C	0	B	D
RIPARIAN VEGETATION	B/C	-	B	C
RIVERINE FAUNA	C	0	B	C
ECOSTATUS	C	0	B	C*
EIS	HIGH			

* The focus for setting EFRs will be on the instream EC of a D

9.2 HYDROLOGICAL CONSIDERATIONS

The wettest and driest months were identified as March and September. Droughts are set at 95% exceedance (flow) and 5% exceedance (stress). Maintenance flows are set at 40% exceedance (flow) and at 60% exceedance (stress).

9.3 LOW FLOW REQUIREMENTS (IN TERMS OF STRESS)

The integrated stress index is used to identify required stress levels at specific durations for the wet and dry month/season.

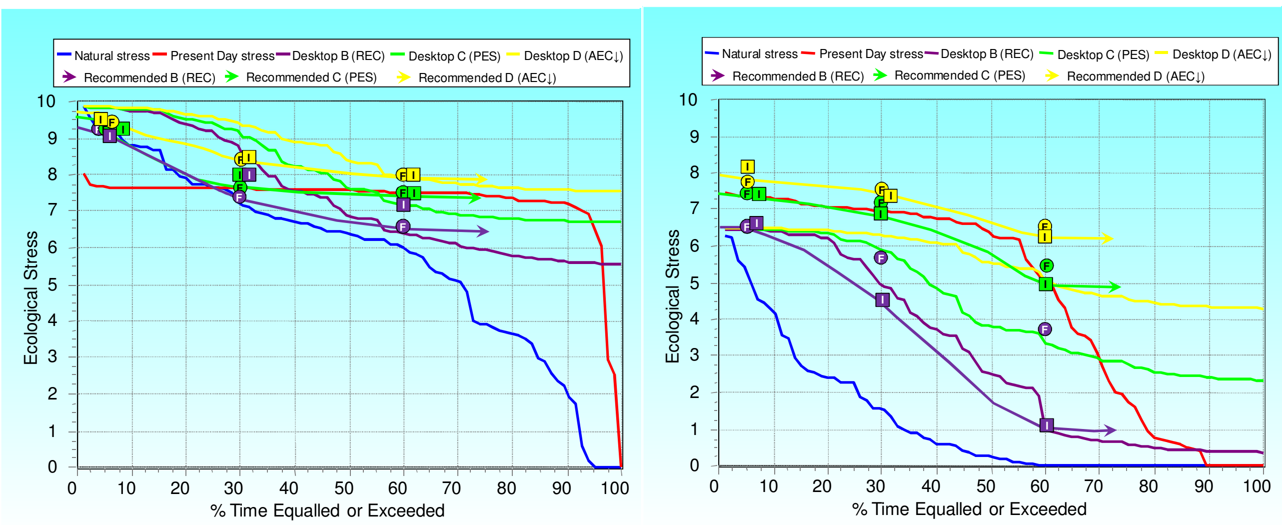
9.3.1 Low flow (in terms of stress) requirements

The fish and macroinvertebrate flow requirements for different Ecological Categories (ECs) are provided in Table 9.1 and graphically illustrated in Figure 9.1. The results are plotted for the wet and dry season on stress duration graphs and compared to the Desktop Reserve Model (DRM) low flow estimates for the same range of ECs. The stress requirements (as a 'hand drawn line') are illustrated in Figure9.1.

For easier reference the range of ECs are colour coded in the Tables and figures:
PES: Green REC: Purple AEC↓: Yellow
Summarised motivations for the final requirements are provided in Table 9.2.

Table 9.1 EFR O3: Species and integrates stress requirements as well as the final integrated stress and flow requirement

Duration	LSR stress	Integrated stress	FDI stress	Integrated stress	FINAL* (Integrated stress)	FLOW (m^3/s)
PES D ECOSTATUS		**FISH: C**		**MACROINVERTEBRATES: C**		
DRY SEASON						
5%	9	**9.2**	9.3	**9.3**	9.2	5.7
30%	7	**7.7**	8	**8**	7.7	15.6
60%	6.8	**7.5**	7.5	**7.5**	7.5	17.5
WET SEASON						
5%	6.6	**7.4**	7.3	**7.3**	7.3	19.5
30%	6.2	**7.1**	7	**7**	7	23
60%	3.8	**5.6**	5	**5**	5	46
REC B ECOSTATUS			**FISH: B**		**MACROINVERTEBRATES: B**	
DRY SEASON						
5%	9	9.2	9.3	9.3	9.2	5.7
30%	6.6	7.4	8	8	7.4	18.5
60%	5.4	6.6	7.1	7.1	6.6	29
WET SEASON						
5%	5.3	6.6	6.7	6.7	6.6	29
30%	4	5.8	4.4	4.4	4.4	50.9
60%	2	3.8	1	1	1	108
AEC↓ C ECOSTATUS		**FISH: D**		**MACROINVERTEBRATES: D**		
DRY SEASON						
5%	9.3	**9.5**	9.6	9.6	9.5	3.6
30%	8	**8.5**	8.6	8.6	8.5	9.8
60%	7.5	**8**	8	8	8	13
WET SEASON						
5%	7	**7.7**	8.1	8.1	7.7	15.6
30%	6.8	**7.5**	7.4	7.4	7.4	18.5
60%	5.3	**6.6**	6.3	6.3	6.3	33.9



SEPT – DRY SEASON **MARCH- WET SEASON**

Figure 9.1 EFR O3: Stress duration curve for a PES, REC and AEC

Table 9.2 EFR O3: Summary of motivations

Month	% Stress duration	Component stress	Integrated stress	Flow m^3/s	Comment
PES D ECOSTATUS		**FISH: C**			**MACROINVERTEBRATES: C**
Sep	5% drought	9 LSR	9.3	5.7	Habitat suitability will be very low in terms of providing cover/abundance, connectivity and water of acceptable quality, but adequate to allow survival of this fish guild and maintenance of PES during droughts in dry season as it compares to natural conditions during dry season droughts.
	60% maintenance	6.8 LSR	7.5	17.5	Habitat suitability will be very low in terms of providing cover/abundance and water of acceptable quality, and moderate in terms of connectivity. Habitat suitability should however be adequate to maintain this fish guild in the PES during dry season.
		7.5 FDI	7.5	17.5	This flow is the same as modelled present-day flows, and any further reducing on flow is likely to an overall reduction in the ecological category.
Mar	5% drought	7.3 FDI	7.3	19.5	This stress was selected on the basis of the shape of the natural flow duration curve
	60% maintenance	5 FDI	5	5	This stress was selected on the basis of the shape of the natural flow duration curve
REC B ECOSTATUS		**FISH: B**			**MACROINVERTEBRATES: B**
Sep	5% drought	9 LSR	9.2	5.7	Habitat suitability will be very low in terms of providing cover/abundance, connectivity and water of acceptable quality, but adequate to allow survival of this fish guild and maintenance of PES during droughts in dry season as it compares to natural conditions during dry season droughts.
	60% maintenance	5.4 LSR	6.6	29	Habitat suitability will be low in terms of providing cover/abundance and water of acceptable quality, and moderate in terms of connectivity. Habitat suitability should however be an improvement from present conditions and should result in an improvement in fish assemblage.
Mar	5% drought	5.3 LSR	6.6	29	Habitat suitability will still be very low in terms of providing spawning habitats, but allow spawning to take place during droughts in the wet season. Habitat suitability will be low in terms of providing cover/abundance and water of acceptable quality, and moderate in terms of connectivity. These conditions are however an improvement from the present day conditions and should result in an overall improvement in the fish assemblage.
	60% maintenance	1 FDI	1	108	This stress was selected on the basis of providing sufficient current speeds (average >0.6 m/s) for the target species, *Amphipsyche scottae*. In addition, this flow will elevate turbidity and provide suitable feeding conditions for filter feeding taxa that need high flow conditions.
AEC↓ C ECOSTATUS		**FISH: D**			**MACROINVERTEBRATES: D**
Sep	5% drought	9.3 LSR	9.5	3.6	Habitat suitability will be very low in terms of providing cover/abundance, connectivity and water of acceptable quality. An overall deterioration can be expected to occur during dry season droughts.
	60% maintenance	7.5 LSR	8	13	Habitat suitability will be very low in terms of providing cover/abundance and water of acceptable quality, and low in terms of connectivity. Deterioration can be

Month	% Stress duration	Component stress	Integrated stress	Flow m^3/s	Comment
					expected to occur.
		8 FDI	8	13	This stress was selected on the basis of the shape of the present-day flow duration curve, adjusted down sufficiently to drop the EC.
Mar	5% drought	7 LSR	7.7	15.6	No spawning is expected to occur under these stress levels resulting. Habitat suitability will also be very low in terms of providing nursery areas, cover/abundance and water of acceptable quality, and low in terms of connectivity. Deterioration in the LSR guild can be expected
	60% maintenance	6.3 FDI	6.3	33.9	This stress was selected on the basis of the shape of the present-day flow duration curve.

9.3.2 EFR O3 Riparian vegetation verification of low flow requirements

The low flow requirements as set by the instream biota is checked (and modified if necessary) to ensure that it caters for any riparian vegetation (specifically marginal) and riverine fauna. This verification is summarised in Table 9.3.

Table 9.3 EFR O3: Verification of low flow requirements for instream biota to maintain riparian vegetation in the required EC.

PES						
Species	Season	Duration	Q	Average Inundation / Height above water level (m)		Note
				lower limit	upper limit	
G. virgatum	Dry	5%	5.7	0.44		Water stress is high and some mortality expected, especially along the upper limit of populations, but this is usual for drought conditions, even in the dry season. Reeds occur at unusually low elevation at this site and some inundation occurs throughout, even dry season drought.
C. marginatus				0.31		
P. australis				-0.29	3.01	
S. mucronata				0.88	1.79	
G. virgatum		60%	17.5	0.36		Water stress quite high and some mortality expected, especially along the upper limit of populations, although plants reduce metabolic requirements during the dry season to improve survival probabilities. PES of vegetation is likely to remain unaltered.
C. marginatus				0.23		
P. australis				-0.37	2.93	
S. mucronata				0.80	1.71	
G. virgatum	Wet	5%	19.5	0.35		Comparable to dry season base flows, but during the wet season these flows are likely to cause reproductive failure / abortion. Flows are however sufficient to ensure survival of existing vegetation and the EC for vegetation is not likely to change from the PES.
C. marginatus				0.22		
P. australis				-0.39	2.91	
S. mucronata				0.79	1.70	
G. virgatum		60%	46	0.20		Wet season base flows are important to ensure survival, support reproduction and also prevent vegetation encroachment from the marginal zone towards the instream environment. On average most populations are not inundated, except for *P. australis* which is inundated to 0.53m at its lower limit. This will prevent the expansion of reed beds towards the instream. The *C. marginatus* population is only just activated, with enough moisture to perform summer biological requirement, but some encroachment towards the instream is likely. Base flows are sufficient to facilitate survival and, together with small floods, reproduction.
C. marginatus				0.07		
P. australis				-0.53	2.77	
S. mucronata				0.64	1.55	
Conclusion: Low flow requirements for instream fauna will suffice to maintain the PES for riparian vegetation (in a B/C class), although the percentage score drops slightly, mostly due to the wet season base flows. This assumes that class I						

and II floods occur. Riparian zone structure and functionality will remain unchanged from current as a result of flow.

Table 9.4 EFR O3: Verification of low flow requirements for instream biota to maintain riverine fauna in the required EC

Season	Duration	Q	Note
Dry	5%	5.7	Some mortality expected in the riparian vegetation, especially along the upper limit of populations. This is natural and the riverine fauna will be adapted to some loss in vegetation. Piscivorous animals will be fine since the fish population will not change much, and lowered water levels will improve the chances of obtaining fish as food.
Dry	60%	18	Water stress quite high, but normal for dry season and the vegetation survival will be sufficient to maintain the habitat for riverine fauna, while the fish and macro-invertebrate abundance will be in satisfactory state for piscivores and invertivores.
Wet	5%	20	Survival of existing vegetation is moderate and not likely to change the PES, and the riverine fauna will react accordingly.
Wet	60%	46	These base flows needed to facilitate habitat diversity, riparian structural diversity and patch mosaic in the riparian zone.
Conclusion: Only during the dry season at 5% will the vegetation show a level of stress, however, the riverine fauna will not respond drastically if the changes in marginal vegetation are small.			

9.3.3 Final low flow requirements

To produce the final results, the DRM results for the specific category are modified according to specialists' requirements (Figure 9.2) There are a range of options one can use to make these modifications, such as changing the total volume required for the year, specific monthly volumes, either drought or maintenance flow durations, seasonal distribution and changing the category rules and shape factors. The following changes were required:

- PES: C EC.
  - Maintenance seasonal distribution set to 0.4.
  - Drought seasonal distribution set to 0.6.
  - Wet season rules:
    - Shape factor set to 10.
    - Lower shift factor set to 95; Upper shift set to 0.
    - Low flow max (%): 130.
  - Dry season rules:
    - Shape factor set to 4.
    - Lower shift factor set to 100; Upper shift set to 0.
    - Low flow max (%): 100.
- REC: B EC.
  - Drought seasonal distribution did not change.
  - Maintenance seasonal distribution set to 1.7.
  - Wet season rules:
    - Shape factor set to 8.
    - Lower shift factor set to 95; Upper shift set to 0.
    - Low flow max (%): 130.
  - Dry season rules:
    - Shape factor set to 5.
    - Lower shift factor set to 100; Upper shift set to 15.
    - Low flow max (%): 160.

- AEC down: D EC.
  - Drought and Maintenance seasonal distributions set to 0.6.
  - Wet season rules:

    - Shape factor set to 8.
    - Lower shift factor set to 95; Upper shift set to 0.
    - Low flow max (%): 130.
- Dry season rules:
    - Shape factor set to 5.
    - Lower shift factor set to 100; Upper shift set to 15.
    - Low flow max (%): 105.
    - Small manual adjustment to dry season maintenance flows.

Dry Season (September) **Wet Season (March)**

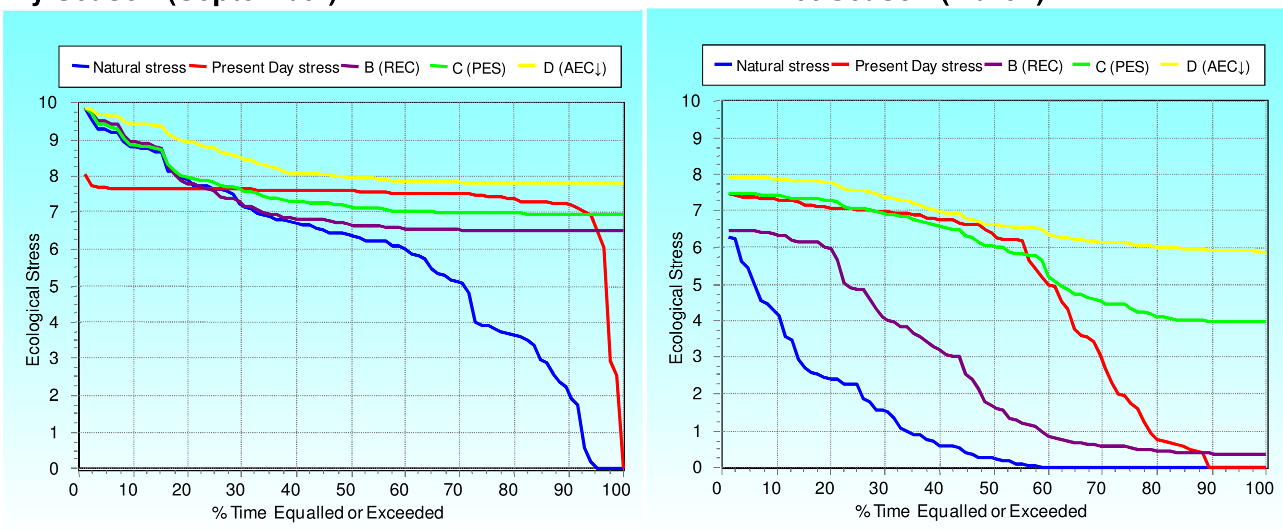


Figure 9.2 EFR O3: Final stress requirements for low flows

9.4 HIGH FLOW REQUIREMENTS

Detailed motivations are provided in Table 9.5 and final high flow results are provided in Table 9.6.

Table 9.5 EFR O3: Identification of instream functions addressed by the identified floods for geomorphology and riparian vegetation

FLOOD RANGE (m3/s) FLOOD CLASS (instantaneous peak)	Geomorphology & riparian vegetation motivation	Fish flood functions						Invertebrate flood functions				Riverine fauna		
		Migration cues & spawning	Migration habitat (depth etc)	Clean spawning substrate	Create nursery areas	Resetting water quality	Inundate vegetation for spawning	Breeding and hatching cues	Clear fines	Scour substrate	Reach or inundate specific areas	Scour lower zone habitats	Create floodplain habitats	Invigorate riparian vegetation habitats
150-200	**Riparian Veg:** Required to inundate 50% on average, of marginal and lower zone obligates (*Gomphostigma virgatum, Cyperus marginatus*, and *Phragmites australis*) and activates (just reaches the lower limit of) the *Salix mucronata* population. Prevents the establishment of terrestrial and exotic (especially *Prosopis glandulosa* and *Nicotiana glaucea*) species in the marginal and lower zones. Removal of fine sediments is important to maintain rheophyte habitat. Required during growing season (spring to summer: Nov - Jan). **Geomorphic:** Regular wet season flushes to remove fines and activate small gravel material. This flow class transport about 10% of the fines at the site and will thus scour accumulated fines from the active channel bed.	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		
300-450	**Riparian:** Required to flood marginal (completely inundates G. virgatum and maintain cobble bars free of sedimentation) and lower zone riparian species (about 50% of S. mucronata and P. australis flooded at 300 m^3/s, and S. mucronata completely flooded at 400 m^3/s). This will facilitate recruitment opportunities at higher levels, but create flooding disturbance at the lower limits which also maintains open habitats and vegetative patchiness. At the upper end of this flood, P. australis is likely to be removed in small isolated patches at its lower limits, an important change towards better conditions. Required during summer (Nov - Jan).**Geomorphic:** Scouring flood to remove fines and activate gravels. This flow class transports more than 15% of the fines at the site and is an important flood for scouring and fines removal. Some scour of low bars and the bed will occur with these flows.	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓
650-780	**Riparian Veg:** Inundation of the Tamarix usneoides population (about 50% of population on average). Important for removing Acacia and Prosopis species, especially on lower zone (as was observed in the field) and also to scour marginal and lower zone habitats and maintain open patches. Needed in the growing season (Jan to Mar).	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓			✓

FLOOD RANGE (m3/s) FLOOD CLASS (instantaneous peak)	Geomorphology & riparian vegetation motivation	Fish flood functions						Invertebrate flood functions				Riverine fauna		
		Migration cues & spawning	Migration habitat (depth etc)	Clean spawning substrate	Create nursery areas	Resetting water quality	Inundate vegetation for spawning	Breeding and hatching cues	Clear fines	Scour substrate	Reach or inundate specific areas	Scour lower zone habitats	Create floodplain habitats	Invigorate riparian vegetation habitats
1200 +	**Riparian Veg:** Required to begin inundation of *Searsia pendulina* (which, in general is also where the tree line starts). These floods will facilitate recruitment and vigour of upper zone woody species, but also prevent their encroachment into the lower zone. Similarly, these floods are also useful for preventing terrestrialisation and expansion of exotic species such as *P. galndulosa* and causing flow in ephemeral back channels where sediments need to be moved and vegetation cleared. **Geomorphic:** This flow class transports more than 20% of the fines and is the effective discharge for fines at this site. Gravels and some larger elements will be mobilised and thus inhibit embeddedness, and mobilise the large lateral bar at the site.	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓			✓

The number of high flow events required for each EC is provided in Table 9.6. The high flows were checked using the observed data from the Neusberg gauging weir. It must be noted however that this weir is situated far upstream of the EFR site.

Table 9.6. EFR O3: The recommended number of high flow events required

FLOOD RANGE (m^3/s)	INVERTEBRATES	FISH	VEGETATION	GEOMORPHOLOGY	FINAL* (No of events)	MONTHS	DAILY AVERAGE (m^3/s)	DURATION
PES: C								
150-200	3	3	3	3	3	Nov, Dec, Jan	150	6
300-450	1	1	1	1	1	Feb	350	8
650-780	1:3		1:3		1:3**	Mar	680	12
1200 +			1:5	1:5	1:5		N/S	N/S
REC: B								
150-200	3	3	3	3	3	Nov, Dec, Jan	150	6
300-450	1	1	1	1	1	Feb	350	8
650-780	1:3		1:3		1:3	Mar	680	12
1200 +			1:5	1:5	1:5		N/S	N/S
AEC↓: D								
150-200	1	2	2	2	2	Nov, Jan	150	6
300-450	1	1	1:2	1	1	Feb	350	8
650-780			1:3		1:3	Mar	680	12
1200 +			1:5	1:5	1:5		N/S	N/S

9.5 FINAL FLOW REQUIREMENTS

The low and high flows were combined to produce the final flow requirements for each EC as:

- An EFR table, which shows the results for each month for high flows and low flows separately (Table 9.7 – 9.9). Floods with a high frequency are not included in the modelled results as they cannot be managed.
- An EFR rule table which provides the recommended EFR flows as a duration table, linked to a natural trigger (natural modelled hydrology in this case). EFR rules are supplied for total flows as well as for low flows only (Table 9.10 – 9.12).

The low flow EFR rule table is useful for operating the system, whereas the EFR table must be used for operation of high flows.

Table 9.7 EFR O3: EFR table for PES: C

Desktop version:		2	Virgin MAR (MCM)	10513.1
BFI	0.321	Distribution type		Vaal
MONTH	LOW FLOWS		HIGH FLOWS	
	Maintenance (m^3/s)	Drought (m^3/s)	Daily average (m^3/s) on top of base flow	Duration (days)
OCTOBER	21.303	0		
NOVEMBER	26.529	4.996	150	6
DECEMBER	28.289	11.503	150	6

Desktop version:		2	Virgin MAR (MCM)	10513.1
BFI	0.321	Distribution type		Vaal
MONTH	LOW FLOWS		HIGH FLOWS	
	Maintenance (m^3/s)	Drought (m^3/s)	Daily average (m^3/s) on top of base flow	Duration (days)
JANUARY	32.818	12.649	150	6
FEBRUARY	41.932	18.259	350	8
MARCH	40.759	17.993	680	12
APRIL	36.835	8.171		
MAY	28.578	8.255		
JUNE	23.44	8.872		
JULY	19.734	7.051		
AUGUST	18.906	6.62		
SEPTEMBER	19.174	0.98		
TOTAL MCM	886.1	275.4	493.3	
% OF VIRGIN	8.43	2.62	4.69	
Total IFR	1379.4			
% of MAR	13.12			

Table 9.8 EFR O3: EFR table for REC: B

Desktop version:		2	Virgin MAR (MCM)	10513.1
BFI	0.321	Distribution type		Vaal
MONTH	LOW FLOWS		HIGH FLOWS	
	Maintenance (m^3/s)	Drought (m^3/s)	Daily average (m^3/s) on top of base flow	Duration (days)
OCTOBER	30.573	0		
NOVEMBER	50.997	4.996	150	6
DECEMBER	60.593	15.102	150	6
JANUARY	80.058	12.649	150	6
FEBRUARY	112.695	29.315	350	8
MARCH	114.188	30.552	680	12
APRIL	95.29	8.171		
MAY	61.835	8.255		
JUNE	37.721	9.622		
JULY	23.829	9.491		
AUGUST	20.268	9.14		
SEPTEMBER	19.389	0.98		
TOTAL MCM	1848	360.7	493.3	
% OF VIRGIN	17.6	3.4	4.7	
Total IFR	2341.3			
% of MAR	22.3			

Table 9.9 EFR O3: EFR table for AEC↓: D

Desktop version:		2	Virgin MAR (MCM)	10513.1
BFI	0.321	Distribution type		Vaal
MONTH	LOW FLOWS		HIGH FLOWS	
	Maintenance (m^3/s)	Drought (m^3/s)	Daily average (m^3/s) on top of base flow	Duration (days)

Desktop version:		2	Virgin MAR (MCM)	10513.1
BFI	0.321	Distribution type		Vaal
MONTH	LOW FLOWS		HIGH FLOWS	
	Maintenance (m^3/s)	Drought (m^3/s)	Daily average (m^3/s) on top of base flow	Duration (days)
OCTOBER	9.487	0		
NOVEMBER	12.636	4.996	150	6
DECEMBER	13.87	8.798		
JANUARY	16.712	10.601	150	6
FEBRUARY	22.016	13.966	350	8
MARCH	21.696	13.762	680	12
APRIL	19.104	8.171		
MAY	14.051	8.255		
JUNE	10.698	6.786		
JULY	8.502	5.393		
AUGUST	7.982	5.063		
SEPTEMBER	8.021	0.98		
TOTAL MCM	431.3	227	459	
% OF VIRGIN	4.1	2.3	4.4	
Total IFR	890.2			
% of MAR	8.5			

Table 9.10 EFR O3: Assurance rules for PES: C

Desktop Version 2, Printed on 2010/11/04
Summary of IFR rule curves for: EFR O3 Natural Flows
Determination based on defined BBM Table with site specific assurance rules.
Regional Type: Vaal PES = C

Data are given in m^3/s mean monthly flow

% Points

Month	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	31.557	31.178	30.480	29.242	27.155	23.841	18.990	12.651	5.723	0.000
Nov	65.933	60.925	56.132	50.999	42.292	36.002	27.841	18.899	11.195	6.982
Dec	68.900	62.971	57.368	51.403	42.074	35.325	27.632	20.516	15.497	13.222
Jan	76.372	69.112	62.097	54.413	43.272	34.906	26.535	19.904	15.927	14.331
Feb	159.208	134.641	113.429	93.237	66.395	51.557	38.472	29.439	24.667	22.895
Mar	184.526	177.511	162.886	139.020	108.533	78.046	54.180	39.555	32.540	30.055
Apr	51.049	49.491	46.254	40.754	33.170	24.759	17.341	12.220	9.515	8.510
May	39.997	39.086	37.217	33.943	29.104	23.159	17.211	12.499	9.673	8.539
Jun	33.355	32.813	31.727	29.787	26.745	22.627	17.932	13.590	10.527	9.138
Jul	28.504	28.148	27.459	26.223	24.194	21.196	17.307	13.045	9.374	7.366
Aug	28.089	27.831	27.356	26.514	25.094	22.840	19.539	15.227	10.513	7.115
Sep	23.717	23.529	23.203	22.645	21.700	20.127	17.579	13.631	7.996	1.988

Reserve flows without High Flows

Oct	31.557	31.178	30.480	29.242	27.155	23.841	18.990	12.651	5.723	0.000
Nov	38.256	37.703	36.635	34.718	31.573	26.926	20.896	14.289	8.597	5.484
Dec	40.268	39.631	38.355	36.076	32.502	27.663	22.148	17.046	13.447	11.816
Jan	45.989	45.032	43.069	39.630	34.547	28.303	22.056	17.107	14.138	12.948
Feb	58.295	56.840	53.818	48.682	41.601	33.747	26.821	22.040	19.514	18.576
Mar	56.174	54.453	50.864	45.008	37.528	30.047	24.192	20.603	18.882	18.272
Apr	51.049	49.491	46.254	40.754	33.170	24.759	17.341	12.220	9.515	8.510
May	39.997	39.086	37.217	33.943	29.104	23.159	17.211	12.499	9.673	8.539
Jun	33.355	32.813	31.727	29.787	26.745	22.627	17.932	13.590	10.527	9.138
Jul	28.504	28.148	27.459	26.223	24.194	21.196	17.307	13.045	9.374	7.366
Aug	28.089	27.831	27.356	26.514	25.094	22.840	19.539	15.227	10.513	7.115
Sep	23.717	23.529	23.203	22.645	21.700	20.127	17.579	13.631	7.996	1.988

Natural Duration curves

Oct	625.022	339.729	238.616	164.643	103.756	76.240	57.239	34.909	18.821	0.000
Nov	914.267	664.780	492.404	364.016	246.127	219.066	162.211	129.147	50.710	8.954
Dec	1012.929	715.192	532.706	406.933	331.291	290.737	204.794	105.802	74.175	24.985
Jan	1262.321	923.439	638.792	513.740	386.914	298.574	219.079	163.956	87.623	34.476
Feb	2068.130	1297.202	903.282	548.251	432.614	313.600	268.556	222.359	128.001	38.447
Mar	1579.234	1029.312	705.279	602.210	475.821	337.481	248.693	196.181	122.525	38.041
Apr	909.772	633.503	413.584	324.093	285.313	244.904	175.428	122.145	72.234	25.667
May	355.152	262.418	195.744	130.589	107.056	81.851	69.739	45.669	32.053	8.793
Jun	190.698	138.897	89.664	74.742	60.035	54.333	41.539	33.013	20.652	11.323
Jul	147.345	99.836	89.595	65.315	45.613	36.989	31.127	24.709	17.085	12.851
Aug	149.029	112.541	83.065	62.724	48.092	34.629	25.291	20.535	14.938	11.137
Sep	224.877	120.988	81.709	60.116	44.159	34.688	26.505	16.725	8.252	3.221

Table 9.11 EFR O3: Assurance rules for REC: B

Desktop Version 2, Printed on 2010/11/04
Summary of IFR rule curves for: EFRO3 Natural Flows
Determination based on defined BBM Table with site specific assurance rules.
Regional Type: Vaal REC = B

Data are given in m^3/s mean monthly flow

% Points

Month	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	45.572	45.145	44.182	42.204	38.529	32.471	23.869	13.822	4.967	0.000
Nov	98.751	93.748	88.716	82.693	71.750	61.056	45.959	28.578	13.718	6.808
Dec	112.793	106.347	99.404	90.547	76.024	61.632	44.979	29.944	20.193	16.890
Jan	131.804	124.946	117.059	106.342	88.710	70.025	48.667	29.796	18.015	14.571
Feb	239.908	216.227	192.258	164.745	125.280	94.919	66.705	46.745	36.637	34.307
Mar	269.643	262.286	246.887	219.882	180.747	134.750	92.006	61.765	46.452	38.041
Apr	121.675	118.015	110.355	96.921	77.453	54.571	33.308	18.264	10.647	8.890
May	79.624	78.350	75.503	69.947	60.639	47.550	32.588	19.369	11.116	8.703
Jun	52.356	51.609	49.950	46.724	41.316	33.667	24.818	16.828	11.646	9.891
Jul	33.211	32.985	32.471	31.410	29.431	26.171	21.571	16.274	11.745	9.639
Aug	30.269	30.071	29.624	28.707	27.003	24.195	20.207	15.549	11.443	9.272
Sep	30.834	30.741	30.397	29.686	28.290	25.729	21.438	15.107	7.476	1.735

Reserve flows without High Flows

Oct	45.572	45.145	44.182	42.204	38.529	32.471	23.869	13.822	4.967	0.000
Nov	70.979	70.350	68.922	65.968	60.464	51.397	38.599	23.865	11.267	5.409
Dec	84.098	82.892	80.214	75.005	66.273	53.924	39.637	26.736	18.370	15.536
Jan	103.110	101.496	97.887	90.845	79.047	62.456	43.491	26.736	16.275	13.217
Feb	144.274	140.567	132.809	119.202	99.485	76.310	54.774	39.537	31.822	30.044
Mar	146.201	142.472	134.667	120.979	101.143	77.829	56.164	40.836	33.074	31.285
Apr	121.675	118.015	110.355	96.921	77.453	54.571	33.308	18.264	10.647	8.890
May	79.624	78.350	75.503	69.947	60.639	47.550	32.588	19.369	11.116	8.703
Jun	52.356	51.609	49.950	46.724	41.316	33.667	24.818	16.828	11.646	9.891
Jul	33.211	32.985	32.471	31.410	29.431	26.171	21.571	16.274	11.745	9.639
Aug	30.269	30.071	29.624	28.707	27.003	24.195	20.207	15.549	11.443	9.272
Sep	30.834	30.741	30.397	29.686	28.290	25.729	21.438	15.107	7.476	1.735

Natural Duration curves

Oct	625.022	339.729	238.616	164.643	103.756	76.240	57.239	34.909	18.821	0.000
Nov	914.267	664.780	492.404	364.016	246.127	219.066	162.211	129.147	50.710	8.954
Dec	1012.929	715.192	532.706	406.933	331.291	290.737	204.794	105.802	74.175	24.985
Jan	1262.321	923.439	638.792	513.740	386.914	298.574	219.079	163.956	87.623	34.476
Feb	2068.130	1297.202	903.282	548.251	432.614	313.600	268.556	222.359	128.001	38.447
Mar	1579.234	1029.312	705.279	602.210	475.821	337.481	248.693	196.181	122.525	38.041
Apr	909.772	633.503	413.584	324.093	285.313	244.904	175.428	122.145	72.234	25.667
May	355.152	262.418	195.744	130.589	107.056	81.851	69.739	45.669	32.053	8.793
Jun	190.698	138.897	89.664	74.742	60.035	54.333	41.539	33.013	20.652	11.323
Jul	147.345	99.836	89.595	65.315	45.613	36.989	31.127	24.709	17.085	12.851
Aug	149.029	112.541	83.065	62.724	48.092	34.629	25.291	20.535	14.938	11.137
Sep	224.877	120.988	81.709	60.116	44.159	34.688	26.505	16.725	8.252	3.221

Table 9.12 EFR O3: Assurance rules for AEC↓: D

Desktop Version 2, Printed on 2010/11/04
Summary of IFR rule curves for: EFR O3 Natural Flows
Determination based on defined BBM Table with site specific assurance rules.
Regional Type: Vaal AEC DOWN = D

Data are given in m^3/s mean monthly flow

	% Points									
Month	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	16.121	15.970	15.629	14.930	13.629	11.487	8.444	4.890	1.757	0.000
Nov	49.902	45.366	41.392	37.554	30.687	26.704	21.082	14.610	9.076	6.502
Dec	23.012	22.764	22.212	21.139	19.340	16.796	13.852	11.195	9.471	8.887
Jan	58.074	52.495	47.468	42.331	34.048	28.510	22.179	16.586	13.094	12.073
Feb	134.775	113.989	96.079	79.193	55.128	42.867	31.473	23.412	19.330	18.389
Mar	188.804	183.511	172.436	153.011	124.862	91.777	61.031	39.280	28.265	25.726
Apr	33.888	33.059	31.323	28.280	23.869	18.684	13.866	10.458	8.732	8.334
May	24.695	24.401	23.746	22.466	20.322	17.307	13.860	10.815	8.914	8.358
Jun	17.749	17.558	17.132	16.305	14.917	12.955	10.684	8.635	7.305	6.855
Jul	14.904	14.813	14.607	14.181	13.388	12.081	10.236	8.113	6.297	5.453
Aug	13.595	13.515	13.335	12.965	12.277	11.143	9.532	7.651	5.993	5.116
Sep	14.752	14.709	14.550	14.222	13.578	12.397	10.418	7.497	3.977	1.328

Reserve flows without High Flows

Oct	16.121	15.970	15.629	14.930	13.629	11.487	8.444	4.890	1.757	0.000
Nov	22.131	21.968	21.597	20.830	19.400	17.046	13.722	9.896	6.625	5.103
Dec	23.012	22.764	22.212	21.139	19.340	16.796	13.852	11.195	9.471	8.887
Jan	29.380	29.045	28.296	26.834	24.385	20.940	17.004	13.525	11.354	10.719
Feb	39.140	38.329	36.630	33.650	29.332	24.257	19.541	16.205	14.515	14.126
Mar	38.572	37.772	36.097	33.161	28.906	23.904	19.256	15.968	14.303	13.919
Apr	33.888	33.059	31.323	28.280	23.869	18.684	13.866	10.458	8.732	8.334
May	24.695	24.401	23.746	22.466	20.322	17.307	13.860	10.815	8.914	8.358
Jun	17.749	17.558	17.132	16.305	14.917	12.955	10.684	8.635	7.305	6.855
Jul	14.904	14.813	14.607	14.181	13.388	12.081	10.236	8.113	6.297	5.453
Aug	13.595	13.515	13.335	12.965	12.277	11.143	9.532	7.651	5.993	5.116
Sep	14.752	14.709	14.550	14.222	13.578	12.397	10.418	7.497	3.977	1.328

Natural Duration curves

Oct	625.022	339.729	238.616	164.643	103.756	76.240	57.239	34.909	18.821	0.000
Nov	914.267	664.780	492.404	364.016	246.127	219.066	162.211	129.147	50.710	8.954
Dec	1012.929	715.192	532.706	406.933	331.291	290.737	204.794	105.802	74.175	24.985
Jan	1262.321	923.439	638.792	513.740	386.914	298.574	219.079	163.956	87.623	34.476
Feb	2068.130	1297.202	903.282	548.251	432.614	313.600	268.556	222.359	128.001	38.447
Mar	1579.234	1029.312	705.279	602.210	475.821	337.481	248.693	196.181	122.525	38.041
Apr	909.772	633.503	413.584	324.093	285.313	244.904	175.428	122.145	72.234	25.667
May	355.152	262.418	195.744	130.589	107.056	81.851	69.739	45.669	32.053	8.793
Jun	190.698	138.897	89.664	74.742	60.035	54.333	41.539	33.013	20.652	11.323
Jul	147.345	99.836	89.595	65.315	45.613	36.989	31.127	24.709	17.085	12.851
Aug	149.029	112.541	83.065	62.724	48.092	34.629	25.291	20.535	14.938	11.137
Sep	224.877	120.988	81.709	60.116	44.159	34.688	26.505	16.725	8.252	3.221

A comparison between the Desktop Reserve Model estimates and the EFR results in terms of percentages of natural flow are provided in Table 9.13.

Table 9.13 EFR O3: Modifications made to the DRM

Changes	PES: C		REC: B		AEC↓: D	
	DRM	EFR	DRM	EFR	DRM	EFR
MLIFR - Maintenance low flow	11.4%	8.4%	19.7%	17.6%	5.5%	4.1%
DLIFR - Drought low flow	3.4%	2.6%	3.4%	3.4%	3.4%	2.2%
MHIFR - Maintenance high flow	9.9%	4.7%	12.1%	4.7%	8.4%	4.4%
Long-term % of virgin MAR	18.2%	11.9%	24.8%	19.2%	14%	9%

10 ECOCLASSIFICATION: EFR O4 (VIOOLSDRIFT)

10.1 EIS RESULTS

The EIS evaluation results in a **HIGH** importance. The highest scoring matrices are:

- Aquatic instream and riparian rare and endangered biota: BKIM, Simulium gariepense, clawless otter, black stork, straw-coloured fruit bat, A. erioloba (IUCN listed as declining). Euclea pseudenus (SANBI protected tree). Veg type = Lower Gariep Alluvial vegetation (Conservation status: Endangered);
- Unique Aquaticinstream biota: Some fish species endemic to the Orange System (ASCL, BAEN, LCAP). BTRI in lower Orange possibly unique population. BHOS endemic to lower Orange, MBRE isolated population in Orange;
- Unique riparian biota: Orange River white-eye restricted to catchment, paradise frog (SA endemic), 6 endemic vegetation plants;
- Riparian migration corridor: An interrupted riparian zone (denuded, trampling, less recruitment) provide a suboptimal migration corridor;
- National parks, wilderness areas, reserves, heritage sites, natural areas: Richtersveld National Park; Ais-Ais National Park.

10.2 REFERENCE CONDITIONS

The reference conditions for the components in EFR O4 are summarised below in Table 10.1

Table 10.1 EFR O4: Reference conditions

Component	Reference conditions	Conf
Hydrology	10335.08 nMAR	3
Physico-chemical	See the description of RC per variable in Table 10.3	2.5
Geomorph	The Orange River Reconnaissance Study (1906-1914) yielded annotated maps (Fig 10.1) of the study area for EFR sites 1, 2, 3 and 4. Around EFR 4, some notes were made about the sediment composition of the bed of the river. Descriptions of the reach noted a variety of sedimentary deposits, from "very muddy banks" (close to the EFR site), to shingly beds (at Vioolsdrift), and then further downstream the Orange is described as having a very sandy bed. Around the Richtersveld the Orange is described as "bed very rocky, banks rough and stony". The banks also are described as well-wooded in places – near the Richtersveld the reach description states that "both banks (are) well wooded with mimosa and bastard ebony", and general notes indicated an "abundance of firewood (was) to be had all along the Orange River".	4
Riparian vegetation	Within the Eastern Gariep Rocky Desert vegetation type. The riparian zone is distinct from the terrestrial zone however, and is catagorised at an azonal vegetation type: the Lower Gariep Alluvial Vegetation. Alluvial terraces and banks are dominated by woody riparian thickets (mainly *Acacia karoo, Ziziphus mucronata, Searsia pendulina*) or stands of *Tamarix usneoides* or reeds (*Phragmitesaustralis*). Cobble or boulder features are characterised by a mix of woody species (*T. usneoides, Gomphostigma virgatum*) and sedges (*Cyperus spp*). Frequently flooded alluvia are open or grassed (*Cynodon dactylon* mainly) and *Salix mucronata* is also common on frequently inundated alluvia. **Marginal Zone**: Expect a mix of open alluvia or cobble/boulder and vegetated areas. Vegetation, similarly, should be a mix of woody (*Gomphostigma virgatum, Salix mucronatasubs mucronata*) and non-woody (*Phragmites australis, Cyperus marginatus*) vegetation. **Lower Zone:** Expect the same as the marginal zone, with *Tamarixus neoides* as well. **Upper Zone:** Terraces should be well vegetated with small % of open areas. Vegetation a mix of reed beds (*P. australis*) or woody thickets (*A karoo, Z mucronata, Searsia pendulina* mainly). **Macro Channel Bank**: Banks should be well vegetated and dominated by woody riparian thickets, with dominant species as outlined above. Also expect *Eucleapseudebenus*.	4.5

Component	Reference conditions	Conf
Fish	Twelve indigenous fish species have a high to definite probability of occurrence. The expected habitat composition at the site under reference conditions also met the requirements of this fish species. The indigenous AMOS is also mentioned as having peripheral occurrence was excluded from reference conditions as this species is not expected to occur naturally in the Orange River and can probably not complete its life-cycle successfully. The expected habitat composition at the site also met the requirements of this fish species. The expected FROC provided in Kleynhans *et al.* (2007) for site D8ORAN-VIOO was broadly used to determine the reference FROC for reach EFR, with alterations made based on all available information.	2.5
Macro-invertebrates	Reference conditions were based on professional judgment and data collected in the area by Palmer (1996). The reference SASS5 Score is 179 and the ASPT is 6.6. The expected number of SASS5 taxa is 27.	4
Riverine Fauna	Potentially 87 animal species inhabited the riverine habitats. Open alluvia in marginal zone utilized by waders. Variety of tree zones (from lower to macro channel bank) with different structural compositions act as refuge, shelter, breeding and feeding habitats, while the intact riparian corridor being used as a migration route for riverine fauna. Mudflats and alluvial soils in lower riparian zone used by burrowing and tunnelling fauna. Reeds and shrubs also utilized as shelter, breeding and feeding habitats.	4.5

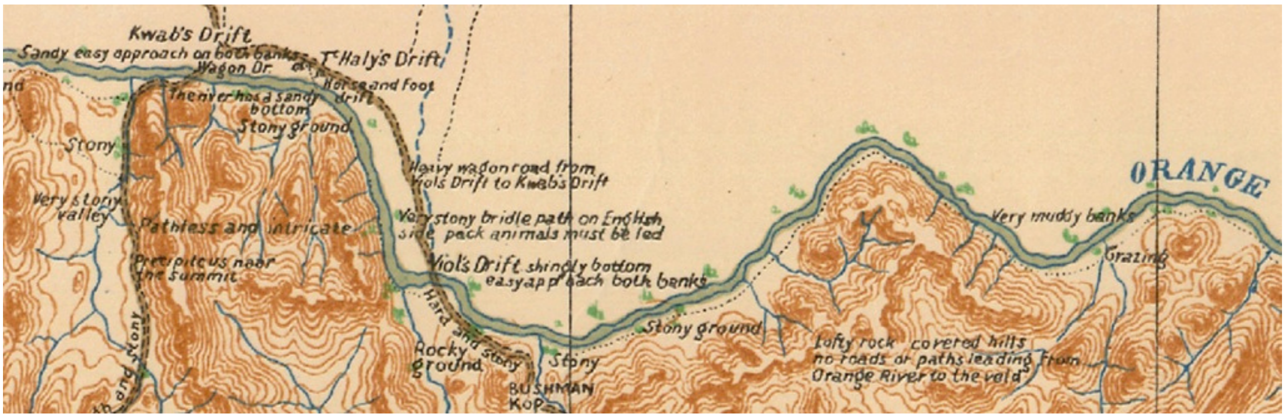


Figure 10.1: Annotated maps from the Orange River Reconnaissance Study (1906-1914) yielded some useful anecdotal evidence of the morphology of the river in this reach.

10.3 PRESENT ECOLOGICAL STATE

The PES reflects the changes in terms of the EC (Table 10.8) from reference conditions. The summarised information is provided in Table 10.2.

Table 10.2 EFR O4: Present Ecological State

Component	PES Description	EC	Conf
Hydrology	3906.75 present day MAR (38% of nMAR)	D	2.5
Physico-chemical	See table 10.3	C/D	2.5
Geomorph	Flood sizes and frequencies are highly reduced and this constrains channel maintenance. Upstream dams trap sediment and the sediment loads are reduced even this far down the river, although amelioration of this occurs through episodic sediment introduction from tributaries. The historical aerial photographic record indicates that small (bedrock core) bars within this pool rapid/riffle reach are, since the 1980's, becoming slightly more extensive and stable (increasingly vegetated). These may be responding to the near absence of moderate and large floods as at EFR 2 and 3. A key issue for this site is the loss of floods that scour and maintain the channel bed and bars. Despite these impacts, the PES is ameliorated by: ▪ Concomitant declines in floods and sediment loads – the reduced sediment supply is ameliorated by the reduced	C	3

Component	PES Description	EC	Conf
	scouring events. ▪ The reach is bedrock controlled and therefore is not very sensitive to the impacts of base flow and small flood changes.		
Riparian vegetation	**Marginal Zone:** Mostly open bedrock with some alluvium. *P. australis*, *S. mucronata* and *G. virgatum* are dominants. **Lower Zone:** Predominantly reeds (*P. australis*) or open unconsolidated alluvium with some woody vegetation. Both *A. karoo* and *Prosopisglandulosa* are recruiting. **Upper Zone:** Open alluvia or dominated by woody vegetation. Extensive mortality of *P. glandulosa* due to recent flooding. **Macro channel bank:** Dominated by woody vegetation. RB is artificial with boulder rubble, road and canal. LB vegetation with distinct browse line except for *P. glandulosa*. Extensive *P. glandulosa* recruitment.	C	3.8
Fish	All the expected fish species are still present in this river reach albeit in a moderately reduced FROC. The species that are thought to have been impacted the most (due to the catchment changes) are BHOS, LUMB, ASCL, BAEN, BKIM.	C	3.5
Macro-invertebrates	The only taxon that was abundant during the site visit was the blackfly *Simulium chutteri*. Empty shells of freshwater limpets (*Burnupia* sp) and bivalves (Unionidae) were found. Instream conditions at these sites are much the same as found further upstream atEFR02 and EFR03, except that water temperatures are significantly warmer, so life-cycles of invertebrates are faster. Outbreaks of pest blackflies (mainly *Simulium chutteri).*	C	4
Riverine fauna	65 of the expected 87 animal species (75%) potentially can occur in this segment. This comprises 36 aquatic and semi-aquatic species, 14 marginal habitat species, and 15 riparian species. Aquatic and semi-aquatic species (78% of expected): The changes in flows impact on the food source (abundance of fish) of piscivorous species. Lower flows eliminate deep pool and slower backwater habitats (ducks, coots, storks). Marginal habitat species (64% of expected): Less waders (sandpipers, plovers) and open habitat animals (plovers, geese) present. Also species that use sand bars and sandbanks loose digging substrate (monitors, bee-eaters, martins). Riparian species (79% of expected): Indigenous tree structure is impacted by browsing, flooding and *Prosopis* invasion, affecting the food source of certain of species (fruit and berries – mousebirds), shelter for retiring species (robins, genet) and the degradation of a migration corridor (cuckoos, white-eyes).	C	3.8

Table 10.3 EFR O4: Present Ecological State: Physico-Chemical

RIVER	Orange River	**WATER QUALITY MONITORING POINTS**		
		RC	Orange River @ Korridor Brand Kaross (D82L; ecoregion II: 25.03) D8H007Q01 (1980; n=35)	
EFR SITE	EFR O4 (D82F; ecoregion II: 28.01)	**PES**	1) Orange River @ Oppenheimer Bridge, Alexander Bay (D82L; ecoregion II: 25.03) D8H012Q01 (1995 – 2003; n=263) 2) Data from diatom sample collection in 2008 (n=9)	
Confidence assessment	Low - moderate confidence. The data record for the present state is not recent and gaps exist for data such as metal ions, pesticides, herbicides. RC data also poor. Note that the EFR site and monitoring points are <u>not</u> in the same EcoRegion level II.			

Water Quality Constituents		**RC Value**	**PES Value**	**Category/Comment**
Inorganic salts (mg/L)	TEACHA was not used for the data assessment.			
Salt ions (mg/L)	Ca	28.06	44.07	PES data show significant elevations for all ions as compared to the natural state.
	Cl	27.10	73.05	
	K	1.92	5.62	
	Mg	12.36	22.08	
	Na	32.34	76.97	
	SO_4	33.16	84.30	
Nutrients (mg/L)	SRP	0.006	0.026	C/D category
	TIN	0.060	0.076	A category
Physical Variables	pH (5^{th} + 95^{th} %ile)	6.77 + 7.53	8.10 + 8.60	A/B category
	Temperature	-	-	Extreme reductions of flow for large parts of the year.
	Dissolved oxygen			

	Turbidity (NTU)	-	10.24 (avg; n=9) (Koekemoer, 2010)	No RC or DWA PES data. Turbidity trapped in dams. A/B category (qualitative assessment).
	Electrical conductivity (mS/m)	38.03 *	72.96	B category
Response variables	Chl a: periphyton (mg/m^2)	-	-	-
	Chl a: phytoplankton (µg/L)	-	Avg: 25.2 (n=9) (Koekemoer, 2010)	D category
	Macroinvertebrates	ASPT:6.6 SASS: 165	ASPT: 6.0 SASS: 96 MIRAI: 63.3%	C category (Palmer, 2010)
	Fish community score		FRAI: 65.2%	C category (Kotzé, 2010)
	Diatoms	-	Avg SPI: 11.5 (n=8)	C category (Koekemoer, 2010)
Toxics	Fluoride (mg/L)	0.38	0.50	A category
	Aluminium (mg/L)	0.02 **	0.042 (n=9) (Koekemoer, 2010)	A category
	Iron (mg/L)	-	0.035 (n=9) (Koekemoer, 2010)	No guideline + insufficient data
	Ammonia (mg/L)	0.001	0.010	A category
	Copper (mg/L)	0.003 **	0.013	E category
	Zinc (mg/L)	0.0002: TWQR 0.0036: CEV (DWAF, 1996)	0.0056	Both guidelines exceeded
	Other	-	-	Impacts expected due to farming activities and large abstractions. References suggest mining impacts
OVERALL SITE CLASSIFICATION		**C/D: 58.24% (from PAI model)**		

** boundary value for the A category recalibrated* *- no data* *** benchmark value, as no data*

10.3.1 EFR O4: Trend

The trend was also assessed. Trend refers to the situation where the responses have not yet stabilised in reaction to catchment changes. The evaluation is therefore based on the existing catchment condition. Only vegetation and riverine fauna have a negative trend. The site has a high degree of physical disturbance (vegetation removal, grazing and trampling) which has already and will continue to promote pioneer species, especially exotic riparian species such as *Prosopis glandulosa* and other perennial and annual species. The site has a high abundance of invasive weeds on the LB and extreme overutilization on the RB. (Confidence 4)The change in riparian structure due to the exotic riparian influx will impact adversely on the riverine fauna assemblage. (Confidence: 4)

10.3.2 EFR O4: PES Causes and Sources

The reasons for changes from reference conditions must be identified and understood. These are referred to as causes and sources ((http://cfpub.epa.gov/caddis/)). The PES for the components at EFR O4as well as the causes and sources for the PES are summarised in Table 10.4.

Table 10.4 EFR O4: PES Causes and Sources

	PES	Conf	Causes	Sources	F[1]/NF[2]	Conf
Hydrology	D	2.5	Decrease of floods.	Upstream dams	F	5

	PES	Conf	Causes	Sources	F[1]/NF[2]	Conf
			Increased base flows during drought and dry seasons and decreased base flows during the wet season	Operation for irrigation and other users	F	
Physico-chemical	C/D	2.5	Toxicant levels elevated, possibly from pesticide use and mining activities.	Cumulative pesticide use from upstream farming and mining activities results in increased toxicant levels	NF	2.5
			Lower flows cause elevated temperatures and drops in oxygen levels.	Abstractions are fewer in this area but evaporation causes reduced dilution effect.	F	3.5
Geomorphology	C	3	Reduced sediment loads due to loss of floods	Upstream dams.	NF	3.5
Riparian vegetation	C	3.8	Altered species composition and loss of indigenous vegetation cover	Exotic vegetation invasion	NF	5
			Reduced non-woody cover and absence of woody recruitment	Intense grazing and trampling pressure, especially on RB	NF	5
			Reduced riparian woody cover and abundance	Physical disturbance and removal, especially due to road and canal construction and maintenance (LB)	NF	5
			Increased reed and non-woody riparian vegetation cover in the marginal and lower zones	Reduced base flows and floods	F	3
Fish	C		Decreased overhanging vegetation as cover.	Erosion, change in flow, agriculture.	F/NF	3.5
			Decrease in FROC and abundance of fish species with preference for fast habitats.	Decreased base flows.	F	
			Decreased water quality affect species with requirement for high water quality.	Presence of toxics, farming, changes hydrology, dams trapping sit.	NF	
			Decreased FROC of species with preference for substrate as preferred cover and habitat for spawning, feeding etc.	Increased algal growth on substrates (increased nutrients from farming)	F/NF	
			Decreased species diversity and abundance.	Presence of alien predatory species.	NF	
			Increased turbidity and disturbed bottom substrates (impact on LUMB breeding habitats)	Presence of alien CCAR.	NF	
			Decreased abundance and FROC of detritus feeders (esp. LUMB)	Competition by introduced indigenous OMOS).	NF	
			Decreased abundance, and therefore FROC	.Poaching and over-fishing using nets (gill and seine nets, often home-made).	NF	
			Reduced spawning success resulting in decreased FROC of many species.	Flow modification: Absence or lag effect of spring flushes.	F	
			Reduced migration success (breeding, feeding and dispersal) of some species.	Some small dams/weirs.	NF	
Macroinvertebrates	C	4	Elevated low flows	Discharges to meet demands for winter power generation and irrigation demands	F	4
			Water quality deterioration	Agricultural return flows	F	2

	PES	Conf	Causes	Sources	F[1]/NF[2]	Conf
			Aseasonal releases	Operation of Vanderkloof Dam	F	4
			Toxic algal blooms, such as *Microcystis*	Annual overturn of vanderKloof Dam plus inputs from Harts River (Spitzkop Dam)	NF	2
Riverine Fauna	C	3.8	Reduced food base for piscivorous species	Changed hydrology.	F	3
			Deteriorate marginal habitat for waders	Loss of floods (dams) and lack of zero flows	F	3
			Deterioration and loss of shelter for retiring species in the mid- and lower slopes affecting the food source of a number of species (fruit and berries),	Trampling by livestock. Changed of woody vegetation structure due to browsing, flooding and *Prosopis* invasion	NF	2.5

1 Flow related 2 Non Flow related

The major issues that have caused the change from reference conditions are the following:

- Decreased frequency of large floods;
- Agricultural return flows, agricultural activities and associated water quality impacts;
- Mining activities;
- Higher low flows than natural in the dry season, drought and dry periods and lack of naturally occurring zero flows;
- Decreased low flows at other times;
- Presence of alien fish species and barrier effects of dams;
- Decreased sedimentation due to lack of large floods and upstream dams;
- Alien vegetation.

10.3.3 EFR O4: PES EcoStatus

To determine the EcoStatus, the macroinvertebrates and fish must first be combined to determine an instream EC. The instream and riparian categories are integrated to determine the EcoStatus. Confidence is used to determine the weight that the EC should carry when integrating into an EcoStatus (riparian, instream and overall). The EC percentages are provided (Table 10.5) as well as the portion of those percentages used in calculating the EcoStatus.

Table 10.5 MRU: EFR O4: Instream

INSTREAM BIOTA	Importance Score	Weight
FISH		
1.What is the natural diversity of **fish** species with different flow requirements	3	80
2.What is the natural diversity of **fish** species with a preference for different cover types	4	100
3.What is the natural diversity of **fish** species with a preference for different flow depth classes	3.5	90
4. What is the natural diversity of **fish** species with various tolerances to modified water quality	2.5	70
MACROINVERTEBRATES		
1. What is the natural diversity of **invertebrate** biotopes	3.5	80
2. What is the natural diversity of **invertebrate** taxa with different velocity requirements	4	100
3. What is the natural diversity of **invertebrate** taxa with different tolerances to modified water quality	2	50

Fish	**3.5**
Macroinvertebrates	**4**
Confidence rating for instream biological information	**3.8**
INSTREAM ECOLOGICAL CATEOGORY	**C**
Riparian vegetation	**C**
Confidence rating for riparian vegetation zone information	3.8
ECOSTATUS	**C**

10.4 RECOMMENDED ECOLOGICAL CATEGORY (REC B):

The REC is determined based on ecological criteria only and considers the EIS, the restoration potential and attainability there-of. The EIS is HIGH, therefore the REC is aimed to improve the PES to a B.

- Reinstate droughts (i.e., lower flows than present during the drought season).
- Improved (higher) wet season base flows.
- Above will not improve water quality which is a concern. Water quality problems here are worse than EFR O3 and does impact on the biota.
- Geomorphology cannot improve without reinstating floods.
- Clear vegetation aliens – will improve condition in the marginal and lower zones.
- Control grazing and trampling

A B/C improvement only could be achieved. This is due to the fact that the PES of a C for fish and macroinvertebrates are very low and that water quality could not be improved.

Table 10.6 EFR O4: REC

	PES	REC	Comments	Conf
Physico-chemical	C/D	C/D	This cannot be achieved with the changes recommended (e.g. improved wet season base flows + more drought flows), as only the institution of flushing flows can improve water quality, which is not practically possible at the site.	n/a
Geomorphology	C	C	To improve the PES, it is necessary to reinstate the large floods and reintroduce sediment that is trapped in upstream dams. This is not possible – dams are too far upstream to manage for the provision of floods at this site, and it is not possible to replenish sediment supplies as the lower catchment is arid and tributary inputs are episodic due to low rainfall.	3.5
Riparian vegetation	C	B	Improvements include slightly reduced reed and annual exotic cover. Additional improvements include reducing the grazing and trampling pressure, especially on the RB. This facilitates some grass cover with an associated reduction in open alluvia. EC improves to 84.3% (B). Additional improvement would be possible if the LB were rehabilitated since it currently consists of dumped boulder rubble from road and canal disturbance.	2.5
Fish	C	B/C	Improved hydrology (especially higher wet season base flows, improved/closer to natural droughts), improved habitat availability (both fast and slow habitats), and condition will lead to an improvement of the FROC of most species (fast habitat - BAEN, BKIM, BHOS, LCAP; and slow habitat BPAU, PPHI, TSPA and BTRI). Recommended control of grazing and trampling may result in an improvement in water and habitat quality (decreased sedimentation), and should benefit the fish species BKIM and BAEN especially during early life stages as well as for habitat.	2.5

	PES	REC	Comments	Conf
Macroinvertebrates	C	B/C	Lower baseflows during the dry season and a wider seasonal range of baseflows is expected to increase habitat variability and thereby increase biodiversity, and also reduce the incidence of outbreaks of the pest blackfly *Simulium chutteri*. Taxa expected to appear under a more natural flow regime and improved management of irrigation return flows include taxa that are found in marginal vegetation, such as Belostomatidae, Coenagrionidae and Notonectidae, as well as taxa that are sensitive to water quality deterioration, such Hydropsychidae (>2 spp), Leptophlebiidae and Corduliiae. Other taxa expected to benefit from these conditions are Porifera, Hydroptilidae and Ceratopogonidae. The total number of SASS5 taxa is expected to increase to 19. The overall SASS Score is expected to be 118, and the ASPT 6.2.	2
Riverine Fauna	C	B/C	The more open areas in the marginal and lower zone will result in the return of faunal species that prefer mudflats (waders), alluvial sandbars (plovers) and shallow edge habitats for waders. The return of herbaceous vegetation will facilitate shelter for smaller fauna in the upper zone.	2.5

10.5 ALTERNATIVE ECOLOGICAL CATEGORY (AEC D):

The scenario includes:

- Increased mining with associated impacts on water quality and decreased wet season base flows;
- Decreased floods;
- Increased vegetation aliens (esp *Prosopis sp.*);
- Habitat loss for a large percentage of time;
- Vegetation: Increased sedges due to increased sedimentation.

Each component is adjusted to indicate the metrics that will react to the scenarios. The rule based models are available electronically and summarised in Table 10.7.

Table 10.7 EFR O4: AEC

	PES	AEC	Comments	Conf
Physico-chemical	C/D	D	Decreased flows (wet season base flows), and expanded mining will cause increased temperatures, nutrients and salts, lower oxygen levels, and instream toxicant level increases.	3
Geomorphology	C	C	Further reduced floods and reduced base flows are expected to cause a decline in the PES of the geomorphology, although this is expected to be within the class. This is because bedrock controlled reaches– the reach type within which this site is situated – is resilient to changes in both flow and also relatively resilient to changes in sediment. The expected change would thus be from a high C to a lower C Ecological Category.	2
Riparian vegetation	C	C/D	Increased reduction in wet season base flows, together with fine alluvial sediments at the site results in an increase in marginal and lower zone non-woody cover, which is a deviation from reference. This alone is not enough to reduce the class and exacerbation of non-flow related impacts is necessary. This includes allowing exotic invasion to increase, and increasing the grazing and trampling pressure. Overall the EC changes from 74% to 61.4%.	2.3
Fish	C	D	Decreased flows (loss of fast habitats) together with increased benthic algal growth on substrates (increased photic depth related to lower flows) will result in deterioration of riffle/rapid/run over rocky substrate habitats with a resultant negative impact on fish species with a requirement for this habitat type (esp. ASCL, BAEN, BKIM and LCAP). Further deterioration in base flows will also negatively impact fish in terms of increased sedimentation of substrate, resulting in further deterioration of fish assemblage (especially BAEN and BKIM). Decreased water quality will impact some fish species (especially early life stages) negatively. Decreased flows may furthermore create more favourable conditions (slow habitats) for alien fish species (esp. CCAR & GAFF) which will result in increased impact on indigenous fish species. Other impacts – decreased habitat quality (loss of fast habitats and deterioration of substrate quality due to algal growth and sedimentation related to increased grazing and	**3**

	PES	AEC	Comments	Conf
			trampling).	
Macroinvertebrates	C	D	Lower baseflows during the dry and wet seasons, increased agricultural development and associated deterioration in water quality are likely to reduce the incidence of outbreaks of the pest blackfly *Simulium chutteri*. A reduced seasonal range of baseflows will also reduce water quality and habitat variability and thereby reduce biodiversity. Taxa expected to disappear include those that are sensitive to water quality deterioration, such as Perlidae, Tricorythidae, Elmidae and Hydropsychidae (>2 spp). The total number of SASS5 taxa is expected to drop to 8. The overall SASS Score is expected to be 3, and the ASPT 4.1.	3
Riverine Fauna	C	C/D	▪ The loss of open areas in the marginal and lower zone will result in the loss of faunal species that prefer mudflats (waders), alluvial sandbars (plovers) and shallow edge habitats for waders. Dense *Prosopis* will change the structure of the riparian tree corridor in such a way that it will deter certain fauna to utilize this habitat. The lack of shrubbery in the upper zone where there is an increase in grazing lawns, the shelter will be lost to smaller fauna.	2.5

10.6 SUMMARY OF ECOCLASSIFICATION RESULTS

Table 10.8 EFR O4: Summary of EcoClassification results

Driver Components	PES	Trend	REC	AEC↓
IHI HYDROLOGY	D			
WATER QUALITY	C/D		C/D	D
GEOMORPHOLOGY	C	0	C	C
INSTREAM IHI	D			
RIPARIAN IHI	D			
Response Components	**PES**	**Trend**	**REC**	**AEC↓**
FISH	C	0	B/C	D
MACRO INVERTEBRATES	C	0	B/C	D
INSTREAM	C	0	B/C	D
RIPARIAN VEGETATION	C	-	B	C/D
RIVERINE FAUNA	C	-	B/C	C/D
ECOSTATUS	C	-	B/C	D
EIS	HIGH			

11 EFR O4 (VIOOLSDRIFT) – DETERMINATION OF STRESS INDICES

Stress indices are set for fish and macroinvertebrates to aid in the determination of low flow requirements. The stress index describes the consequences of flow reduction on flow dependant biota. It therefore describes the habitat conditions for fish and macroinvertebrates indicator species for various low flows. These habitat conditions for different flows and the associated habitat conditions are rated from 10 (zero flows) to 0, which is optimum habitat for the indicator species.

11.1 INDICATOR SPECIES OR GROUP

11.1.1 Fish indicator group: Large semi - rheophilic species (BAEN)

See 5.1.1 and Table 5.1

11.1.2 Macroinvertebrate indicator group: Ampipsyche scottae

See 5.1.2

11.2 STRESS FLOW INDEX

A stress flow index is generated for every component, and describes the progressive consequences to the flow dependent biota of flow reduction. The stress flow index is generated in terms of habitat response and biotic response and is discussed below.

11.2.1 Habitat response

The habitat flow index is described separately for fish and macroinvertebrates as an instantaneous response of habitat to flow in terms of a 0 – 10 index relevant for the specific site where:

- 0 - Optimum habitat (fixed at the natural maximum base flow which is based on the 10% annual value using separated natural baseflows).
- 10 – Zero discharge (Note: Surface water may still be present).

The instantaneous response of fish and invertebrate breeding habitat, abundance, cover, connectivity, and water quality are derived by considering (amongst others) rated velocity depth classes (in terms of abundance) to flow changes based on a 0 (VD class absent) - 5 (VD class very abundant).

Fish and invertebrate habitat is then rated separately according to a 0 (no habitat) – 5 (optimum occurrence of habitat).

11.2.2 Biota response

The biota stress index is the instantaneous response of biota to change in habitat (and therefore flow), based on a scale of 0 – 10 where:

- 0 = Optimum habitat with least amount of stress possible for the indicator groups ***at the site*** (fixed at the natural maximum baseflow in the same way as for the habitat response).
- 10 = Zero discharge. The biota response will depend on the indicator groups present, i.e. rheophilics will have left whereas semi-rheophilics will still be present and survive.
-

The instantaneous response of fish and invertebrate breeding habitat, abundance, cover, connectivity, and water quality are derived by considering (amongst others) rated velocity depth classes (in terms of abundance) to flow changes based on a 0 (VD class absent) - 5 (VD class very abundant).Fish and invertebrate habitat is then rated separately according to a 0 (no habitat) – 5 (optimum occurrence of habitat).

11.2.3 Integrated stress curve

The integrated stress curve represents the highest stress for either fish or macroinvertebrates at a specific flow.

The species stress discharges in Table 11.1 indicate the discharge evaluated by specialists to determine the biota stress. The highest discharge representing a specific stress is used to define the integrated stress curve. Figure 11.1 illustrates this graphically.

In this specific case, the LSR fish stress index represents the integrated stress range 7 – 10. Therefore the blue curve (representing the LSR stress index) is lying 'beneath' the integrated stress line (black). The FDI stress index represents the integrated stress range 0 – 7, therefore the red curve (representing the FDI stress index) is lying 'beneath' the integrated stress line (black) (Figure 11.1).

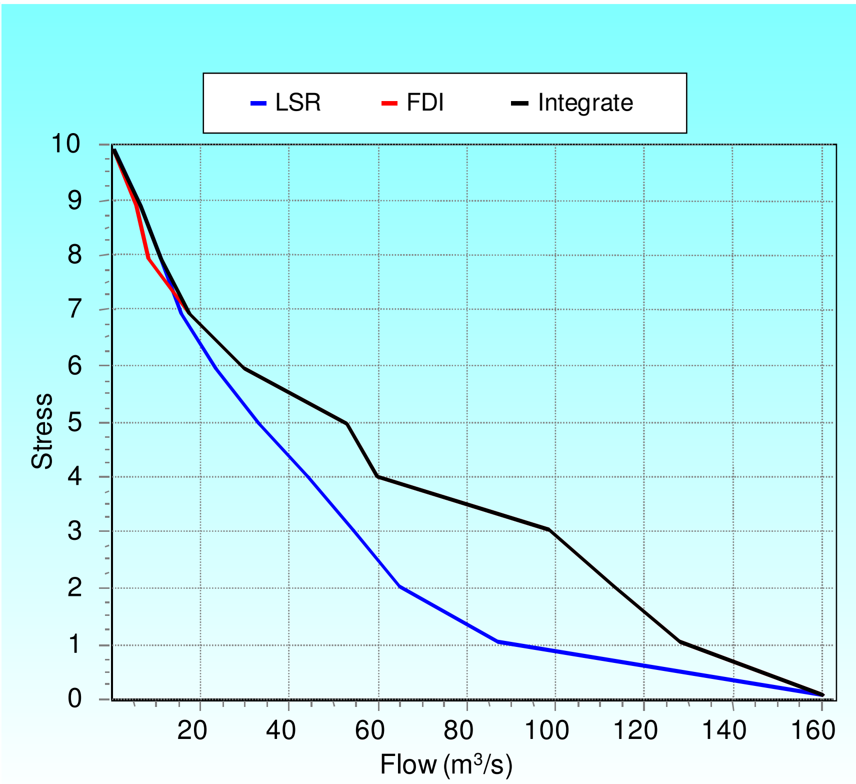


Figure 11.1 EFR O4: Species stress discharges used to determine biotic

Table 11.1 EFR O4: Species stress discharges used to determine biotic stress

Stress	Flow (m^3/s)		Integrated Flow (m^3/s)
	LSR	FDI	
0	163	163	163
1	88.4	130	130
2	65.8	115	115
3	55.3	100	100
4	44.5	60.5	60.5
5	33.6	53.5	53.5
6	23.6	30	30
7	15.3	17.2	17.2
8	10.7	8	10.7
9	6	5	6
10	0.001	0.001	0.001

Table11.2 provides the summarised biotic response for the integrated stresses.

Table 11.2 EFR O4: Integrated stress and summarised habitat/biotic responses

Integrated stress	Flow (m^3/s)	Driver (fish/inverts/both)	Habitat and/or Biotic responses
0	163	Both	Habitat suitability for semi-rheophilic fish guild optimal for all criteria (spawning habitat, nursery habitat, abundance, cover, connectivity and water quality) evaluated. The turbidity is suitable for the blackly *Simulium gariepense*.
1	130	Invertebrate	Instream biotopes plentiful and suitable for a wide variety of taxa, including flow-sensitive species, with critical habitats (FCS and VFCS) comprising about 27% of the cross-section. The river bed becomes light-limited, with Secchi depth typically 8 - 17 cm. The high turbidity and current speeds (average current speed 0.6 m/s) favours the mayflies *Tricorythus discolor* and *Baetis glaucus,* and the caddisflies *Amphipsyche scottae* and *Aethaloptera maxima.*
2	115	Invertebrate	Critical habitats sufficient for flow-sensitive taxa, except for those that prefer high turbidity. Critical habitats comprise 5% of the cross-section.
3	100	Invertebrate	High concentration of planktonic algae provides food for filter-feeding invertebrates such as *Simulium chutteri* and *Tricorythus discolor*. Average current speeds 0.53 m/s, which is lower than the preferred current speeds of species such as *Simulium chutteri* and *Aethaloptera maxima.*
4	60.5	Invertebrate	The lower marginal vegetation, mainly *Phragmites austraulis* and some sedge, starts to provide suitable habitat for invertebrates, such as the freshwater shrimp *Caridina nilotica* and Leptoceridae. Critical habitats (FCS and VFCS) comprising about 16% of the cross-section.
5	53.5	Invertebrate	Critical habitats very reduced. Conditions suitable for scrapers, such as *Burnupia*.FCS and VFCS comprise about 15% of the cross-section.
6	30	Invertebrate	Critical habitat residual (11%) and flow-sensitive species reduced. Average current speed on 0.19 m/s. High water clarity, providing suitable conditions for taxa such as the midge *Cardiocladius africanus, Euthraulus elegans* and the blackfly *Simulium damnosum.*
7	17.2	Invertebrate	Very little critical habitat (3%). Most flow-sensitive taxa disappear. Low turbidity, slow current speeds and limited dilution leads to excessive growth of benthic algae, which limits suitability of instream habitats.
8	10.7	Fish	In terms of habitat suitability for large semi-rheophilic fish guild, spawning habitat and nursery habitat will be of very low suitability, while abundance, cover, connectivity and water quality in low/poor condition.
9	6	Fish	In terms of habitat suitability for large semi-rheophilic fish guild, nursery habitat, abundance, cover, connectivity and water quality are of very low suitability while no spawning habitat will be available.
10	0	Both	No flow. Macroinvertebrates diapause phase triggered. Habitat not suitable for any of the criteria assessed (spawning habitat, nursery habitat, and abundance, cover, connectivity and water quality) for the large-semi-rheophilic fish guild.

12 EFR O4 (VIOOLSDRIF) - DETERMINATION OF EFR SCENARIOS

12.1 ECOCLASSIFICATION SUMMARY OF EFR O4

EFRO4

EIS: HIGH
Highest scoring metrics are instream & riparian rare /endangered biota, unique instream and riparian biota, migration corridor, National Park.

PES: B/C
Decreased frequency of large floods. Agricultural return flows and mining activities – water quality problems. Higher low flows than natural in the dry season, drought and dry periods. Decreased low flows at other times. Presence of alien fish species and barrier effects of dams. Decreased sedimentation due to lack of large floods and upstream dams. Alien vegetation.

REC:
Improved (higher) wet season base flows. Clear vegetation aliens. Control grazing and trampling

AEC:
Increased mining with associated impacts on water quality and decreased wet season base flows. Decreased floods. Increased vegetation aliens (esp *Prosopis sp.*).Habitat loss for a large percentage of time due to decreased flows. Vegetation: Increased sedges due to increased sedimentation.

Driver Components	PES	Trend	REC	AEC↓
IHI HYDROLOGY	D			
WATER QUALITY	C/D		C/D	D
GEOMORPHOLOGY	C	0	C	C
INSTREAM IHI	D			
RIPARIAN IHI	D			
Response Components	**PES**	**Trend**	**REC**	**AEC↓**
FISH	C	0	B/C	D
MACRO INVERTEBRATES	C	0	B/C	D
INSTREAM	C	0	B/C	D
RIPARIAN VEGETATION	C	-	B	C/D
RIVERINE FAUNA	C	-	B/C	C/D
ECOSTATUS	C	-	B/C	D
EIS	HIGH			

12.2 HYDROLOGICAL CONSIDERATIONS

The wettest and driest months were identified as March and September. Droughts are set at 95% exceedance (flow) and 5% exceedance (stress). Maintenance flows are set at 40% exceedance (flow) and at 60% exceedance (stress).

12.3 LOW FLOW REQUIREMENTS (IN TERMS OF STRESS)

The integrated stress index is used to identify required stress levels at specific durations for the wet and dry month/season.

12.3.1 Low flow (in terms of stress) requirements

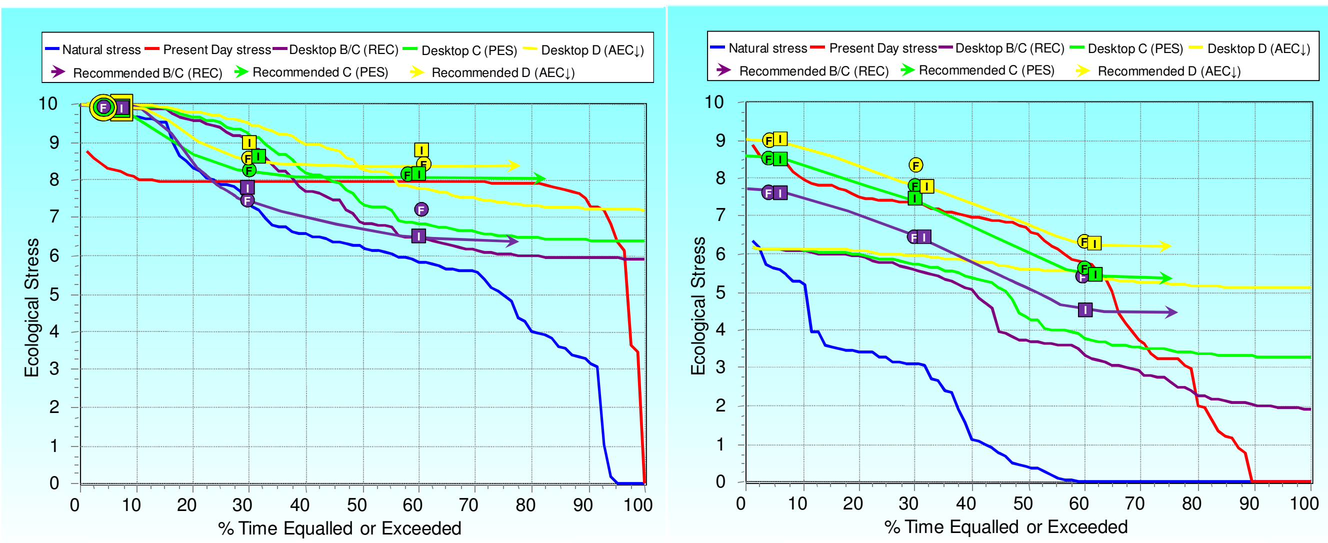
The fish and macroinvertebrate flow requirements for ECs are provided in Table 12.1 and graphically illustrated in Figure 12.1 and 12.2. The results are plotted for the wet and dry season on stress duration graphs and compared to the Desktop Reserve Model (DRM) low flow estimates for the same range of ECs. The stress requirements (as a 'hand drawn line') are illustrated in Figures12.1 and 12.2.

For easier reference the range of ECs are colour coded in the Tables and figures:
PES and REC: Green REC: Purple AEC↓: Yellow

Summarised motivations for the final requirements are provided in Table 12.2.

Table 12.1 EFR O4: Species and integrates stress requirements as well as the final integrated stress and flow requirement

Duration	LSR stress	Integrated stress	FDI stress	Integrated stress	FINAL* (Integrated stress)	FLOW (m^3/s)
PES C ECOSTATUS		**FISH: C**		**MACRO INVERTEBRATES: C**		
DRY SEASON						
5%	10	**10**	10	**10**	10	0
30%	8.2	**8.2**	8.1	**8.7**	8.2	9.7
60%	8.2	**8.2**	7.7	**8.1**	8.1	10.2
WET SEASON						
5%	8.6	**8.6**	7.9	**8.4**	8.4	8.8
30%	7.9	**7.9**	7.3	**7.4**	7.4	14.1
60%	5.1	**5.6**	5.5	**5.5**	5.5	42.1
REC B/C ECOSTATUS		**FISH: B/C**		**MACRO INVERTEBRATES: B/C**		
DRY SEASON						
5%	10	10	10	10	10	0
30%	7.5	7.6	7.6	7.9	7.6	12.9
60%	6.9	7.2	6.6	6.6	6.6	21.4
WET SEASON						
5%	7.3	7.5	7.1	7.4	7.4	14.1
30%	6.1	6.5	6.6	6.6	6.5	22.5
60%	4	5.4	4.6	4.6	4.6	55.9
AEC↓D ECOSTATUS		**FISH: D**		**MACRO INVERTEBRATES: D**		
DRY SEASON						
5%	10	**10**	10	10	10	0
30%	8.6	**8.6**	8.7	9	8.6	7.9
8.4	8.4	**8.4**	8.2	8.8	8.4	8.8
WET SEASON						
5%	9	**9**	8.7	9	9	6
30%	8.4	**8.4**	7.5	7.8	7.8	11.8
60%	6	**6.4**	6.3	6.3	6.3	25.2



SEPT – DRY SEASON **MAR – WET SEASON**

Figure 12.1 EFR O4: Stress duration curve for a PES, REC and AEC

Table 12.2 EFR O4: Summary of motivations

Month	% Stress duration	Component stress	Integrated stress	Flow m^3/s	Comment
PES& REC: EcoStatus FISH: MACROINVERTEBRATES:					
Sep	5% drought	10 LSR	10	0	Habitat suitability will be very low in terms of providing cover/abundance, connectivity and water of acceptable quality, but adequate to allow survival of this fish guild and maintenance of PES during droughts in dry season as it compares to natural conditions during dry season droughts.
		10 FDI	10	0	This site is naturally dry at this time.
	60% maintenance	7.7 FDI	8.1	10.2	This stress is the same as the current
Mar	5% drought	7.9 FDI	8.4	8.8	This stress is the same as the current
	60% maintenance	5.5 FDI	5.5	42.1	This stress is the same as the current
AEC: EcoStatus FISH: MACROINVERTEBRATES:					
Sep	5% drought	10 LSR	10	0	Habitat suitability will be very low in terms of providing cover/abundance, connectivity and water of acceptable quality, but adequate to allow survival of this fish guild and maintenance of PES during droughts in dry season as it compares to natural conditions during dry season droughts.
		10 FDI	10	0	
	60% maintenance	6.6 FDI	6.6	21.4	This stress was based on the shape of the present-day flow-duration curve. The flow at this stress is 22 m^3/s, compared to the present flows of 11.9 m^3/s. This change is expected to improve the condition of the river by one category.
Mar	5% drought	7.1 FDI	7.4	14.1	The flow at this stress is 16 m^3/s, compared to the present flows of 8.7 m^3/s. This change is expected to improve the condition of the river by one category
	60% maintenance	4.6 FDI	4.6	55.9	The flow at this stress is 50 m^3/s, compared to the present flows of 36.3 m^3/s. This change is expected to improve the condition of the river by one category.
AEC↓D ECOSTATUS FISH: D MACRO INVERTEBRATES: D					
Sep	5% drought	10 LSR	10	0	Habitat suitability will be very low in terms of providing cover/abundance, connectivity and water of acceptable quality. It will however be of lower suitability than under present conditions and an overall deterioration can be expected to occur during dry season droughts.
		10 FDI	10	0	
	60% maintenance	8.4 LSR	8.4	8.8	Habitat suitability will be very low in terms of providing cover/abundance, connectivity and water of acceptable quality. Conditions will be worse than under present day dry season and deterioration can be expected to occur.
Mar	5% drought	9 LSR	9	6	No spawning is expected to occur under these stress levels resulting in deteriorated conditions in the LSR fish guild. Habitat suitability will also be very low in terms of providing nursery areas, cover/abundance, water of acceptable quality and connectivity. Overall the habitats will be deteriorated from the present state and deterioration in the LSR guild can be expected.
		8.7 FDI	9	6	The flow at this stress is 6.0 m^3/s, compared to the present flows of 8.7 m^3/s. This change is expected to reduce the condition of the river by one category.
	60% maintenance	6.3 FDI	6.3	25.2	The flow at this stress is 26 m^3/s, compared to the present flows of 36.3 m^3/s. This change is expected to reduce the condition of the river by one category.

12.3.2 EFR O4 Riparian Vegetation and Riverine Fauna Verification of Low Flow Requirements

The low flow requirements as set by the instream biota is checked (and modified if necessary) to ensure that it caters for any riparian vegetation (specifically marginal) and riverine fauna. This verification is summarised in Table 12.3 and 12.4.

Table 12.3 EFR O4: Verification of low flow requirements for instream biota to maintain riparian vegetation in the required EC.

PES						
Species	**Season**	**Duration**	**Q**	**Average Inundation / Height above water level (m)**		**Note**
				lower limit	**upper limit**	
G. virgatum	Dry	5%	10.2	0.52	1.51	Water stress is high and some mortality expected, especially along the upper limit of populations, but this is usual for drought, even in the dry season.
C. marginatus				0.54	1.62	
P. decipiens				0.55	1.01	
P. lapathifolia				0.65	1.49	
P. australis				0.7	1.62	
S. mucronata				0.76	1.36	
G. virgatum		60%	28.8	0.35	1.34	Water stress quite high, but normal for dry season and because plants reduce metabolic requirements, survival will be sufficient for PES to be unaltered.
C. marginatus				0.37	1.45	
P. decipiens				0.38	0.84	
P. lapathifolia				0.48	1.32	
P. australis				0.53	1.45	
S. mucronata				0.59	1.19	
G. virgatum	Wet	5%	30.8	0.33	1.33	Comparable to dry season base flows, but during the wet season these flows are likely to cause reproductive failure / abortion. Survival of existing vegetation is however likely to be high and not likely to change the PES.
C. marginatus				0.36	1.44	
P. decipiens				0.36	0.82	
P. lapathifolia				0.46	1.31	
P. australis				0.52	1.43	
S. mucronata				0.58	1.17	
G. virgatum		60%	60	0.11	1.11	On average most populations are not inundated, although up to 20 cm of inundation can occur at selected low points. These base flows are sufficient to facilitate survival and, together with small floods, reproduction. The PES is not likely to change.
C. marginatus				0.14	1.22	
P. decipiens				0.14	0.61	
P. lapathifolia				0.24	1.09	
P. australis				0.3	1.21	
S. mucronata				0.36	0.95	
Conclusion: Proposed flows will result in low water stress for riparian vegetation and will maintain the PES. Riparian zone structure and functionality will remain unchanged from current as a result of flow.						

Table 12.4 EFR O4: Verification of low flow requirements for instream biota to maintain riverine fauna in the required EC

Season	Duration	Q	Note
Dry	5%	5.7	Some mortality expected in the riparian vegetation, especially along the upper limit of populations. This happened naturally and the riverine fauna will be adapted to some loss in vegetation. Piscivorous animals will be fine since the fish population will not change much (abundance still high), and lowered water levels will improve the chances of obtaining fish as food.
Dry	60%	10.2	Flows are sufficient to ensure survival through the dry season and will be sufficient to maintain the habitat for riverine fauna, while the fish and macro-invertebrate abundance will be in satisfactory state for piscivores and invertivores.
Wet	5%	8.8	Flows are sufficient to ensure survival of riparian vegetation through the drought with no mortality expected. Riverine fauna will react to the riparian template and will not be affected adversely.
Wet	60%	42.1	Flows are sufficient to meet summer water demands and facilitate successful reproduction of riparian vegetation. Riverine fauna will react to the riparian template and will not be affected adversely.
Conclusions: Only during the dry season at 5% will the vegetation show a level of stress, however, the riverine fauna will not respond drastically if the changes in marginal vegetation are small.			

12.3.3 Final low flow requirements

To produce the final results, the DRM results for the specific category are modified according to specialists' requirements (Figure 12.3). There are a range of options one can use to make these modifications, such as changing the total volume required for the year, specific monthly volumes, either drought or maintenance flow durations, seasonal distribution and changing the category rules and shape factors. The following changes were required:
(Note that revised approach using separated base flows for the natural and PD stress curves were used for this site.)

- PES: C EC.
  - Drought seasonal distribution did not change.
  - Maintenance seasonal distribution set to 0.8.
  - Wet season rules:
    - Shape factor set to 9.
    - Lower shift factor set to 95; Upper shift set to 0.
    - Low flow max (%): 130.
  - Dry season rules:
    - Shape factor set to 4.
    - Lower shift factor set to 95; Upper shift set to 0.
    - Low flow max (%): 100.
- REC: B/C EC.
  - Drought seasonal distribution did not change.
  - Maintenance seasonal distribution set to 0.6.
  - Wet season rules:
    - Shape factor set to 8.
    - Lower shift factor set to 95; Upper shift set to 0.
    - Low flow max (%): 130.
  - Dry season rules:
    - Shape factor set to 6.
    - Lower shift factor set to 95; Upper shift set to 0.
    - Low flow max (%): 140.

- AEC down: D EC.
  - Drought and Maintenance seasonal distributions set to 0.8.
  - Wet season rules:
    - Shape factor set to 8.
    - Lower shift factor set to 95; Upper shift set to 0.
    - Low flow max (%): 130.
  - Dry season rules:
    - Shape factor set to 4.
    - Lower shift factor set to 95; Upper shift set to 10.
    - Low flow max (%): 100.

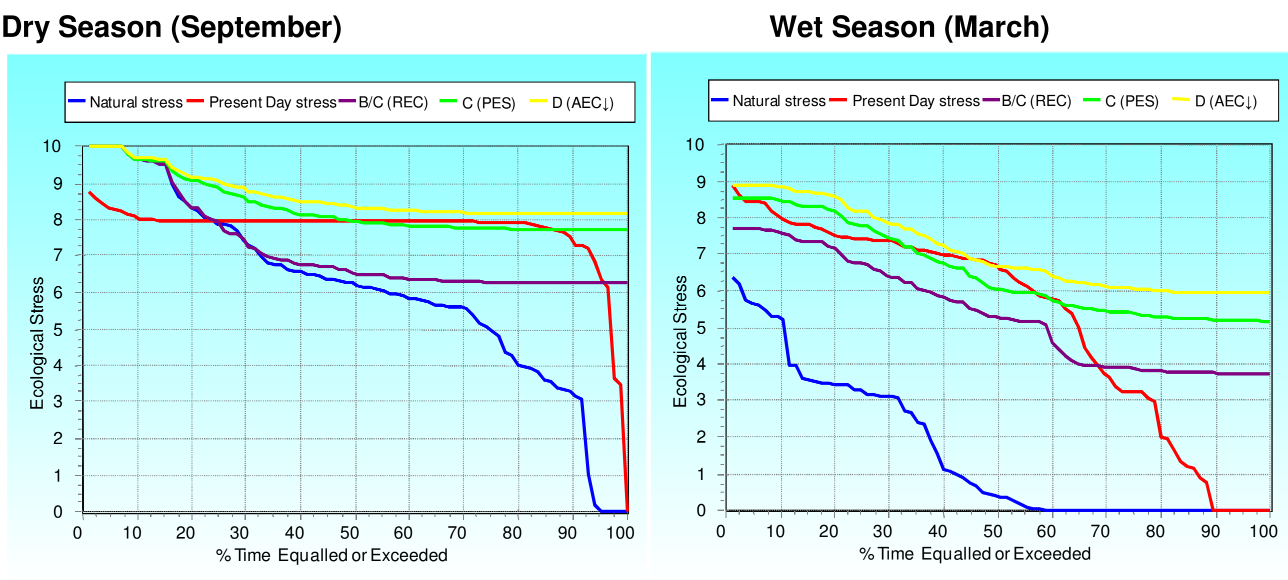


Figure 12.2 EFR O4: Final stress requirements for low flows

12.4 HIGH FLOW REQUIREMENTS

Detailed motivations provided in Table 12.5 and final high flow results are provided in Table 12.6.

Table 12.5 EFR O4: Identification of instream functions addressed by the identified floods for geomorphology and riparian vegetation

FLOOD RANGE (m3/s) FLOOD CLASS (instantaneous peak)	Geomorphology & riparian vegetation motivation	Fish flood functions						Invertebrate flood functions				Riverine fauna		
		Migration cues & spawning	Migration habitat (depth etc)	Clean spawning substrate	Create nursery areas	Resetting water quality	Inundate vegetation for spawning	Breeding and hatching cues	Clear fines	Scour substrate	Reach or inundate specific areas	Scour lower zone habitats	Create floodplain habitats	Invigorate riparian vegetation habitats
60-70	**Riparian Veg:** Required to inundate 50% on average, of marginal and lower zone obligates (mainly Gomphostigma virgatum and Phragmites australis) and activates (just reaches the lower limit of) the Salix mucronata population. Prevents the establishment of terrestrial and exotic species (especially Prosopis glandulosa of flood mortalities were recorded within the limits of this flood class) in the marginal and lower zones. Required during growing season (spring to summer: Nov - Jan).	✓	✓	□	□	□	□	✓	✓	✓	✓	✓		
170	**Geomorphic:** Regular wet season flushes to remove fines and activate small gravel material. This flow class transport about 8% of the fines at the site and will thus scour accumulated fines from the active channel bed.	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		□
340	**Riparian:** Required to flood marginal (completely inundates G. virgatum) and lower zone riparian species (about 60% of S. mucronata and P. australis flooded at 140 m3/s, and S. mucronata completely flooded at 200 m3/s). This will facilitate recruitment opportunities at higher levels, but create flooding disturbance at the lower limits which also maintains open habitats and vegetative patchiness. At the upper end of this flood, P. australis may be removed in small isolated patches at its lower limits, an important change towards better conditions. This flood class also inundates a small proportion of the current population of P. glandulosa, but more importantly has resulted in flood-induced mortality of P. glandulosa that were growing lower down. Required during summer (Nov - Jan). **Geomorphic: S**couring flood to remove fines and activate gravels. This flow class transports more than 15% of the fines at the site and is an important flood for scouring and fines removal. Some scour of low bars and the bed will occur with these flows.	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓

FLOOD RANGE (m3/s) FLOOD CLASS (instantaneous peak)	Geomorphology & riparian vegetation motivation	Fish flood functions						Invertebrate flood functions				Riverine fauna		
		Migration cues & spawning	Migration habitat (depth etc)	Clean spawning substrate	Create nursery areas	Resetting water quality	Inundate vegetation for spawning	Breeding and hatching cues	Clear fines	Scour substrate	Reach or inundate specific areas	Scour lower zone habitats	Create floodplain habitats	Invigorate riparian vegetation habitats
450-600	**Riparian Veg:** Activation of the Tamarix usneoides population. Important for removing Prosopis species, especially on lower zone (as was observed in the field) and also to scour marginal and lower zone habitats and maintain open patches. Needed in the growing season (Jan to Mar). **Geomorphic:** This is an important small scour flow for gravels and fines. The flood class is responsible for more than 10% of the sand and small gravel transport, so this will scour the bed and low bars.	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓
1000+	**Riparian Veg:** Large and infrequent flood to inundate about 50% of the T. usneoides population. Important to maintain T. usneoides recruitment. Also begins inundation of Searsia pendulina (up to 0.7m, which, in general is also where the tree line starts). These floods will facilitate recruitment and vigour of upper zone woody species, but also prevent their encroachment into the lower zone. Similarly, these floods are also useful for preventing terrestrialisation and expansion of exotic species such as P. galndulosa and causing flow in ephemeral back channels where sediments need to be moved and vegetation cleared. **Geomorphic:** This flood class transports more than 30% of the fines and more than 40% of the small gravels, acting as the present day effective discharge for fines and small gravels. Gravels and some larger elements will be mobilised and thus inhibit embeddedness. This flood class occurred almost annually under natural conditions.	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓

The number of high flow events required for each EC is provided in Table 12.6. The availability of high flows was verified using the observed data at gauge D8H003/13.

Table 12.6 EFR O4: The recommended number of high flow events required

FLOOD RANGE (m^3/s)	INVERTEBRATES	FISH	VEGETATION	GEOMORPHOLOGY	FINAL* (No of events)	MONTHS	DAILY AVERAGE(m^3/s)	DURATION
PES: C								
60-70	3		4		4	Dec	60	5
170	1	3		3	3	Nov, Dec, Jan	170	6
340	1:3	1	1	1	1	Feb	340	8
450-600			1:2	1:2	1:2	Mar	500	12
1000+			1:5	1:3	1:3		-	-
REC: B/C								
60-70	3	3	4		4	Dec	60	5
170	1	3		3	3	Nov, Dec, Jan	170	6
340	1:3	1	1	1	1	Feb	340	8
450-600			1:2	1:2	1:2	Mar	500	12
1000+			1:5	1:3	1:3		-	-
AEC↓: D								
60-70	1	2	2		2		60	5
170	1			2	2	Nov, Jan	170	6
340			1	1	1	Feb	340	8
450-600			1:2	1:2	1:2	Mar	500	12
1000+			1:5	1:3	1:3		-	-

* Final refers to the agreed on number of events considering the individual requirements for each component.
**Refers to frequency of occurrence, i.e. the flood will occur once in three years.

12.5 FINAL FLOW REQUIREMENTS

The low and high flows were combined to produce the final flow requirements for each EC as:

- An EFR table, which shows the results for each month for high flows and low flows separately (Table 12.7 – 12.9). Floods with a high frequency are not included in the modelled results as they cannot be managed.
- An EFR rule table which provides the recommended EFR flows as a duration table, linked to a natural trigger (natural modelled hydrology in this case). EFR rules are supplied for total flows as well as for low flows only (Table 12.10 – 12.12).

The low flow EFR rule table is useful for operating the system, whereas the EFR table must be used for operation of high flows.

Table 12.7 EFR O4: EFR table for PES: C

Desktop version:		2	Virgin MAR (MCM)	103351.1
BFI	0.312	Distribution type		Vaal
MONTH	LOW FLOWS		HIGH FLOWS	
	Maintenance (m^3/s)	Drought (m^3/s)	Daily average (m^3/s) on top of base flow	Duration (days)
OCTOBER	12.783	0		
NOVEMBER	18.34	0	170	6
DECEMBER	20.708	2.233	60 170	5 6
JANUARY	25.928	2.319	170	6
FEBRUARY	35.255	7.875	340	8
MARCH	35.235	7.856	500	12
APRIL	30.393	3.854		
MAY	21.409	4.829		
JUNE	15.308	3.498		
JULY	11.408	2.639		
AUGUST	10.311	2.356		
SEPTEMBER	10.034	0		
TOTAL MCM	646.3	97.7	439.1	
% OF VIRGIN	6.25	0.94	4.25	
Total IFR	1085.5			
% of MAR	10.5			

Table 12.8 EFR O4: EFR table for REC: B/C

Desktop version:		2	Virgin MAR (MCM)	103351.1
BFI	0.312	Distribution type		Vaal
MONTH	LOW FLOWS		HIGH FLOWS	
	Maintenance (m^3/s)	Drought (m^3/s)	Daily average (m^3/s) on top of base flow	Duration (days)
OCTOBER	22.199	0		
NOVEMBER	30.049	0	170	6
DECEMBER	33.18	2.233	60 170	5 6
JANUARY	40.414	2.319	170	6
FEBRUARY	53.819	12.333	340	8
MARCH	53.311	12.303	500	12
APRIL	46.751	3.854		
MAY	34.152	5.081		
JUNE	25.848	5.478		
JULY	20.294	4.133		
AUGUST	18.773	2.356		
SEPTEMBER	18.54	0		
TOTAL MCM	1039.8	130.2	439.1	
% OF VIRGIN	10.1	1.26	4.25	
Total IFR	1478.92			
% of MAR	14.31			

Table 12.9 EFR O4: EFR table for AEC↓: D

Desktop version:		2	Virgin MAR (MCM)	103351.1
BFI	0.312	Distribution type		Vaal
MONTH	LOW FLOWS		HIGH FLOWS	
	Maintenance (m^3/s)	Drought (m^3/s)	Daily average (m^3/s) on top of base flow	Duration (days)
OCTOBER	6.363	0		
NOVEMBER	9.13	0	170	6
DECEMBER	10.309	2.233		
JANUARY	12.907	2.319	170	6
FEBRUARY	17.55	6.276	340	8
MARCH	17.54	6.272	500	12
APRIL	15.13	3.854		
MAY	10.658	3.811		
JUNE	7.621	2.725		
JULY	5.679	2.031		
AUGUST	5.133	1.835		
SEPTEMBER	4.995	0		
TOTAL MCM	321.7	81.8	387.9	
% OF VIRGIN	3.11	0.79	3.8	
Total IFR	709.6			
% of MAR	6.9			

Table 12.10 EFR O4: Assurance rules for PES: C

```
Desktop Version 2, Printed on 2010/11/05
Summary of IFR rule curves for: EFRO4 Natural Flows
Determination based on defined BBM Table with site specific assurance rules.
Regional Type: Vaal     PES = C

Data are given in m3/s mean monthly flow
% Points
Month     10%      20%      30%      40%      50%      60%      70%      80%      90%      99%
Oct    18.927   18.675   18.198   17.333   15.852   13.492   10.084    5.827    1.688    0.000
Nov    57.741   52.179   46.926   41.387   31.962   25.570   17.583    9.487    3.514    0.000
Dec    72.078   63.462   55.516   47.320   34.552   26.293   17.409    9.971    5.545    4.425
Jan    70.583   62.303   54.184   45.173   32.261   22.852   14.108    7.922    4.790    4.068
Feb   146.798  122.512  100.934   79.747   51.969   36.569   24.104   16.465   13.024   12.277
Mar   143.662  138.431  127.394  108.778   83.896   57.826   36.723   23.790   17.966   16.700
Apr    42.016   40.453   37.157   31.597   24.165   16.379   10.077    6.214    4.475    4.096
May    29.914   29.105   27.412   24.443   20.141   15.084   10.384    7.060    5.376    4.988
Jun    21.732   21.280   20.353   18.682   16.081   12.663    8.987    5.908    4.077    3.613
Jul    16.449   16.194   15.686   14.760   13.236   11.012    8.233    5.417    3.339    2.726
Aug    15.297   15.125   14.799   14.207   13.195   11.581    9.251    6.340    3.510    2.438
Sep    12.402   12.289   12.088   11.734   11.119   10.076    8.364    5.720    2.113    0.000

Reserve flows without High Flows
Oct    18.927   18.675   18.198   17.333   15.852   13.492   10.084    5.827    1.688    0.000
Nov    26.382   25.894   24.924   23.156   20.243   15.995   10.687    5.307    1.337    0.000
Dec    29.357   28.684   27.304   24.819   20.951   15.867   10.397    5.819    3.094    2.405
Jan    36.161   35.070   32.786   28.781   22.976   16.154    9.814    5.328    3.057    2.533
Feb    48.810   47.134   43.598   37.634   29.663   21.311   14.550   10.406    8.541    8.135
Mar    48.782   47.107   43.571   37.609   29.639   21.289   14.529   10.387    8.521    8.116
Apr    42.016   40.453   37.157   31.597   24.165   16.379   10.077    6.214    4.475    4.096
May    29.914   29.105   27.412   24.443   20.141   15.084   10.384    7.060    5.376    4.988
Jun    21.732   21.280   20.353   18.682   16.081   12.663    8.987    5.908    4.077    3.613
Jul    16.449   16.194   15.686   14.760   13.236   11.012    8.233    5.417    3.339    2.726
Aug    15.297   15.125   14.799   14.207   13.195   11.581    9.251    6.340    3.510    2.438
Sep    12.402   12.289   12.088   11.734   11.119   10.076    8.364    5.720    2.113    0.000
```

Natural Duration curves

Oct	617.290	332.064	230.880	156.915	96.778	68.504	49.507	27.274	11.092	0.000
Nov	905.096	654.931	482.554	354.171	236.273	209.336	152.365	119.425	40.860	0.000
Dec	1002.860	704.824	522.461	396.565	321.263	280.369	194.437	95.456	63.937	4.734
Jan	1252.087	913.206	628.491	503.655	376.613	288.986	208.748	153.655	77.326	24.190
Feb	2063.864	1293.461	898.313	539.790	424.611	305.035	260.007	213.802	119.444	29.882
Mar	1577.203	1023.167	701.430	596.027	472.200	331.343	242.742	190.181	116.629	31.851
Apr	906.879	629.217	411.092	322.631	281.034	241.238	171.188	117.909	67.948	21.323
May	352.830	259.244	192.753	127.412	104.600	78.995	66.577	42.641	28.902	5.619
Jun	188.345	136.535	87.346	72.380	58.627	51.979	39.182	30.687	18.326	9.340
Jul	144.710	97.420	86.962	63.045	43.037	34.353	28.491	22.073	14.490	10.215
Aug	145.128	108.639	79.648	58.830	44.194	30.727	21.408	16.637	11.036	5.238
Sep	218.835	114.934	75.656	54.063	38.171	28.546	20.455	10.683	2.218	0.000

Table 12.11 EFR O4: Assurance rules for REC: B/C

Desktop Version 2, Printed on 2010/11/05
Summary of IFR rule curves for: EFRO4 Natural Flows
Determination based on defined BBM Table with site specific assurance rules.
Regional Type: Vaal REC = B/C

Data are given in m^3/s mean monthly flow

% Points

Month	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	31.766	31.447	30.704	29.141	26.200	21.373	14.701	7.399	1.800	0.000
Nov	74.473	69.078	63.966	58.310	48.043	39.468	27.617	14.645	4.699	0.000
Dec	86.512	77.922	69.818	60.962	46.615	35.624	23.222	12.514	6.096	4.514
Jan	85.724	78.848	71.898	63.615	50.112	38.119	24.586	12.902	5.899	4.173
Feb	163.354	142.077	122.406	102.019	72.867	54.170	36.795	24.502	18.278	16.843
Mar	161.737	157.177	147.634	130.898	106.645	78.140	51.650	32.909	23.419	21.231
Apr	61.069	59.224	55.363	48.591	38.778	27.243	16.525	8.942	5.102	4.217
May	44.994	44.266	42.629	39.424	34.059	26.559	18.097	10.790	6.411	5.332
Jun	34.071	33.550	32.377	30.081	26.237	20.865	14.802	9.568	6.431	5.658
Jul	29.066	28.816	28.233	27.005	24.697	20.908	15.672	9.940	5.546	4.289
Aug	26.878	26.632	26.059	24.852	22.582	18.855	13.705	8.068	3.746	2.509
Sep	26.715	26.506	26.061	25.162	23.454	20.449	15.694	9.267	2.218	0.000

Reserve flows without High Flows

Oct	31.766	31.447	30.704	29.141	26.200	21.373	14.701	7.399	1.800	0.000
Nov	42.999	42.567	41.562	39.445	35.465	28.930	19.900	10.015	2.437	0.000
Dec	43.684	42.929	41.228	37.900	32.328	24.540	15.750	8.162	3.614	2.493
Jan	53.204	52.277	50.189	46.103	39.263	29.702	18.913	9.597	4.015	2.639
Feb	70.452	68.578	64.656	57.777	47.808	36.092	25.204	17.501	13.601	12.701
Mar	69.789	67.935	64.055	57.251	47.392	35.803	25.034	17.415	13.557	12.667
Apr	61.069	59.224	55.363	48.591	38.778	27.243	16.525	8.942	5.102	4.217
May	44.994	44.266	42.629	39.424	34.059	26.559	18.097	10.790	6.411	5.332
Jun	34.071	33.550	32.377	30.081	26.237	20.865	14.802	9.568	6.431	5.658
Jul	29.066	28.816	28.233	27.005	24.697	20.908	15.672	9.940	5.546	4.289
Aug	26.878	26.632	26.059	24.852	22.582	18.855	13.705	8.068	3.746	2.509
Sep	26.715	26.506	26.061	25.162	23.454	20.449	15.694	9.267	2.218	0.000

Natural Duration curves

Oct	617.290	332.064	230.880	156.915	96.778	68.504	49.507	27.274	11.092	0.000
Nov	905.096	654.931	482.554	354.171	236.273	209.336	152.365	119.425	40.860	0.000
Dec	1002.860	704.824	522.461	396.565	321.263	280.369	194.437	95.456	63.937	4.734
Jan	1252.087	913.206	628.491	503.655	376.613	288.986	208.748	153.655	77.326	24.190
Feb	2063.864	1293.461	898.313	539.790	424.611	305.035	260.007	213.802	119.444	29.882
Mar	1577.203	1023.167	701.430	596.027	472.200	331.343	242.742	190.181	116.629	31.851
Apr	906.879	629.217	411.092	322.631	281.034	241.238	171.188	117.909	67.948	21.323
May	352.830	259.244	192.753	127.412	104.600	78.995	66.577	42.641	28.902	5.619
Jun	188.345	136.535	87.346	72.380	58.627	51.979	39.182	30.687	18.326	9.340
Jul	144.710	97.420	86.962	63.045	43.037	34.353	28.491	22.073	14.490	10.215
Aug	145.128	108.639	79.648	58.830	44.194	30.727	21.408	16.637	11.036	5.238
Sep	218.835	114.934	75.656	54.063	38.171	28.546	20.455	10.683	2.218	0.000

Table 12.12 EFR O4: Assurance rules for AEC↓: D

Desktop Version 2, Printed on 2010/11/05
Summary of IFR rule curves for: EFRO4 Natural Flows
Determination based on defined BBM Table with site specific assurance rules.
Regional Type: Vaal AEC DOWN = D

Data are given in m^3/s mean monthly flow
% Points

Month	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	11.698	11.606	11.412	11.018	10.270	8.954	6.872	4.058	1.165	0.000
Nov	47.442	42.319	37.838	33.512	25.749	21.281	15.107	8.349	3.168	0.000
Dec	17.057	16.787	16.179	14.988	12.996	10.210	7.067	4.353	2.727	2.326
Jan	55.147	48.828	43.132	37.305	27.912	21.664	14.615	8.528	4.880	3.981
Feb	124.010	103.806	86.382	69.935	46.492	34.505	23.366	15.485	11.495	10.575
Mar	141.555	137.452	128.864	113.803	91.977	66.324	42.485	25.620	17.080	15.111
Apr	26.789	26.050	24.502	21.787	17.853	13.230	8.933	5.893	4.354	3.999
May	18.705	18.433	17.822	16.626	14.624	11.826	8.668	5.941	4.307	3.905
Jun	12.621	12.440	12.034	11.240	9.910	8.050	5.952	4.140	3.055	2.787
Jul	9.945	9.866	9.681	9.291	8.558	7.356	5.694	3.874	2.479	2.081
Aug	9.448	9.389	9.262	9.006	8.519	7.662	6.308	4.476	2.593	1.883
Sep	9.928	9.870	9.758	9.546	9.148	8.420	7.131	4.988	1.865	0.000

Reserve flows without High Flows

Oct	11.698	11.606	11.412	11.018	10.270	8.954	6.872	4.058	1.165	0.000
Nov	15.968	15.808	15.434	14.648	13.170	10.743	7.390	3.719	0.905	0.000
Dec	17.057	16.787	16.179	14.988	12.996	10.210	7.067	4.353	2.727	2.326
Jan	22.627	22.257	21.424	19.793	17.064	13.248	8.942	5.224	2.996	2.447
Feb	31.108	30.308	28.632	25.693	21.433	16.427	11.775	8.484	6.818	6.433
Mar	31.091	30.290	28.615	25.678	21.421	16.418	11.768	8.479	6.813	6.429
Apr	26.789	26.050	24.502	21.787	17.853	13.230	8.933	5.893	4.354	3.999
May	18.705	18.433	17.822	16.626	14.624	11.826	8.668	5.941	4.307	3.905
Jun	12.621	12.440	12.034	11.240	9.910	8.050	5.952	4.140	3.055	2.787
Jul	9.945	9.866	9.681	9.291	8.558	7.356	5.694	3.874	2.479	2.081
Aug	9.448	9.389	9.262	9.006	8.519	7.662	6.308	4.476	2.593	1.883
Sep	9.928	9.870	9.758	9.546	9.148	8.420	7.131	4.988	1.865	0.000

Natural Duration curves

Oct	617.290	332.064	230.880	156.915	96.778	68.504	49.507	27.274	11.092	0.000
Nov	905.096	654.931	482.554	354.171	236.273	209.336	152.365	119.425	40.860	0.000
Dec	1002.860	704.824	522.461	396.565	321.263	280.369	194.437	95.456	63.937	4.734
Jan	1252.087	913.206	628.491	503.655	376.613	288.986	208.748	153.655	77.326	24.190
Feb	2063.864	1293.461	898.313	539.790	424.611	305.035	260.007	213.802	119.444	29.882
Mar	1577.203	1023.167	701.430	596.027	472.200	331.343	242.742	190.181	116.629	31.851
Apr	906.879	629.217	411.092	322.631	281.034	241.238	171.188	117.909	67.948	21.323
May	352.830	259.244	192.753	127.412	104.600	78.995	66.577	42.641	28.902	5.619
Jun	188.345	136.535	87.346	72.380	58.627	51.979	39.182	30.687	18.326	9.340
Jul	144.710	97.420	86.962	63.045	43.037	34.353	28.491	22.073	14.490	10.215
Aug	145.128	108.639	79.648	58.830	44.194	30.727	21.408	16.637	11.036	5.238
Sep	218.835	114.934	75.656	54.063	38.171	28.546	20.455	10.683	2.218	0.000

A comparison between the Desktop Reserve Model estimates and the EFR results in terms of percentages of natural flow are provided in Table 12.13.

Table 12.13 EFR O4: Modifications made to the DRM

Changes	PES: C		REC: B/C		AEC↓: D	
	DRM	EFR	DRM	EFR	DRM	EFR
MLIFR - Maintenance low flow	11.2%	6.3%	15.5%	10.1%	5.3%	3.1%
DLIFR - Drought low flow	2%	0.9%	2%	1.3%	2%	0.8%
MHIFR - Maintenance high flow	10%	4.2%	11%	4.2%	8.5%	3.8%
Long-term % of virgin MAR	17.4%	8.9%	20.6%	12.2%	13.2%	6.9%

13 ECOCLASSIFICATION: EFR C5 (UPPER CALEDON)

13.1 EIS RESULTS

The EIS evaluation results in a **LOW** importance. The highest scoring matrices were:

- Rare and endangered riparian species: Three IUCN listed declining species (*Crinum* sp, *Gunnera perpensa* and Eastern Freestate Sandy Grassland type);
- Aquatic instream biota – taxon richness: Approximately 28 macroinvertebrate taxa;
- Instream habitat: Sensitivity to flow changes: The river is physically small (narrow), which means that a small loss of flow will result potentially in a large habitat loss.

13.2 REFERENCE CONDITIONS

The reference conditions for the components in EFR C5 are summarised below in Table 13.1.

Table 13.1 EFR C5: Reference conditions

Component	Reference conditions	Conf
Hydrology	nMAR 56.904	2.5
Physico-chemical	See the description of Reference condition (RC) per variable in Table 16.3.	3.5
Geomorph	This reach of the river probably was a well defined channel with sand, gravel and cobble bed elements. The banks would have been well-vegetated, although cut banks along bends would be common as it was a net erosional (incising) system.	3.5
Riparian vegetation	Eastern Free State Sandy Grassland vegetation type, which occurs within the Grassland Biome and the Mesic Highveld Grassland Bioregion. Marginal zone: Would be dominated by sedge and hydrophilic grass species, with the small woody, *Gomphostigma virgatum* restricted to riffle/cobble habitats. Where the marginal zone is narrow and steep, sedges are not supported easily, and woody obligates are expected (*Salix mucronata* and *Cliffortia nitidula* mainly). Lower zone: A mix of grasses and sedges in a patchy mosaic would be expected. Where cobble and boulder have higher probability of flooding, *S.mucronata* and *G. virgatum* are expected to be fairly common. Upper zone: These zones would be grassland dominated and pockets of indigenous woody species (e.g. *Leucosidea sericea, Rhus dentata, Buddleja salvifolia, Ilex mitis*) would occur along rocky kloofs or in areas where fire is generally excluded.	3.5
Fish	Four fish species (BANO, BAEN, LCAP and ASCL) would be present at high FROC.	3
Macro-invertebrates	The reference SASS5 Score is 188 and the Average Score Per Taxon (ASPT) is 6.5. The expected number of SASS5 taxa is 29.	3

13.3 PRESENT ECOLOGICAL STATE

The PES reflects the changes in terms of the EC from reference conditions. The summarised information is provided in Table 13.2.

Table 13.2 EFR C5: Present Ecological State

Component	PES Description	EC	Conf
Hydrology	<56.904 MCM. present day MAR (<100% of nMAR). Present day MAR is close to natural as there is some use upstream.	A/B	2
Physico-chemical	See Table 13.3.	B/C	3.5
Geomorp	This is primarily attributed to the high sediment loads (sands and fines) being introduced from the eroding upstream hill slopes and associated drainage lines, and destabilisation of	C	3.5

Component	PES Description	EC	Conf
	the banks along the channel. These impacts have caused large changes to the condition of the instream habitats through reduction in cobble and gravel in-channel habitats, and loss of marginal vegetation.		
Riparian vegetation	Marginal Zone: Patchy, open boulder/cobble with *Gomphostigma virgatum* and *Salix mucronata* as woody indigenous riparian obligates. Alluvial deposits with cobble areas dominated by sedges, especially *Cyperus marginatus*. Composition is close to reference, but cover has been reduced by high grazing and trampling pressure. Reduced base flows would favour sedge establishment, but this is marginally evident due to the overriding effect of domestic stock (grazing and trampling). Because grasses are more palatable than sedges, the latter has increased at the expense of the former under the current grazing regime. Increased sediment loads do not appear to have resulted in changes to riparian vegetation as an impact on its own, but together with grazing, has favoured the establishment of *Cyperus marginatus*. Lower Zone: Portions of the lower zone are dominated by low density sedges (*C. marginatus*) and mixed with hydrophilic grasses. Grassed terraces have a high degree of trampling which has caused bank slumping and accelerated erosion. Exotic woody species occur in the zone (20% cover). Increased sediment loads do not appear to have resulted in changes to the riparian vegetation. Upper Zone: Grassland dominated, with grasses that indicate overutilization common. High cover (% aerial) by *Artemisia affra* also supports the overgrazed landuse. Woody exotic cover is high (20% aerial cover), especially where banks have been destabilized by overgrazing and trampling.	C	3.3
Fish	Two of the expected fish species (ASCL and LCAP) have disappeared from this river reach, primarily as a result of habitat deterioration. Both these species have a preference for fast habitats over rocky substrates, which have been extensively altered by sedimentation in this reach. The FROC of the two fish species presently occurring within this reach have been reduced. BAEN is also thought to have been primarily impacted by the deterioration of bottom substrates by siltation, while the impact on overhanging vegetation as cover (trampling, overgrazing, bank erosion) probably have the biggest impact on the FROC of BANO. The presence of predatory alien fish species (OMYK and STRU) is thought to be another primary impact on the fish assemblage of this reach.	D	4
Macro-invertebrates	A total of 17 SASS5 taxa was observed, out of 29 expected (i.e. 59%). The observed SASS5 score was 97 (52%), and the ASPT was 5.7 (88%). Key taxa expected but not observed included Perlidae, Heptageniidae, Dytiscidae, Caenidae, Hydracarina, Dixidae, Ecnomidae, and Lymnaeidae. Only two species of Baetidae were recorded, and only one species of hydropsychid caddisflies was recorded. The fauna was dominated by baetid mayflies (mainly *Baetis harrisoni),* and blackflies (mainly *Simulium nigritarse and S. medusaeforme).* These species are highly tolerant of water quality deterioration.	C	3

Table 13.3 EFR C5: Present Ecological State: Physico-chemical variables

RIVER	Caledon River	**WATER QUALITY MONITORING POINTS**		
		RC	Little Caledon River @ Caledonspoort (D21C; EcoRegion II: 15.03) D2H012Q01 (1975 – 1977; n = 84)	
EFR SITE	C5 (D21A; EcoRegion II: 15.03)	**PES**	1) Little Caledon River @ Caledonspoort (D21C; EcoRegion II: 15.03). D2H012Q01 (2002 – 2010; n = 47/48) 2) Data from diatom sample collection in 2008 and 2009	
Confidence assessment	Moderate confidence. Although sufficient data, data gaps exist. Data for PES are also below 60 records, and on the Little Caledon River.			
Water Quality Constituents		**RC Value**	**PES Value**	**Category/Comment**
Inorganic salts (mg/L)	TEACHA was not used for data assessment, as salinity levels not elevated.			
Salt ions (mg/L)	Ca	50.97	44.88	Concentrations similar for the PES. RC values indicate naturally elevated salinity levels for the Caledon River system.
	Cl	7.27	10.26	
	K	2.91	2.93	
	Mg	22.49	21.77	
	Na	21.16	16.09	
	SO_4	19.24	23.15	
Nutrients (mg/L)	SRP	0.018 *	0.039	B/C category
	TIN	0.060	0.134	A category
Physical Variables	pH (5^{th} + 95^{th} %ile)	7.06 and 8.09	7.8 and 8.5	A/B category
	Temperature	-	-	No data but no impacts expected.

	Dissolved oxygen	-	-	
	Turbidity (NTU)	-	Avg: 11.31 Median: 3.34 95th %ile: 30.34	No RC data. Turbid system that naturally carries sediments.
	Electrical conductivity (mS/m)	47.5 *	45.8	A category
Response variables	Chl a: periphyton (mg/m²)	-	-	-
	Chl a: phytoplankton (µg/L)	-	Avg: 1.67 (n = 3)	A category
	Macroinvertebrates	ASPT: 6.4 SASS: 174	ASPT: 5.7 SASS: 97 MIRAI: 63%	C category
	Fish community score	-	FRAI: 43%	D category
	Diatoms	-	SPI - tribs: B (avg: 14.2)	B category
Toxics	Fluoride (mg/L)	1.5 **	0.083	A category
	Aluminium (mg/L)	0.02 **	0.100 (n = 3)	C category
	Iron (mg/L)	-	0.155 (n = 3)	No guideline and insufficient data.
	Other	-	-	Impacts expected due to farming-related pesticides and fertilizer use.
OVERALL SITE CLASSIFICATION (Based on PAI model)		**B/C:80.8%**		

* Boundary value for the A category recalibrated - no data ** Benchmark value, as no data

13.3.1 Trend

The trend was also assessed. Trend refers to the situation where the responses have not yet stabilised in reaction to catchment changes. The evaluation is therefore based on the existing catchment condition. Geomorphology only indicated a negative trend and this was due to erosion that will still increase with resulting increased sedimentation. This however did not affect the other components which were all stable (Table 13.7). It must be noted that riparian vegetation is largely stable because grazing prevents exotic vegetation from increasing.

13.3.2 EFR C5: PES causes and sources

The reasons for changes from reference conditions must be identified and understood. These are referred to as causes and sources (http://cfpub.epa.gov/caddis/). The PES for the components at EFR C5 as well as the causes and sources for the PES are summarised in Table 13.4.

Table 13.4 EFR C5: PES causes and sources

	PES	Conf	Causes	Sources	F[1]/NF[2]	Conf
Hydrology	A/B	2	Decreased low flows.	Tributary dams and abstraction.	F	5
			Decreased small floods.	Tributary dams.		
Physico-chemical	B/C	3.5	Although this system is naturally turbid, elevated sediment levels are present due to land-use activities, particularly from the Lesotho Lowlands area. These activities also result in elevated nutrients and potential toxicant loads due to fertilizer and pesticide use.	Agriculture - Some toxicant and nutrient loading expected.	NF	3.5
Geom	C	3.5	Increased sediment yields from catchment	Clearing of catchment for cultivation; high grazing pressure.	NF	3.5

	PES	Conf	Causes	Sources	F[1]/NF[2]	Conf
			Bank destabilization.	Grazing/trampling, tree removal, high fine loads deposited over more stable original cobble beds due to increased sediment yields.		
Riparian vegetation	C	3.3	Reduced vegetation cover and abundance.	Grazing and trampling	NF	5
			Species compositional changes.	Perennial (15% average) and annual (5% average) exotic species.		
Fish	D	4	Decreased overhanging vegetation as cover for fish.	Agriculture – bank erosions	NF	3.5
			Deterioration of substrate as habitat (clogging interstitial spaces, loss of important spawning habitats, etc.).	Bank erosion and extensive overgrazing.		
			Decreased substrate quality related to increased benthic growth.	Agriculture: increased nutrients and organics.		
			Impact on species with requirement for high water quality.	Over grazing, human settlements and agriculture.		
			Decreased species diversity and abundance (especially small species).	Presence of aggressive alien predatory species.		
			Increased turbidity and disturbed bottom substrates.	Erosion (agriculture).		
			Presence of migration barriers reduces migration success (breeding, feeding and dispersal) of some species.	Small barriers in tributaries and larger weirs downstream of site in Caledon River.		
Macro-invertebrates	C	3	Increased sedimentation.	Farming activities (crops).	NF	3
			Increased nutrient loads.	Livestock.		

1: Flow related 2: Non Flow related

The major issues that have caused the change from reference conditions are increased nutrients, exotic vegetation, sedimentation and exotic fish. The dominant factor seems to be the increased sedimentation.

13.3.3 PES EcoStatus

To determine the EcoStatus, the macroinvertebrates and fish results are combined to determine an instream category. The instream and riparian categories are integrated to determine the EcoStatus. Confidence is used to determine the weight which the EC should carry when integrating into an EcoStatus (riparian, instream and overall). The EC percentages are provided (Table 13.5) as well as the portion of those percentages used in calculating the EcoStatus.

Table 13.5 MRU A/B: EFR C5: Instream

INSTREAM BIOTA	Importance Score	Weight
FISH		
1.What is the natural diversity of **fish** species with different flow requirements	1	80
2.What is the natural diversity of **fish** species with a preference for different cover types	2	100
3.What is the natural diversity of **fish** species with a preference for different flow depth classes	2	100
4. What is the natural diversity of **fish** species with various tolerances to modified water quality	0.5	50
MACROINVERTEBRATES		

1. What is the natural diversity of **invertebrate** biotopes	3	70
2. What is the natural diversity of **invertebrate** taxa with different velocity requirements	4	100
3. What is the natural diversity of **invertebrate** taxa with different tolerances to modified water quality	3	70
Fish	D	
Macroinvertebrates	C	
Confidence rating for instream biological information	3.6	
INSTREAM ECOLOGICAL CATEOGORY	**D**	
Riparian vegetation	C	
Confidence rating for riparian vegetation zone information	3.3	
ECOSTATUS	**C**	

13.4 RECOMMENDED ECOLOGICAL CATEGORY (REC): C/D

The determination of the REC was based on ecological criteria only and considered the EIS, the restoration potential and the attainability there-of. The EIS was LOW, and therefore the REC was to maintain the PES in a C/D.

13.5 ALTERNATIVE ECOLOGICAL CATEGORY (AEC↓): D

The main causes for the PES were non-flow related and therefore an improved AEC of the PES was not considered (i.e., increased flows will not improve). An AEC down (AEC↓) was assessed:

- Decreased flows due to increased abstraction.
- Increased sedimentation due to continued erosion.
- Reduced flows will result in reduced dilution which will impact on water quality variables such as temperature and oxygen.
- Habitat loss for a large percentage of time.
- Vegetation – increased sedges due to increased sedimentation.

Each component was adjusted to indicate the metrics that would react to the scenarios. The rule based models are available electronically and summarised in Table 13.6.

Table 13.6 EFR C5: AEC↓

	PES	AEC↓	Comments	Conf
Physico-chemical	B/C	C	Reduced flows will result in lower dilution capacities, thereby increasing the impact of toxicants available in the system. Slightly higher sediment loads are expected, as well as increased temperatures and reduced oxygen concentrations. Nutrient conditions will deteriorate; the extent of increases depending on how much flows are reduced and for how long.	4
Geomorph	C	C/D	This scenario would cause further in-channel sedimentation and exacerbate the smothering of cobbles and gravels in the channel.	3
Riparian vegetation	C	C	Marginal and Lower Zones: Reduced flows are unlikely to influence survival of current adult woody population, but will reduce recruitment probabilities (already low due to browsing goats). G. *virgatum* is a cobble-loving species, so with increased sedimentation and loss of this substrate, this species may reduce in cover and abundance (small change). *C. marginatus* is likely to be favoured by additional sediments (geomorphology trend with reduced flows) and will increase from this perspective, although grazing and trampling pressure is likely to mitigate this increase. This species has a cover which is already higher than expected under reference due to reduced flows and increased sediments and this trend is likely to continue. As sedges increase, species composition will also change.	2.9

	PES	AEC↓	Comments	Conf
Fish	D	E	If flows are decreased, habitats and water quality will further deteriorate, and it can be expected that especially BAEN will be further impacted by this deterioration of their required habitats (especially due to loss of quality of rocky substrates in fast habitats).	3
Macroinvertebrates	C	C/D	Lower flows are likely to cause deterioration in water quality, so macro invertebrate taxa sensitive to water quality deterioration are likely to disappear. In addition, the suitability of substrates is expected to decrease through increased growth of benthic algae. Most taxa recorded at the site are tolerant of water quality, so biomonitoring scores are unlikely to drop dramatically. The only taxon that is expected to disappear under this scenario is Leptophlebiidae. In addition, the overall biodiversity is expected to drop through loss of taxa such as Empididae and Hydraenidae. The total number of SASS5 taxa is expected to drop to 14. The overall SASS score is expected to be 60, and the ASPT 4.3.	2

The above information indicates that the fish will decrease to an E as it is already in a very low D EC. It was therefore decided that any further abstraction will decrease the fish EC and EFR scenario for this will not assessed.

13.6 SUMMARY OF ECOCLASSIFICATION RESULTS

Table 13.7 EFR C5: Summary of EcoClassification results

Driver Components	PES	Trend	AEC↓
IHI HYDROLOGY	A/B		
WATER QUALITY	B/C		C
GEOMORPHOLOGY	C	-	C/D
INSTREAM IHI	B/C		
RIPARIAN IHI	C		
Response Components	**PES**	**Trend**	**AEC↓**
FISH	D	0	E
MACRO INVERTEBRATES	C	0	C/D
INSTREAM	D	0	D
RIPARIAN VEGETATION	C	0	C
ECOSTATUS	C/D		D
EIS	LOW		

14 EFR C5 (UPPER CALEDON) – DETERMINATION OF STRESS INDICES

Stress indices were set for fish and macroinvertebrates to aid in the determination of low flow requirements. The stress index describes the consequences of flow reduction on flow dependant biota. It therefore describes the habitat conditions for fish and macroinvertebrates indicator species for various low flows. These habitat conditions for different flows and the associated habitat conditions are rated from 10 (zero flows) to 0, which is optimum habitat for the indicator species.

14.1 INDICATOR SPECIES OR GROUP

14.1.1 Fish indicator group: Large semi - rheophilic species (BAEN)

See 5.1.1

14.1.2 Macro invertebrate indicator group: Leptophlebiidae

Leptophlebiidae (*Adenophlebia auriculata* and *Choroterpes elegans*) are flow dependent (FDI) mayflies that prefer moderate to slow currents with cobble substrates. The minimum depth requirements for these taxa are 10 cm, and maximum depths are about 20 cm. The optimal current speeds are 0.2 to 0.3 m/s. These taxa are sensitive to deterioration in water quality, and are expected to be affected if average current speeds drop below 0.2 m/s.

14.2 STRESS FLOW INDEX

A stress flow index was generated for every component, and describes the progressive consequences to the flow dependent biota of flow reduction. The stress flow index is generated in terms of habitat response and biotic response and is discussed below.

14.2.1 Habitat response

The habitat flow index is described separately for fish and macroinvertebrates as an instantaneous response of habitat to flow in terms of a 0 – 10 index relevant for the specific site where:

- 0 - Optimum habitat (fixed at the natural maximum base flow which is based on the 10% annual value using separated natural baseflows).
- 10 – Zero discharge (Note: Surface water may still be present).

The instantaneous response of fish and invertebrate breeding habitat, abundance, cover, connectivity, and water quality are derived by considering (amongst others) rated velocity depth classes (in terms of abundance) to flow changes based on a 0 (VD class absent) - 5 (VD class very abundant).

Fish and invertebrate habitat is then rated separately according to a 0 (no habitat) – 5 (optimum occurrence of habitat).

14.2.2 Biota response

The biota stress index is the instantaneous response of biota to change in habitat (and therefore flow), based on a scale of 0 – 10 where:

- 0 = Optimum habitat with least amount of stress possible for the indicator groups at the site (fixed at the natural maximum baseflow in the same way as for the habitat response).
- 10 = No flow (there can still be surface water in pools). The biota response will depend on the indicator groups present, i.e. rheophilics will have left whereas semi-rheophilics will still be present and survive.

The instantaneous response of fish and invertebrate breeding habitat, abundance, cover, connectivity, and water quality are derived by considering (amongst others) rated velocity depth classes (in terms of abundance) to flow changes based on a 0 (VD class absent) - 5 (VD class very abundant).Fish and invertebrate habitat is then rated separately according to a 0 (no habitat) – 5 (optimum occurrence of habitat).

14.2.3 Integrated stress curve

The integrated stress curve represents the highest stress for either fish or macroinvertebrates at a specific flow.

The species stress discharges in Table 14.1 indicate the discharge evaluated by specialists to determine the biota stress. The highest discharge representing a specific stress is used to define the integrated stress curve. Figure 14.1 illustrates this graphically.

In this specific case, the LSR fish stress index represents the integrated stress index (these values are the highest flow for a stress) for stress 0 – 10, therefore the blue curve (representing the LSR stress index) is lying 'beneath' the integrated stress line (black) (Figure 14.1).

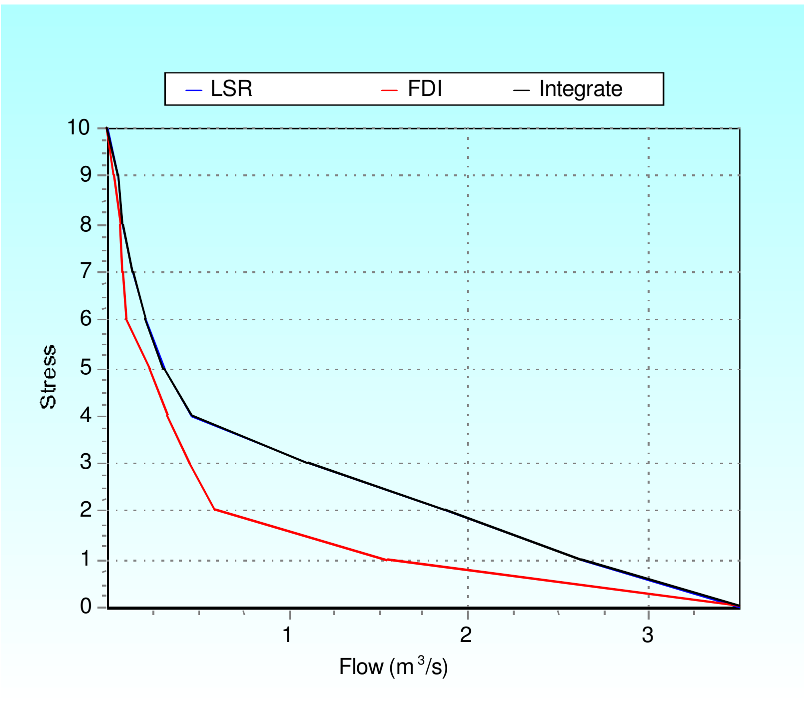


Figure 14.1 EFR C5: Species stress discharges used to determine biotic stress

Table 14.1 EFR C5: Species stress discharges used to determine biotic stress

Stress	Flow (m^3/s)		Integrated Flow (m^3/s)
	LSR	FDI	
0	1.3	1.3	1.3
1	2.625	1.55	2.625
2	1.873	0.6	1.873
3	1.109	0.457	1.109
4	0.467	0.34	0.467
5	0.311	0.24	0.311
6	0.217	0.11	0.217
7	0.147	0.086	0.147
8	0.093	0.067	0.093
9	0.06	0.044	0.06
10	0.001	0.001	0.001

Table 14.2 provides the summarised biotic response for the integrated stresses.

Table 14.2 EFR C5: Integrated stress and summarised habitat/biotic responses

Integrated stress	Flow (m^3/s)	Driver (fish/inverts/both)	Habitat and/or Biotic responses
0	1.3	Fish	Habitat suitability for semi-rheophilic fish guild optimal for all criteria (spawning habitat, nursery habitat, abundance, cover, connectivity and water quality) evaluated.
1	2.6	Fish	Connectivity good while the rest of criteria (nursery habitat, abundance, cover, connectivity and water quality) optimal for semi-rheophilic fish guild.
2	1.9	Fish	In terms of habitat suitability for large semi-rheophilic fish guild, all criteria in good condition while nursery habitats that are still optimal.
3	1.1	Fish	In terms of habitat suitability for large semi-rheophilic fish guild, all criteria in moderate condition while water quality and nursery habitats are still rated as good.
4	0.5	Fish	In terms of habitat suitability for large semi-rheophilic fish guild, all criteria are of moderate suitability.
5	0.3	Fish	In terms of habitat suitability for large semi-rheophilic fish guild, all criteria in moderate condition while connectivity is rated as low (poor).
6	0.2	Fish	In terms of habitat suitability for large semi-rheophilic fish guild, all criteria are of low suitability, while nursery habitats are still of moderate condition.
7	0.2	Fish	In terms of habitat suitability for large semi-rheophilic fish guild, all criteria in very low condition while water quality and nursery habitats are still rated as low.
8	0.090	Fish	In terms of habitat suitability for large semi-rheophilic fish guild, all criteria in very low condition while nursery habitats are still rated as low.
9	0.060	Fish	In terms of habitat suitability for large semi-rheophilic fish guild, all criteria are of very low suitability.
10	0.001	Fish	Habitat not suitable for any of the criteria assessed (spawning habitat, nursery habitat, and abundance, cover, connectivity and water quality) for the large-semi-rheophilic fish guild.

15 EFR C5: UPPER CALEDON - DETERMINATION OF EFR SCENARIOS

15.1 ECOCLASSIFICATION SUMMARY OF EFR C5

EFR C5 (Upper Caledon River)

EIS: LOW.
Highest scoring metrices are rare and endangered riparian species, instream biota's taxon richness, and sensitive instream habitat (to flow changes).

PES: C/D
Grazing and trampling, bank erosion, sedimentation, exotic vegetation and fish species.

REC:C/D
EIS is low - provides no motivation for improvement. The problems are also all non-flow related.

AEC ↓: D
Decreased flows due to increased abstraction. Reduced dilatation - impact temperature and oxygen. Increased sedimentation (continued erosion). Habitat loss for a large percentage of time. Vegetation – increased sedges due to increased sedimentation

Driver Components	PES	Trend	AEC↓
IHI HYDROLOGY	A/B		
WATER QUALITY	B/C		C
GEOMORPHOLOGY	C	-	C/D
INSTREAM IHI	B/C		
RIPARIAN IHI	C		
Response Components	**PES**	**Trend**	**AEC↓**
FISH	D	0	E
MACRO INVERTEBRATES	C	0	C/D
INSTREAM	D	0	D
RIPARIAN VEGETATION	C	0	C
ECOSTATUS	C/D		D
EIS	LOW		

15.2 HYDROLOGICAL CONSIDERATIONS

The wettest and driest months were identified as March and September. Droughts are set at 95% exceedance (flow) and 5% exceedance (stress). Maintenance flows are set at 40% exceedance (flow) and at 60% exceedance (stress).

15.3 LOW FLOW REQUIREMENTS (IN TERMS OF STRESS)

The integrated stress index was used to identify required stress levels at specific durations for the wet and dry month/season.

15.3.1 Low flow (in terms of stress) requirements

The fish and macroinvertebrate flow requirements for different ECs are provided in Table 15.1 and graphically illustrated in Figure 15.1. The results are plotted for the wet and dry season on stress duration graphs and compared to the Desktop Reserve Model (DRM) low flow estimates for the same range of ECs. The stress requirements (as a 'hand drawn line') are illustrated in Figures15.1.

For easier reference the range of ECs are colour coded in the tables and figures:
PES and REC: Green

Summarised motivations for the final requirements are provided in Table 15.2.

Table 15.1 EFR C5: Species and integrates stress requirements as well as the final integrated stress and flow requirement

Duration	LSR stress	Integrated stress	FDI stress	Integrated stress	FINAL* (Integrated stress)	FLOW (m^3/s)
PES and REC: C/D ECOSTATUS			**FISH: D**		**MACROINVERTEBRATES: C**	
DRY SEASON						
5%	8.4	8.4	8.5	9.1	8.4	0.08
30%	7.9	7.9	6.5	8.1	7.9	0.1
60%	6.5	6.5	5.6	6.9	6.5	0.18
WET SEASON						
5%	7	7	5	5.7	6**	0.15
30%	4.8	4.8	4.4	5.1	4.8	0.35
60%	4	4	1.7	3.4	4***	0.5

* Final refers to the final stress selected as the EFR requirement, usually the lowest integrated stress
**A final integrated stress of 6 rather than 5.7 was selected as an integrated stress of 5.7 is higher than natural
***A much higher LSR confidence motivated for using the LSR requirement as the final requirement

DRY SEASON (SEPTEMBER) **WET SEASON (MARCH)**

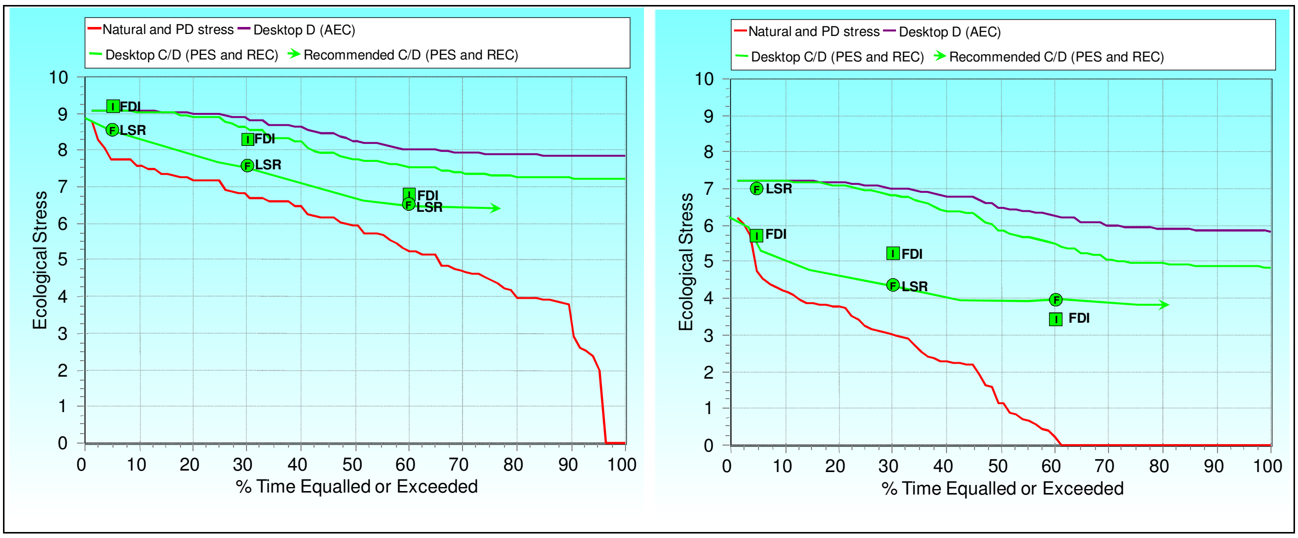


Figure 15.1 EFR C5: Stress duration curve for a PES and REC

Table 15.2 EFR C5: Summary of motivations

Month	% Stress duration	Component stress	Integrated stress	Flow m^3/s	Comment
PES: EcoStatus C/D			**FISH: D**		**MACROINVERTEBRATES: C**
Sep	5% drought	8.4 LSR	8.4	0.08	Habitat to maintain abundance, cover, connectivity and water quality are of very low suitability. Only slightly lower than PD in terms of the optimal habitats for this guild and adequate to maintain the PES during dry season droughts.
	60% maintenance	6.5 LSR	6.5	0.18	Habitat to maintain abundance, cover, connectivity and water quality during the dry season will be of moderate to poor suitability Only slightly lower than PD.
Mar	5% drought	5.7 FDI	6	0.15	A stress of 5.0 was recommended for FDI, but according to the available hydrology this was more than natural. A higher stress was used. If higher confidence hydrology becomes available, this should be reviewed.

Month	% Stress duration	Component stress	Integrated stress	Flow m^3/s	Comment
	60% maintenance	4 LSR	4	0.5	Habitat suitability moderate and adequate to allow this fish guild to remain within the PES in the wet season.

15.3.2 EFR C5 Riparian Vegetation Verification of Low Flow Requirements

The low flow requirements, set by the instream biotic components were checked (and modified if necessary) to ensure that it catered for any riparian vegetation (specifically marginal). This verification is summarised in Table 15.3.

Table 15.3 EFR C5: Verification of low flow requirements for instream biota to maintain riparian vegetation in the required EC.

PES and REC: C/D					
Species	**Season**	**Q**	**Average Inundation/Height above water level (m)**		**Note**
			Lower limit	**Upper limit**	
Cyperus marginatus	Dry drought	0.08	0.14	1.06	These flows will result in high levels of water stress with some mortality, particularly of younger individuals.
Gomphostigma virgatum			0.32	0.71	
Salix mucronata			0.89	1.43	
Cyperus marginatus	Dry (30%)	0.11	0.12	1.04	These flows result in periods of high stress for marginal and lower zone vegetation, but survival will be sufficient. EC remains C.
Gomphostigma virgatum			0.30	0.70	
Salix mucronata			0.87	1.41	
Cyperus marginatus	Dry (60%)	0.17	0.10	1.01	These flows result in periods of high stress for marginal and lower zone vegetation, but survival will be sufficient and a small proportion of *C. marginatus* remains inundated. EC remains a C EC.
Gomphostigma virgatum			0.28	0.67	
Salix mucronata			0.84	1.38	
Cyperus marginatus	Wet drought	0.15	0.10	1.02	These flows will result in high levels of water stress with some mortality, particularly of younger individuals. Reproductive output will be reduced dramatically with non-development or abortion of fruiting structures if flows persist.
Gomphostigma virgatum			0.29	0.68	
Salix mucronata			0.85	1.39	
Cyperus marginatus	Wet (30%)	0.35	0.04	0.96	Survival of marginal and lower zone vegetation is ensured, with some inundation of the sedge population. *S. mucronata* may not recruit under these flows, but this is currently the situation at the site due to browsing of seedlings.
Gomphostigma virgatum			0.22	0.62	
Salix mucronata			0.79	1.33	
Cyperus marginatus	Wet (60%)	0.50	0.01	0.93	Sufficient to sustain summer (growing) season water requirements for growth, reproduction and recruitment, although flows are lower than originally determined which means that class 1 floods will additionally be important to maintain vegetation status. These flows, together with the 30% flows and class 1 floods are likely to result in the AEC down for riparian vegetation being achieved, which is still an EC of C (69%, down from 76.6%).
Gomphostigma virgatum			0.20	0.59	
Salix mucronata			0.76	1.30	
Conclusions: Low flow requirements for instream fauna will suffice to maintain the EC for riparian vegetation in a C class, although the percentage score has dropped, provided that class I floods are provided. Riparian zone structure and					

PES and REC: C/D					
Species	Season	Q	Average Inundation/Height above water level (m)		Note
			Lower limit	Upper limit	
functionality will remain unchanged from current as a result of flow (especially since the major impacts are non-flow related).					

15.3.3 Final low flow requirements

To produce the final results, the DRM results for the specific category were modified according to specialists' requirements (Figure 15.2). There are a range of options one can use to make these modifications, such as changing the total volume required for the year, specific monthly volumes, either drought or maintenance flow durations, seasonal distribution and changing the category rules and shape factors. The following changes were required:

- PES and REC: C/D EC.
- Maintenance and drought seasonal distributions changed to 0.75 and 0.2 respectively.
- Most shape factors set to 8 with Mar set at 6 and Apr at 7.
- Most upper shift factors set to 98 with Feb/Mar/Apr set at 100.
- Note that revised approach using separated baseflows for the natural and PD stress curves were used for this site.
-

Dry Season (September) **Wet Season (March)**

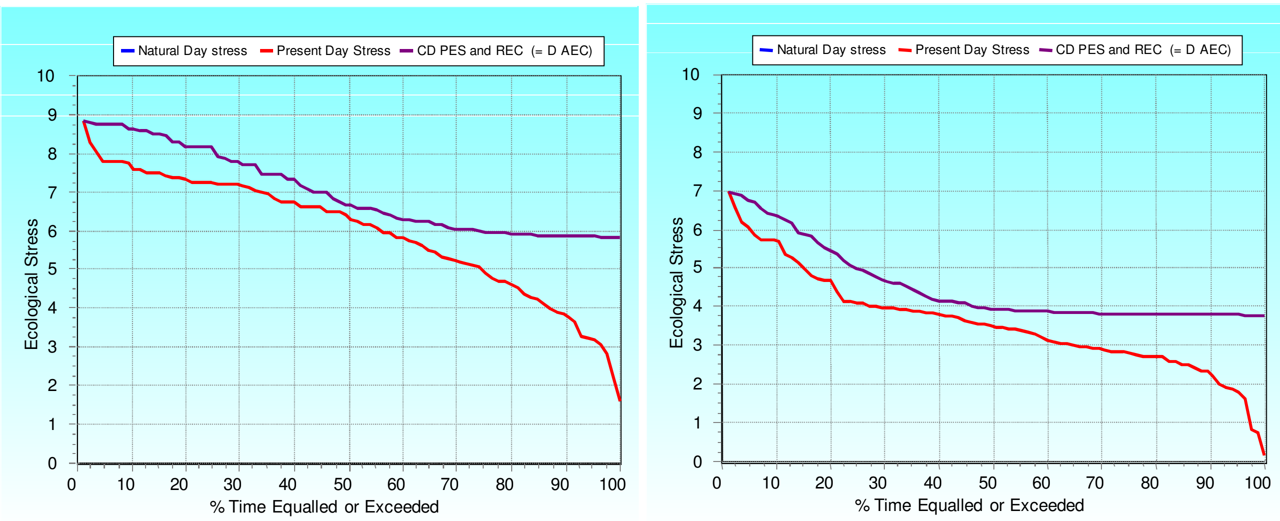


Figure 15.2 EFR C5: Final stress requirements for low flows

15.4 HIGH FLOW REQUIREMENTS

Detailed motivations are provided in Table 15.4 and final high flow results provided in Table 15.5.

Table 15.4 EFR C5: Identification of instream functions addressed by the identified floods for geomorphology and riparian vegetation

FLOOD RANGE (m^3/s) (instantaneous peak)	Geomorphology & riparian vegetation motivation	Fish flood functions						Invertebrate Flood Functions			
		Migration cues & spawning	Migration habitat (depth etc.)	Clean spawning substrate	Create nursery areas	Resetting water quality	Inundate vegetation for spawning	Breeding and hatching cues	Clear fines	Scour substrate	Reach or inundate specific areas
3-5	**Geomorphic:** Regular wet season flushes to remove fines and activate gravels. These flows transport about 30% of the fines and gravels at the site.	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
7-10	**Riparian Veg:** Required to inundate marginal zone vegetation (75% of *G. virgatum* population and 50% *C. marginatus* population). Prevents establishment of terrestrial species in the marginal zone. Required during growing season (spring to summer, 3-5 days). **Geomorphic:** Scouring flood to remove fines and activate gravels. This flow class transports more than 25% of the fines and gravels at the site, and is the effective discharge for the site.	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
15-20	**Riparian Veg:** Required to flood marginal zone and wet lower portion of lower zone. Prevents establishment of terrestrial species in lower portions of lower zone. Activates (wets) lower limit of *S. mucronata* which will create recruitment opportunities. Required during late summer. **Geomorphic:** Annual scouring event that flushes fines, scours the bed and scours gravels and cobbles.	✓	✓	✓	✓	✓	✓				
35-45	**Riparian Veg:** Required to inundate lower zone: Inundates about 50% of *S. mucronata* population, and reaches the start of the lower limit of *L. sericea*. Maintains overall patchiness of different vegetation lifeforms, prevents domination of macro-channel features by woody species, and reduces terrestrialisation on upper zone bars.	✓	✓	✓	✓	✓	✓				

The number of high flow events required for each EC is provided in Table 15.5. The high flows could not be checked as no observed daily data was available because there was no flow gauge near the site.

Table 15.5 EFR C5: The recommended number of high flow events required

FLOOD RANGE (m^3/s)	INVERTEBRATES	FISH	VEGETATION	GEOMORPHOLOGY	FINAL* (No of events)	MONTHS	DAILY AVERAGE(m^3/s)	DURATION
PES and REC: C/D								
3 - 5	3	4		4	2	Nov, Apr	2.5	3
7 - 10	2	2	4	2	4	Nov, Dec, Jan, Feb	5	4
15 - 20		1	1:1	1:1	1:1	March	10	5
35 - 45			1:3		1:3**	Summer or late summer	N/S	N/S

* Final refers to the agreed on number of events considering the individual requirements for each component
**Refers to frequency of occurrence, i.e. the flood will occur once in three years.
N/S Not Specified.

15.5 FINAL FLOW REQUIREMENTS

The low and high flows were combined to produce the final flow requirements for each EC as:

- An EFR table, which shows the results for each month for high flows and low flows separately (Table 15.6) Floods with a high frequency are not included in the modelled results as they cannot be managed.
- An EFR rule table which provides the recommended EFR flows as a duration table, linked to a natural trigger (natural modelled hydrology in this case). EFR rules are supplied for total flows as well as for low flows only (Table 15.7).

The low flow EFR rule table is useful for operating the system, whereas the EFR table must be used for operation of high flows.

Table 15.6 EFR C5: EFR table for PES and REC: C/D

Desktop version:		2	Virgin MAR (MCM)	56.904
BFI	0.333	Distribution type		Vaal
MONTH	LOW FLOWS		HIGH FLOWS	
	Maintenance (m^3/s)	Drought (m^3/s)	Daily average (m^3/s) on top of base flow	Duration (days)
OCTOBER	0.18	0.052		
NOVEMBER	0.248	0.058	2.5 5	3 4
DECEMBER	0.246	0.101	5	4
JANUARY	0.288	0.135	5	4
FEBRUARY	0.357	0.112	5	4
MARCH	0.365	0.15	10	5
APRIL	0.35	0.149	2.5	3
MAY	0.275	0.132		
JUNE	0.22	0.124		
JULY	0.17	0.101		
AUGUST	0.152	0.086		
SEPTEMBER	0.15	0.066		
TOTAL MCM	7.86	3.33	6.46	
% OF VIRGIN	13.82	5.85	11.35	
	14.32			
	25.17			

Table 15.7 EFR C5: Assurance rules for PES and REC: C/D

Desktop Version 2, Printed on 2010/11/02
Summary of IFR rule curves for: EFRC5 Natural Monthly Flows
Determination based on defined BBM Table with site specific assurance rules.
Regional Type: Vaal PES and REC = D

Data are given in m^3/s mean monthly flow
% Points

Month	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	0.280	0.273	0.259	0.234	0.198	0.154	0.111	0.078	0.060	0.053
Nov	1.576	1.319	1.099	0.894	0.601	0.452	0.307	0.197	0.135	0.113
Dec	1.186	1.010	0.859	0.714	0.507	0.394	0.285	0.202	0.155	0.101
Jan	1.252	1.075	0.921	0.773	0.561	0.442	0.327	0.239	0.190	0.153
Feb	1.408	1.243	1.096	0.952	0.727	0.594	0.442	0.302	0.203	0.158
Mar	1.610	1.587	1.543	1.463	1.332	1.139	0.888	0.613	0.376	0.217
Apr	0.754	0.741	0.715	0.668	0.595	0.495	0.382	0.278	0.204	0.170

May	0.429	0.420	0.402	0.369	0.322	0.264	0.209	0.166	0.142	0.134
Jun	0.343	0.337	0.323	0.299	0.264	0.222	0.181	0.149	0.132	0.125
Jul	0.266	0.261	0.250	0.232	0.206	0.174	0.143	0.120	0.107	0.102
Aug	0.237	0.233	0.223	0.207	0.183	0.153	0.125	0.103	0.091	0.087
Sep	0.234	0.229	0.218	0.200	0.173	0.141	0.109	0.085	0.072	0.067

Reserve flows without High Flows

Oct	0.280	0.273	0.259	0.234	0.198	0.154	0.111	0.078	0.060	0.053
Nov	0.386	0.376	0.355	0.320	0.267	0.204	0.143	0.096	0.069	0.060
Dec	0.383	0.375	0.357	0.327	0.281	0.227	0.174	0.133	0.111	0.101
Jan	0.449	0.440	0.420	0.386	0.336	0.275	0.216	0.171	0.146	0.137
Feb	0.571	0.561	0.540	0.504	0.447	0.370	0.282	0.200	0.143	0.117
Mar	0.603	0.596	0.581	0.555	0.512	0.449	0.367	0.277	0.199	0.157
Apr	0.560	0.551	0.533	0.500	0.449	0.380	0.301	0.228	0.177	0.153
May	0.429	0.420	0.402	0.369	0.322	0.264	0.209	0.166	0.142	0.134
Jun	0.343	0.337	0.323	0.299	0.264	0.222	0.181	0.149	0.132	0.125
Jul	0.266	0.261	0.250	0.232	0.206	0.174	0.143	0.120	0.107	0.102
Aug	0.237	0.233	0.223	0.207	0.183	0.153	0.125	0.103	0.091	0.087
Sep	0.234	0.229	0.218	0.200	0.173	0.141	0.109	0.085	0.072	0.067

Natural Duration curves

Oct	4.051	1.919	1.004	0.541	0.418	0.299	0.235	0.179	0.131	0.078
Nov	6.617	5.015	3.156	1.971	1.335	0.544	0.417	0.336	0.201	0.120
Dec	5.585	3.890	2.606	1.837	1.098	0.612	0.411	0.343	0.202	0.101
Jan	6.459	5.615	3.360	2.083	1.471	0.806	0.474	0.358	0.243	0.153
Feb	8.428	5.907	3.848	3.084	2.488	1.550	0.653	0.587	0.372	0.215
Mar	6.705	5.578	4.432	3.502	2.535	1.680	1.113	0.624	0.441	0.217
Apr	5.359	4.059	3.225	2.211	1.551	1.262	0.833	0.691	0.455	0.359
May	2.662	1.744	1.441	0.956	0.683	0.575	0.474	0.414	0.291	0.228
Jun	1.937	0.938	0.710	0.563	0.440	0.394	0.347	0.313	0.201	0.150
Jul	0.803	0.538	0.467	0.414	0.340	0.280	0.250	0.213	0.157	0.105
Aug	0.803	0.538	0.414	0.302	0.254	0.220	0.187	0.168	0.119	0.093
Sep	1.184	0.490	0.363	0.289	0.224	0.201	0.170	0.139	0.116	0.081

A comparison between the Desktop Reserve Model estimates and the EFR results in terms of percentages of natural flow are provided in Table 15.8.

Table 15.8 EFR C5: Modifications made to the DRM

Changes	PES and REC: C/D	
	DRM	EFR
MLIFR - Maintenance low flow	5.1	13.8
DLIFR - Drought low flow	4.8	5.8
MHIFR - Maintenance high flow	8.6	11.4
Long-term % of virgin MAR	14.5%	26%

16 ECOCLASSIFICATION: EFR C6 (LOWER CALEDON)

16.1 EIS RESULTS

The EIS evaluation results in a **LOW** importance. The highest scoring matrix was:

- Riparian rare and endangered species: One IUCN listed declining species (*Crinum* sp). Vegetation type predominantly Upper Gariep alluvial vegetation which has a conservation status of "vulnerable".

16.2 REFERENCE CONDITIONS

The reference conditions for the components in EFR C6 are summarised below in Table 16.1

Table 16.1 EFR C6: Reference conditions

Component	Reference conditions	Conf
Hydrology	nMAR 1347.96.	3
Physico-chemical	See the description of RC per variable in Table 19.3	3.5
Geomorphology	Under RC (100 – 200 years ago), this reach of the river probably was a well defined braided channel with sand and gravel bed. The banks would have been relatively well-vegetated, with poorly vegetated more dynamic low-lying active channel braid and lateral bars.	3
Riparian vegetation	The site exists within the Grassland Biome (but is close to the Grassland/Nama-Karoo Ecotone) and the Dry Highveld Grassland Bioregion, and the riparian zone is surrounded by the Besemkaree Koppies Shrubland Vegetation type. The riparian zone itself however is classified as an azonal vegetation type, the Upper Gariep Alluvial Vegetation type. Marginal zone: Expected to be dominated by sedge and hydrophilic grass species, with the small woody i.e. *G. virgatum* restricted to riffle habitats. Where the marginal zone is narrow and steep and does not support sedges easily, woody obligates expected (*S. mucronata*). Lower zone: A mix of grasses and sedges in a patchy mosaic is expected. Where cobble and boulder have higher probability of flooding, *G. virgatum* is expected to be fairly common, with *S. mucronata* common along alluvial bars. Reeds should be locally dominant, but overall patchy and not the main alluvial vegetation type. Upper zone: It is expected that alluvial terraces and channel banks be dominated by riparian woody thickets, with dominant species being *Acacia karoo, Diospyros lycioides, Celtis africana and Rhus pyroides*. A mix of hydrophilic and terrestrial grasses also expected in-between. Reeds are not expected to dominate the upper zone.	3.5
Fish	Eight indigenous fish species have a high probability of occurrence.	3
Macro-invertebrates	The reference SASS5 score is 113 and the ASPT is 5.9. The expected number of SASS5 taxa is 19.	2

16.3 PRESENT ECOLOGICAL STATE

The PES reflects the changes in terms of the Ecological Category (EC) from reference conditions. The summarised information is provided in Table 16.2.

Table 16.2 EFR C6: Present Ecological State

Component	PES Description	EC	Conf
Hydrology	1134.6 MCM. Present day MAR (84.1% of nMAR)	E	1.5
Physico-chemical	See Table 19.3.	C	4
Geomorphology	High sediment loads (sands and fines) being introduced from the eroding upstream hill slopes and drainage lines, bottom release flushes (from Welbedacht Dam) during low flows. Sedimentation of the lower riparian zone and smothering of the instream habitats through reduction in deep areas and gravels.	C/D	3.5

Component	PES Description	EC	Conf
Riparian vegetation	Marginal zone: Mostly open cobble/boulder and alluvial deposits. Scour damage from recent floods is high. Sedges and *G. virgatum* are sparse and a mix of *P. australis* and *S. mucronata* dominates steeper alluvial banks. Lower zone: Extensive new alluvial deposits in the lower zone (clear evidence of smothered existing vegetation), with some open bedrock. Recolonisation by grasses especially prevalent, but sedges also occur). Upper zone: Alluvial terraces are similar to the lower zone. Channel banks are dominated by woody vegetation, mainly *D. lycioides, Olea europea africana* and *R. pyroides.*	B	3.7
Fish	Loss of some FS and FD habitat as a result of flow modification, loss of SD due to sedimentation of pools, loss of rocky bottom substrates as a result of sedimentation, water quality deterioration (especially increased turbidity levels). Loss of marginal zone overhanging vegetation furthermore reduces cover for especially BANO and BPAU. The presence of the bottom feeding alien CCAR can especially be detrimental in this reach due to the already altered bottom substrates (sedimentation) and high turbidity. This species can lead to further deterioration in bottom substrates and increased turbidity. Potential presence of predatory alien species (OMYK) may further impact on indigenous fish species. The presence of some complete migratory obstructions (Gariep Dam and Welbedacht Dam) as well as various smaller dams/weirs reduces migration success of species with requirement for movement between reaches.	D	3
Macro-invertebrates	A total of 10 SASS5 taxa was observed, out of 19 expected (i.e. 53%). The observed SASS5 score was 52 (46%), and the ASPT was 5.2 (87%). Key taxa expected but not observed included Heptageniidae, Elmidae, Coenagrionidae, Caenidae and Leptophlebiidae. Gomphidae were notably scarce, despite the abundance of suitable sediments. Only one species of Hydropsychid caddisflies recorded. Abundance of all taxa very low, with no taxon exceeding 100 specimens per sample (i.e. >B abundance).	D	2

Table 16.3 EFR C6: Present Ecological State: Physico-chemical variables

RIVER	Caledon River	**WATER QUALITY MONITORING POINTS**	
		RC	Caledon River @ Jammerdrift (D23G; EcoRegion II: 11.03) D2H001Q01 (1976 – 1979; n = 92)
EFR SITE	C6 (D24J; EcoRegion II: 26.03)	**PES**	1) Caledon River @ Kommissiedrift (D24G; EcoRegion II: 11.10) D2H036Q01 (2000 – 2010; n = 90 - 96) 2) Weldam Raw (Bloem Water intake: **labelled BW**) (D23J; EcoRegion II: 11.03) (2001 – 2010; n = 230. 3) Data from Slabbert (2007)
Confidence assessment	Moderate – High confidence.		

Water Quality Constituents		RC Value	PES Value	Category/Comment
Inorganic salts (mg/L)	TEACHA was not used for data assessment, as salinity levels not elevated.			
Salt ions (mg/L)	Ca	34.3	40.96; BW: 34.3	Limited data, but concentrations similar for the PES.
	Cl	6.85	16.15; BW: 18.61	
	K	7.59	3.67; BW: 3.45	
	Mg	16.00	22.5; BW: 14.37	
	Na	15.74	24.9; BW: 25.66	
	SO_4	21.63	25.79; BW: 24.18	
Nutrients (mg/L)	SRP	0.018*	0.037; BW: 0.05	B/C category
	TIN	0.45*	0.188 (n = 89); BW: 0.74	B category C category
Physical Variables	pH (5th + 95th %ile)	6.67 and 7.58	7.44 and 8.40 BW: 6.68 and 8.11	A/B category
	Temperature	-	-	No data but some impacts expected downstream Welbedacht Dam.
	Dissolved oxygen	-	-	
	Turbidity (NTU) [WMS: n = 90] [BW: n = 60]	-	**WMS** / **BW** Avg: 249 / 429 Median: 45.75 / 332 95th%ile: 1 027 / 987	No RC data. Highly turbid system although naturally carries sediments.
	Avg: 4 186 50th %ile: 3066 95th %ile: 10862.3	-	Very high levels recorded in the 1970s.	Suspended solids (mg/L)

	Electrical conductivity (mS/m)	35.3*	37.94	A category
Response variables	Chl a: phytoplankton (µg/L)	-	6.7	A category (Slabbert, 2007)
	Macroinvertebrates	ASPT: 5.9 SASS: 113	ASPT: 5.2 SASS: 52 MIRAI: 57	D category
	Fish community score	-	FRAI: 55%	D category
	Diatoms	-	SPI - tribs: B (avg: 14.05) SPI – site: A	C category (as high flows responsible for high category at site).
Toxics	Fluoride (mg/L)	1.5**	0.318 (n = 90); BW: 0.230	A category
	Ammonia (mg/L)	0.015**	0.016	A category
	Aluminium (mg/L)	0.02**	BW: 0.46	E category, but low confidence as no RC value.
	Copper (mg/L)	0.0015**	BW: 0.02	E category, but low confidence as no RC value.
	Iron (mg/L)		BW: 0.24	No RC data and no guidelines.
	Other	-	-	No other data, but impact expected due to farming-related pesticides and fertilizer use and upstream industrial inputs.
OVERALL SITE CLASSIFICATION (Based on PAI model)		**C:62.8%**		

* Boundary value for the A category recalibrated - no data ** Benchmark value, as no data

16.3.1 Trend

The trend was also assessed as stable for all components (see Table 16.7). The trend for all components were stable.

16.3.2 EFR C6: PES causes and sources

The reasons for changes from reference conditions must be identified and understood. These are referred to as causes and sources (http://cfpub.epa.gov/caddis/). The PES for the components at EFR C5 as well as the causes and sources for the PES are summarised in Table 16.4.

Table 16.4 EFR C6: PES causes and sources

	PES	Conf	Causes	Sources	F/NF	Conf
Hydro	E	1.5	Decreased base flows	Operation of Welbedacht Dam for agriculture and domestic use	F	4
			Sediment loaded flood releases	Releases to clear sediment for dam	F	
Physico-chemical	C	4	Turbidity levels are highly elevated	Poor land management.	NF	3.5
			Elevated nutrients and potential toxicant loads.	Agriculture. Upstream towns, with industrial/urban activities and poorly functioning STW. The most likely source of aluminium in is due to aluminium sulphate used in most water treatment processes as a flocculating agent for suspended solids.		
			Impact on temperature & oxygen levels.	Bottom releases (Welbedacht Dam).	F	
Geomorph	C/D	3.5	Increased sediment yields from catchment.	Agriculture.	NF	3
			Back up effects of Welbedacht Dam.	Backup of dam.	NF	
			Bottom releases from Welbedacht Dam.	Sediment slugs released during low flow periods.	F	
rian vege tatio	B	3.7	Reduced vegetation cover and abundance.	Sediment deposition (dam flushing & catchment).	NF	3.8

	PES	Conf	Causes	Sources	F/NF	Conf
			Changes to species composition.	Reduced flows and increased sedimentation.	NF	
			Reduced woody species cover in marginal zone.	Reduced base flows.	F	
Fish	D	3	Decrease in FROC and abundance of fish species with preference for fast habitats.	Decreased base flows.	F	3
			Decrease in FROC and abundance of fish species with preference for SD habitats.	Loss of SD habitats through sedimentation of pools.		
			Deterioration of spawning habitat	Bank erosion and extensive overgrazing.	F & NF	
			Decreased substrate quality increased benthic growth.	Increased nutrients and organics.	NF	
			Decreased overhanging vegetation (cover).	Increased bank erosion.		
			Decreased water quality affect species with requirement for high water quality.	High turbidity and possibly toxins (aluminum).		
			Decreased species diversity and abundance (especially small species)	Aggressive alien predatory species (OMYK & STRU).		
			Increased turbidity and disturbed bottom.	Presence of alien CCAR.		
			Reduced migration success (breeding, feeding and dispersal) of some species.	Large dam wall and small dams/weirs.		
Maco-invertebrates	D	2	Sediments (high turbidity).	Agriculture (crops).	NF	3.8
			Flow cessation.	Regulation.	F	
			A-seasonal releases.	Regulation.		

The major issues that have caused the change from reference conditions are increased nutrients, sedimentation (and associated turbidity), decreased base flows as well as presence of exotic fish. The dominant factors were increased sedimentation.

16.3.3 PES EcoStatus

To determine the EcoStatus, the macroinvertebrates and fish results are combined to determine an instream category. The instream and riparian categories are integrated to determine the EcoStatus. Confidence is used to determine the weight which the EC should carry when integrating into an EcoStatus (riparian, instream and overall). The EC percentages are provided (Table 16.5) as well as the portion of those percentages used in calculating the EcoStatus.

Table 16.5 MRU D: EFR C6: Instream

INSTREAM BIOTA	Importance Score	Weight
FISH		
1.What is the natural diversity of **fish** species with different flow requirements	2	70
2.What is the natural diversity of **fish** species with a preference for different cover types	2.5	90
3.What is the natural diversity of **fish** species with a preference for different flow depth classes	3	100
4. What is the natural diversity of **fish** species with various tolerances to modified water quality	2	70
MACROINVERTEBRATES		
1. What is the natural diversity of **invertebrate** biotopes	4	100
2. What is the natural diversity of **invertebrate** taxa with different velocity requirements	3	60
3. What is the natural diversity of **invertebrate** taxa with different tolerances to modified water quality	2	40

Fish	D
Macroinvertebrates	D
Confidence rating for instream biological information	2.6
INSTREAM ECOLOGICAL CATEOGORY	**D**
Riparian vegetation	B
Confidence rating for riparian vegetation zone information	3.7
ECOSTATUS	**C**

Riparian vegetation EC of a B is an outlier due to the protection that the locality within the Tussen-Twee-Riviere Nature Reserve provides. When setting low flows D rules should therefore be used for producing the final results.

16.4 EFR C6: REC

The REC is determined based on ecological criteria only and considers the EIS, the restoration potential and attainability there-of. The EIS was LOW, and therefore the REC was to maintain the PES in D.

16.5 AEC↑:

No AEC↓ was be evaluated as an EC lower than a D does not represent a sustainable river. An AEC↑was evaluated.

This hypothetical scenario included:

- Bottom releases taking place during the wet season and not during low flow conditions;
- Improvement of low flows;
- Limited duration of zero flows or no zero flows;
- These conditions would lead to improvement in the fish and macro invertebrate components as well as the marginal riparian vegetation zone due to an increase in G*omphostigma*.

Each component was adjusted to indicate the metrics that would react to the scenario. The rule-based models are available electronically and summarised in Table 16.6.

Table 16.6 EFR C6: AEC↑

	PES	AEC ↑	Comments	Conf
Physico-chemical	C	C	Improved low flows and no zero flows will result in a greater dilution capacity and an improvement in nutrient and toxicant loads, oxygen and temperature conditions, and probably a slight improvement in turbidity levels. Bottom releases during high flows will also result in better mixing, which will expedite the impact of bottom releases on oxygen and temperature state.	3
Geom	C/D	C	This scenario should result in an improved condition of the low flow channel through increased gravel and deep habitats and result in a slight improvement of the EC.	2.5
Fish	D	C	Improved marginal zone vegetation will create more favourable habitats and cover for species such as BANO with an expected improved FROC. Increased flows will improve the availability of FS and FD habitats, and create more favourable habitats for species such as ASCL and BKIM, for which an improved FROC can be expected.	2.5
Macro-invertebrates	D	C	Perennial flows and improved seasonality are likely to benefit flow dependent macroinvertebrates that are expected but not recorded at the site, such as Leptophlebiidae. Lower marginal vegetation is expected to improve, and this is likely to benefit Coenagrionidae. The suitability of sediments for macro invertebrate colonisation is expected to improve, so the abundance of Gomphidae is expected to increase. The total	3

	PES	AEC ↑	Comments	Conf
			number of SASS5 taxa is expected to increase to 14. The overall SASS score is expected to be 83, and the ASPT 5.9. Turbidity is expected to remain high, so instream primary productivity is expected to remain low.	

16.6 SUMMARY OF ECOCLASSIFICATION RESULTS

Table 16.7 EFR C6: Summary of EcoClassification results

Driver Components	PES	Trend	AEC↑
IHI HYDROLOGY	E		
WATER QUALITY	C		C(+)
GEOMORPHOLOGY	C/D	0	C
INSTREAM IHI	E		
RIPARIAN IHI	B/C		
Response Components	**PES**	**Trend**	**AEC↑**
FISH	D	0	C
MACRO INVERTEBRATES	D	0	C
INSTREAM	D	0	C
RIPARIAN VEGETATION	B	0	B
ECOSTATUS	C		B/C
EIS	LOW		

17 EFR C6 (LOWER CALEDON) – DETERMINATION OF STRESS INDICES

Stress indices are set for fish and macroinvertebrates to aid in the determination of low flow requirements. The stress index describes the consequences of flow reduction on flow dependant biota. It therefore describes the habitat conditions for fish and macroinvertebrates indicator species for various low flows. These habitat conditions for different flows and the associated habitat conditions are rated from 10 (zero flows) to 0, which is optimum habitat for the indicator species.

17.1 INDICATOR SPECIES OR GROUP

17.1.1 Fish indicator group: Large semi - rheophilic species (BAEN and BKIM)

As a result of the absence of any true rheophilic fish species in this system, the LSR fish guild was selected as indicator group for setting flows. This group generally requires FS, FI and FD flow-depth categories over good quality substrate (gravel and cobbles) for spawning. Egg and embryo development also takes place in these habitats, while larvae prefer SD with substrate as optimal habitats. Juvenile and adult specimens have a high preference for SD, FS, FI and FD habitats with substrate and water column as cover. Flows should furthermore remain adequate to allow migration between reaches, thus depth in riffle and rapids should remain adequate, especially during the wet season. Emphasis was placed on the requirements of the *Labeobarbus* species (BKIM and BAEN) within this group in setting flows.

Table 17.1 Summarised habitat requirements for different life stage of the large semi-rheophilic indicator group.

Species	Spawning	Egg and embryo development	Larvae	Juveniles	Adults
BAEN	Table 5.1				
BKIM	Flow habitat: **FS and FD with substrates** (Gravel, cobbles) flowing water, well oxygenated and low sediments loads. The breeding season extends from mid to late summer. The species requires **gravel beds** in flowing water to spawn.	Flow habitat: **FS and FI with substrate (gravel / cobbles).** Flows to last long enough for the embryos to develop and hatch out. The incubation period for BKIM is two to three days and larvae become mobile after a further three to four days at 23 - 25°C.	Flow habitat: **SD with substrate.**	Flow habitat: **FI and SD with substrates.**	Flow habitat: **SD, FD and FI with substrates and water column.**

17.1.2 Macro invertebrate indicator group: Hydropsychidae

Hydropsychidae are common flow-dependent (FDI) taxa that prefer fast currents with cobble substrates. The minimum depth requirements for these taxa are 10 cm, and maximum depths are about 30 cm. The optimal current speeds are 0.4 m/s. These taxa are not sensitive to deterioration in water quality, and are expected to tolerate wide fluctuations in flow and water quality conditions.

17.2 STRESS FLOW INDEX

A stress flow index is generated for every component, and describes the progressive consequences to the flow dependent biota of flow reduction. The stress flow index is generated in terms of habitat response and biotic response and is discussed below.

17.2.1 Habitat response

The habitat flow index is described separately for fish and macroinvertebrates as an instantaneous response of habitat to flow in terms of a 0 – 10 index relevant for the specific site where:

- 0 - Optimum habitat (fixed at the natural maximum base flow which is based on the 10% annual value using separated natural baseflows).
- 10 - Zero discharge (Note: Surface water may still be present).

The instantaneous response of fish and invertebrate breeding habitat, abundance, cover, connectivity, and water quality are derived by considering (amongst others) rated velocity depth classes (in terms of abundance) to flow changes based on a 0 (VD class absent) - 5 (VD class very abundant).Fish and invertebrate habitat is then rated separately according to a 0 (no habitat) – 5 (optimum occurrence of habitat).

17.2.2 Biota response

The biota stress index is the instantaneous response of biota to change in habitat (and therefore flow), based on a scale of 0 – 10 where:

- 0 = Optimum habitat with least amount of stress possible for the indicator groups ***at the site*** (fixed at the natural maximum baseflow in the same way as for the habitat response).
- 10 = Zero discharge. The biota response will depend on the indicator groups present, i.e. rheophilics will have left whereas semi-rheophilics will still be present and survive.

17.2.3 Integrated stress curve

The integrated stress curve represents the highest stress for either fish or macroinvertebrates at a specific flow.

The species stress discharges in Table 17.2 indicate the discharge evaluated by specialists to determine the biota stress. The highest discharge representing a specific stress is used to define the integrated stress curve. Figure 17.1 illustrates this graphically.

In this specific case, the LSR(blue curve) stress index represents the integrated stress index (these values are the highest flow for a stress) for stress 4 – 10, while the FDI stress index represents the integrated stress for stress 1 – 4, and is lying 'beneath' the integrated stress curve (black) Both FDI and LSR have the same stress flow relationships for the 0 – 1 stress.(Figure 17.1).

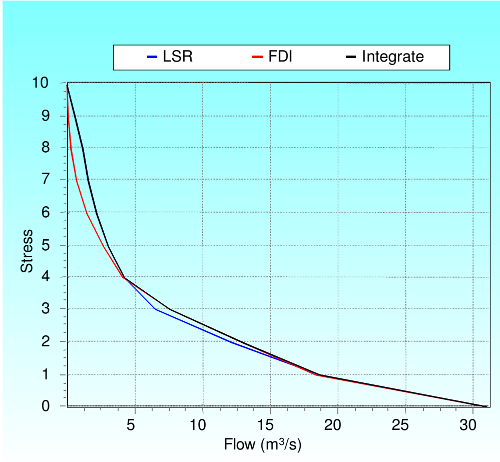


Figure 17.1 EFR C6: Component and integrated stress

Table 17.2 EFR C6: Species stress discharges used to determine biotic stress

Stress	Flow (m^3/s)		Integrated Flow (m^3/s)
	LSR	FDI	
0	31.2	31.2	31.2
1	18.9	18.5	18.9
2	12.17	13.1	13.1
3	6.6	7.7	7.7
4	4.3	4.2	4.3
5	3.11	2.8	3.11
6	2.24	1.5	2.24
7	1.58	0.7	1.58
8	1.15	0.35	1.15
9	0.6	0.14	0.6
10	0	0	0.001

Table 17.3 provides the summarised biotic response for the integrated stresses.

Table 17.3 EFR C6: Integrated stress and summarised habitat/biotic responses

Integrated stress	Flow (m^3/s)	Driver (fish/inverts/both)	Habitat and/or Biotic responses
0	31.2	Fish	Habitat suitability for LSR fish guild optimal for all criteria (spawning habitat, nursery habitat, abundance, cover, connectivity and water quality) evaluated.
1	18.9	Fish	Spawning habitat good and the rest of criteria (nursery habitat, abundance, cover, connectivity and water quality) optimal for LSR fish guild.
4	4.3	Fish	In terms of habitat suitability for LSR fish guild, all criteria in moderate condition except nursery habitats that are still good.
5	3.12	Fish	In terms of habitat suitability for LSR fish guild, all criteria in moderate condition except spawning habitat and connectivity (especially lateral) that is low.
6	2.24	Fish	In terms of habitat suitability for LSR fish guild, all criteria are of low suitability.
7	1.58	Fish	In terms of habitat suitability for LSR fish guild, all criteria are of low suitability except spawning habitat and connectivity

Integrated stress	Flow (m^3/s)	Driver (fish/inverts/both)	Habitat and/or Biotic responses
			(especially lateral) which are of very low suitability.
8	1.15	Fish	In terms of habitat suitability for LSR fish guild, all criteria are of very low suitability.
9	0.6	Fish	In terms of habitat suitability for LSR fish guild, all criteria are of very low suitability.
10	0.001	Fish	Habitat not suitable for any of the criteria assessed ((spawning habitat, nursery habitat, abundance, cover, connectivity and water quality) for the LSR fish guild.

18 EFR C6 (LOWER CALEDON) - DETERMINATION OF EFR SCENARIOS

18.1 ECOCLASSIFICATION SUMMARY OF EFR C6

EFR C6 (Lower Caledon River)

EIS: LOW
The highest scoring matrices are rare and endangered riparian species.

PES:C
Sedimentation (bank erosion), significantly reduced base flows, alien fish species.

REC:C
EIS is low - provides no motivation for improvement.

AEC ↑: B/C
Bottom releases must take place during the wet season and not during low flow conditions. Low flows must be improved. No zero flows or limited duration

Driver Components	PES	Trend	AEC↑
IHI HYDROLOGY	E		
WATER QUALITY	C		C(+)
GEOMORPHOLOGY	C/D	0	C
INSTREAM IHI	E		
RIPARIAN IHI	B/C		
Response Components	**PES**	**Trend**	**AEC↑**
FISH	D	0	C
MACRO INVERTEBRATES	D	0	C
INSTREAM	D	0	C
RIPARIAN VEGETATION	B	0	B
ECOSTATUS	C		B/C
EIS	LOW		

18.2 HYDROLOGICAL CONSIDERATIONS

The wettest and driest months were identified as March and September. Droughts are set at 95% exceedance (flow) and 5% exceedance (stress). Maintenance flows are set at 40% exceedance (flow) and at 60% exceedance (stress).

18.3 LOW FLOW REQUIREMENTS (IN TERMS OF STRESS)

The integrated stress index is used to identify required stress levels at specific durations for the wet and dry month/season.

18.3.1 Low flow (in terms of stress) requirements

The fish and macroinvertebrate flow requirements for different Ecological Categories (ECs) are provided in Table 18.1 and graphically illustrated in Figure 18.1. The results are plotted for the wet and dry season on stress duration graphs and compared to the Desktop Reserve Model (DRM) low flow estimates for the same range of ECs. The stress requirements (as a 'hand drawn line') are illustrated in Figure 18.1.

For easier reference the range of ECs are colour coded in the Tables and figures:
PES & REC (instream): Green AEC↑ (instream): Purple

Summarised motivations for the final requirements are provided in Table 18.2.

Table 18.1 EFR C6: Species and integrated stress requirements as well as the final integrated stress and flow requirement

Duration	LSR stress	Integrated stress	FDI stress	Integrated stress	FINAL* (Integrated stress)	FLOW (m³/s)
PES and REC: D INSTREAM ECOSTATUS			**FISH: D**		**MACROINVERTEBRATES: D**	
			DRY SEASON			
5%	10	10	10	10	**10**	**0**
30%	10	10	10	10	**10**	**0**
60%	9.3	9.3	7.7	9.3	**9.3**	**0.4**
			WET SEASON			
5%	8.8	8.8	7.7	9.3	**8.8**	**0.7**
30%	3.7	3.8	3	3	**3.8****	**5**
60%	1.4	1.8	2	2	**1.8**	**16**
AEC↑: C INSTREAM ECOSTATUS				**FISH: C**		**MACROINVERTEBRATES: C**
			DRY SEASON			
5%	9.5	9.5	9	9.8	**9.5**	**0.3**
30%	8.3	8.3	8	9.4	**8.3**	**1**
60%	7.4	7.4	6.5	8.2	**7.4**	**1.4**
			WET SEASON			
5%	5.1	5.1	Improved wet season flows will not improve the macroinvertebrates EC.		**5.1**	**3**
30%	2.4	2.6			**2.6**	**9.7**
60%	0.9	0.9			**0.9**	**21.4**

* Final refers to the final stress selected as the EFR requirement, usually the lowest integrated stress.

**A much higher LSR confidence motivated for using the LSR requirement as the final requirement

DRY SEASON (SEPTEMBER) **WET SEASON (MARCH)**

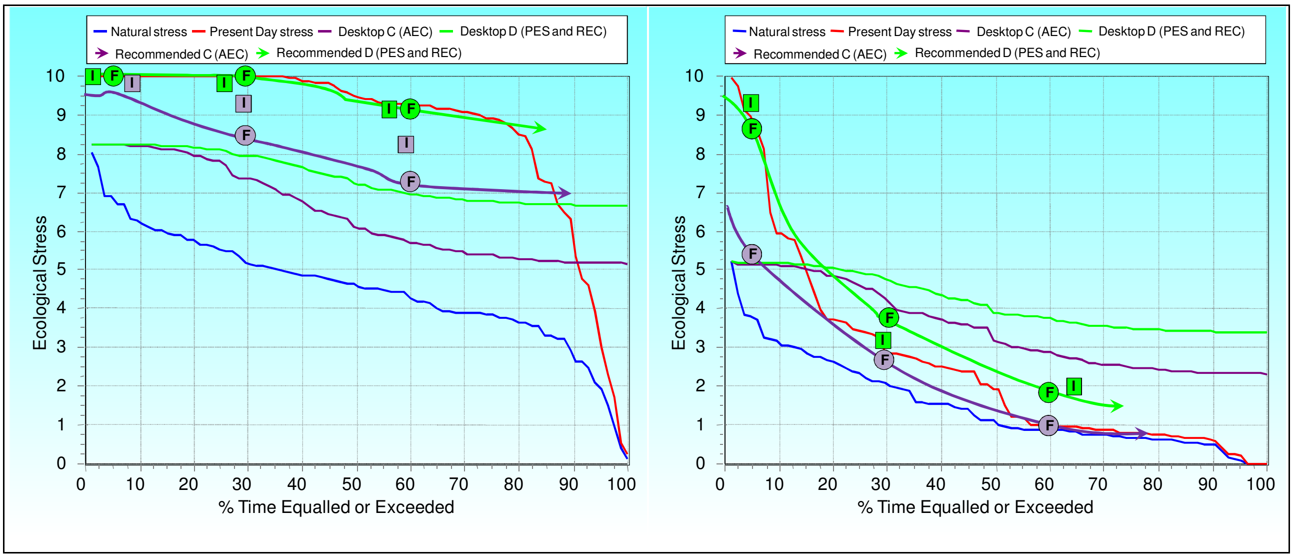


Figure 18.1 EFR C6: Stress duration curve for a PES and REC and AEC↑

Table 18.2 EFR C6: Summary of motivations

Month	% Stress duration	Component stress	Integrated stress	Flow m³/s	Comment
PES and REC: D INSTREAM ECOSTATUS				**FISH: D**	**MACROINVERTEBRATES: D**
Sep	5% drought	10 LSR	10	0	Currently zero flows occur during dry season.
	60% maintenance	9.3 LSR	9.3	0.4	Habitat suitability will be very low and may maintain a small population of LSR, while most will probably seek refuge in Gariep Dam and pools (if available). This is the scenario

Month	% Stress duration	Component stress	Integrated stress	Flow m^3/s	Comment
					occurring at the site under present flows.
Mar	5% drought	8.8 LSR	8.8	0.7	Habitat suitability poor, but similar to present day conditions and will maintain its PES for the wet season.
	60% maintenance	1.4 LSR	1.8	16	Due to the poor condition prevailing in the dry season, it is important to maintain good conditions during the wet season. At this flow, habitat suitability will be good to optimal and ensure the maintenance of LSR.
AEC↑: C INSTREAM ECOSTATUS				**FISH: C**	**MACROINVERTEBRATES: C**
Sep	5% drought	9.5 LSR	9.5	0.3	This flow will be an improvement of the zero flows occurring at present at the site, and therefore maintain some suitable habitat (although of very low quality) to allow survival of fish at the site (especially juveniles).
	60% maintenance	7.4 LSR	7.4	1.4	Although habitat suitability will still be low (poor) at this stress level, it will be a vast improvement from the present very poor habitat suitability (absence), and provide habitat for survival of a proportion of the population at the site/reach, resulting in an overall improvement in EC of the site.
Mar	5% drought	5.1 LSR	5.1	3	Further improvement towards reference flows should improve the overall habitat suitability resulting in an improved EC.
	60% maintenance	0.9 LSR	0.9	21.4	

18.3.2 EFR C6: Riparian Vegetation and Geomorphological Flow Requirements Verification of Low Flow Requirements

The low flow requirements, set by the instream biotic components were checked (and modified if necessary) to ensure that it catered for any riparian vegetation (specifically marginal) and geomorphological requirements. This verification is summarised in Table 18.3.

Base flows for Geomorphology: The proposed dry season base flow and wet season base flow are important for flushing fine sediments in the low flow channel at this cross-section and will be sufficient to achieve this.

Table 18.3 EFR C6: Verification of low flow requirements for instream biota to maintain riparian vegetation in the required EC.

PES and REC: D Instream EcoStatus					
Species	**Season**	**Q**	**Average Inundation/Height above water level (m)**		**Note**
			Lower limit	**Upper limit**	
Cyperus marginatus	Dry drought	0	1.62	2.28	High levels of water stress with some mortality, particularly of younger individuals. Extended periods of zero flows have resulted in less cover in the marginal and lower zones which is why the EC for these zones is a B while the upper zone EC is an A/B
Gomphostigma virgatum			1.38	2.99	
Salix mucronata			2.59		
Cyperus marginatus	Dry (60%)	0.4	1.01	1.67	Periods of high stress for marginal and lower zone vegetation, which is the main impact resulting in an EC of B and not better i.e. vegetation survives, but becomes reduced in vigour and density.
Gomphostigma virgatum			0.77	2.38	
Salix mucronata			1.98		
Cyperus marginatus	Wet (60%)	16	0.17	0.83	Sufficient to sustain summer (growing) season water requirements for growth and survival, but

Species	Season	Q	Average Inundation/Height above water level (m) Lower limit	Upper limit	Note
PES and REC: D Instream EcoStatus					
Gomphostigma virgatum			-0.07	1.54	will probably not support sufficient reproduction without sufficient flooding. EC drops to 83%, and although close to B/C, remains a B.
Salix mucronata			1.14		
Conclusions: Low flow requirements for instream fauna will suffice to maintain the EC for riparian vegetation, albeit with high levels of water stress in the dry season. Riparian zone structure and functionality will remain unchanged.					
AEC↑: C Instream EcoStatus					
Cyperus marginatus	Dry drought	0.12	1.16	1.82	Although plant water stress will be less than PES conditions, the EC will not change.
Gomphostigma virgatum			0.92	2.53	
Salix mucronata			2.14		
Cyperus marginatus	Dry (60%)	1.4	0.80	1.46	These flows will reduce dry season stress and result in better fecundity in the following wet season. EC improves slightly but remains a B.
Gomphostigma virgatum			0.56	2.17	
Salix mucronata			1.78		
Cyperus marginatus	Wet (60%)	21.	0.07	0.73	Sufficient to sustain summer (growing) season water requirements for growth and reproduction. EC remains B.
Gomphostigma virgatum			-0.18	1.43	
Salix mucronata			1.04		
Conclusions: EC remains within the category, but vigour is expected to improve					

18.3.3 Final low flow requirements

To produce the final results, the DRM results for the specific category were modified according to specialists' requirements (Figure 18.1). There are a range of options one can use to make these modifications, such as changing the total volume required for the year, specific monthly volumes, either drought or maintenance flow durations, seasonal distribution and changing the category rules and shape factors. The following changes were required:

Note that revised approach using separated baseflows for the natural and PD stress curves were used for this site.

Region 20 (Vaal) was applied, but with rules already modified for original Desktop run to:

- Shape factors: Set to 7 (all months).
- Upper shift: Set to 100 (all months).
- PES and REC: D EC.
  - Maintenance and drought seasonal distributions set to 8.5.
  - September upper shift set to 75; all other months adjusted.
  - September lower shift set to 15; all other months adjusted.
- AEC↑: C EC.
  - Drought seasonal distributions set to 1.56.
  - Maintenance seasonal distribution set to 3.2.

Dry Season (September) **Wet Season (March)**

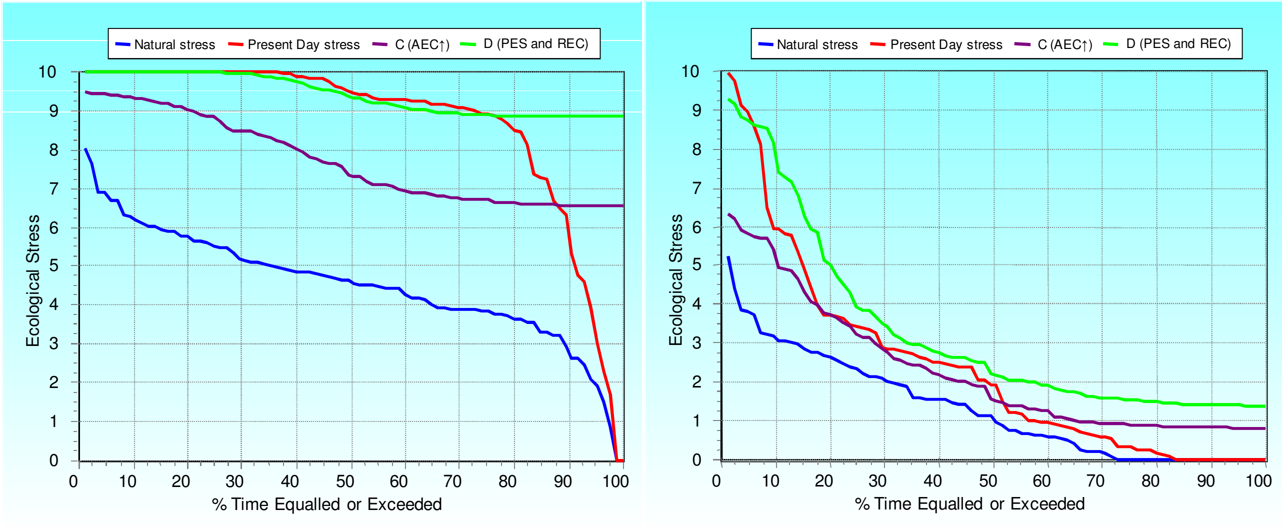


Figure 18.2 EFR C6: Final stress requirements for low flows

18.4 HIGH FLOW REQUIREMENTS

Detailed motivations provided in Table 18.4 and final high flow results are provided in Table 18.5.

Table 18.4 EFR C6: Identification of instream functions addressed by the identified floods for geomorphology and riparian vegetation

FLOOD RANGE (m^3/s) (instantaneousous peak)	Geomorphology & riparian vegetation motivation	Fish flood functions						Invertebrate Flood Functions			
		Migration cues & spawning	Migration habitat (depth etc.)	Clean spawning substrate	Create nursery areas	Resetting water quality	Inundate vegetation for spawning	Breeding and hatching cues	Clear fines	Scour substrate	Reach or inundate specific areas
50-70	**Riparian Veg:** Required to inundate marginal zone vegetation (at least 50% of both *G. virgatum* and *Cyperus marginatus* populations inundated). Prevents establishment of terrestrial species in the marginal zone and restricts reeds to form narrow bands and not extensive reed beds. Required during growing season (spring to summer, 3 - 5 days). **Geomorphic:** Regular wet season flushes to remove fines and activate gravels. These flows transport about 15% of the fines at the site.	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
100-130	**Riparian Veg:** Required to flood marginal zone and wet lower portion of lower zone. Prevents establishment of terrestrial species in lower portions of lower zone. Activates (wets) lower limit of *S. mucronata* which will create recruitment opportunities. Required during late summer. **Geomorphic:** Scouring flood to remove fines and activate gravels. This flow class transports more than 15% of the fines at the site.	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

FLOOD RANGE (m^3/s) (instantaneousous peak)	Geomorphology & riparian vegetation motivation	Fish flood functions						Invertebrate Flood Functions			
		Migration cues & spawning	Migration habitat (depth etc.)	Clean spawning substrate	Create nursery areas	Resetting water quality	Inundate vegetation for spawning	Breeding and hatching cues	Clear fines	Scour substrate	Reach or inundate specific areas
200-400	**Geomorphic:** Scouring flood to remove fines and activate gravels. This flow class transports more than 35% of the fines and gravels at the site, and is the effective discharge for the site (the flow class responsible for most sediment movement).	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
+650	**Riparian Veg:** Required to inundate upper zone terrace and ephemeral channel. Maintains overall patchiness of different vegetation life forms, prevents domination of macro-channel features by woody species, and reduces terrestrialisation on upper zone bars. **Geomorphic:** These large, infrequent scouring floods are required for the reach to reset the morphology and keep gross sedimentation in check (at the site however, it is likely to accelerate sedimentation due to backup impacts, but in this case we are considering the reach rather than the site).	✓	✓	✓	✓	✓	✓				

The number of high flow events required for each EC is provided in Table 18.5. The high flows were checked using the gauge at Welbedacht Dam. However this gauge is not ideal as it is very far upstream from the site.

Table 18.5 EFR C6: The recommended number of high flow events required

FLOOD RANGE (m^3/s)	INVERTEBRATES	FISH	VEGETATION	GEOMORPHOLOGY	FINAL* (No of events)	MONTHS	DAILY AVERAGE(m^3/s)	DURATION
PES and REC: D								
50-70	2	4	4	4	4	Nov, Dec, Jan, Feb	50	5
100-130	1	2	1:1	2	2	Jan, Feb	110	6
200-400			1:3	2:3	2:3	Mar	200	7
+650			1:5+	1:5	1:5	Summer to late summer	N/S	N/S
AEC↑:C								
FLOOD RANGE (m^3/s)	**INVERTEBRATES**	**FISH**	**VEGETATION**	**GEOMORPHOLOG Y**	**FINAL (No of events)**	**MONTHS**	**DAILY AVERAGE (m^3/s)**	**DURATION**
50-70	3	4	4	5	5	Nov, Dec (2), Jan, Feb	50	5
100-130	2	2	1:1	3	3	Jan, Feb, Mar	110	6
200-400			1:3	1:1	1:1	Mar	200	7

+650			1:5+	1:5	1:5	Summer to late summer	N/S	N/S

* Final refers to the agreed on number of events considering the individual requirements for each component.
**Refers to frequency of occurrence, i.e. the flood will occur once in three years.
N/S Not Specified.

18.5 FINAL FLOW REQUIREMENTS

The low and high flows were combined to produce the final flow requirements for each EC as:

- An EFR table, which shows the results for each month for high flows and low flows separately (Table 18.6 – 18.7). Floods with a high frequency are not included in the modelled results as they cannot be managed.
- An EFR rule table which provides the recommended EFR flows as a duration table, linked to a natural trigger (natural modelled hydrology in this case). EFR rules are supplied for total flows as well as for low flows only (Table 18.8 – 18.9).

The low flow EFR rule table is useful for operating the system, whereas the EFR table must be used for operation of high flows.

Table 18.6 EFR C6: EFR table for PES and REC: C (D Instream)

Desktop version:		2	Virgin MAR (MCM)	1348
BFI	**0.304**	**Distribution type**	**Vaal**	
MONTH	**LOW FLOWS**		**HIGH FLOWS**	
	Maintenance (m^3/s)	**Drought (m^3/s)**	**Daily average (m^3/s) on top of base flow**	**Duration (days)**
OCTOBER	1.39	0.05		
NOVEMBER	3.063	0.12	50	5
DECEMBER	3.724	0.15	50	5
JANUARY	6.027	0.24	50 110	5 6
FEBRUARY	7.814	0.3	50 110	5 6
MARCH	8.958	0.32	200	7
APRIL	7.491	0.3		
MAY	3.892	0.15		
JUNE	1.705	0.05		
JULY	0.53	0.01		
AUGUST	0.268	0		
SEPTEMBER	0.367	0		
TOTAL MCM	118.01	4.41	141.9	
% OF VIRGIN	8.76	0.33	10.52	
Total IFR	259.9			
% of MAR	19.3			

Table 18.7 EFR C6: EFR table for AEC↑: C

Desktop version:		2	Virgin MAR (MCM)	1348
BFI	**0.304**	**Distribution type**	**Vaal**	
MONTH	**LOW FLOWS**		**HIGH FLOWS**	
	Maintenance (m^3/s)	**Drought (m^3/s)**	**Daily average (m^3/s) on top of base flow**	**Duration (days)**
OCTOBER	2.888	0.48		
NOVEMBER	5.544	0.798	50	5

Desktop version:		2	Virgin MAR (MCM)	1348
BFI	0.304	Distribution type		Vaal
MONTH	LOW FLOWS		HIGH FLOWS	
	Maintenance (m^3/s)	Drought (m^3/s)	Daily average (m^3/s) on top of base flow	Duration (days)
DECEMBER	6.562	0.914	50 50	5 5
JANUARY	10.187	1.342	50 110	5 6
FEBRUARY	13.075	1.697	50 110	5 6
MARCH	14.8	1.886	110 200	6 7
APRIL	12.515	1.621		
MAY	6.826	0.945		
JUNE	3.406	0.546		
JULY	1.534	0.32		
AUGUST	1.122	0.272		
SEPTEMBER	1.3	0.297		
TOTAL MCM	208.3	29.06	176.9	
% OF VIRGIN	15.5	2.16	13.12	
Total IFR	385.18			
% of MAR	28.6			

Table 18.8 EFR C6: Assurance rules for PES and REC: D

```
Desktop Version 2, Printed on 2010/11/02
Summary of IFR rule curves for: EFRC6 Natural Monthly Flows
Determination based on defined BBM Table with site specific assurance rules.
Regional Type : Vaal     PES and REC = D

Data are given in m3/s mean monthly flow

       % Points
Month    10%      20%      30%      40%      50%      60%      70%      80%      90%      99%
Oct     2.583    2.544    2.437    2.193    1.751    1.140    0.533    0.152    0.066    0.066
Nov    14.507   12.789   11.240    9.654    7.097    5.393    3.471    1.812    0.817    0.572
Dec    15.390   13.664   12.077   10.447    7.898    6.201    4.266    2.477    1.214    0.642
Jan    40.662   34.956   30.007   25.341   18.048   14.250    9.920    5.915    3.090    1.810
Feb    47.119   40.757   35.185   29.855   21.525   16.972   11.782    6.982    3.595    2.060
Mar    43.120   42.214   40.398   37.156   32.072   25.190   17.345   10.088    4.969    2.649
Apr    13.789   13.490   12.891   11.823   10.147    7.878    5.292    2.899    1.212    0.447
May     7.164    7.009    6.697    6.142    5.270    4.090    2.746    1.502    0.624    0.226
Jun     3.138    3.070    2.933    2.688    2.304    1.785    1.193    0.645    0.259    0.084
Jul     0.981    0.963    0.923    0.845    0.715    0.532    0.327    0.149    0.042    0.016
Aug     0.498    0.490    0.469    0.421    0.334    0.214    0.095    0.020    0.003    0.003
Sep     0.682    0.677    0.648    0.565    0.400    0.187    0.036    0.004    0.004    0.004

Reserve flows without High Flows
Oct     2.583    2.544    2.437    2.193    1.751    1.140    0.533    0.152    0.066    0.066
Nov     5.668    5.567    5.340    4.894    4.148    3.106    1.929    0.914    0.305    0.155
Dec     6.855    6.706    6.409    5.878    5.045    3.917    2.631    1.442    0.603    0.223
Jan    11.094   10.854   10.372    9.512    8.163    6.338    4.257    2.331    0.974    0.358
Feb    14.383   14.071   13.446   12.331   10.581    8.212    5.511    3.014    1.252    0.453
Mar    16.489   16.131   15.413   14.132   12.123    9.403    6.303    3.436    1.413    0.496
Apr    13.789   13.490   12.891   11.823   10.147    7.878    5.292    2.899    1.212    0.447
May     7.164    7.009    6.697    6.142    5.270    4.090    2.746    1.502    0.624    0.226
Jun     3.138    3.070    2.933    2.688    2.304    1.785    1.193    0.645    0.259    0.084
Jul     0.981    0.963    0.923    0.845    0.715    0.532    0.327    0.149    0.042    0.016
Aug     0.498    0.490    0.469    0.421    0.334    0.214    0.095    0.020    0.003    0.003
Sep     0.682    0.677    0.648    0.565    0.400    0.187    0.036    0.004    0.004    0.004
```

Natural Duration curves

Oct	84.237	37.784	21.479	16.334	9.860	6.291	4.794	3.670	2.905	1.505
Nov	133.665	74.533	53.472	41.258	33.117	23.252	15.089	9.333	4.417	2.361
Dec	107.475	82.658	58.513	44.889	32.680	25.907	22.510	13.852	10.081	2.042
Jan	176.467	115.875	92.757	68.694	49.500	32.967	25.930	16.424	8.639	3.308
Feb	211.004	158.172	95.176	74.024	46.970	36.822	26.852	21.028	12.140	4.824
Mar	195.971	149.705	95.523	77.457	51.979	46.532	32.994	21.558	12.377	4.940
Apr	171.840	89.853	57.450	47.948	29.865	21.493	17.701	12.137	7.299	4.367
May	62.231	36.249	15.879	12.922	9.704	8.038	6.433	5.234	4.667	2.595
Jun	27.037	14.387	9.961	7.296	6.647	5.849	4.753	3.974	3.465	2.284
Jul	10.107	7.960	6.653	5.735	5.066	4.760	3.737	3.218	2.718	1.770
Aug	13.015	8.109	5.996	5.167	4.443	3.778	3.394	2.793	2.404	1.729
Sep	13.534	10.177	6.416	5.147	4.062	3.387	3.048	2.593	2.215	1.304

Table 18.9 EFR C6: Assurance rules for AEC↑: C

Desktop Version 2, Printed on 2010/11/02
Summary of IFR rule curves for: EFRC6 Natural Monthly Flows
Determination based on defined BBM Table with site specific assurance rules.
Regional Type: Vaal AEC UP = C

Data are given in m^3/s mean monthly flow

	% Points									
Month	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	4.100	4.020	3.859	3.572	3.123	2.514	1.820	1.178	0.725	0.519
Nov	16.688	14.902	13.255	11.560	8.908	7.130	5.104	3.229	1.907	1.308
Dec	26.384	23.042	20.090	17.227	12.752	10.201	7.292	4.601	2.704	1.844
Jan	44.024	38.268	33.219	28.374	20.800	16.622	11.859	7.453	4.345	2.936
Feb	51.290	44.866	39.171	33.622	24.947	19.927	14.206	8.913	5.180	3.488
Mar	54.780	53.671	51.448	47.480	41.257	32.833	23.229	14.347	8.081	4.940
Apr	17.759	17.402	16.686	15.407	13.402	10.687	7.593	4.731	2.712	1.797
May	9.687	9.494	9.106	8.413	7.327	5.856	4.180	2.630	1.536	1.040
Jun	4.835	4.740	4.550	4.210	3.677	2.956	2.133	1.372	0.836	0.593
Jul	2.179	2.138	2.055	1.908	1.677	1.364	1.008	0.678	0.446	0.340
Aug	1.594	1.565	1.506	1.401	1.237	1.015	0.761	0.527	0.361	0.286
Sep	1.847	1.812	1.744	1.621	1.428	1.168	0.871	0.596	0.402	0.314

Reserve flows without High Flows

Oct	4.100	4.020	3.859	3.572	3.123	2.514	1.820	1.178	0.725	0.519
Nov	7.868	7.712	7.398	6.838	5.959	4.770	3.414	2.160	1.276	0.875
Dec	9.313	9.127	8.754	8.089	7.045	5.632	4.022	2.532	1.482	1.005
Jan	14.456	14.166	13.584	12.545	10.915	8.709	6.195	3.869	2.228	1.485
Feb	18.554	18.181	17.432	16.097	14.003	11.167	7.935	4.945	2.836	1.880
Mar	21.001	20.578	19.729	18.215	15.840	12.625	8.960	5.569	3.178	2.094
Apr	17.759	17.402	16.686	15.407	13.402	10.687	7.593	4.731	2.712	1.797
May	9.687	9.494	9.106	8.413	7.327	5.856	4.180	2.630	1.536	1.040
Jun	4.835	4.740	4.550	4.210	3.677	2.956	2.133	1.372	0.836	0.593
Jul	2.179	2.138	2.055	1.908	1.677	1.364	1.008	0.678	0.446	0.340
Aug	1.594	1.565	1.506	1.401	1.237	1.015	0.761	0.527	0.361	0.286
Sep	1.847	1.812	1.744	1.621	1.428	1.168	0.871	0.596	0.402	0.314

Natural Duration curves

Oct	84.237	37.784	21.479	16.334	9.860	6.291	4.794	3.670	2.905	1.505
Nov	133.665	74.533	53.472	41.258	33.117	23.252	15.089	9.333	4.417	2.361
Dec	107.475	82.658	58.513	44.889	32.680	25.907	22.510	13.852	10.081	2.042
Jan	176.467	115.875	92.757	68.694	49.500	32.967	25.930	16.424	8.639	3.308
Feb	211.004	158.172	95.176	74.024	46.970	36.822	26.852	21.028	12.140	4.824
Mar	195.971	149.705	95.523	77.457	51.979	46.532	32.994	21.558	12.377	4.940
Apr	171.840	89.853	57.450	47.948	29.865	21.493	17.701	12.137	7.299	4.367
May	62.231	36.249	15.879	12.922	9.704	8.038	6.433	5.234	4.667	2.595
Jun	27.037	14.387	9.961	7.296	6.647	5.849	4.753	3.974	3.465	2.284
Jul	10.107	7.960	6.653	5.735	5.066	4.760	3.737	3.218	2.718	1.770
Aug	13.015	8.109	5.996	5.167	4.443	3.778	3.394	2.793	2.404	1.729
Sep	13.534	10.177	6.416	5.147	4.062	3.387	3.048	2.593	2.215	1.304

A comparison between the Desktop Reserve Model estimates and the EFR results in terms of percentages of natural flow are provided in Table 18.10.

Table 18.10 EFR C6: Modifications made to the DRM

Changes	PES and REC: D		AEC↑: C	
	DRM	EFR	DRM	EFR
MLIFR - Maintenance low flow	4.8%	8.8%	10.4%	15.5%
DLIFR - Drought low flow	4.5%	0.3%	4.5%	2.2%
MHIFR - Maintenance high flow	8.7%	10.5%	13%	13.1%
Long-term % of virgin MAR	15.6%	20.1%	20.2%	26.1%

19 ECOCLASSIFICATION: EFR K7 (LOWER KRAAI)

19.1 EIS RESULTS

The EIS evaluation results in a **MODERATE** importance. The highest scoring matrices were:

- Unique riparian biota: Rhus dentata, Leucosidea sericea, Miscanthus capensis, Lycium hirsutum and Schoenoplectus paludicolawhichare endemic to South Africa;
- Aquatic instream biota – intolerant to physico-chemical changes: *Labeo capensis* (LCAP) and *Perlidae*.

19.2 REFERENCE CONDITIONS

The reference conditions for the components in EFR K7 are summarised below in Table 19.1.

Table 19.1 EFR K7: Reference conditions

Component	Reference conditions	Conf
Hydrology	nMAR 682.50	4
Physico-chemical	See the description of Reference condition (RC) per variable in Table 19.3.	3.5
Geomorphology	Under RC (100 – 200 years ago), this reach of the river probably was a well defined pool-riffle system with a gravel/cobble bed. The lateral and braided bars would be highly mobile and cobbles and gravels would not be embedded, and the bars probably not vegetated. A series of terraces in the riparian zone could be expected to be associated with infrequent floods.	3
Riparian vegetation	The site exists within the Grassland Biome and the Dry Highveld Grassland Bioregion, and the riparian zone is surrounded by the Aliwal North Dry Grassland vegetation type. Marginal zone: Expected to be dominated by sedge and hydrophilic grass species, with a small woody, *G. virgatum* restricted to riffle habitats. Where the marginal zone is narrow and steep (and does not support sedges easily, woody obligates are expected (*S. mucronata* mainly). Lower zone: Expected to be a mix of grasses and sedges in a patchy mosaic. Where cobble and boulder have higher probability of flooding. *G. virgatum* is expected to be fairly common, with *S. mucronata* and *Cliffortia nitidula* common along alluvial bars. Reeds should be locally dominant, but overall patchy and not the main alluvial vegetation type i.e. they should not dominate. Upper zone alluvial terraces and channel banks are expected to be dominated by riparian woody thickets, with dominant species being *Acacia karoo, Diospyros lycioides, Celtis africana* and *Rhus pyroides*. A mix of hydrophilic and terrestrial grasses is also expected.	3.5
Fish	Seven indigenous fish species (ASCL, BANO, BAEN, BKIM, CGAR, LCAP and LUMB) have a high to definite probability of occurrence. ASCL was included as this species are known from localities both up- and downstream (Orange River) of the reach. The expected habitat composition at the site also met the requirements of this fish. The expected FROC provided in Kleynhans *et al*. (2007) for site D1KRAAI-CORAN, located 37 km downstream of the EFR site was broadly used to determine the reference FROC for the reach.	3
Macro-invertebrates	Reference conditions were based on professional judgment and information from the river health database. The reference SASS5 score is 123 and the ASPT is 6.2. The expected number of SASS5 taxa is 19.	2

19.3 PRESENT ECOLOGICAL STATE

The PES reflects the changes in terms of the Ecological Category (EC) from reference conditions. The summarised information is provided in Table 19.2.

Table 19.2 EFR K7: Present Ecological State

Component	PES Description	EC	Conf
Hydrology	641.3 present day MAR (94% of nMAR)	A/B	4.5
Physico-chemical	See Table 19.3	B/C	3
Geomorphology	The PES is close to RC and is only slightly modified from natural. Although base flows are slightly reduced the small farm dams and weirs upstream, and extensive agriculture in the catchment, have not had a measurable impact on the geomorphology at the site. High flows and floods are relatively unimpacted by the changes in the catchment, and the geomorphology at this site – dominated by larger cobble/gravel bed elements – is not sensitive to the small changes in base flows.	A/B	4
Riparian vegetation	Marginal zone: Mostly open cobble/boulder and some alluvial deposits. *G. virgatum, S. mucronata* and *C. marginatus* are dominant species. Lower zone: Also mostly an open cobble bed, with low vegetation cover. Dominant species are the same as the marginal zone, together with *C. dactylon* and *Sporobolis spp.* Upper zone: Alluvial terraces and banks are dominated by woody vegetation, mainly *Salix (*both indigenous and exotic*), L. hirsutum (*endemic) and *Phragmites australis.* Alien vegetation is present in all the zones – especially the upper zone.	C	4
Fish	All the expected fish species are still present in this river reach albeit in a slightly reduced FROC. The primary changes responsible for deterioration in the fish assemblage include the loss of some FS and FD habitat as a result of flow modification, possibly slight deterioration in bottom substrate habitats related to some sedimentation and benthic algal growth, water quality deterioration (especially toxins and possibly nutrients). Some loss of marginal zone overhanging vegetation furthermore reducing cover for especially BANO. The presence of the bottom feeding alien CCAR contributes to bottom substrate disturbance while the potential presence of predatory alien species may further impact on indigenous fish. Presence of small migration barriers has a further contribution to the PES.	C	3.5
Macro-invertebrates	A total of 13 SASS5 taxa was observed, out of 19 expected (i.e. 68%). The observed SASS5 score was 81 (66%), and the ASPT was 6.2 (96%). Key taxa expected but not observed included Heptageniidae, Dytiscidae, Hydracarina, Corixidae, Coenagrionidae, Oligochaeta and Ancylidae. Only two species of Baetidae were recorded, and only one species of hydropsychid caddisflies was recorded. The fauna was dominated by Chironomidae, which were very abundant (D abundance). Baetid mayflies were dominated by the highly tolerant *Baetis harrisoni,* and blackflies were dominated by the pest blackfly *Simulium damnosume).* Sensitive taxa recorded included stoneflies (Perlidae) and Leptophlebiidae. The high abundance of Chironomidae indicates organic enrichment.	C	2

Table 19.3 EFR K7: Present Ecological State: Physico-chemical variables

RIVER	Kraai River	**WATER QUALITY MONITORING POINTS**		
		RC	Kraai River @ Roodewal (D13L; EcoRegion II: 26.03) D1H011Q01 (1974 – 1977; n = 80)	
EFR SITE	K7 (D13M; EcoRegion II: 26.03)	**PES**	1) Kraai River @ Roodewal (D13L; EcoRegion II: 26.03) D1H011Q01 (2000 – 2010; n = 64 - 66) 2) Data from diatom sample collection in 2008 and 2009	
Confidence assessment	Moderate confidence. Although data is sufficient, data gaps exist. Data for PES are also below 60 records, and on the Little Caledon River.			
Water Quality Constituents		**RC Value**	**PES Value**	**Category/Comment**
Inorganic salts (mg/L)	TEACHA was not used for data assessment, as salinity levels not elevated.			
Salt ions (mg/L)	Ca	37.12	35.74	Concentrations similar or lower for the PES.
	Cl	8.22	7.92	
	K	2.32	1.50	
	Mg	17.53	15.81	
	Na	13.84	8.70	
	SO_4	12.61	13.92	
Nutrients	SRP	0.031*	0.033	A category

(mg/L)	TIN	0.08	0.083	A category
Physical Variables	pH (5th + 95th %ile)	7.03 and 8.17	7.5 and 8.4	A/B category
	Temperature	-	-	No data but no impacts expected.
	Dissolved oxygen	-	-	
	Turbidity (NTU)	Avg: 45 over whole data record, i.e. 1993 - 2010 (n = 214)	Avg: 28.72 Median: 5.3 95th %ile: 192.6	
	Electrical conductivity (mS/m)	36.2*	34.48	A category. RC shows slightly elevated natural salt levels.
Response variables	Chl a: periphyton (mg/m^2)	-	-	Benthic algal growth seen on rocks.
	Chl a: phytoplankton (µg/L)	-	3 (n = 1)	A category
	Macroinvertebrates	ASPT: 6.5 SASS: 123	ASPT: 81 SASS: 6.2 MIRAI: 77%	C category
	Fish community score	-	FRAI: 73.7%	C category
	Diatoms	-	SPI – 11.5 (n = 3)	C category
Toxics	Fluoride (mg/L)	0.281	0.195 (n = 63)	A category
	Ammonia (mg/L)	0.015 **	0.009	A category
	Aluminium (mg/L)	0.02 **	0.159 (n = 1)	D category
	Iron (mg/L)	-	0.116 (n = 1)	No guideline and insufficient data
	Other	-	-	Some impacts expected due to farming-related pesticides and fertilizer use. Diatoms and macroinvertebrates indicate intermittent polluting events.
OVERALL SITE CLASSIFICATION (Based on PAI model)		**B/C:81.54%**		

* Boundary value for the A category recalibrated - no data ** Benchmark value, as no data

19.3.1 EFR K7: Trend

The trend was also assessed as stable for all components (Table 19.7). The trend for all components was stable except riparian vegetation which was negative due to the presence of exotic vegetation. Riparian vegetation had a negative trend due to increased growth of alien vegetation, however this did not affect the other components which were all stable.

19.3.2 EFR K7: PES causes and sources

The reasons for changes from reference conditions must be identified and understood. These are referred to as causes and sources ((http://cfpub.epa.gov/caddis/)). The PES for the components at MRU Caledon A, EFR C5 as well as the causes and sources for the PES are summarised in Table 19.4.

Table 19.4 EFR K7: PES causes and sources

	PES	Conf	Causes	Sources	F/NF	Conf
Hydro	A/B	4.5	Decreased base flows	Upstream abstractions and dams for domestic use in tributaries	F	4
Physico-chemical	B/C	3	Elevated nutrients and potential toxicant loads. Elevations in turbidity levels.	Agricultural activities	NF	2.5

Geom	A/B	4	Slight increased sediment yields from catchment.	Cultivation has cleared some slopes. Change in flow	F/NF	3
Riparian vegetation	C	4	Reduced indigenous cover on marginal and lower zone.	Reduced base flows	F	3.8
			Reduced indigenous cover, abundance& species composition.	Exotic species	NF	
			Reduced recruitment.	Grazing and trampling pressure (right bank) and competition with exotic species.		
Fish	C	3.5	Decrease in FROC and abundance fish species with preference for fast habitats.	Slight decreased base flows.	F	2
			Deterioration of substrate habitat	Bank erosion and some catchment erosion (sedimentation)	F/NF	
			Decreased substrate quality related to increased benthic growth.	Increased nutrients and organics.	NF	
			Decreased water quality.	High nutrients, organics and possibly toxins (aluminum) - agriculture		
			Decreased species diversity and abundance (especially small species)	Presence of aggressive alien predatory species.		
			Increased turbidity and disturbed bottom substrates.	Presence of alien CCAR.		
			Decreased overhanging vegetation as cover.	Increased bank erosion and alien vegetation.		
			reduced migration success (breeding, feeding and dispersal) of some species.	Barriers: Some small dams/weirs.		
Macro-invertebrates	C	2	Zero flows	Abstraction	F	2
			Organic enrichment.	Irrigated agriculture.	NF	

Agricultural practices in the catchment seem to be the main impact in this reach leading to small driver changes which include decreased flows, zero flows, increased nutrient levels. Alien fish and riparian vegetation species also impact on the site.

19.4 EFR K7: PES ECOSTATUS

To determine the EcoStatus, the macroinvertebrates and fish results are combined to determine an instream category. The instream and riparian categories are integrated to determine the EcoStatus. Confidence is used to determine the weight which the EC should carry when integrating into an EcoStatus (riparian, instream and overall). The EC percentages are provided (Table 19.5) as well as the portion of those percentages used in calculating the EcoStatus.

Table 19.5 MRU Kraai C: EFR K7: Instream

INSTREAM BIOTA	Importance Score	Weight
FISH		
1.What is the natural diversity of **fish** species with different flow requirements	2.5	80
2.What is the natural diversity of **fish** species with a preference for different cover types	3	100
3.What is the natural diversity of **fish** species with a preference for different flow depth classes	3	100
4. What is the natural diversity of **fish** species with various tolerances to modified water quality	2	60
MACRO INVERTEBRATES		
1. What is the natural diversity of **invertebrate** biotopes	3	70

2. What is the natural diversity of **invertebrate** taxa with different velocity requirements	2	50
3. What is the natural diversity of **invertebrate** taxa with different tolerances to modified water quality	4	100
Fish	C	
Macro Macroinvertebrates	C	
Confidence rating for instream biological information	3.25	
INSTREAM ECOLOGICAL CATEOGORY	**C**	
Riparian vegetation	C	
Confidence rating for riparian vegetation zone information	3.3	
ECOSTATUS	**C**	

19.5 RECOMMENDED ECOLOGICAL CATEGORY (REC): C

The REC was determined based on ecological criteria only and considered the EIS, the restoration potential and the attainability there-of. The EIS was MODERATE, therefore the REC was to maintain the PES in a C.

19.6 EFR K7: AEC↑

The scenario included:

- Decreased abstraction, i.e. higher base flows;
- No zero flows;
- The above flow changes will result in improved water quality;
- Landuse changes and catchment management will also improve water quality;
- Alien vegetation should be cleared.

Each component was adjusted to indicate the metrics that would react to the scenarios. The rule based models are available electronically and summarised in Table 19.6.

Table 19.6 EFR K7: AEC↑

	PES	AEC↑	Comments	Conf
Physico-chemical	B/C	A/B	No zero flows, improved base flows and improved land-use management (e.g. resulting in improved pesticide and fertilizer use) should improve nutrient and toxicant loads in the system.	3
Geom	A/B	A/B	Component already close to natural.	N/A
Riparian vegetation	C	B/C	Will improve the cover and abundance of indigenous riparian woody species as well as opportunities for successful recruitment. This will also improve population structure which is currently skewed towards older individuals. Species composition will also improve as exotic species are removed.	3
Fish	C	B	Improvement in the availability of fast habitats (FS, FI and FD) with an expected improvement in FROC of species with a preference for fast habitats, such as ASCL, BAEN, BKIM and LCAP. The tolerant species CGAR should also be able to occur at close to natural FROC. Improvement of SD habitats (associated with improved flows) should also have an overall improvement in the FROC of species such as LUMB. These conditions will only improve the fish if alien fish species were not present. The improvements could also favour the alien species.	2.5

	PES	AEC↑	Comments	Conf
Macro-invertebrates	C	B	Macroinvertebrate taxa sensitive to water quality, such as *Heptageniidae* and *Ancylidae*, are likely to appear. In addition, the quality of marginal vegetation is likely to improve, and the overall macroinvertebrate biodiversity is expected to increase through gain of taxa such as *Coenagrionidae, Notonectidae, Corixidae* and *Oligochaeta*. At least three species of *Baetidae* are expected under these conditions. The total number of SASS5 taxa is expected to increase to 19. The overall SASS Score is expected to be 118 and the ASPT 6.2.	2

19.6.1 AEC↓

The scenario includes the following:

- Increased abstraction.
- More frequent periods of zero flows.
- Increased abstraction and associated increase in farming activities will have a negative impact on water quality.
- Decrease in small floods (e.g. an increase of dams in the tributaries)
- Slightly higher sedimentation in areas (due to decreased flushing from dams)

Each component was adjusted to indicate the metrics that would react to the scenarios. The rule based models are available electronically and summarised in Table 19.7.

Table 19.7 EFR K7: AEC↓

	PES	AEC↓	Comments	Conf
Physico-chemical	B/C	C	Higher abstractions for farming and more zero flows, with concomitant increased fertilizer and pesticide use, more erosion and potentially more sedimentation, would result in a deteriorated water quality state. More dams in small tributaries, with fewer small floods, reduce flushing and dilution capacity.	3
Geom	A/B	B/C	This is expected to result in reduced flushing of the fines, reduced bed scour and activation of the gravels and cobbles and possibly some embeddedness of sediment. The component will deteriorate to a B/C condition.	2.5
Riparian vegetation	C	C	Reductions of cover and abundance of woody riparian species in the marginal and lower zones. The upper zone remains unchanged. Reduced recruitment opportunities will also result in populations farther skewed towards older individuals. Sedge cover in the marginal zone is also likely to increase as sedimentation occurs. The EC stays within a C, albeit lower	2.7
Fish	C	D	Overall deterioration of especially the species with a preference for fast flowing habitats with substrate as cover (ASCL, BAEN, BKIM & LCAP). If this impact is large, it can be expected to have a large impact on the FROC, comprising 50% of the species expected in the reach, with a resultant decrease in the EC to a lower category (D).	2.5
Macro-invertebrates	C	D	Macroinvertebrate taxa sensitive to water quality deterioration, such as Perlidae and Leptophlebiidae, are likely to disappear. In addition, marginal vegetation is likely to decrease even further, and the overall macroinvertebrate biodiversity is expected to drop through loss of taxa such as Empididae and Elmidae. The total number of SASS5 taxa is expected to drop to 9. The overall SASS score is expected to be 46 and the ASPT 5.1.	2

19.7 SUMMARY OF ECOCLASSIFICATION RESULTS

Table 19.8 EFR K7: Summary of EcoClassification results

Driver Components	PES	Trend	AEC↓	AEC↑
IHI HYDROLOGY	A/B			
WATER QUALITY	B/C		C	A/B
GEOMORPHOLOGY	A/B	0	B/C	A/B
INSTREAM IHI	B/C			
RIPARIAN IHI	C			
Response Components	**PES**	**Trend**	**AEC↓**	**AEC↑**
FISH	C	0	D	B
MACRO INVERTEBRATES	C	0	D	B
INSTREAM	C	0	D	B
RIPARIAN VEGETATION	C	-	C-	B/C
ECOSTATUS	C		C	B
EIS	MODERATE			

20 EFR K7 (LOWER KRAAI) – DETERMINATION OF STRESS INDICES

Stress indices are set for fish and macroinvertebrates to aid in the determination of low flow requirements. The stress index describes the consequences of flow reduction on flow dependant biota. It therefore describes the habitat conditions for fish and macroinvertebrates indicator species for various low flows. These habitat conditions for different flows and the associated habitat conditions are rated from 10 (zero flows) to 0, which is optimum habitat for the indicator species.

20.1 INDICATOR SPECIES OR GROUP

20.1.1 Fish indicator group: Large semi - rheophilic species

Emphasis was placed on the requirements of the *Labeobarbus* species (BKIM and BAEN) within this group in setting flows. Refer to section 17.1.1.

20.1.2 Macroinvertebrate indicator taxa

Stoneflies (Perlidae: *Neoperla spio* complex) are flow-dependent macroinvertebrates that prefer fast currents (>0.6 m/s) with cobble and boulder substrates. Optimal depth requirements range between 15 and 30 cm. Stoneflies are highly sensitive to deterioration in water quality.

20.2 STRESS FLOW INDEX

A stress flow index is generated for every component, and describes the progressive consequences to the flow dependent biota of flow reduction. The stress flow index is generated in terms of habitat response and biotic response and is discussed below.

20.2.1 Habitat response

The habitat flow index is described separately for fish and macroinvertebrates as an instantaneous response of habitat to flow in terms of a 0 – 10 index relevant for the specific site where:

- 0 - Optimum habitat (fixed at the natural maximum base flow which is based on the 10% annual value using separated natural baseflows).
- 10 – Zero discharge (Note: Surface water may still be present).

The instantaneous response of fish and invertebrate breeding habitat, abundance, cover, connectivity, and water quality are derived by considering (amongst others) rated velocity depth classes (in terms of abundance) to flow changes based on a 0 (VD class absent) - 5 (VD class very abundant).

Fish and invertebrate habitat is then rated separately according to a 0 (no habitat) – 5 (optimum occurrence of habitat).

Biota response

The biota stress index is the instantaneous response of biota to change in habitat (and therefore flow), based on a scale of 0 – 10 where:

- 0 = Optimum habitat with least amount of stress possible for the indicator groups ***at the site*** (fixed at the natural maximum baseflow in the same way as for the habitat response).
- 10 = Zero discharge. The biota response will depend on the indicator groups present, i.e. rheophilics will have left whereas semi-rheophilics will still be present and survive.

The instantaneous response of fish and invertebrate breeding habitat, abundance, cover, connectivity, and water quality are derived by considering (amongst others) rated velocity depth classes (in terms of abundance) to flow changes based on a 0 (VD class absent) - 5 (VD class very abundant).Fish and invertebrate habitat is then rated separately according to a 0 (no habitat) – 5 (optimum occurrence of habitat).

20.2.2 Integrated stress curve

The integrated stress curve represents the highest stress for either fish or macroinvertebrates at a specific flow.

The species stress discharges in Table 20.1 indicate the discharge evaluated by specialiststo determine the biota stress. The highest discharge representing a specific stress is used to define the integrated stress curve. Figure 20.1 illustrates this graphically.

In this specific case, the FDI stress index represents the integrated stress index (these values are the highest flow for each stress level). Therefore the red curve (representing the macroinvertebrate stress index) is lying 'beneath' the integrated stress curve (black) (Figure 20.1).

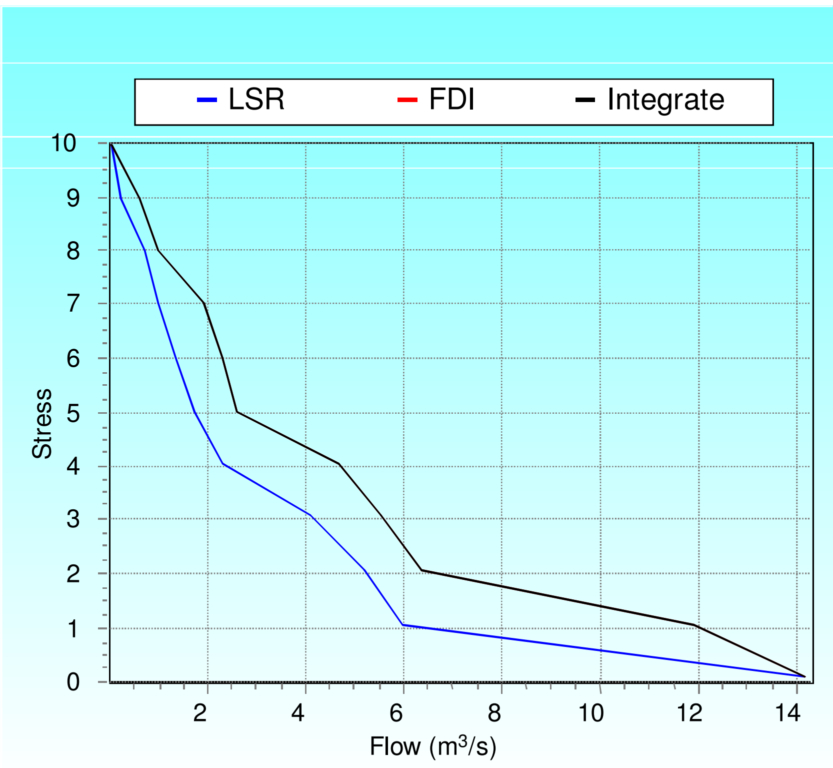


Figure 20.1 EFR K7: Component and integrated stress curves

Table 20.1 EFR K7: Species stress discharges used to determine biotic stress

Stress	Flow (m^3/s)		Integrated Flow (m^3/s)
	LSR	FDI	
0	14.3	14.3	14.3
1	6	12	12
2	5.22	6.4	6.4
3	4.1	5.55	5.55
4	2.3	4.7	4.7
5	1.7	2.6	2.6
6	1.3	2.3	2.3
7	1	1.9	1.9
8	0.667	1	1
9	0.188	0.6	0.6
10	0	0	0.001

Table 20.2 provides the summarised biotic response for the integrated stresses.

Table 20.2 EFR K7: Integrated stress and summarised habitat/biotic responses - macroinvertebrates

Integrated stress	Flow (m^3/s)	Driver (fish/inverts/both)	Habitat and/or Biotic responses
0	14.3	Both	Median wet season base flow
1	12.0	Invertebrates	All habitats plentiful, high quality. Average current speeds exceed 0.6 m/s, which is the target flow speed for the indicator group - Perlidae.
2	6.4	Invertebrates	Critical habitats (VFCS) sufficient (30%); Overall habitat diversity slightly reduced: Wetted perimeter slightly reduced (89%)
3	5.6	Invertebrates	Reduced critical habitat (24%), Cobble bar suitably inundated; Average current velocity 0.47 m/s.
4	4.7	Invertebrates	Observed flow (photographs). Critical habitats (VFCS) limited (16%). Main cobble bar on left bank largely exposed. Moderate quality of hydraulic diversity, moderate velocity (average current speed 0.4 m/s). Wetted perimeter moderately reduced (87%). Marginal vegetation exposed (not available) at these flows. Large areas of bedrock on right bank exposed.
5	2.6	Invertebrates	Critical habitat very reduced 5.8%), moderate/low quality. Moderate/slow velocity (0.28 m/s); wetted perimeter moderately reduced (82%).
6	2.3	Invertebrates	Observed flow (photographs). Critical habitat (VFCS) residual (4.5%). Current velocity too slow for indicator group (Perlidae) average current speed 0.2 m/s).
7	1.9	Invertebrates	Very little critical habitat (4%), other habitats moderate to low quality. Average current speed very slow (0.25 m/s).
8	1.0	Invertebrates	Flowing water habitats residual low quality. Current speed slow trickle (0.19 m/s).
9	0.6	Invertebrates	Standing water habitats only, very low quality.
10	0.0	Invertebrates	Only hyporheic refugia, no surface water.

21 EFR K7 (LOWER KRAAI) - DETERMINATION OF EFR SCENARIOS

21.1 ECOCLASSIFICATION SUMMARY OF EFR K7

EFR K7 (Lower Kraai River)

EIS: MODERATE
The highest scoring matrix were unique riparian biota.

PES: C
Reduced base flows, exotic vegetation and fish species, grazing and trampling, bank erosion.

REC: C
The EIS is moderate which does not provide motivation for improvement.

AEC↓: C
Increased abstraction; more frequent 0 flows. Negative impact on water quality. Decrease in small floods (e.g. by an increase of dams in the tributaries).Slightly higher sedimentation in areas.

AEC↑: B
Decreased abstraction (higher base flows) and no zero flows. Improved water quality. Alien vegetation should be cleared

Driver Components	PES	Trend	AEC↓	AEC↑
IHI HYDROLOGY	A/B			
WATER QUALITY	B/C		C	A/B
GEOMORPHOLOGY	A/B	0	B/C	A/B
INSTREAM IHI	B/C			
RIPARIAN IHI	C			
Response Components	**PES**	**Trend**	**AEC↓**	**AEC↑**
FISH	C	0	D	B
MACRO INVERTEBRATES	C	0	D	B
INSTREAM	C	0	D	B
RIPARIAN VEGETATION	C	-	C-	B/C
ECOSTATUS	C		C	B
EIS	MODERATE			

21.2 HYDROLOGICAL CONSIDERATIONS

The wettest and driest months were identified as March and September. Droughts are set at 95% exceedance (flow) and 5% exceedance (stress). Maintenance flows are set at 40% exceedance (flow) and at 60% exceedance (stress).

21.3 LOW FLOW REQUIREMENTS (IN TERMS OF STRESS)

The integrated stress index is used to identify required stress levels at specific durations for the wet and dry month/season.

21.3.1 Low flow (in terms of stress) requirements

The fish and macroinvertebrate flow requirements for different ECs are provided in Table 21.1 and graphically illustrated in Figure 21.1. The results are plotted for the wet and dry season on stress duration graphs and compared to the Desktop Reserve Model (DRM) low flow estimates for the same range of ECs. The stress requirements (as a 'hand drawn line') are illustrated in Figure 21.1.

For easier reference the range of ECs are colour coded in the Tables and figures:
PES and REC: Green AEC↑: Purple AEC↓: Yellow

Summarised motivations for the final requirements are provided in Table 21.2.

Table 21.1 EFR K7: Species and integrates stress requirements as well as the final integrated stress and flow requirement

Duration	LSR stress	Integrated stress	FDI stress	Integrated stress	FINAL* (Integrated stress)	FLOW (m^3/s)
PES and REC: CINSTREAM ECOSTATUS			**FISH: C**		**MACROINVERTEBRATES: C**	
			DRY SEASON			
5%	10	10	10	10	**10**	**0**
30%	8.77	9.6	9.17	9.2	**9.2**	**0.5**
60%	5.6	7.6	7.03	7	**7**	**1.9**
			WET SEASON			
5%	9.5	9.9	9.83	9.8	**9.8**	**0.14**
30%	4.83	7.2	5.33	5.3	**5.3**	**2.4**
60%	2.2	3.7	4.24	4.2	**3.7**	**5.1**
AEC↑: B INSTREAM ECOSTATUS MACROINVERTEBRATES: B				**FISH: B**		
			DRY SEASON			
5%	8.4	9.3	9.33	9.3	**9.3**	**0.5**
30%	6.7	7.9	7.78	7.8	**7.8**	**1.2**
60%	4.17	6.5	6.27	6.3	**6.3**	**2.2**
			WET SEASON			
5%	9	9.7	9	9	**9**	**0.6**
30%	3.54	4.7	4.57	4.6	**4.6**	**3.4**
60%	0.85	1.9	1.84	1.8	**1.8**	**7.3**
AEC↓: D INSTREAM ECOSTATUS MACROINVERTEBRATES: D				**FISH: D**		
			DRY SEASON			
5%	10	10	10	10	**10**	**0**
30%	8.97	9.7	9.5	9.5	**9.5**	**0.4**
60%	7	8	8.25	8.3	**8**	**1**
			WET SEASON			
5%	9.7	9.97	10	10	**9.97**	**0.02**
30%	6.33	7.8	6.8	6.8	**6.8**	**2**
60%	3.6	4.8	5.33	5.3	**4.8**	**2.9**

DRY SEASON (SEPTEMBER) **WET SEASON (MARCH)**

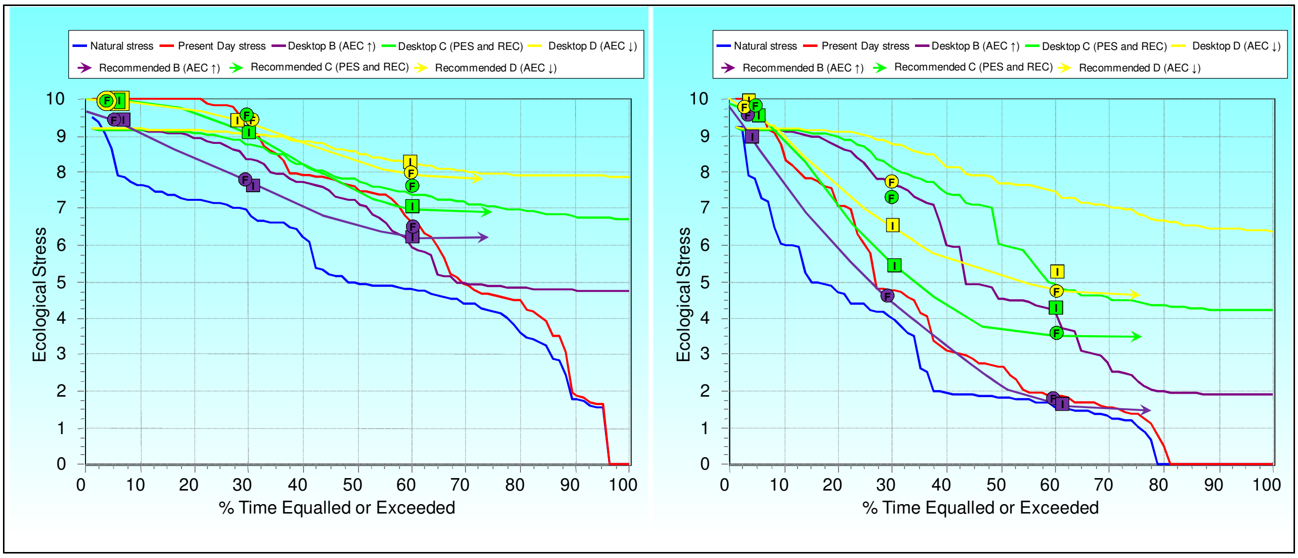


Figure 21.1 EFR C6: Stress duration curve for a PES and REC, AEC↑ and AEC↓

Table 21.2 EFR K7: Summary of motivations

Month	% Stress duration	Component stress	Integrated stress	Flow m^3/s	Comment
PES: EcoStatus FISH: FRAI = C, FFH = C MACROINVERTEBRATES:					
Sep	5% drought	10 LSR	10	0	Based on the available information (present day hydrology) zero flows occur during dry season. It can therefore be assumed that the PES will be maintained if zero flows occur in the dry season during droughts (semi-rheophilic species could survive in pools during cessation of flow).
		10 FDI	10	0	Macroinvertebrates currently present at the site are able to withstand periodic flow cessation. No change from present needed to maintain invertebrates in present state of Category C.
	60% maintenance	7.03 FDI	7	1.9	This stress-duration will provide an average current velocity is 0.24 m/s. Suitable habitats (VFC) comprises 1.2 m of wetted perimeter, which represents 3.9% of instream habitats available.
Mar	5% drought	9.5 LSR	9.9	0.14	In general habitat suitability will be very poor but should be adequate to ensure survival of the semi-rheophilic fish guild during droughts, and maintain the PES.
		9.83 FDI	9.8	0.14	This stress-duration will provide an average current velocity is 0.15 m/s. Suitable habitats (VFCS) comprise 0.1 m of wetted perimeter, which represents 0.7% of instream habitats available.
	60% maintenance	2.2 LSR	3.7	5.1	At this stress level, habitat suitability will be moderate for spawning habitats, while it will be good in terms of nursery habitats, cover/abundance, connectivity and water quality. It is therefore expected that the semi-rheophilic guild would be maintained in PES.
AEC-UP: EcoStatus FISH: FRAI = B, FFH = B MACROINVERTEBRATES					
Sep	5% drought	8.4 LSR	9.3	0.5	The removal of zero flows from this reach during drought periods will ensure the maintenance of better overall conditions for the semi-rheophilic guild, and is expected to result in an overall improvement of the fish assemblage.
		9.33 FDI	9.3	0.5	This stress-duration will provide an average current speed of 0.17 m/s needed for wet season drought. of 0.14 m. Suitable habitats (VFCS) comprises 0.2 m of wetted perimeter, which represents 1% of instream habitats.
	60% maintenance	4.17 LSR	6.5	2.2	At these stress levels, the habitat suitability to maintain cover, abundance, connectivity and water quality will be better (moderate to good) than under present conditions and should result in overall improvement in the EC of the fish assemblage at the site.
		6.27 FDI	6.3	2.2	This stress-duration will provide 1.3 m (4%) of instream habitat that is suitable for *Perlidae*, the target indicator group for this site. Average current velocities are 0.25 m/s, which is within the lower-range suitable for the indicator group.
Mar	5% drought	9 FDI	9	0.6	This stress-duration will provide an average current velocity is 0.15 m/s. Suitable habitats (VFCS) comprises 0.1 m of wetted perimeter, which represents 0.7% of instream habitats available.
	60% maintenance	0.85 LSR	1.9	7.3	At this stress level, habitat suitability will be optimal in terms of spawning habitats, nursery habitats, cover, and abundance and water quality. It is therefore expected that the semi-rheophilic guild would be able to occur at their optimal level and ensure overall improvement in EC.
		1.84 FDI	1.8	7.3	This stress-duration will provide an average current velocity is 0.48 m/s, and this will provide suitable flows for flow-dependent invertebrates, including Perlidae.
AEC: EcoStatus FISH: MACROINVERTEBRATES:					
Sep	5% drought	10 LSR	10	0	Based on available information (present day hydrology), zero flows occur under present condition. An increase in the

Month	% Stress duration	Component stress	Integrated stress	Flow m³/s	Comment
					duration or occurrence of zero flows during the drought season can be expected to result in overall deterioration of this fish guild.
		10 FDI	10	0	Macroinvertebrates currently present at the site are able to withstand periodic flow cessation. Cannot be better than present state.
	60% maintenance	7 LSR	8	1	At this stress level, habitat suitability to maintain cover, abundance and connectivity will be poor while water quality will be very poor and therefore less suitable than under PES. An overall deterioration in the EC therefore expected.
Mar	5% drought	9.7 LSR	9.97	0.02	In general habitat suitability will be very poor to absent. An overall deterioration in the semi-rheophilic fish guild can therefore be expected.
	60% maintenance	3.6 LSR	4.8	2.9	At these stress levels lower than expected under present condition, the habitat suitability to maintain cover, abundance, connectivity and water quality will be moderate to good but lower than under present conditions and should result in overall deterioration in the EC of the fish assemblage at the site.

21.3.2 Riparian Vegetation Verification of Low Flow Requirements

The low flow requirements as set by the instream biota is checked (and modified if necessary) to ensure that it caters for any riparian vegetation (specifically marginal). This verification is summarised in the Table 21.4.

Table 21.3 EFR K7: Verification of low flow requirements for instream biota to maintain riparian vegetation in the required EC

PES					
Species	Season	Q	Average Inundation / Height above water level (m) lower limit	upper limit	Note
Cyperus marginatus	dry drought	0.00	0.78	1.58	High levels of water stress with some mortality, particularly of younger individuals, especially if coupled with increasing grazing pressure
Salix mucronata (small)			0.80		
Gomphostigma virgatum			1.02	1.90	
Salix mucronata (large)			4.00	6.89	
Cyperus marginatus	dry (30%)	0.50	0.42	1.22	Periods of high stress for marginal and lower zone vegetation, but survival will be sufficient. EC remains C.
Salix mucronata (small)			0.44		
Gomphostigma virgatum			0.66	1.54	
Salix mucronata (large)			3.64	6.53	
Cyperus marginatus	dry (60%)	1.90	0.29	1.10	No inundation of existing vegetation. High levels of water stress (normal for this period) but survival will be sufficient. Growth and fecundity do not occur during the dry season, so water is only required to maintain survival.
Salix mucronata (small)			0.31		
Gomphostigma virgatum			0.54	1.42	
Salix mucronata (large)			3.52	6.40	
Cyperus marginatus	wet drought	0.14	0.51	1.31	High levels of water stress with some mortality, particularly of younger individuals. Fruiting is likely to fail or abort depending on the timing of the drought.
Salix mucronata (small)			0.53		
Gomphostigma virgatum			0.75	1.63	
Salix mucronata (large)			3.73	6.61	
Cyperus marginatus	wet (30%)	2.40	0.27	1.07	Sustain summer (growing) season water requirements for growth and a reduced rate of reproduction. Flows
Salix mucronata (small)			0.29		

Gomphostigma virgatum			0.51	1.39	lower than expected in that it is very unusual for base flows to result in zero inundation, especially of seges and rheophytes. Recruitment will be promoted lower down in the marginal zone. Either the flows that are being set are too low to effectively maintain the PES, or (more likely) the assessment (of vegetation) is obscured by the clearing of otherwise present vegetation by previous and recent floods. Nevertheless, these flows will not reduce the overall EC since non-flow related impacts superceded those of reduced flows and will likely remain C. The EC of the marginal and lower zones (currently B/C) reduces however, but does not cause an overall change in class.
Salix mucronata (large)			3.49	6.38	
Cyperus marginatus	wet (60%)	5.10	0.17	0.97	
Salix mucronata (small)			0.19		
Gomphostigma virgatum			0.41	1.29	
Salix mucronata (large)			3.39	6.27	

Conclusions: Flows seem to be lower than what is suggested by current vegetation at the site. As stated before, this could be due to recent removal of indicators by flooding disturbance, in which case plant remnant indicators may exaggerate preferable flows. EC remains within the category.

REC					
Species	**Season**	**Q**	**Inundation / Height above water level (m)**		**Note**
			lower limit	**upper limit**	
Cyperus marginatus	dry drought	0.50	0.42	1.22	Flows are characteristic of dry season water stress and are sufficient to sustain survival, the most important biological process during periods of increased dormancy.
Salix mucronata (small)			0.44		
Gomphostigma virgatum			0.66	1.54	
Salix mucronata (large)			3.64	6.53	
Cyperus marginatus	dry (30%)	1.20	0.34	1.14	
Salix mucronata (small)			0.36		
Gomphostigma virgatum			0.58	1.46	
Salix mucronata (large)			3.57	6.45	
Cyperus marginatus	dry (60%)	2.20	0.28	1.08	
Salix mucronata (small)			0.30		
Gomphostigma virgatum			0.52	1.40	
Salix mucronata (large)			3.50	6.39	
Cyperus marginatus	wet drought	0.60	0.40	1.21	Again, these flows still do not result in any inundation of marginal zone riparian obligates. The current marginal zone is likely to shift towards the channel and colonise available habitat which is currently not colonised. VEGRAI showed that the main impact on the marginal zone was flow reduction, but resulted in a PES of B/C (for marginal and lower zones only). The overall PES was C however, due to the condition of the upper zone where impacts were all non-flow related. The increase in base flows here will result in a slight improvement, but are still too low to cause inundation (based on current vegetation at the site), and the only way to improve the PES to B/C (REC) was to also remove aliens plants. From a flow perspective these flows are not likely to change the PES for vegetation.
Salix mucronata (small)			0.42		
Gomphostigma virgatum			0.65	1.53	
Salix mucronata (large)			3.63	6.51	
Cyperus marginatus	wet (30%)	3.40	0.23	1.03	
Salix mucronata (small)			0.25		
Gomphostigma virgatum			0.47	1.35	
Salix mucronata (large)			3.45	6.33	
Cyperus marginatus	wet (60%)	7.30	0.10	0.91	
Salix mucronata (small)			0.12		
Gomphostigma virgatum			0.34	1.23	
Salix mucronata (large)			3.33	6.21	

Conclusions: The increase in base flows here will result in a slight improvement, but are still too low to cause inundation (based on current vegetation at the site), and the only way to improve the PES to B/C (REC) was to also remove aliens plants. From a flow perspective these flows are not likely to change the PES for vegetation.

AEC Down					
Species	Season	Q	Inundation / Height above water level (m)		Note
			lower limit	upper limit	
Cyperus marginatus	dry drought	0.00	0.78	1.58	Flows are characteristic of dry season water stress and are sufficient to sustain survival, the most important biological process during periods of increased dormancy.
Salix mucronata (small)			0.80		
Gomphostigma virgatum			1.02	1.90	
Salix mucronata (large)			4.00	6.89	
Cyperus marginatus	dry (30%)	0.40	0.44	1.24	
Salix mucronata (small)			0.45		
Gomphostigma virgatum			0.68	1.56	
Salix mucronata (large)			3.66	6.54	
Cyperus marginatus	dry (60%)	1.00	0.36	1.16	
Salix mucronata (small)			0.38		
Gomphostigma virgatum			0.60	1.48	
Salix mucronata (large)			3.58	6.47	
Cyperus marginatus	wet drought	0.02	0.60	1.41	Flows likely to result in some mortality, particularly in the lower zone, but marginal zone will shift towards the channel as rheophytes colonise available substrate and additional sediment that is damp. This reduces the PES to C in both the marginal and lower zones (which was B/C before) and although the overall PES remains C, it is reduced from 76.3% to 73%.
Salix mucronata (small)			0.62		
Gomphostigma virgatum			0.85	1.73	
Salix mucronata (large)			3.83	6.71	
Cyperus marginatus	wet (30%)	2.00	0.29	1.09	
Salix mucronata (small)			0.31		
Gomphostigma virgatum			0.53	1.41	
Salix mucronata (large)			3.51	6.39	
Cyperus marginatus	wet (60%)	2.90	0.25	1.05	
Salix mucronata (small)			0.27		
Gomphostigma virgatum			0.49	1.37	
Salix mucronata (large)			3.47	6.35	
Conclusions: Marginal and lower zones deteriorate in category (both B/C to C), but the overall EC does not change.					

21.3.3 Final low flow requirements

To produce the final results, the DRM results for the specific category were modified according to specialists' requirements (Figure 21.2). There are a range of options one can use to make these modifications, such as changing the total volume required for the year, specific monthly volumes, either drought or maintenance flow durations, seasonal distribution and changing the category rules and shape factors. The following changes were required:

Note that revised approach using separated baseflows for the natural and PD stress curves were used for this site.

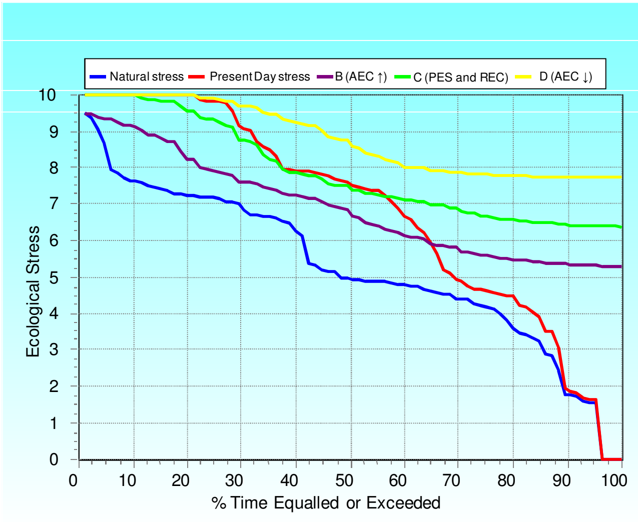
Region 9 (Eastern Cape) was applied, but with rules already modified for original Desktop run to:

- PES and REC: C EC.
  - Maintenance seasonal distributions set to 1.
  - September upper shift set to 90; all other months adjusted.
  - All shape factors set to 6.
  - Dry higher flows set to 120; others adjusted as well.
- AEC↑: B EC.
  - Drought seasonal distributions set to 0.02.
  - Maintenance seasonal distribution set to 1.2.
  - All shape factors set to 6.
  - All upper shifts set to 100.

- Dry higher flows set to 120.

▪ AEC↓: D EC.
  - Maintenance seasonal distribution set to 1.0.
  - All shape factors set to 6.
  - September upper shift set to 80; other months adjusted.
  - Dry higher flows set to 120.

Dry Season (September)



Wet Season (March)

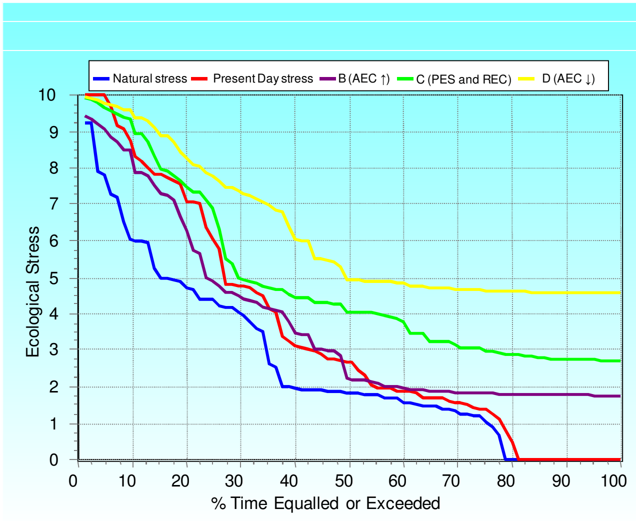


Figure 21.2 EFR K7: Final stress requirements for low flows

21.4 HIGH FLOW REQUIREMENTS

The high flow classes were identified as follows:

- The geomorphologist and riparian vegetation specialist identified the range of flood classes required and listed the functions of each flood.
- The instream specialists then indicated which of the instream flooding functions were addressed by the floods identified for geomorphology and riparian vegetation (indicated by a ✓ in Table 21.4).
- Any of the floods required by the instream biota and not addressed by the floods already identified, were then described (in terms of ranges and functions) for the instream biota.
-

Detailed motivations provided in Table 21.3 and final high flow results are provided in Table 21.4.

Table 21.4 EFR K7: Identification of instream functions addressed by the identified floods for geomorphology and riparian vegetation

		Fish flood functions						Invertebrate flood functions			
FLOOD RANGE (m3/s) FLOOD CLASS (instantaneous peak)	Geomorphology & riparian vegetation motivation	Migration cues & spawning	Migration habitat (depth etc)	Clean spawning substrate	Create nursery areas	Resetting water quality	Inundate vegetation for spawning	Breeding and hatching cues	Clear fines	Scour substrate	Reach or inundate specific areas

		Fish flood functions						Invertebrate flood functions			
FLOOD RANGE (m3/s) FLOOD CLASS (instantaneous peak)	Geomorphology & riparian vegetation motivation	Migration cues & spawning	Migration habitat (depth etc)	Clean spawning substrate	Create nursery areas	Resetting water quality	Inundate vegetation for spawning	Breeding and hatching cues	Clear fines	Scour substrate	Reach or inundate specific areas
14	**Geomorphic:** regular wet season flows to flush fines from the active channel bed, and to activate the low bars and side channels/backwaters.	✓	✓	✓	✓	✓	✓	✓	✓		
30 - 60	**Geomorphic:** Scouring flood to remove fines, turn over gravels and inundate the lower terrace (active bars). This flow class is responsible for about 30% of the fines and gravels transported through the site annually. **Rip Veg**: Inundate marginal zone vegetation (40-60% of *Gomphostigma virgatum* and *Cyperus marginatus* population inundated). Smaller Salix mucronata individuals growing on the marginal zone also inundated, but not older individuals growing on upper zone). Prevents establishment of terrestrial species (including non-riparian exotics) in the marginal zone. Required during growing season (spring to summer, 3-5 days).	✓	✓	✓	✓	✓	✓	✓	✓		
100-150	**Geomorphic:** Large, infrequent scouring floods are required to mobilise the bed (gravels and cobbles) and keep sedimentation in check and prevent embeddedness. Effective discharge for the site, responsible for more than 35% of the fines and gravel transport annually. **Rip Veg:** Flood marginal zone and wet lower portion of lower zone. Prevents establishment of terrestrial species in lower portions of lower zone (including non-riparian exotic species). Creates recruitment opportunities for *Salix mucronata* and *Gomphostigma virgatum*. Required during summer or late summer.										
300-400	**Geomorphic:** Large scouring flood will remove fines and mobilise the gravel and cobbles. Effective discharge for the small cobbles at the site. **Rip Veg:** Required to inundate lower zone. Begins to inundate upper zone *Salix mucronata* population (LB), which will create recruitment opportunities. This will also reduce terrestrialisation on the lower zone (including non-riparian exotic species). Helps maintain overall patchiness of different vegetation life forms in the marginal & lower zones &prevents domination of active-channel by woody species (especially *Salix babylonica and Salix fragilis)*. Summer or late summer.	✓	✓	✓	✓	✓	✓	✓	✓		
550-650	**Rip Veg**: Required to wet or inundate upper zone terrace (especially RB). Performs the same ecological function as 300-400, but on the upper zone. Preferable in late summer.	✓	✓	✓	✓	✓	✓	✓	✓		

The number of high flow events required for each EC is provided in Table 11.4. The high flows were checked using gauge D1H011.

Table 21.5 EFR K7: The recommended number of high flow events required

FLOOD RANGE (m^3/s)	INVERTEBRATES	FISH	VEGETATION	GEOMORPHOLOGY	FINAL* (No of events)	MONTHS	DAILY AVERAGE (m^3/s)	DURATION
PES and REC: C								
14	3			4	2	Nov, Dec	10	4
30-60	3	4	4	3	4	Nov, Dec, Jan, Feb	35	5
125		1	1	1	1	Mar	110	6
300-400			1:3	1:3	1:3		N/S	N/S
550-650			1:5+				N/S	N/S
AEC↑B								
14	3			4	2	Nov, Dec	10	4
30-60	3	4	4	3	4	Nov, Dec, Jan, Feb	35	5
125		1	1	1	1	Mar	110	6
300-400			1:3	1:3	1:3		N/S	N/S
550-650			1:5+				N/S	N/S
AEC↓: D								
14	2			2	1	Nov	10	4
30-60	2	3	3	2	3	Dec, Jan, Feb	35	5
125			1	1	1	Mar	110	6
300-400			1:3	1:3	1:3		N/S	N/S
550-650			1:5+				N/S	N/S

1 Final refers to the agreed on number of events considering the individual requirements for each component
2 n/s – not specified
3 Refers to frequency of occurrence, i.e. the flood will occur once in two years.

21.5 FINAL FLOW REQUIREMENTS

The low and high flows were combined to produce the final flow requirements for each EC as:

- An EFR table, which shows the results for each month for high flows and low flows separately (Table 21.6 - -21.8). Floods with a high frequency are not included in the modelled results as they cannot be managed.
- An EFR rule table which provides the recommended EFR flows as a duration table, linked to a natural trigger (natural modelled hydrology in this case). EFR rules are supplied for total flows as well as for low flows only (Table 21.9 – 21.11).

The low flow EFR rule table is useful for operating the system, whereas the EFR table must be used for operation of high flows.

Table 21.6 EFR K7: EFR table for PES and REC: C

Desktop version:		2	Virgin MAR (MCM)	682.5
BFI	0.29	Distribution type		Eastern Cape
MONTH	LOW FLOWS		HIGH FLOWS	
	Maintenance (m^3/s)	Drought (m^3/s)	Daily average (m^3/s) on top of base flow	Duration (days)

Desktop version:		2	Virgin MAR (MCM)	682.5
BFI	0.29	Distribution type		Eastern Cape
MONTH	LOW FLOWS		HIGH FLOWS	
	Maintenance (m^3/s)	Drought (m^3/s)	Daily average (m^3/s) on top of base flow	Duration (days)
OCTOBER	1.8	0		
NOVEMBER	2.3	0	10 35	4 5
DECEMBER	2.4	0	10 35	4 5
JANUARY	2.5	0	35	5
FEBRUARY	3.2	0	35	5
MARCH	4	0	110	6
APRIL	3.6	0		
MAY	2.7	0		
JUNE	2.2	0		
JULY	1.7	0		
AUGUST	1.55	0		
SEPTEMBER	1.6	0		
TOTAL MCM	77.5	0	57.5	
% OF VIRGIN	11.4	0	8.4	
Total IFR	135			
% of MAR	19.8			

Table 21.7 EFR K7: EFR table for AEC↑: B

Desktop version:		2	Virgin MAR (MCM)	682.5
BFI	0.29	Distribution type		Eastern Cape
MONTH	LOW FLOWS		HIGH FLOWS	
	Maintenance (m^3/s)	Drought (m^3/s)	Daily average (m^3/s) on top of base flow	Duration (days)
OCTOBER	2.467	0.291		
NOVEMBER	3.409	0.289	10 35	4 5
DECEMBER	3.525	0.217	10 35	4 5
JANUARY	3.716	0.294	35	5
FEBRUARY	4.865	0.327	35	5
MARCH	6.007	0.299	110	6
APRIL	5.406	0.104		
MAY	3.939	0.295		
JUNE	3.087	0.096		
JULY	2.273	0.291		
AUGUST	2.046	0.243		
SEPTEMBER	2.104	0.3		
TOTAL MCM	112.3	8.01	57.5	
% OF VIRGIN	16.5	1.2	8.4	
Total IFR	169.7			
% of MAR	24.9			

Table 21.8 EFR K7: EFR table for AEC↓: D

Desktop version:		2	Virgin MAR (MCM)	682.5
BFI	0.29	Distribution type		Eastern Cape
MONTH	LOW FLOWS		HIGH FLOWS	
	Maintenance (m^3/s)	Drought (m^3/s)	Daily average (m^3/s) on top of base flow	Duration (days)
OCTOBER	0.785	0		
NOVEMBER	1.058	0	10	4
DECEMBER	1.088	0	35	5
JANUARY	1.143	0	35	5
FEBRUARY	1.48	0	35	5
MARCH	1.799	0	110	6
APRIL	1.629	0		
MAY	1.207	0		
JUNE	0.965	0		
JULY	0.73	0		
AUGUST	0.665	0		
SEPTEMBER	0.684	0		
TOTAL MCM	34.7	0	48.5	
% OF VIRGIN	5.1	0	7.11	
Total IFR	83.19			
% of MAR	12.2			

Table 21.9 EFR K7: Assurance rules for PES and REC: C

Desktop Version 2, Printed on 2010/11/02
Summary of IFR rule curves for: EFR K7 Natural Monthly Flows
Determination based on defined BBM Table with site specific assurance rules.
Regional Type: E.Cape PES and REC: = C

Data are given in m^3/s mean monthly flow

% Points

Month	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	2.411	2.363	2.267	2.089	1.796	1.373	0.861	0.373	0.056	0.015
Nov	10.355	9.125	8.017	6.924	5.056	4.029	2.759	1.496	0.599	0.370
Dec	10.307	9.116	8.046	6.995	5.198	4.215	2.976	1.697	0.719	0.265
Jan	6.694	6.583	6.365	5.972	5.326	4.376	3.159	1.863	0.806	0.308
Feb	8.110	7.980	7.729	7.279	6.540	5.448	4.032	2.480	1.142	0.411
Mar	25.399	22.142	19.314	16.699	12.208	10.238	7.681	4.880	2.467	0.638
Apr	5.111	5.026	4.862	4.567	4.084	3.370	2.443	1.428	0.553	0.075
May	3.779	3.713	3.585	3.354	2.975	2.416	1.700	0.938	0.317	0.024
Jun	3.035	2.980	2.872	2.674	2.350	1.875	1.276	0.658	0.186	0.019
Jul	2.311	2.267	2.180	2.020	1.757	1.374	0.900	0.429	0.094	0.015
Aug	2.076	2.035	1.952	1.799	1.546	1.182	0.741	0.321	0.048	0.013
Sep	2.142	2.098	2.007	1.838	1.560	1.163	0.693	0.267	0.014	0.014

Reserve flows without High Flows

Oct	2.411	2.363	2.267	2.089	1.796	1.373	0.861	0.373	0.056	0.015
Nov	3.127	3.068	2.949	2.733	2.377	1.859	1.218	0.580	0.128	0.020
Dec	3.311	3.251	3.133	2.918	2.563	2.045	1.392	0.718	0.202	0.021
Jan	3.499	3.438	3.320	3.106	2.754	2.237	1.574	0.869	0.293	0.022
Feb	4.543	4.467	4.321	4.060	3.630	2.995	2.172	1.269	0.492	0.067
Mar	5.757	5.662	5.477	5.145	4.601	3.796	2.752	1.609	0.623	0.084
Apr	5.111	5.026	4.862	4.567	4.084	3.370	2.443	1.428	0.553	0.075
May	3.779	3.713	3.585	3.354	2.975	2.416	1.700	0.938	0.317	0.024
Jun	3.035	2.980	2.872	2.674	2.350	1.875	1.276	0.658	0.186	0.019
Jul	2.311	2.267	2.180	2.020	1.757	1.374	0.900	0.429	0.094	0.015
Aug	2.076	2.035	1.952	1.799	1.546	1.182	0.741	0.321	0.048	0.013

Sep	2.142	2.098	2.007	1.838	1.560	1.163	0.693	0.267	0.014	0.014

Natural Duration curves

Oct	26.908	18.832	10.805	9.304	6.422	5.089	3.286	2.009	1.154	0.803
Nov	85.316	35.652	26.790	14.676	10.606	8.349	5.721	3.437	1.393	0.370
Dec	68.444	46.345	30.559	19.486	11.985	9.834	6.089	3.584	1.411	0.265
Jan	56.459	40.267	27.908	21.405	14.897	8.326	5.063	3.648	1.822	0.523
Feb	90.943	56.316	37.785	26.360	17.415	14.178	7.660	5.820	2.505	0.934
Mar	126.426	66.991	42.380	33.946	24.462	15.057	11.574	8.247	5.238	0.638
Apr	83.144	57.323	41.289	22.600	14.877	10.440	7.971	5.802	2.890	0.945
May	39.139	21.942	13.482	10.055	7.396	6.216	5.048	3.073	2.061	0.784
Jun	24.745	11.547	7.276	6.069	5.162	4.653	3.248	2.650	1.535	0.579
Jul	14.139	9.009	5.518	4.716	3.913	3.271	2.852	2.535	1.751	0.455
Aug	11.466	8.352	5.485	4.596	3.454	2.767	2.449	1.979	1.759	0.329
Sep	25.864	12.824	7.589	5.170	3.731	3.048	2.481	1.867	1.377	0.579

Table 21.10 EFR K7: Assurance rules for AEC↑: B

Desktop Version 2, Printed on 2010/11/02
Summary of IFR rule curves for: EFR K7 Natural Monthly Flows
Determination based on defined BBM Table with site specific assurance rules.
Regional Type: E.Cape AEC UP = B

Data are given in m^3/s mean monthly flow

% Points

Month	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	2.923	2.879	2.794	2.643	2.394	2.026	1.549	1.026	0.576	0.330
Nov	11.335	10.108	9.012	7.952	6.138	5.176	3.927	2.559	1.381	0.370
Dec	11.310	10.116	9.042	7.993	6.200	5.212	3.931	2.527	1.317	0.265
Jan	7.605	7.488	7.262	6.856	6.190	5.206	3.929	2.530	1.324	0.523
Feb	9.478	9.330	9.046	8.536	7.699	6.461	4.856	3.097	1.582	0.753
Mar	27.345	24.060	21.179	18.469	13.823	11.622	8.767	5.639	2.944	0.638
Apr	6.823	6.712	6.496	6.109	5.473	4.534	3.316	1.982	0.831	0.203
May	4.897	4.821	4.673	4.408	3.973	3.329	2.495	1.581	0.793	0.363
Jun	3.775	3.714	3.596	3.384	3.036	2.522	1.855	1.124	0.494	0.150
Jul	2.738	2.697	2.619	2.478	2.246	1.904	1.461	0.975	0.556	0.327
Aug	2.424	2.388	2.318	2.192	1.986	1.681	1.286	0.852	0.479	0.275
Sep	2.493	2.457	2.386	2.260	2.053	1.746	1.349	0.913	0.537	0.332

Reserve flows without High Flows

Oct	2.923	2.879	2.794	2.643	2.394	2.026	1.549	1.026	0.576	0.330
Nov	4.104	4.041	3.918	3.699	3.338	2.805	2.113	1.355	0.702	0.345
Dec	4.312	4.244	4.113	3.877	3.489	2.917	2.175	1.361	0.660	0.265
Jan	4.620	4.548	4.409	4.160	3.751	3.146	2.362	1.503	0.762	0.357
Feb	6.144	6.047	5.860	5.525	4.975	4.162	3.108	1.952	0.957	0.412
Mar	7.703	7.580	7.342	6.916	6.215	5.181	3.838	2.368	1.101	0.408
Apr	6.823	6.712	6.496	6.109	5.473	4.534	3.316	1.982	0.831	0.203
May	4.897	4.821	4.673	4.408	3.973	3.329	2.495	1.581	0.793	0.363
Jun	3.775	3.714	3.596	3.384	3.036	2.522	1.855	1.124	0.494	0.150
Jul	2.738	2.697	2.619	2.478	2.246	1.904	1.461	0.975	0.556	0.327
Aug	2.424	2.388	2.318	2.192	1.986	1.681	1.286	0.852	0.479	0.275
Sep	2.493	2.457	2.386	2.260	2.053	1.746	1.349	0.913	0.537	0.332

Natural Duration curves

Oct	26.908	18.832	10.805	9.304	6.422	5.089	3.286	2.009	1.154	0.803
Nov	85.316	35.652	26.790	14.676	10.606	8.349	5.721	3.437	1.393	0.370
Dec	68.444	46.345	30.559	19.486	11.985	9.834	6.089	3.584	1.411	0.265
Jan	56.459	40.267	27.908	21.405	14.897	8.326	5.063	3.648	1.822	0.523
Feb	90.943	56.316	37.785	26.360	17.415	14.178	7.660	5.820	2.505	0.934
Mar	126.426	66.991	42.380	33.946	24.462	15.057	11.574	8.247	5.238	0.638
Apr	83.144	57.323	41.289	22.600	14.877	10.440	7.971	5.802	2.890	0.945
May	39.139	21.942	13.482	10.055	7.396	6.216	5.048	3.073	2.061	0.784
Jun	24.745	11.547	7.276	6.069	5.162	4.653	3.248	2.650	1.535	0.579
Jul	14.139	9.009	5.518	4.716	3.913	3.271	2.852	2.535	1.751	0.455
Aug	11.466	8.352	5.485	4.596	3.454	2.767	2.449	1.979	1.759	0.329
Sep	25.864	12.824	7.589	5.170	3.731	3.048	2.481	1.867	1.377	0.579

Table 21.11 EFR K7: Assurance rules for AEC↓: D

```
Desktop Version 2, Printed on 2010/11/02
Summary of IFR rule curves for: EFR K7 Natural Monthly Flows
Determination based on defined BBM Table with site specific assurance rules.
Regional Type: E.Cape     AEC DOWN = D

Data are given in m³/s mean monthly flow

       % Points
Month    10%      20%      30%      40%      50%      60%      70%      80%      90%      99%
Oct     1.436    1.401    1.327    1.188    0.960    0.648    0.312    0.066    0.009    0.009
Nov     3.419    3.137    2.844    2.493    1.900    1.395    0.814    0.317    0.086    0.086
Dec     7.623    6.675    5.823    4.985    3.550    2.778    1.841    0.949    0.370    0.265
Jan     6.016    5.912    5.706    5.333    4.718    3.818    2.684    1.514    0.619    0.304
Feb     7.128    7.015    6.795    6.402    5.755    4.801    3.562    2.205    1.036    0.397
Mar    23.118   19.899   17.144   14.660   10.385    8.733    6.591    4.243    2.220    0.638
Apr     3.116    3.064    2.964    2.784    2.490    2.054    1.489    0.871    0.337    0.046
May     2.284    2.242    2.161    2.012    1.768    1.411    0.960    0.495    0.140    0.014
Jun     1.806    1.770    1.698    1.564    1.345    1.028    0.645    0.279    0.042    0.011
Jul     1.351    1.321    1.260    1.146    0.959    0.695    0.390    0.130    0.009    0.009
Aug     1.217    1.187    1.125    1.007    0.813    0.549    0.264    0.056    0.008    0.008
Sep     1.250    1.216    1.143    1.002    0.774    0.475    0.183    0.008    0.008    0.008

Reserve flows without High Flows
Oct     1.436    1.401    1.327    1.188    0.960    0.648    0.312    0.066    0.009    0.009
Nov     1.958    1.915    1.826    1.662    1.390    1.007    0.565    0.188    0.012    0.012
Dec     2.036    1.996    1.914    1.764    1.516    1.160    0.727    0.315    0.047    0.013
Jan     2.162    2.123    2.046    1.906    1.674    1.336    0.909    0.469    0.132    0.014
Feb     2.831    2.784    2.693    2.530    2.262    1.866    1.353    0.791    0.306    0.042
Mar     3.476    3.418    3.307    3.107    2.778    2.292    1.662    0.971    0.376    0.051
Apr     3.116    3.064    2.964    2.784    2.490    2.054    1.489    0.871    0.337    0.046
May     2.284    2.242    2.161    2.012    1.768    1.411    0.960    0.495    0.140    0.014
Jun     1.806    1.770    1.698    1.564    1.345    1.028    0.645    0.279    0.042    0.011
Jul     1.351    1.321    1.260    1.146    0.959    0.695    0.390    0.130    0.009    0.009
Aug     1.217    1.187    1.125    1.007    0.813    0.549    0.264    0.056    0.008    0.008
Sep     1.250    1.216    1.143    1.002    0.774    0.475    0.183    0.008    0.008    0.008

Natural Duration curves
Oct    26.908   18.832   10.805    9.304    6.422    5.089    3.286    2.009    1.154    0.803
Nov    85.316   35.652   26.790   14.676   10.606    8.349    5.721    3.437    1.393    0.370
Dec    68.444   46.345   30.559   19.486   11.985    9.834    6.089    3.584    1.411    0.265
Jan    56.459   40.267   27.908   21.405   14.897    8.326    5.063    3.648    1.822    0.523
Feb    90.943   56.316   37.785   26.360   17.415   14.178    7.660    5.820    2.505    0.934
Mar   126.426   66.991   42.380   33.946   24.462   15.057   11.574    8.247    5.238    0.638
Apr    83.144   57.323   41.289   22.600   14.877   10.440    7.971    5.802    2.890    0.945
May    39.139   21.942   13.482   10.055    7.396    6.216    5.048    3.073    2.061    0.784
Jun    24.745   11.547    7.276    6.069    5.162    4.653    3.248    2.650    1.535    0.579
Jul    14.139    9.009    5.518    4.716    3.913    3.271    2.852    2.535    1.751    0.455
Aug    11.466    8.352    5.485    4.596    3.454    2.767    2.449    1.979    1.759    0.329
Sep    25.864   12.824    7.589    5.170    3.731    3.048    2.481    1.867    1.377    0.579
```

A comparison between the Desktop Reserve Model estimates and the EFR results in terms of percentages of natural flow are provided in Table 21.12.

Table 21.12 EFR K7: Modifications made to the DRM

Changes	PES and REC: C		AEC↑: B		AEC↓: D	
	DRM	EFR	DRM	EFR	DRM	EFR
MLIFR - Maintenance low flow	9.3%	11.4%	16.1%	16.5%	4%	5.1%
DLIFR - Drought low flow	1.8%	0%	1.8%	1.2%	1.8%	0%
MHIFR - Maintenance high flow	10.8%	8.4%	13.8%	8.4%	9.1%	7.1%
Long-term % of virgin MAR	15.9%	18.1%	21.8%	21.8%	11.9%	12.9%

22 ECOCLASSIFICATION: EFR M8 (MOLOPO WETLANDS)

The EFR site represented a section of the wetland in MRU A which stretches from the gauging weir (D4H030) to the crossing at Bosbokpark (Figure 22.1). This section was selected as it is the only section in the wetland with permanent water and provides specific instream habitat (under present conditions) which could potentially be impacted by changing flows. The Bosbokpark crossing could also be managed by lowering it and/or changing the design.

It must be noted that the Molopo wetlands extend up to Mafikeng. For the purposes of this study the focus is on the area immediately downstream of the EFR site to the end of MRU A. Therefore this stretch is considered in terms of consequences of scenarios which are discussed in Chapter 23. Any scenarios, evaluated at the EFR site, resulting in an improvement of the site would therefore as a minimum maintain or improve the rest of the MRU.

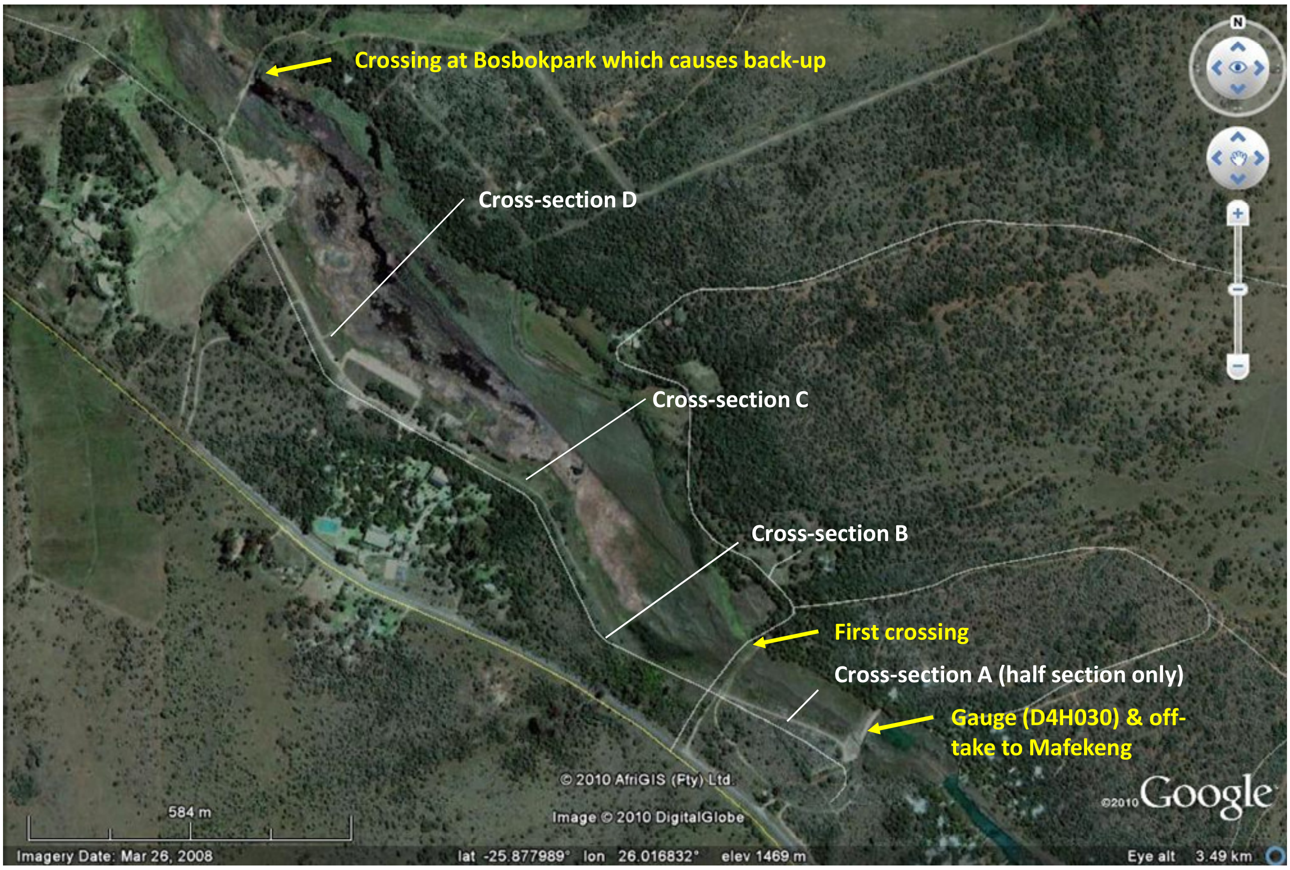


Figure 22.1 Google Earth image of EFR 8 (Molopo wetland)

22.1 EIS RESULTS

The EIS model was adjusted to cater for the wetland by assessing all biota under the wetland metrics rather than an instream and wetland/riparian component. Although the EIS was moderate the score was very close to high and it was decided to treat the EIS result as **HIGH**. The wetland scored moderate as the assessment was based on the present condition which considered the very temporary impacts of reed spraying. If one ignored this, the wetland would score HIGH (it only required the improvement of one metric from a score of 2 to 3). The uniqueness of the wetland habitat in this dry region also contributed to the decision that the EIS should be HIGH. The highest scoring metrics were:

- Rare and endangered: Carletonville Dolomite Grassland with 1.8% protected and 76% remaining. Part of veldtype would be in riparian zone. *Gunnera perpensa* - possibility that it could occur. *Crinum* sp.
- Unique: *Barbus brevipinnis* (BBRI) and *Tilapia sparrmanii* (TSPA (potential new species)). Unique, new species of invertebrates (JLB Smith report, 1994).
- Refugia and critical habitat: Refuge due to permanent water and good water quality.
- Proclaimed areas: Currently a conservancy. In the process of being proclaimed a Natural Protected Environment (NEMA[4]).

22.2 REFERENCE CONDITIONS

The reference conditions for the components in EFR M8 are summarised below in Table 22.1

Table 22.1 EFR M8: Reference conditions

Component	Reference conditions	Conf
Hydrology	nMAR 10.33 MCM	4
Physico-chemical	No data available	n/a
Wetland Condition	This reach was an unchannelled or weakly channelled wetland. Historical aerial photographs, and nearby similar dolomitic wetland systems which are far less impacted, provide very good information on the expected reference conditions.	4
Riparian vegetation	The assessed area at EFR 8 is completely contained within the Carletonville Dolomite Grassland vegetation type, which occurs within the Grassland Biome and the Dry Highveld Grassland Bioregion. This vegetation type is poorly protected (1.8% is under protection) with 76.1% remaining, and consequently has a conservation status of “Vulnerable”. Current conservation target is set at 24%. (Mucina & Rutherford, 2006). It is however, minimally influenced by this and would more aptly be classified as the azonal vegetation type: Eastern Temperate Freshwater Wetlands. A wide, weakly channelled, valley bottom wetland with permanent inundation or wettness is expected. The dominant species by far would be *Phragmites australis.*	4
Fish	The FROC database (Kleynhans, 2007) includes 2 sites within the upper Molopo River within EcoRegion 11.01 (same as EFR site), and indicate the presence of BAEN (translocated), BBRI, BPAL, BPAU, MSAL, PPHI and TSPA. Due to the absence of fish data for reference conditions, and the translocation of fish species into the upper Molopo system (known introduced species include OMOS, BAEN, TREN, MSAL, CCAR and possibly MBRE) it is very difficult to determine the reference fish assemblage for this river section. This decreases the confidence of the PES assessment in terms of fish, which is further reduced as a result of the natural (expected) low fish species richness. The expected fish species of site EFR M8 was therefore based on all the available information regarding fish species previously sampled in the area, with special emphasis on expected habitat composition of the area under natural conditions. Based on available information (other drivers and responses) this area seems to have been a shallow (<0.5m on average) wide valley bottom wetland with primarily reeds as vegetative cover available to fish. The expected species list is therefore determined by the preference or ability of fish species that would occur in such habitats. Six fish species, namely BPAL, BBRI (cf), BPAU, CGAR, PPHI and TSPA is expected in this reach under natural conditions. There is some uncertainty regarding the identification of BBRI and BPAL. The type locality for BBRI is the Sabie River in Mpumalanga and it is presently thought that this (or similar) species found in some other regions may in fact be a different species. The presence of BPAL also seem doubtful, but this species in presently known to occur in the main stem and tributaries of the Orange-Vaal River system. Should the occurrence therefore be true, it may be a reflection of the association of the Molopo to the Orange-Vaal system, while the presence of BBRI again provides evidence of the historic connection of the Molopo River with the Limpopo system.	2
Macro-invertebrates	Natural invertebrate fauna is likely to have been characterised by the presence of shrimps (Atyidae), Ecnomidae, Hydroptilidae, Hydrophilidae, Caenidae and a high diversity of Leptoceridae.	3

[4]National Environmental Management Act.

22.3 PRESENT ECOLOGICAL STATE

The PES reflects the changes in terms of the EC (Table 12.2) from reference conditions. The summarised information is provided in Table 12.2.

Table 22.2 EFR M8: Present Ecological State

Component	PES Description	EC	Conf
Hydrology	Hydrological data was not available for this site. It is however known that a significant portion of the outflow of the eye is diverted to Mafekeng. There have been times that all water has been diverted with zero flow going down the river.	D/E	3.5
Physico-chemical	The summarised information is provided in Table 22.3. The water quality assessment shown in the table was extracted from the Wetland IHI. The assessment for EFR M8 is restricted to the zone around the wetland..	B	1.9
Wetland condition (Wetland Index of Habitat Integrity)	The wetland is still a well-vegetated valley bottom, although some sections are channelized and others are impacted by impoundments. Vegetation has changed due to desiccation of large sections of the wetland due to reduced flows, and through spraying and die-off of Phragmites. This has promoted terrestrialisation of the former and invasion of more weedy species in the latter area.	D	3
Rip veg	Currently a channelized wetland with deep pools and a patchy mosaic of reeds (*P. australis*), bullrushes (T. capensis), aquatic vegetation (*P. sweinfurthii*) and Pesicaria *spp*. The wetland was divided into 2 section for vegetation assessment. The upper wetland extended from the weir to the first road crossing, about 240m of wetland (Figure 22.1) and the lower wetland from the same road crossing (with culvert) to the next road crossing (with steel pipes), about 1350m of wetland (Figure 22.1). The distinction was made because each section of wetland falls between distinct hydraulic controls and because the structure and composition of wetland vegetation differs. In the upper wetland it is apparent that there is a canalised area where most of the flow occurs and this affects the vegetation structure: Wetter areas facilitate taller and more dense reed stands while dryer areas reduce reed stature, density and fecundity. In the lower wetland there was a "dead zone" where no plants were growing, but dead plant matter indicate that they were at some time before the assessment. Anecdotal data suggest that herbicide application in 2006 caused large-scale plant death. Some areas have been subsequently colonised, others remain uncolonised with high amounts of rotting plant matter. Plant species form a patchy mosaic within the wetland and this is not the structure one would expect for a peat land in reference condition. Expectations for reference would not include deep pool areas, and would be dominated by extensive stands of *P. australis*. The occurrence of large stands of *Typha capensis, Presicaria sp* and *Potamogeton* species are all deviations from the reference condition. Impacts include altered vegetation composition and structure, and likely altered passage of water through the wetland due to canalisation and backup from hydraulic controls. Impacts also include the presence of exotic species.	C/D	3.4
Fish	It is estimated that all the expected fish species are still present in this river reach albeit in a reduced FROC. The primary changes responsible for deterioration in the fish assemblage is associated with the presence of the alien predatory fish species MSAL, and potentially also increased presence of omnivorous indigenous CGAR (due to increased availability of SD habitats). Some change in habitat from SS to SD has also altered the FROC of the species such as BPAL and BBRI. Flow modification has impacted on some species (esp. BBRI), while the presence of migration barriers results in further decrease in biotic integrity of the system.	C	2
Macroinvertebrates	Key taxa that were expected but not recorded during the field survey in April 2010 included Ecnomidae, Atyidae, Lestidae, Leptoceridae and Hydrophilidae. The fauna was dominated by Chironomidae and Simuliidae (C abundance). Four species of blackflies were recorded, including *Simulium hargreavesi*, which is a typical indicator of seasonal flow cessation. No taxa that are sensitive to water quality deterioration were recorded.	C	3

Table 22.3 EFR M8 Present Ecological State : Physico-Chemical

		RATING	Weighting	Confidence (1-5)
Water Quality	pH	0.0	100	1
	Salts	1.0	70	2
	Nutrients	1.0	50	2
	Water Temp.	1.0	10	2
	Turbidity	0.0	10	2
	Oxygen	1.0	10	1
	Toxics	2.0	50	3
			300.0	**13.0**

Water Quality: overall scores			
Rating:	**0.8**	**Confidence:**	**1.8**
Percentage:	**84.0**		
PES Category:	**B**		

22.3.1 EFR M8: PES causes and sources

The reasons for changes from reference conditions must be identified and understood. These are referred to as causes and sources ((http://cfpub.epa.gov/caddis/)). The PES for the components at EFR M8as well as the causes and sources for the PES are summarised in Table 22.4.

Table 22.4 EFR M8: PES causes and sources

	PES	Conf	Causes	Sources	F[1]/NF[2]	Conf
Hydro	D/E	3.5	Abstraction.	Domestic supply to Mafikeng. Agriculture.	F	5
Physico-chemical	B	3	Toxicant levels elevated. Some impact of nutrients and temperatures.	Pesticide spraying. Backup from the crossing. Activities in the area, i.e. horses, cattle, septic tanks.	NF	2.5
Wetland IHI	D	3	Desiccation of large sections of the wetland.	Abstraction of water. Backup.	NF	4
			Inundation and artificially deep water areas.	Backup effects from poorly designed road crossings, and possible excavation to create open water areas for fishing and boating.		
			Die off of *Phragmites* reeds.	Ongoing spraying and/or burning of reeds has caused extensive die-off of reeds and invasion by more weedy species.		
Riparian vegetation	C/D	3.4	Altered species composition and loss of vegetation cover.	Inundation of wetland	F	4
			Altered species composition and reduced vegetation cover.	Poisoning and removal of reeds, and occurrence of exotic species.	NF	
Fish	C	2	Decreased availability of fast habitats preferred and required by some fish species during certain life stages (esp. BBRI).	Flow modification through abstraction from eye (Mafikeng water supply) and irrigation.	F	2
			Decreased water quality affect species with requirement for high water quality (esp. BBRI).	Spraying of pests and possibly reeds, septic tanks, spillage during construction activities and possibly farming activities.	NF	3
			Decreased species diversity and abundance (especially Barbus species)	Presence of aggressive alien predatory species (MSAL).		2

	PES	Conf	Causes	Sources	F[1]/NF[2]	Conf
			Decreased species diversity and abundance.	Increased occurrence of SD habitats as result of inundation by dams/weirs/river crossings resulting in increased abundance and occurrence of omnivorous indigenous CGAR.		3
			Presence of migration barriers reduces migration success (breeding, feeding and dispersal) of some species.	Some small dams/weir/river crossings.		4
Macro-invertebrates[7]	C	3	Flow cessation.	Abstraction.	F	5
			Permanent inundation (increased depth).	Stream crossing design.	NF	5
			Oxygen depletion.	Burning and spraying of reeds & inundation.		3
			Toxins.	Spraying of reeds.		1
			Nutrient enrichment.	Burning and spraying of reeds.		3

1 Flow related 2 Non Flow related 3 Hydrology

The major sources of problems were:

- Spraying and burning of reeds.
- Decreased flows.
- Backup caused by crossings, especially the lower cross-section at the end of the EFR site.
- Pools (open) created by the backup and resulting depth that does not favour reeds, as well as physically opening of pools.
- Barriers to fish migration and presence of MSAL and CGAR.

22.4 PES ECOSTATUS

To determine the EcoStatus, the macroinvertebrates and fish results are combined to determine an instream category. The instream and riparian categories are integrated to determine the EcoStatus. Confidence is used to determine the weight which the EC should carry when integrating into an EcoStatus (riparian, instream and overall). The EC percentages are provided Table 22.5 as well as the portion of those percentages used in calculating the EcoStatus.

Table 22.5 MRU: EFR M8: Instream

INSTREAM BIOTA	Score
Fish	C
Macro Macroinvertebrates	C
Confidence rating for instream biological information	2
INSTREAM ECOLOGICAL CATEOGORY	**C**
Riparian vegetation	C/D
Confidence rating for riparian vegetation zone information	3.4
ECOSTATUS	**C/D**

22.5 RECOMMENDED ECOLOGICAL CATEGORY (REC):

The REC is determined based on ecological criteria only and considers the EIS, the restoration potential and attainability there-of. The EIS is HIGH; therefore the REC is to improve the PES.The main objectives set for EFR 8 to that would achieve improvements were to:

- Cease spraying.

- Revert back to a functioning wetland.

To achieve these objectives the following physical changes to the wetland would be needed:

- Improved *Phragmites* cover.
- Reinstatement of shallow areas with constant depth.

An additional aim would be to achieve a greater area of wetted wetland, i.e. that some flows and dampness increased in the wetland downstream of the Bosbokpark crossing.

The objectives could be achieved by dropping the level (height) of the Bosbokpark crossing without altering PD flows. However, it was important to determine at which height wetland depth is lost to a state of dampness.

22.6 SUMMARY OF ECOCLASSIFICATION RESULTS

The results for setting EFR scenarios are summarised in Table 22.8.

Table 22.6 EFR M8: Summary of EcoClassification results

Driver Components	PES	REC
IHI HYDROLOGY	D/E	
WATER QUALITY	B	B
GEOMORPHOLOGY	B	B
Response Components	**PES**	**REC**
FISH	C	B
MACRO INVERTEBRATES	C	B
INSTREAM	C	B
RIPARIAN VEGETATION	C/D	B/C
ECOSTATUS	C/D	B
WETLAND IHI	D	C
LARGER WETLAND / MRU ECOSTATUS	C	B

23 EFR M8 (MOLOPO WETLANDS) – EVALUATION OF OPERATIONAL SCENARIOS AND EFR RECOMMENDATION

23.1 APPROACH FOR SETTING EFR

The approach had to consider the following constraints:

- Mafikeng presently has water shortages and it is highly unlikely that there is any scope to decrease abstractions in order to increase flow to the wetland.
- The Bosbokpark crossing causes back-up and is a major impact on the wetland. Increased water to the wetland will probably not have the desired effect without addressing the back-up problems.

Setting flow requirements within such a modified system will serve no purpose as increased flow on its own will not improve the system due to the back-up effect of the lower crossing (Bosbokpark). In order to improve the wetland the main objectives set for EFR 8 were to revert back to a functioning wetland which can be achieved by:

- Improved *Phragmites* cover.
- Reinstatement of shallow areas with constant depth.
- Cease spraying of toxic pesticides for control of *Quelea quelea* and reeds.

An additional aim would be to achieve a greater area of wetted wetland, i.e. that some flows and dampness increased in the wetland downstream of the Bosbokpark crossing.

The process followed was a scenario based approach where each scenario was evaluated in terms of the component responses and change in Ecological Category. The steps followed were:

- Determining a realistic set of the scenarios.
- Providing the hydro-dynamic implication of each scenario indicating the extent of pooled areas, and depth and velocity in areas not affected by back-up.
- Providing the physical and ecological responses to each scenario.
- Ranking the scenarios in terms of most preferable, i.e., those that would achieve the REC and ranking according to changes from the present situation.
- Determining whether there were any additional mitigation measures or management actions that needed to be taken that could improve a scenario resulting in the achievement of the REC.

23.2 BOSBOKPARK ROAD CROSSING

The road crossing at the end of EFR M8 was originally constructed during 1965 to link the two portions of the farm Trekdrift. This road crossing was upgraded by the farmer during March 2005. The upgrade involved raising the height of the road and inserting six pipes. The permanent inundation and subsequent loss of connectivity in this section of the wetland was raised as a concern at the North West Wetland Forum. Working for Wetlands volunteered to rehabilitate the road crossing during 2007. They inserted gabion structures, but the upstream inundation problems and the downstream erosion caused by the discharge through the pipes remained a concern.

23.3 HYDRAULIC DESCRIPTION OF THE EFR 8 WETLAND REACH

The (second) road crossing – Bosbokpark - consists of an elevated roadway (approx. 2.5 m) with eight 205 mm diameter pipes positioned below the road surface. It therefore acts as a substantial impoundment, backing up the water level over an upstream distance of approx. 1.2 km. Three (bank-to-bank) cross-sections(XS) (refer to Figure 23.1 and 23.2) were surveyed in the section upstream of the impoundment at distances of approximately 500 m (D), 800 m (C) and 1200 m (B). A further road crossing exists approximately 230 m downstream of the gauging weir (i.e. 1.43 km upstream of the second road crossing). A left bank cross-section (A) was surveyed between the weir and the first road crossing (dense reeds prevented a complete bank-to-bank survey). The first road crossing incorporates a rectangular culvert (width: 1.65m (upstream) to 0.61m (downstream)).

At the time of the survey, the discharge into the wetland (after the diversion to Mafikeng) was $0.15 m^3/s$. The maximum measured flow depths at cross-sections A to D were 0.64 m, 0.56 m, 1.57 m and 2.25 m, respectively. In addition, the maximum depths in the wetland upstream and downstream of the first road crossing were 0.43 m and 0.49 m respectively. Consequently, the average depth at this discharge for unimpounded areas of the wetland is estimated at approx. 0.50 m (the survey indicates that cross-sections C and D are within the backup area). The average depth at cross-section B at this flow was approx. 0.15 m. This average depth at cross-section C (though currently backed-up), corresponds to a maximum depth of 0.43 m - supporting the above approximate maximum depth value of 0.50 m at $0.15 m^3/s$. At average depths of 0.15 m at cross-sections B and C (and $0.15 m^3/s$), the average velocities range from approximately 0.02 m/s to 0.09 m/s.

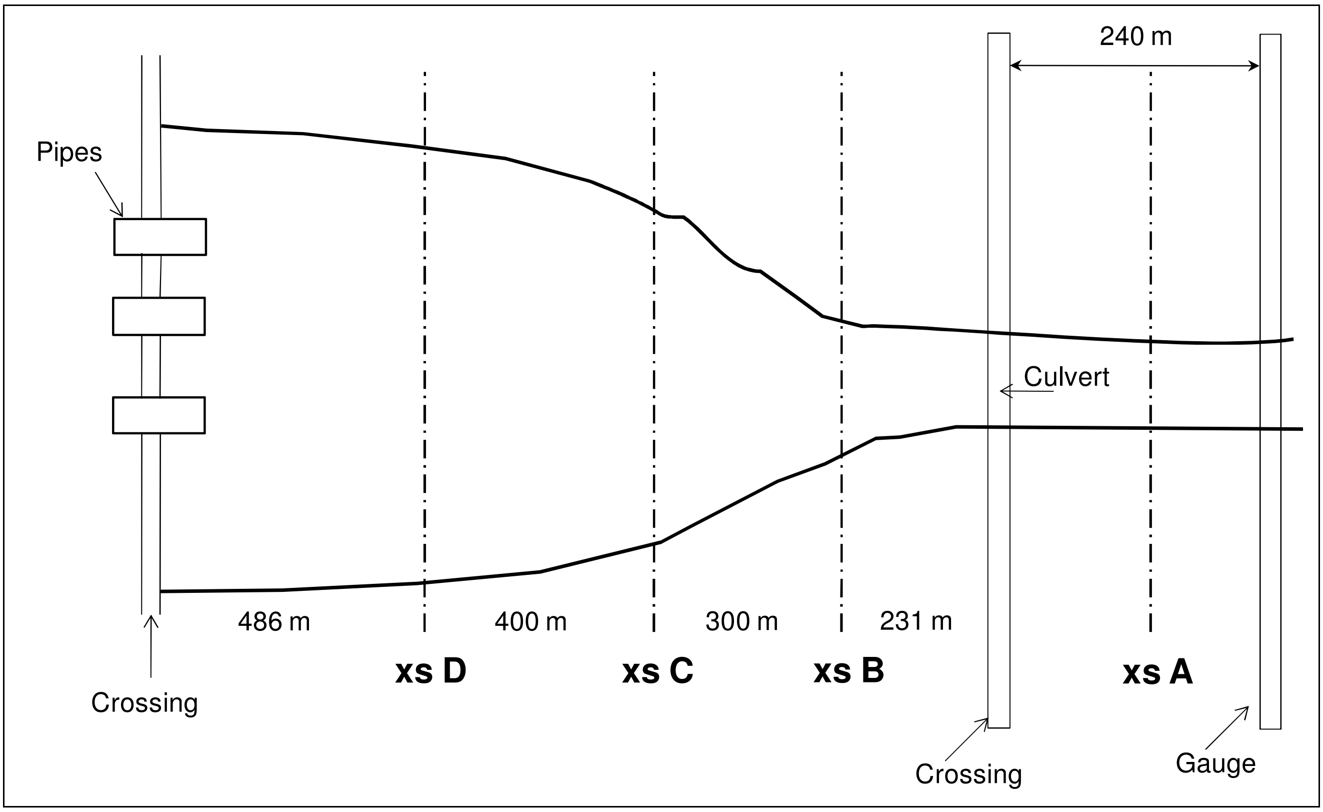


Figure 23.1 Plan view of study sites, cross-sections and crossings

23.4 DESCRIPTION OF MANAGEMENT SCENARIOS

The description of the hydraulically-related scenarios devised for the Molopo wetland are listed below while Figure 23.2 depicts these scenarios as well as the implications of the size of pooled areas.

- **Present Day**: Indicated in black in Figure 23.2.
- **Scenario 1** (indicated in red): Considered a reduction in water level of 1.2 m at the Bosbokpark road crossing such that the backup extended upstream to cross-section C. Inflow remains at present day levels.
- **Scenario 2** (indicated in blue): A reduction in water level by 2.2m with backup extending to cross-section D. Inflow remains at present day levels. Average depth in pool that remains will be 30 cm and it will become overgrown with reeds.
- **Scenario 3** (indicated in pink): Drop road crossing to original bed level (inflow remains at PD levels). This implies assessing no substantial backup from the road crossing. For this scenario the hydraulic parameters represented:
  - Velocity: 2 – 9 m/s
  - Maximum depth: 49 – 64 cm; and
  - Average depth: 15 cm.
- **Scenario 4**: Represented present day flow with no spraying to kill reeds (i.e. increased vegetation growth). This scenario was based on the assumption that current structures would not change.
- **Scenario 5**: A reduction in the discharge to 0.075 m^3/s (50% flow of present day) was considered (increased abstractions to Mafikeng), with the existing impoundment remaining in place. This related to a loss of 10 cm depth in unimpaired sections with backup as is and no spraying.

A sixth scenario was also considered which represented 75% of present day flows to the wetland with a loss of 5 cm depth in unimpaired sections with backup. However, a distinction could not be made between this scenario and Scenario 5 and only Scenario 5 is considered further.

Note: Under Scenario 1 - 3, the flows in the wetland remain unchanged from present day conditions. Under present day conditions, the backup extends to approximately cross-section B (Figure 23.2).

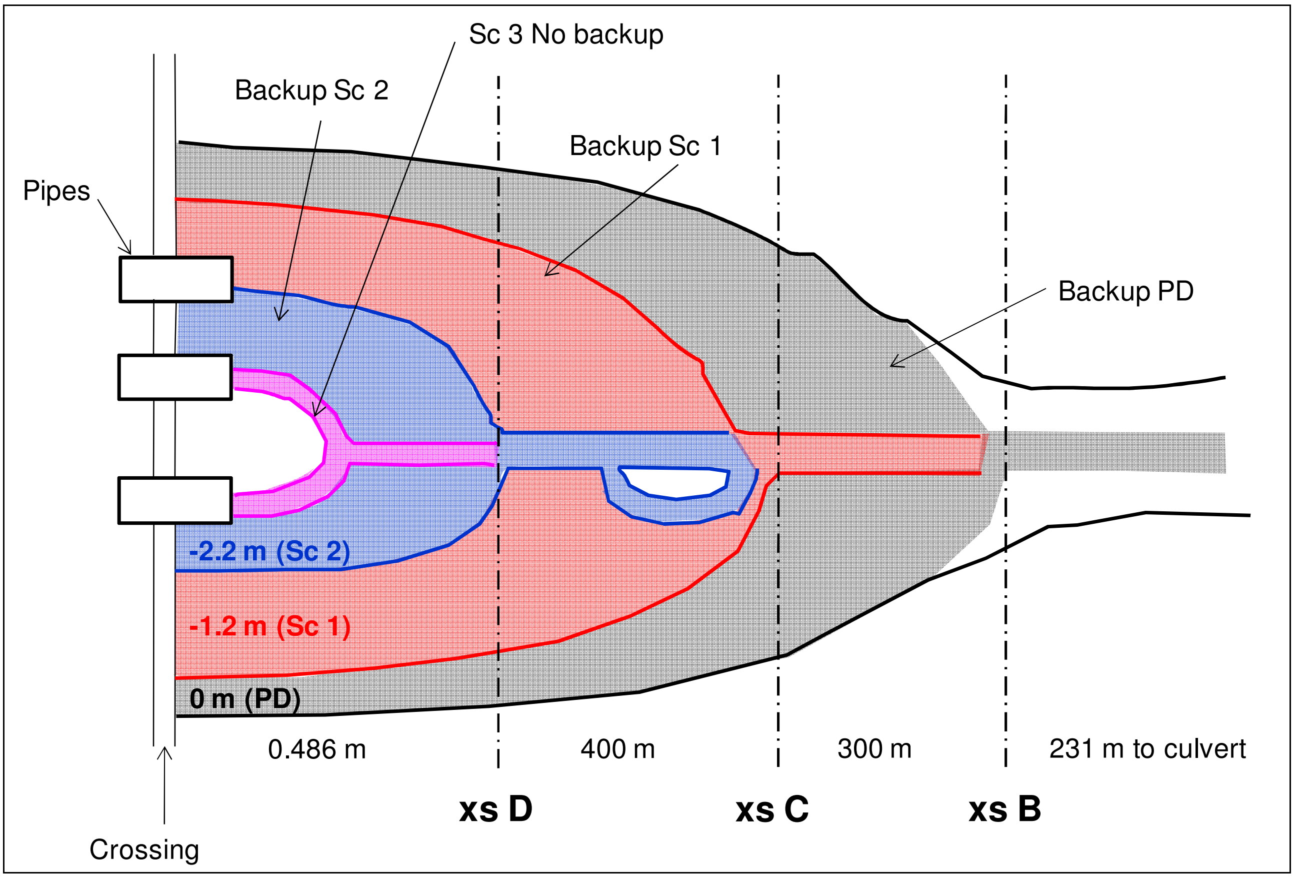


Figure 23.2 Description of Scenario 1 to 5 and the implications on the size of pooled areas

23.5 CONSEQUENCES OF EACH SCENARIO

The consequences for each scenario for each wetland component is discussed separately below and summarised in Section 23.6.

23.5.1 Wetland Index of Habitat Integrity

Using the hydraulic data provided, estimates were made of the expected EC changes to the wetland at the site and for the larger Management Resource Unit (MRU A). Scenarios 1 and 2 offered the best scenario for ecological improvement of the wetland, since the section currently impounded would improve, and more water would flow to the downstream wetland sections. Scenario 5 (reduction of inflows) caused rapid declines in the Ecological Condition of the site – deteriorating to a D/E Ecological Category respectively for the MRU.

Table 23.1 Scenario assessment for the EFR site

SCENARIO	EFR 8	MRU A	DESCRIPTION	CONF
	Wetland IHI EC			
SCENARIO 1: Drop road crossing by 1.2m	C/D	C	Although inflows will remain low, backup area should be reduced by 50%. Flows to the downstream wetland area will increase by 35%.	2
SCENARIO 2: Drop road crossing by 2m	C	B	Although inflows will remain low, backup area should be reduced by 75%. Flows to the downstream wetland area will increase by 50%.	2
SCENARIO 3: Drop road crossing to original bed level	C	B	Although inflows will remain low, backup area should be reduced by 85%. Flows to the downstream wetland area will increase by 60%.	2
SCENARIO 4: Present day without spraying.	D	C	No significant change from PES expected. No change to the flows to the downstream wetland.	1.5

SCENARIO	EFR 8	MRU A	DESCRIPTION	CONF
	Wetland IHI EC			
SCENARIO 5: Reduced inflows (50% of Present Day),	**D**	**D/E**	Wetland at EFR 8 site becomes desiccated more frequently, and flows to the downstream wetland area will decrease by 94%	1
SCENARIO 6: Reduced inflows (75% of Present Day),	**D**	**D**	Wetland at EFR 8 site becomes desiccated more frequently, and flows to the downstream wetland area will decrease by 50%	1

23.5.2 Riparian vegetation

The rules used to assess the scenarios were based on the expected sorting of species along a hydraulic gradient. General zonation would consist of an outer grass and sedge zone (hydrophilic grasses such as *Imperata cylindrica* as well as several species of *Cyperus* and *Juncus*) followed by an extensive reed zone (*Phragmites australis*) followed by a deep water aquatic vegetation zone (*Potamogeton sweinfurthii*). *Phragmites*has a higher tolerance to drying than *Typha capensis* which would occur in the lower, wetter part of the reed zone. Wetter environments such as current conditions would favour the establishment of *T. capensis* especially if reeds are being poisoned and/or removed. Increasing overall wetland dryness would afford *P. australis* a competitive advantage and species compositional shifts towards reeds would occur as water levels drop. The same principle would apply to grasses and sedges on the outskirts, thus too much drying (or incision) would reduce reed cover and density on the outer edges and grasses and sedges would increase.

Table 23.2 Consequences of the scenarios on riparian vegetation

Sc	EC	Motivation
PD	C/D (60.4%)	Main impacts are changes in species composition due to impoundment of water and a much wetter than natural wetland in general. The poisoning of reeds has exacerbated this. Deep pools and associated aquatic vegetation are not natural. (Confidence 3.4)
Sc 1	C (70.1%)	Open water is reduced: Aquatic species reduce by approximately 50% due to loss of available habitat. Aquatic species will further reduce in cover as emergent vegetation (mainly *Phragmites australis* and *Typha capensis*) colonise shallower water. Emergent vegetation also respond to no spraying i.e. biomass will improve. (Confidence 3)
Sc 2	B/C (78.5%)	Aquatics species will disappear as does open water. Emergent species will completely cover the wetland area. *Typha capensis* will be reduced in cover and density, especially at the dryer edges of the wetland, which promotes overall reed cover (an improvement for species composition). Conditions at the dryer edges of the wetland will result in lower density reeds with an associate increase in hydrophilic grasses. The prevailing depth of water is not deep enough to exclude vegetation i.e. water will be completely vegetated. (Confidence 2.5)
Sc 3	C (74.2%)	Similar to Scenario 2, but an overall dryer state. Hydrophilic grasses will increase along the edges of the wetland (with an associated thinning of *P. australis*) which increases the reed, non-woody and species composition. This scenario has the danger of incising a channel because of the way that water is routed through it. Should this happen the wetland will dry out from the edges inwards and species composition will completely change. The final EC would then likely be worse or similar to the current PES. (Confidence 2.5)
Sc 4	C (64.6%)	Emergent vegetation will increase in cover as spraying is stopped. This will reduce open water area, and although deep pools remain, aquatic vegetation will be reduced due to increased shading. Patchiness of reed and bullrush clumps likely to remain with this much water over the wetland. (Confidence 3)
Sc 5	C/D	Will not make a difference to the vegetation EC since the main impacts are as a result of water impoundment and this, together with the extent of backup does not change. (Confidence 3)

23.5.3 Fish

Each scenario was evaluated by running the FRAI do determine possible changes in the fish EC. The results are summarised in Table 23.3.

Table 23.3 Consequences of the scenarios on fish

Sc	EC	DESCRIPTION	CONF
Sc 1	C (64.7%)	No significant or evident change from PES expected.	1
Sc 2	B (85%)	Fish assemblage expected to improve significantly to a higher category than PES due to improved habitat for barb species (SD habitats transformed to SS), improved water quality in terms of no reed spraying. The loss of all SD habitats under this scenario is expected to result in the eradication or decrease in abundance and occurrence of MSAL and CGAR, which will furthermore have a positive impact on the indigenous fish species due to decreased predation pressure. Should the road crossing also be improved to allow movement of fish up- and downstream, it could further improve the biotic integrity (in terms of fish) under this scenario.	0.5
Sc 3	B (85%)	Fish assemblage expected to improve significantly to a higher category than PES due to improved habitat for barb species (SS), removal of migration barrier that will allow more natural movement of all fish species, improved water quality in terms of no reed spraying, as well as eradication or decrease of the abundance and occurrence of MSAL and CGAR (due to loss of SD habitats).	1
Sc 4	C (64.7%)	No significant or evident change from PES expected.	2
Sc 5	D (52.5%)	Assuming BBRI was identified correctly and is still present under present conditions, and this reduction in flow is significant enough to result in loss of this species from this reach, then the EC will drop into a category D. The FROC of the rest of the species is not expected to change significantly under this scenario (slight decrease in FROC may be expected due to loss in habitat).	0.5

If scenarios 2 or 3 were implemented and the MSAL population controlled or eradicated, the restoration of the connectivity between the wetland reach and the Molopo Eye through the erection of a fishway should be considered.

23.5.4 Macroinvertebrates

Each scenario was evaluated by running the FRAI do determine possible changes in the fish EC. The results are summarised in Table 23.4.

Table 23.4 Consequences of the scenarios on the macroinvertebrates

SC	EC	COMMENT	CONF
Sc 1	C (72%)	Taxa expected to return under this scenario include taxa sensitive to toxins (snails and Leptoceridae), and taxa that prefer vegetation (Nepidae and Gyrinidae).	1
Sc 2	B/C (80%)	Taxa expected to return under this scenario include taxa sensitive to toxins (snails and Leptoceridae), and taxa that prefer vegetation (Nepidae, Hydrophilidae, Gyrinidae, Hydrometridae and Lestidae).	1
Sc 3	B/C (80%)	Taxa expected to return under this scenario include taxa sensitive to toxins (snails and Leptoceridae), and taxa that prefer vegetation (Nepidae, Hydrophilidae, Gyrinidae, Hydrometridae and Lestidae).	1
Sc 4	C (66%)	Taxa expected to return under this scenario include taxa sensitive to toxins (e.g. snails and Leptoceridae). However, the overall category is not expected to change significantly from present-day.	1
Sc 5	C/D (60%)	Taxa expected to return under this scenario are snails; but flow-dependent taxa are expected to disappear (i.e. Simuliidae; Atyidae, Leptoceridae, Hydroptilidae, Ecnomidae).	2

23.6 SUMMARY OF CONSEQUENCES

Figure 23.3 summarises the consequences of each scenario indicating the change from PES in the Ecological Category. Based on the results in the table section of the figure, the scenarios are ranked in terms of the achievement of the REC, and if the REC is not met ranking is based on the degree to which the REC is not achieved. The ranking is depicted by means of a traffic diagram where good indicates the achievement of the REC and red indicates non-achievement. One could also view this ranking in terms of the changes from PES which is pegged in the middle of the traffic diagram.

None of the scenarios achieve the REC of a B for all components. Both Sc 2 and 3 achieve an improvement to a B/C and it is felt that with the following appropriate additional measures, the REC can be achieved.

- Sc 2: The construction of a fishway to connect the wetland to the upstream Molopo Eye.
- Sc 3: Would require mitigation measures to address erosion and incision. The construction of a fishway to connect the wetland to the upstream Molopo Eye.

Scenario 2 and 3 are similar apart from riparian vegetation which improves more under Sc 2. It is therefore ranked marginally higher than Sc 3 (Figure 23.3). Scenario 1 and 4 result in marginal improvements of the PES.

Scenario 5, i.e. a decrease of flow to the wetland, will significantly drop the EC to a D/C and is therefore ranked close to the bottom of the traffic diagram.

Driver Components	PES	REC	Sc1	Sc 2	Sc 3	Sc 4	Sc 5
IHI HYDROLOGY	D/E		D/E	D/E	D/E	D/E	E/F
WATER QUALITY	B	B	B	B	B	B	B
Response Components	**PES**	**REC**	**Sc1**	**Sc 2**	**Sc 3**	**Sc 4**	**Sc 5**
FISH	C	B	C	B	B	C	D
MACRO-INVERTEBRATES	C	B	C+	B/C	B/C	C+	C/D
INSTREAM	C	B	C	B/C	B/C	C	D
RIPARIAN VEGETATION	C/D	B/C	C	B/C	C	C	C/D
ECOSTATUS	C	B	C+	B/C	B/C	C+	C/D
WETLAND IHI	D	C	C/D	C	C		D
LARGER WETLAND / MRU	C	B	C	B	B	C	D/E

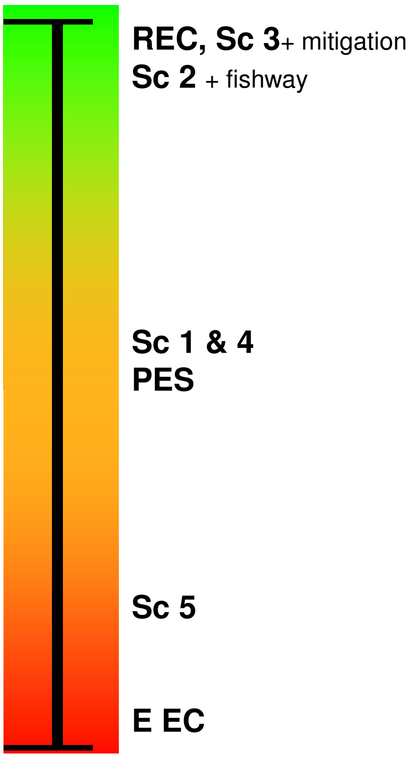


Figure 23.3 Consequences of scenarios and ranking

The conclusion is that either Scenario 2 or 3 can be implemented and considering the requirement of crossing by landowners, Scenario 2 (which will require dropping, but not removing the crossing) will probably be the preferred option.

24 CONCLUSIONS AND RECOMMENDATIONS

24.1 ECOCLASSIFICATION

The EcoClassification results are summarised below in Table 24.1.

Table 24.1 EcoClassification Results summary

EFR 01 (HOPETOWN)

EIS: MODERATE
The highest scoring metrics are instream and riparian rare and endangered biota, unique riparian biota, instream biota intolerant to flow, taxon richness of riparian biota, critical riparian habitat and refugia and riparian migration corridor.

PES: C
The major issues that have caused the change from reference conditions are the releases for hydropower, barrier effects of the dams, water quality problems and the destruction of and removal of vegetation on floodplains for agriculture. The dominant factor seems to be the hydro-electric releases.

Driver Components	PES	TREND
IHI HYDROLOGY	E	
WATER QUALITY	D	
GEOMORPHOLOGY	C/D	-
INSTREAM IHI	D/E	
RIPARIAN IHI	C	
Response Components	**PES**	**TREND**
FISH	C/D	0
MACRO INVERTEBRATES	C	0
INSTREAM	C	0
RIPARIAN VEGETATION	B/C	0
RIVERINE FAUNA	C	0
ECOSTATUS	C	0
EIS	MODERATE	

EFR 02 (BOEGOEBERG)

EIS: HIGH
Highest scoring metrics are instream and riparian rare /endangered biota, unique riparian biota, instream biota intolerant to flow, taxon richness of riparian biota, diversity of riparian habitat types, critical riparian habitat, refugia, and migration corridor.

PES: C
Loss of frequency of large floods, agricultural return flows, higher low flows than natural in the dry season, drought and dry periods, decreased low flows at other times, release of sediment, presence of alien fish species and barrier effects of dams.

REC: B/C
Instream improvement was not possible due to constraints and no EFR will be set for REC.

AEC D (instream)
Decreased low flows in the wet and dry season. Decreased floods, decreased dilution resulting in worse water quality. Reduced low flows will result in less light penetration which will result in algal and benthic growth.

Driver Components	PES	TREND	REC	AEC↓
IHI HYDROLOGY	E			
WATER QUALITY	C		C	D
GEOMORPHOLOGY	C	0	C	C
INSTREAM IHI	C/D			
RIPARIAN IHI	B/C			
Response Components	**PES**	**TREND**	**REC**	**AEC↓**
FISH	C	0	C	D
MACRO INVERTEBRATES	C	0	C	D
INSTREAM	C	0	C	D
RIPARIAN VEGETATION	B	0	A/B	B/C
RIVERINE FAUNA	C	0	B	C
ECOSTATUS	C	0	B/C	C
EIS	HIGH			

EFR 03 (AUGRABIES)

EIS: HIGH
Highest scoring metrics are instream and riparian rare /endangered biota, unique instream and riparian biota, taxon richness of riparian biota, diversity of riparian habitat types, critical riparian habitat, refugia, migration corridor, National Park.

PES: C
Decreased frequency of large floods. Agricultural return flows, agricultural activities and associated water quality impacts. Higher low flows than natural in the dry season, drought and dry periods. Decreased low flows at other times. Presence of alien fish species and barrier effects of dams and alien vegetation. Decreased sedimentation.

REC: B
Reinstate droughts (i.e., lower flows than present during the drought season).Improved (higher) wet season base flows. Clear vegetation. Improved agricultural practices.

AEC: D
Increased agriculture with associated impacts on water quality and decreased wet season base flows. Decreased floods. Increased vegetation aliens.

Driver Components	PES	TREND	REC	AEC↓
IHI HYDROLOGY	E			
WATER QUALITY	C		C	D
GEOMORPHOLOGY	C	0	C	C-
INSTREAM IHI	D			
RIPARIAN IHI	C/D			
Response Components	**PES**	**TREND**	**REC**	**AEC↓**
FISH	C	0	B	D
MACRO INVERTEBRATES	C	0	B	D
INSTREAM	C	0	B	D
RIPARIAN VEGETATION	B/C	-	B	C
RIVERINE FAUNA	C	0	B	C
ECOSTATUS	C	0	B	C*
EIS	HIGH			

* The focus for setting EFRs will be on the instream EC of a D

EFR 04 (VIOOLSDRIF)

EIS: HIGH
Highest scoring metrics are instream and riparian rare /endangered biota, unique instream and riparian biota, migration corridor, National Park.

PES: B/C
Decreased frequency of large floods. Agricultural return flows and mining activities – water quality problems. Higher low flows than natural in the dry season, drought and dry periods. Decreased low flows at other times. Presence of alien fish species and barrier effects of dams. Decreased sedimentation due to lack of large floods and upstream dams. Alien vegetation.
REC:
Improved (higher) wet season base flows. Clear vegetation aliens. Control grazing and trampling.
AEC:
Increased mining with associated impacts on water quality and decreased wet season base flows. Decreased floods. Increased vegetation aliens (esp *Prosopis sp.*).Habitat loss for a large percentage of time due to decreased flows. Vegetation: Increased sedges due to increased sedimentation.

Driver Components	PES	Trend	REC	AEC↓
IHI HYDROLOGY	D			
WATER QUALITY	C/D		C/D	D
GEOMORPHOLOGY	C	0	C	C
INSTREAM IHI	D			
RIPARIAN IHI	D			
Response Components	**PES**	**Trend**	**REC**	**AEC↓**
FISH	C	0	B/C	D
MACRO INVERTEBRATES	C	0	B/C	D
INSTREAM	C	0	B/C	D
RIPARIAN VEGETATION	C	-	B	C/D
RIVERINE FAUNA	C	-	B/C	C/D
ECOSTATUS	C	-	B/C	D
EIS	HIGH			

EFR C5 (UPPER CALEDON)

EIS: LOW.
Highest scoring metrices are rare and endangered riparian species, instream biota taxon richness, and sensitive instream habitat (to flow changes).

PES: C/D
Grazing and trampling, bank erosion, sedimentation, exotic vegetation and fish species.

REC:C/D
EIS is low - provides no motivation for improvement. The problems are also all non-flow related.

AEC ↓: D
Decreased flows due to increased abstraction. Reduced dilatation - impact temperature and oxygen. Increased sedimentation (continued erosion). Habitat loss for a large percentage of time. Vegetation – increased sedges due to increased sedimentation.

Driver Components	PES	Trend	AEC↓
IHI HYDROLOGY	A/B		
WATER QUALITY	B/C		C
GEOMORPHOLOGY	C	-	C/D
INSTREAM IHI	B/C		
RIPARIAN IHI	C		
Response Components	**PES**	**Trend**	**AEC↓**
FISH	D	0	E
MACRO INVERTEBRATES	C	0	C/D
INSTREAM	D	0	D
RIPARIAN VEGETATION	C	0	C
ECOSTATUS	C/D		D
EIS	LOW		

EFR C6 (LOWER CALEDON)

EIS: LOW
The highest scoring matrices are rare and endangered riparian species.

PES:C
Sedimentation (bank erosion), significantly reduced base flows, alien fish species.

REC:C
EIS is low - provides no motivation for improvement.

AEC ↑: B/C
Bottom releases must take place during the wet season and not during low flow conditions. Low flows must be improved. No zero flows or limited duration.

Driver Components	PES	Trend	AEC↑
IHI HYDROLOGY	E		
WATER QUALITY	C		C(+)
GEOMORPHOLOGY	C/D	0	C
INSTREAM IHI	E		
RIPARIAN IHI	B/C		
Response Components	**PES**	**Trend**	**AEC↑**
FISH	D	0	C
MACRO INVERTEBRATES	D	0	C
INSTREAM	D	0	C
RIPARIAN VEGETATION	B	0	B
ECOSTATUS	C		B/C
EIS	LOW		

EFR K7 (LOWER KRAAI)

EIS: MODERATE
The highest scoring matrix was unique riparian biota.

PES: C
Reduced base flows, exotic vegetation and fish species, grazing and trampling, bank erosion.

REC: C
The EIS is moderate which does not provide motivation for improvement.

AEC↓: C
Increased abstraction; more frequent zero flows. Negative impact on water quality. Decrease in small floods (e.g. by an increase of dams in the tributaries).Slightly higher sedimentation in areas.

AEC↑: B
Decreased abstraction (higher base flows) and no zero flows. Improved water quality. Alien vegetation should be cleared.

Driver Components	PES	Trend	AEC↓	AEC↑
IHI HYDROLOGY	A/B			
WATER QUALITY	B/C		C	A/B
GEOMORPHOLOGY	A/B	0	B/C	A/B
INSTREAM IHI	B/C			
RIPARIAN IHI	C			
Response Components	**PES**	**Trend**	**AEC↓**	**AEC↑**
FISH	C	0	D	B
MACRO INVERTEBRATES	C	0	D	B
INSTREAM	C	0	D	B
RIPARIAN VEGETATION	C	-	C-	B/C
ECOSTATUS	C		C	B
EIS	MODERATE			

EFR M8 (MOLOPO WETLANDS)

EIS: HIGH
Wetland is a unique habitat in this dry region. Highest scoring matrix were Rare and endangered vegetation types. Unique fish and macroinvertebrate species. Critical habitat and refuge and a Proclaimed area.

PES: C
Pesticide spraying. Backup effect from poorly designed road crossings. Burning of reeds. Alien fish species.

REC: B
As the EIS is HIGH, the REC is an improvement of the PES.

Driver Components	PES	REC
IHI HYDROLOGY	D/E	
WATER QUALITY	B	B
GEOMORPHOLOGY	B	B
Response Components	**PES**	**REC**
FISH	C	B
MACRO INVERTEBRATES	C	B
INSTREAM	C	B
RIPARIAN VEGETATION	C/D	B/C
ECOSTATUS	C/D	B
WETLAND IHI	D	C
LARGER WETLAND / MRU ECOSTATUS	C	B

24.1.1 Confidence In Results

The confidence in EcoClassification is provided in Table 24.2 and is based on data availability and EcoClassification where:

- Data availability: Evaluation based on the adequacy of any available data for interpretation of the Ecological Category and AEC.
- EcoClassification: Evaluation based on the confidence in the accuracy of the Ecological Category.

The confidence score is based on a scale of 0 – 5 and colour coded where:

0 – 1.9: Low 2 – 3.4: Moderate 3.5 – 5: High

These confidence ratings are applicable to scoring provided in this chapter.

Table 24.2 Confidence in EcoClassification

	Data availability									EcoClassification								
EFR site	Hydrology	Physico-chemical	Geomorph	IHI	Fish	Macro-invertebrates	Vegetation	Average	Median	Hydrology	Physico-chemical	Geomorp	IHI	Fish	Macro-invertebrates	Vegetation	Average	Median
O1	2.5	3.3	2	3	3	2	4.5	2.9	3.00	4	3	2.5	2.6	3	3	4	3.2	3
O2	2.5	3.3	4	3.5	3	4	4.5	3.5	3.5	3	3.5	3.5	2.6	3	4	4	3.4	3.5
O3	2	3	3	3.5	3	4	4.5	3.3	3	3	3.5	3	3	3.5	4	3.8	3.4	3.5
O4	2	2.25	3.5	3.5	3	4	4.5	3.3	3.5	3	2.5	3	3	3.5	4	3.8	3.3	3
C5	2.5	3.5	2.5	3.5	3	2	4.5	3.1	3	2.5	3.5	3.5	3.5	4	3	3.3	3.3	3.5
C6	2	3.8	3	3.5	3	2	4.5	3.1	3	3	4	3.5	3.2	3	3	3.7	3.3	3.2
K7	4	3.8	3	3	3	2	4.5	3.3	3.	3	3	4	3.5	3.5	2	4	3.3	3.5
M8	4	0.5	1.5	3.5	3	4	4.5	3.4	3.8	2	1.9	3	3.3	2	3	3.4	2.7	3

24.1.2 Conclusions

The results indicate an overall moderate to high confidence. Considering that only one biophysical survey was undertaken, the confidence is higher than expected. This is probably due to the moderate to high confidence in the data availability. The only low confidence is linked to the lack of physico-chemical data at EFR M8 and the lack of available geomorphological data.

24.2 ENVIRONMENTAL FLOW REQUIREMENTS

24.2.1 Summary of Final Results

The natural MARs as provided by WRP are given in Table 24.4. The final flow requirements are expressed as a percentage of the natural MAR in Table 24.5.

Table 24.3 Natural and PD MARs of the EFR sites

Site	NATURAL MAR	Present MAR
EFR O2	10573.7	4629.6
EFR O3	10513.1	4628.5
EFR O4	10335.1	3906.8
EFR C5	56.904	±56.904
EFR C6	1347.96	1134.948
EFR K7	682.5	641.292
EFR M8	10.33	4.42

Table 24.4 Summary of results as a percentage of the natural MAR

EFR site	EC	Maintenance low flows		Drought low flows		High flows		Long term mean	
		(%nMAR)	MCM	(%nMAR)	MCM	(%nMAR)	MCM	(% nMAR)	MCM
Virgin MARs									
EFR O2	PES/REC	11.6	1226.55	4.4	465.24	5.4	570.98	15.2	1607.20
	AEC↓: D	5.8	613.27	3.1	327.78	5	528.69	11.3	1194.83
EFR O3	PES: C	8.4	883.10	2.6	273.34	4.7	494.12	11.9	1251.06
	REC: B	17.6	1850.31	3.4	157.37	4.7	494.12	19.2	2018.52
	AEC↓: D	4.1	431.04	2.2	231.29	4.4	462.58	9	946.18
EFR O4	PES: C	6.3	651.11	0.9	35.16	4.2	434.07	8.9	919.82
	REC: B/C	10.1	1043.85	1.3	134.36	4.2	434.07	12.2	1260.88
	AEC↓: D	3.1	320.39	0.8	31.25	3.8	392.73	6.9	713.12
EFR C5	PES/REC: C/D	13.8	7.85	5.8	3.30	11.4	6.49	26	14.80
EFR C6	PES/REC: D	8.8	118.62	0.3	3.40	10.5	141.54	20.1	270.94
	AEC↑: C	15.5	208.93	2.2	29.66	13.1	176.58	26.1	351.82
EFR K7	PES/REC: C	11.4	77.81	0	0.00	8.4	57.33	18.1	123.53
	AEC↑: B	16.5	112.61	1.2	7.70	8.4	57.33	21.8	148.79
	AEC↓: D	5.1	34.81	0	0.00	7.1	48.46	12.9	88.04

24.2.2 Confidences

24.2.2.1 Confidence in low flow EFR

The question the confidence assessment should answer is the following:

> 'How confident are you that the low flow (with the associated high flows) recommended will achieve the EC?'

To determine the confidence, one should consider:

- The quality of available data; and
- Whether your requirement represents the critical requirement. For example, if the macroinvertebrate stress requirement of a 4 at 30% was the final recommendation, and fish was 7 at 30%, then fish should have very high confidence that the recommended flow will achieve the EC. This is because the fish will receive more flow than required, so even if the fish data availability and understanding of habitat requirements are of low confidence, the confidence that this much higher requirement that is being recommended, based on

macroinvertebrates, will cater for fish requirements and should result in a high confidence that the EC will be maintained/achieved.

The low flow confidence evaluation is representative of the component (fish or macroinvertebrates) confidence which drove the flow requirement. If both components drove the flow requirement, then an average of the confidence is provided.

Table 24.6 provides the confidence for the low flow biotic components (fish, macroinvertebrates and riparian vegetation). The shaded green columns indicate which of these components dictated the final requirements. The final confidence is representative of these requirements.

Table 24.5 Confidence in low flows for biotic responses

EFR SITE	FISH	MACRO-INVERTS	RIP VEG	COMMENT	OVERALL CONFIDENCE
EFR O2	3	2	3	**Fish:** These flows should be adequate to attain the specific EC for fish, as the requirements for the different life-stages of the indicator guild (semi-rheophilic) are well documented and were strongly considered in determining the stress index. **Macroinvertebrates:** The low flows requested appear not to meet the preferred hydraulic conditions for the indicator species, *Amphipsyche scottae*. This may be because the hydraulic cross-section was located in a slow run, which is not the preferred habitat for this species. The flows requested are unlikely to inundate the lower marginal zone, but there was no justification for requesting higher flows than present day to maintain the PES. **Riparian vegetation:** Low flow requirements for instream fauna will suffice to maintain the PES for riparian vegetation, provided that Class I floods are provided. Confidence in the assessment is high since an accurate hydraulic profile was done and many vegetation indicators were surveyed.	2.7
EFR O3	3	3	3	**Fish:** In most cases fish were the driver. It is thought that the recommended flows (stress levels) should be adequate to attain the specific EC for fish, as the requirements for the different life-stages of the indicator guild (semi-rheophilic) are well documented and were strongly considered. **Macroinvertebrates:** The flows requested are unlikely to inundate the lower marginal zone, but there was no justification for requesting higher flows than present day to maintain the PES. **Riparian Vegetation:** Confidence in the assessment is high since an accurate hydraulic profile is available and many vegetation indicators were surveyed (see notes for detailed species explanations).	3
EFR O4	3	3	3.5	**Fish:** In most cases fish were the driver. It is thought that the recommended flows (stress levels) should be adequate to attain the specific EC for fish, as the requirements for the different life-stages of the indicator guild (semi-rheophilic) are well documented and were strongly considered. **Macroinvertebrates:** The flows requested are unlikely to inundate the lower marginal zone, but there was no justification for requesting higher flows than present-day to maintain the PES. **Riparian Vegetation:** Confidence in the assessment is high since an accurate hydraulic profile is available and many vegetation indicators were surveyed (see notes for detailed species explanations).	3
EFR C5	3.5	1	3	**Fish:** The requirements for the different life-stages of the indicator species is well documented and could therefore be considered with high confidence during the process. **Macroinvertebrates:** The final recommended low flows for the dry season are expected to maintain the macroinvertebrates within the PES, but the final low flows recommended for the wet season were significantly lower than that considered necessary to maintain the macroinvertebrates in a Category C, considering the sensitive nature of the indicator taxa that are found at the site (Heptageniidae and Leptophlebiidae). **Riparian Vegetation:** Confidence in the assessment is high since an accurate hydraulic profile was done and vegetation indicators were surveyed (see notes for detailed species explanations).	3.5
EFR C6	3	3	3.5	**Fish:** In some cases, more flows were assigned due to macroinvertebrate requirements being higher than for the indicator fish. In cases where fish were the driver in determining the flows, it is thought that these flows should be adequate to attain the specific EC for fish. The low confidence in present day hydrology however decreases the confidence levels in setting low flows for fish. The requirements for the different life-stages of the indicator guild (semi-rheophilic) are well documented. **Macroinvertebrates:** The final recommended low flows for the dry season are expected to maintain the macroinvertebrates within the PES, whereas the final low flows recommended for the wet season were slightly lower than that considered necessary to maintain the macroinvertebrates in a Category C. The final flows recommended for the AEC (up) exceeded the requirements for macroinvertebrates during the dry season. Higher wet season flows were not expected to improve the EC for macroinvertebrates.	3

				Riparian Vegetation: Low flow requirements for instream fauna will suffice to maintain the EC for riparian vegetation, albeit with high levels of water stress in the dry season. Riparian zone structure and functionality will remain unchanged. Confidence in the assessment is high since an accurate hydraulic profile was done and vegetation indicators were surveyed (see Appendix F, Volume 3 for detailed species explanations).	
EFR K7	4	2	2	**Fish:** The requirements for the different life-stages of the indicator guild (semi-rheophilic) are well documented. As various non-flow related impacts are responsible for the PES, the confidence is however slightly reduced as it is uncertain how these secondary (non-flow related) impacts may react.	**3**
				Macroinvertebrates: The final flows requested are based mainly on the requirements of two sensitive FDI taxa; Perlidae and Leptophlebiidae, so the margin for risk of not meeting their requirements is narrow.	
				Riparian Vegetation: Flows seem to be lower than what is suggested by current vegetation at the site. As stated before, this could be due to recent removal of indicators by flooding disturbance, in which case plant remnant indicators may exaggerate preferable flows.	

24.2.2.2 Confidence in high flow EFR

The question the confidence assessment should answer is the following:
'How confident are you that the high flow (with the associated high flows) recommended will achieve the EC?'

To determine the confidence, one should consider:

- The quality of available data; and
- Whether the vegetation requirement was increased to cater for a larger requirement recommended for geomorphology. Then the riparian vegetation confidence could be high as more water is provided.

The high flow confidence (Table 24.7) represents an average of the riparian vegetation and geomorphology confidence as these two components determine the flood requirements.

Table 24.6 Confidence in high flows

EFR SITE	FISH	MACRO-INVERTEBRATES	RIPARIAN VEGETATION	GEOMORPHOLOGY	COMMENT	OVERALL CONFIDENCE
EFR O2	4	4	3	3.5	**Fish:** The floods recommended will be adequate to ensure that all applicable flood requirements of the fish assemblages (including migration cues, flushing of sediment, etc.) will be provided.	**3.3**
					Macroinvertebrates: The high flows requested will provide periodic flushing needed to trigger hatching of macroinvertebrate eggs, such as Caenidae and *Simulium chutteri*. The requested high flows will also provide elevated turbidity needed to create feeding conditions suitable for the threatened blackfly *Simulium gariepense*.	
					Riparian vegetation: The high flows that have been set will maintain the PES (B for riparian vegetation) and are based on vegetative cues at the site.	
					Geomorphology: Confidence is relatively high since the planform behaviour in response to large floods is well-known for these bedrock anastomosing reaches. The hydrological record available for the site is extremely long – more than 70 years – with less than 0.5% of missing data from this record. This allowed for a higher confidence assessment of the site.	
EFR O3	4	4	3	4	**Fish:** The floods recommended will be adequate to ensure that all applicable flood requirements of the fish assemblages (including migration cues, flushing of sediment, etc.) will be provided.	**3.5**
					Macroinvertebrates: The high flows requested will provide periodic flushing needed to trigger hatching of macroinvertebrate eggs, such as Caenidae and *Simulium chutteri*. The requested high flows will also provide elevated turbidity needed to create feeding conditions suitable for the threatened blackfly *Simulium gariepense.*	
					Riparian Vegetation: The high flows that have been set will maintain the PES (B/C for riparian vegetation) and are based on vegetative cues at the site as well as surveyed vegetation points and a hydraulic profile.	

EFR SITE	FISH	MACRO-INVERTEBRATES	RIPARIAN VEGETATION	GEOMORPHOLOGY	COMMENT	OVERALL CONFIDENCE
					Geomorphology: Confidence is relatively high at the site since the flood requirements identified through sediment transport modelling matched the morphological indicators at the site and the cues identified by the vegetation specialist.	
EFR O4	4	4	3	2.5	**Fish:** The floods recommended will be adequate to ensure that all applicable flood requirements of the fish assemblages (including migration cues, flushing of sediment, etc.) will be provided. **Macroinvertebrates:** The high flows requested will provide periodic flushing needed to trigger hatching of macroinvertebrate eggs, such as Caenidae and *Simulium chutteri*. The requested high flows will also provide elevated turbidity needed to create feeding conditions suitable for the threatened blackfly *Simulium gariepense*. **Riparian vegetation:** The high flows that have been set will maintain the PES (C for riparian vegetation) and are based on vegetative cues at the site as well as surveyed vegetation points and a hydraulic profile. **Geomorphology:** Confidence is slightly lower at the site because the morphological cues are less-well defined, hence confirming the flood requirements identified through sediment transport modelling to the morphological indicators was not very clear, and similarly the vegetation specialist had slightly lower confidence at this site than the upstream EFR O2 and O3.	**2.8**
EFR C5	4.5	4	3	3	**Fish:** The floods recommended will be adequate to ensure that all applicable flood requirements by the fish assemblages (including migration ques, flushing of sediment, etc.) will be provided. **Macroinvertebrates:** The high flows requested will provide adequate mobilisation of the stream bed to maintain benthic habitat and appropriate triggers to stimulate hatching of macroinvertebrate eggs. **Riparian vegetation:** The high flows that have been set will maintain the EC (PES = C for riparian vegetation) and are based on vegetative cues at the site and well surveyed vegetation points and a hydraulic profile. **Geomorphology:** The confidence at this site is low because: - There are no clear morphological cues. - The channel is rapidly eroding, so any high banks and terraces are not related to the contemporary hydraulics of the site (channel is deepening and widening, so the flows that deposited terrace sediments no longer reach those stages as often). - The available hydrology – vital for undertaking sediment transport potential to identify key flow categories for channel maintenance – is derived from a gauge far (60 km) downstream, and the gauge itself does not record accurate flows. However, using scaled hydrological data, the results from the sediment transport modelling coincide moderately well with the other biotic cues at the site.	**3**
EFR C6	4.5	4	3	3	**Fish:** The floods recommended will be adequate to ensure that all applicable flood requirements by the fish assemblages (including migration ques, flushing of sediment, etc) will be provided. **Macroinvertebrates:** The high flows requested will provide adequate mobilisation of the stream bed to maintain benthic habitat and appropriate triggers to stimulate hatching of macroinvertebrate eggs. **Riparian vegetation:** The high flows that have been set will maintain the EC (PES = B for riparian vegetation) and are based on vegetative cues at the site and well surveyed vegetation points. The flood requirements for geomorphology seem to be slightly higher, but this will not change the EC for riparian vegetation. **Geomorphology:** The confidence at this site is moderate to low because: - There are few clear morphological cues. - The channel is aggrading due to the assumed backup impacts of the dam, the very elevated sediment inputs from upstream and occasional bottom release sediment from the upstream dam. This is smothering the morphology, and also means that very large floods have lost their ability to scour the bed. This reach is therefore storing increasing volumes of sediment, altering hydraulic profiles and reducing access of biota to the original coarse bed sediment habitats. Additionally, the available hydrology – vital for undertaking sediment transport potential to identify key flow categories for channel maintenance – is derived from a gauge far upstream of the EFR site.	**3**
EFR K7	4.5	4	3	3	**Fish:** The floods recommended will be adequate to ensure that all applicable flood requirements by the fish assemblages (including migration ques, flushing of sediment, etc.) are provided. **Macroinvertebrates:** The high flows requested will provide adequate mobilisation of the stream bed to maintain benthic habitat and appropriate triggers to stimulate hatching of macroinvertebrate eggs	**3**

EFR SITE	FISH	MACRO-INVERTEBRATES	RIPARIAN VEGETATION	GEOMORPHOLOGY	COMMENT	OVERALL CONFIDENCE
					Riparian vegetation: The high flows that have been set will maintain the EC (PES = C for riparian vegetation) and are based on vegetative cues at the site and well surveyed vegetation points and a hydraulic profile.	
					Geomorphology: The confidence at this site is high because: - There are morphological cues. - The available hydrology is derived from a long (40 year) record from a relatively reliable gauge immediately upstream of the site and the high flow hydrology is only moderately altered from Reference. - There are no large dams, or extensive catchment-wide erosion, so the sediment load is relatively natural. This reach is therefore close to Reference condition, and the hydrological records and sediment data are representative of the original condition.	

24.2.2.3 Hydrology confidence

Note: If natural hydrology is used to guide requirements, then that confidence will carry a higher weight than normal. Hydrology confidence is provided from the perspective of its usefulness to EFR assessment. This will be different than the confidence in the hydrology for water resources management and planning. The scale of requirements is very different, and that is why high confidence hydrology for water resource management purposes often does not provide sufficient confidence for EFR assessment. The confidence in hydrology is provided in Table 24.8.

Table 24.7 Confidence in hydrology

EFR site	Natural hydrology	Present hydrology	Observed hydrology	Local knowledge/information	Comment	Confidence: Median	Confidence: Average
O2	3.5	3	5	3	Due to the availability of an observed gauge at the site with a long data record, the confidence is relatively high.	3.3	3.5
O3	3.5	1.5	1	2	There are two gauges upstream and downstream of the site. Due the significant distance between the gauges and the site, it was assumed that the present hydrology did not necessarily reflect the flows at the site. These gauges could also not be used to set flow requirements	1.7	2
O4	3	2.5	3	2	Even though a gauge was located very close to the site, the gauge did not measure low flows accurately.	2.8	2.6
C5	2.5	2.5	0	1.5	No gauge for observed hydrology was available close to the site. The available Caledon hydrology also did not include accurate present day hydrology as the present uses in the catchment was not known.	2	1.6
C6	3	2	1	3.5	There was no gauge located nearby and the present hydrology did not reflect the observations regarding zero flows in the area.	2.5	2.4
K7	4	2	4	0.5	A gauge was available close to the EFR site with good daily data. Present day hydrology confidence was moderate only as there was not extensive re-evaluation of present uses.	2.3	2.6
M8	4	4	4	2.5	The site is immediately below a gauge, an as the norml EFR process was not required, this data was more than adequate for the process followed.	4	3.6

24.2.2.4 Overall confidence

The overall confidence in the results are linked to the confidence in the hydrology and hydraulics as the hydrology provides the check and balance of the results and the hydraulics convert the requirements in terms of hydraulic parameters to flow. Therefore, the following rationale is applied when determining the overall confidence:

- If the hydraulics confidence is lower than the biological responses column, the hydraulics confidence becomes the overall confidence. Hydrology confidence is also considered, especially if used to guide the requirements.
- If the biological confidence is lower than the hydraulics confidence, the biological confidence becomes the overall confidence. Hydrology confidence is also considered. If hydrology is used to guide requirements, than that confidence will be overriding.

Table 24.8 Overall Confidence in EFR results

Site	Hydrology	Biological responses Low flows	Hydraulic: Low Flows	OVERALL: LOW FLOWS	COMMENT	Biophysical responses: High flows	Hydraulics: High Flows	OVERALL: HIGH FLOWS	COMMENT
EFR O2	3.5	2.7	2.5	**2.5**	Hydraulic confidence is not high as the measured flows were all higher than the flows required.	3.3	5	**3.3**	Even though the hydraulics confidence was high, the biophysical responses was moderate and that became the overall confidence.
EFR O3	2	3	2	**2**	See above for hydraulic confidence. As the hydraulic confidence was lower than the biological responses, this became the overall confidence.	3.5	5	**3.5**	Even though the hydraulics confidence was high, the biophysical responses was lower (although still high) and that became the overall confidence.
EFR O4	2.6	3	2.5	**2.5**	See above.	2.8	5	**2.8**	Even though the hydraulics confidence was high, the biophysical responses were moderate and that became the overall confidence.
EFR C5	1.6	3.5	3.5	**3.5**	The hydraulic and biological confidences are both high.	3	3	**3**	The hydraulic and biolophysical confidence are both moderate.
EFR C6	2.4	3	2	**2**	See above for hydraulic confidence. As the hydraulic confidence was lower than the biological responses, this became the overall confidence.	3	4	**3**	Even though the hydraulics confidence was high, the biophysical responses were moderate and that became the overall confidence.
EFR K7	2.6	3	3	**3**	The hydraulic and biological confidences are both moderate.	3	3	**3**	The hydraulic and biolophysical confidence are both moderate.

24.2.3 RECOMMENDATIONS

The low flow confidences range from MODERATE to HIGH with only EFR C5 rated as high. This is due to high confidence hydraulics and biological response information. Even though the hydroloy is low, this does not play a significant role, as flow is not the driver at this site.

Hydraulics confidences range from 2 - 2.5 for EFR O2, O3, O4 and C6. The confidence can only be improved by obtaining additional low flow calibration data that at lower flows than measured during the study.

The confidence in biological information is mostly moderate as only one survey was undertaken. Additional surveys in different seasons should be undertaken to refine the baseline.

The high flow confidences range from MODERATE to HIGH with only EFR O3 rated as high due to high confidence hydraulics and biological response information. The hydraulic confidence at EFR

C5 and K7 were moderate as flood conditions were absent at these sites during hydraulic calibration. However an improvement in hydraulic confidence alone will not improve the overall confidence and therefore the confidence in biophysicl responses should also be improved by undertaking monitoring.

It is strongly recommended that an Ecological Water Resources Monitoring (EWRM) programme is initiated as soon as possible. The information gathered during this study is suitable for the baseline, but if too much time relapses between the baseline and monitoring, new surveys and EcoClassification process will have to be undertaken.

Table 24.10 provides a summary of the recommendations.

Table 24.9 Summary of recommendations required to improve confidences

EFR sites	Low flow confidence	High flow confidence	Recommendations
O2	2.5	3.3	Initiate EWRM programme. Obtain hydraulic low flow calibrations.
O3	2	3.5	Initiate EWRM programme.Obtain hydraulic low flow calibrations.
O4	2.5	2.8	Initiate EWRM programme.Obtain hydraulic low flow calibrations.
C5	3.5	3	Initiate EWRM programme. Obtain hydraulic high flow calibrations.
C6	2	3	Initiate EWRM programme. Obtain hydraulic low flow calibrations.
K7	3	3	Initiate EWRM programme. Obtain hydraulic low and high flow calibrations.
M8			Hydraulic confidence in the areas of the wetland that does not receive backup from the crossing was moderate (3). It is however not recommended that more hydraulic calibrations are done as it would be more cost-effective to implement the recommendation (Sc 2 - lowering the Bosbokpark crossing by 2.2 m) and monitoring the biological responses. Monitoring should include the impact on the lower wetland to determine whether the required improvements in these sections are achieved.

25 REFERENCES

Agnew J. D. 1965. A note on the invertebrate fauna in the lower Orange River. South African Journal of Science 61: 126-128.

Birkhead, A.L. (2010). The role of Ecohydraulics in the South African Ecological Reserve. In: Ecohydraulics for South African Rivers, James, C.S. and King, J.M. (eds), Water Research Commission report no. TT K5/1767/1, Pretoria, South Africa.

Brown C and King, J. (2001) Environmental flow assessment for rivers. A summary of the DRIFT process. Southern Waters information Report No 01/00.

De Kock, K.N., Pretorius, S.J., Van Eeden, J.A. 1974 Voorlopige kommentaar aangaande die voorkoms van die waterslakke in die Oranjerivier Die Opvanggebied report, paper presented at the Limnological Society of Southerm Africa's second conference on the Orange River Project\ Bloemfontein, pp 187- 202

Department of Water Affairs and Forestry, South Africa (DWAF). 1999. Resource directed measures for the protection of water resources. Volume 3: River ecosystems, version 1.0.

Hughes DA and Forsyth DA. (2006).A generic database and spatial interface for the application of hydrological and water resource models. Computers and Geosciences 32, 1389-1402.

Iversen TM, Madsen BL and Bøgestrand J. (2000). River conservation in the European Community, including Scandinavia.In: "Global Perspectives on River Conservation: Science Policy and Practice", Edited by P.J. Boon, B.R. Davies and G.E. Petts, John Wiley & Sons Ltd

IWR Source-to-Sea (eds). (2004).A Comprehensive Ecoclassification and Habitat Flow Stressor Response Manual.Prepared for IWQS: DWAF, Project no: 2002-148.

King JM and Louw D. (1998) Instream flow assessments for regulated rivers in South Africa using the Building Block Methodology. Aquatic Ecosystem Health and Management 1: 109-124.

Kleynhans, C.J. 2007 Module D: Fish response Assessment Index in River Ecoclassification manual for Ecostatus determination (version 2) Joint water research commission and Department of Water Affairs and Forestry Report WRC Report No. TT 330/08

Kleynhans CJ, Louw MD, and Graham M.(2009). Module G: EcoClassification and EcoStatus determination in River EcoClassification: Index of Habitat Integrity (Section 1, Technical manual) Joint Water Research Commission and Department of Water Affairs and Forestry report. WRC Report No. TT330/08.

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

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

Kleynhans, C.J., Louw, M.D., Thirion, C., Rossouw, N.J., and Rowntree, K. 2005. River EcoClassification: Manual for EcoStatus determination (Version 1). Joint Water Research Commission and Department of Water Affairs and Forestry report. WRC Report No. KV 168/05.

Kleynhans, C.J., Thirion, C. And Moolman, J. 2005 A level I River Ecoregion Classification System for South Africa, Lesotho and Swaziland Report No. N/0000/00/REQ0104 Resource Quality services, Department of Water Affairs and Forestry, Pretoria, South Africa

Kleynhans, C.J., Thirion, C., Moolman, J. and Gaulana, L. 2007a. A Level II River Ecoregion classification System for South Africa, Lesotho and Swaziland. Report No. N/0000/00/REQ0104. Resource Quality Services, Department of Water Affairs and Forestry, Pretoria, South Africa.

Louw, MD. 2010. Work package 5: Assessment of Environmental Flow Requirements. Deliverable 10: Resource Unit delineation. Draft Report prepared for ORASECOM, July 2010.

Mucina,L and Rutherford, M.C. (eds) 2006 The Vegetation of South Africa, Lesotho and Swaziland Strelizia 19 South African National Biodiversity Institute, Pretoria

Noss RF (1990). Indicators for monitoring biodiversity: a hierarchical approach. Conservation Biology 4:355-364.

Noss RF (1990). Indicators for monitoring biodiversity: a hierarchical approach. Conservation Biology 4:355-364.

O'Keefe, J.H. and Hughes, D.A. 2004. Flow-Stressor Response approach to environmental flow requirement assessment. In: Hughes, D.A. (editor): SPATSIM, and integrating framework for ecological Reserve Determination and implementation. WRC Report no: TT245/04. Water Research Commission, Pretoria, South Africa.

O'Keeffe JH, Hughes DA and Tharme R. (2002).Linking ecological responses to altered flows, for use in enviromental flow assessments: the Flow Stress-Response method.Proceedings of the International Association of Theoretical and Applied Limnology, 28, 84-92.

Palmer, R. W. 1997a. Principles of Integrated Control of Blackflies (Diptera: Simuliidae) in South Africa. WRC Report No. 650/1/97. Water Research Commission, Pretoria, South Africa.

Palmer, R. W. 1996. Macroinvertebrates in the Orange River, with emphasis on conservation and management. Southern African Journal of Aquatic Sciences 22(1/2): 3-51.

Palmer, R. W. 1997b. Changes in the abundance of invertebrates in the stones-in-current biotope in the middle Orange River over five years. Water Research Commission Report No KV130/00.

Pitchford, R.J. and Visser, P.S. 1975 The effect of large dams on river water temperature below the dam with special reference to Bilharzia and the Verwoerd Dam South African Journal of Science 71: 212-213

Pretorius, S.J., de Kock, K.N. and van Eeden, J.A. 1974 Voorlopige kommentaar aangaande die voorkoms van die waterslakke in die Oranjerivier 2. Die Hendrik Verwoerd Dam paper presented at the Limnological Society of Southern Africa's second conference on the Orange River Project\ Bloemfontein, pp 205 – 211

Rountree K and du Preez L (in prep). Geomorphology Driver Assessment Index. Joint Water Research Commission and Department of Water Affairs and Forestry report. Water Research Commission, Pretoria, South Africa.

Rutherford, M.C. and Westfall, R.H. 1986 Biomes of Southern Africa – An Objective Categorisation: Memoirs of the Botanical Survey of South Africa Botanical Research Institute, Department of Agricultural and Water Supply Pretoria

Thirion C. (2007). Module E: Macroinvertebrate Response Assessment Index in River EcoClassification: Manual for EcoStatus Determination (version 2). Joint Water Research Commission and Department of Water Affairs and Forestry report. WRC Report No. TT330/08.

Van Wyk, B. and van Wyk, P. 1997 Field Guide to Trees of Southern Africa Struik, Cape Town

Van Wyk, B. & Van wyk, P. 1997 Field Guide to Trees of Southern Africa Struik, Cape Town, South Africa

Louw D, Kotze P, Mackenzie J. 2010. Scoping study to identify priority areas for detailed EFR and other assessments. Produced for WRP as part of Support to Phase II ORASECOM Basin Wide Integrated Water Resources Management Plan.