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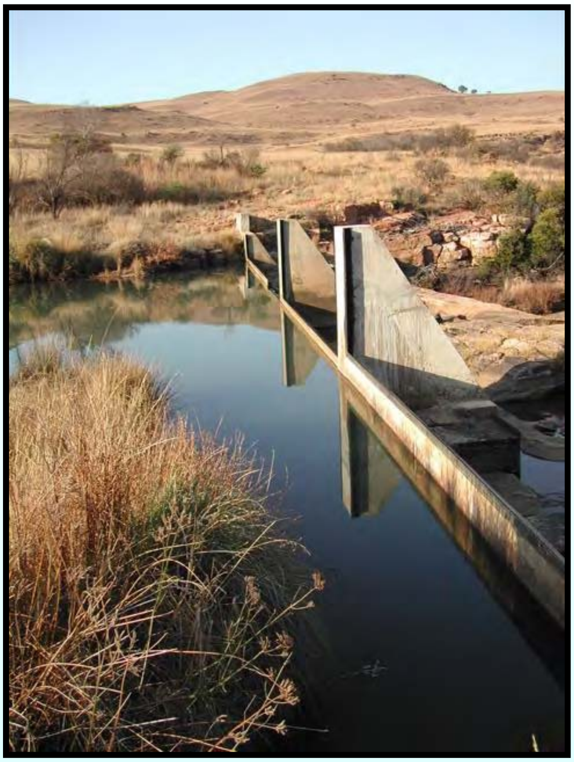

KOMATI CATCHMENT ECOLOGICAL WATER REQUIREMENTS STUDY

QUANTITY REPORT

December 2005

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REPUBLIC OF SOUTH AFRICA

DIRECTORATE: RESOURCE DIRECTED MEASURES

KOMATI CATCHMENT ECOLOGICAL WATER REQUIREMENTS STUDY – QUANTITY REPORT

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Reporting Layout

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  DWAF Report No. RDM X100-00-CON-COMPR2-0103
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      - **Hydrology and System Operation Report**
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EXECUTIVE SUMMARY

KOMATI RIVER CATCHMENT ECOLOGICAL WATER REQUIREMENTS STUDY –

QUANTITY REPORT

INTRODUCTION

Background

The Department of Water Affairs and Forestry (DWAF) identified the Komati River Catchment as a priority catchment for quantifying environmental needs in line with the new legislation (DWAF 2004 a,b). This report forms part of a comprehensive assessment of the Ecological Water Requirements of the Komati River Catchment.

Aims

The aim of this report was to record the proceedings of two Specialist Meetings that were held to determine the Ecological Water Requirement (EWR) Quantity component of the Ecological Reserve for selected sites in the Komati River Catchment. The report documents the methods used and presents the Present Ecological State (PES), EcoStatus, Ecological Importance and Sensitivity (EIS), Socio-cultural Importance, the Recommended Ecological Category (REC) and alternative categories for each Resource Unit in which there were EWR sites selected. The final result of the EWR process was a table of monthly assurance rules for each selected EWR site.

Assumptions and Limitations

This report does not present the water quality implications of the recommended flow requirements, as this forms part of a separate report on water quality. This report does not address problems associated with the river that are not directly related to flow. However, where such problems are identified, they are flagged so that they can be addressed as part of a catchment management plan for the catchment.

STUDY AREA

The study area for this project was initially defined by the D: RDM as the Komati River Catchment (X1) within South Africa. This area comprises two distinct sections: Komati West, comprising the area upstream of Swaziland, and Komati North, comprising the area downstream of Swaziland. The study focussed on the Komati River and main tributaries, namely: Lomati, Teespruit, Gladdespuit and Seekoeispruit. In January 2005 the study area was expanded to include Swaziland.

Sites Selected

Seven sites were selected for EWR assessment (Table A).

Table A. Sites selected and the corresponding river and Resource Unit.

Site Name	*River*	*Resource Unit*
Komati River		
K1-Gevonden	*Upper Komati*	*B*
K2-Kromdraai	*Upper Komati*	*C*
M1-Silingani	*Middle Komati*	*Swaziland*
K3-Tonga	*Lower Komati*	*D*
Tributaries		
G1-Vaalkop	*Gladdespruit*	*G*
T1-Teespruit	*Teespruit*	*T*
L1-Kleindoringkop	*Lomati*	*M*

APPROACH AND METHODS

General Approach

The general approach used to assess EWRs in this study was the Building Block Method (BBM), adapted to include alternative scenarios. Low flows were assessed using the Habitat-Flow-Stress-Response (HFS-R) Method, and high flows were detemined using the Downstream Response to Imposed Flow Transformation (DRIFT) method. The methods focus on identifying the size, duration and timing of specific flows and flow patterns that are considered to be the most important for maintaining the abiotic (e.g. geomorphology) and biotic components (plants and animals) of a stretch of river in a particular condition, or Ecological Category (EC). Flows were specified for recommended and alternative categories.

Data Collection

At each site one or more cross-sectional profiles were selected and surveyed. The profiles were used as the basis for hydraulic modelling. Detailed data on geomorphology, riparian vegetation, fish and aquatic invertebrates were collected at each site.

Specialist Meetings

Two Specialist Meetings were held as follows:

	Meeting 1:	***Meeting 2:***
Venue:	*Bundu Lodge (Nelspruit)*	*CSIR (Pretoria)*
Dates:	*25-29 October 2004*	*31 January-1 February 2005*
EWR sites:	*K1, K2, K3, L1, G1, T1*	*EWR M1*

EcoClassification

Prior to the Specialist Meetings, the PES for the main habitat drivers (hydrology, geomorphology and water quality) and ecological responses (riparian vegetation, aquatic invertebrates and fish), was determined for each Resource Unit in which there was an EWR *site. The results of individual ecosystem components were integrated into an overall Present Ecological State, or EcoStatus, using a swing rule-based method developed by DWAF: Resource Quality Services.*

Trends

For each EWR site an assessment was made of Ecological Trends (i.e. change) that are likely to take place at the site, and by extrapolation within each Resource Unit, for each ecological component (geomorphology, riparian vegetation, aquatic invertebrates and fish). The assessment assumed no change in development conditions at the time of the assessment (2003).

Importance

An assessment of the overall "importance" of the river was based on an assessment of Ecological Importance and Sensitivity (EIS) and Socio-cultural Importance (SI), using a simple scoring system.

Ecological Categories (ECs)

A Recommended Ecological Category (REC) was determined for each EWR site. The REC was based on a combination of factors including: the PES; the EIS; the Socio-cultural Importance; the ecological trends; and the practical feasibility of implementing recommended changes.

Key Months

Maintenance flows were determined for two ecologically important (key) months of the year, based on the distribution of low-flows only. Flows for the remaining months were interpolated from the shape of the natural low-flow seasonal hydrograph. The key months were:

- ***September**: a typical dry month, when the biota is most stressed due to low flows and higher water temperatures;*
- ***February:** a typical wet month.*

Objectives

For each site, the specific objectives that were required to meet the Recommended and Alternative Ecological Categories were described. Typical objectives included the following:

Low-flows

- *To maintain perennial flow and the most important components of the natural seasonal variation in flow;*
- *To maintain riffle areas for flow-sensitive species, such as stoneflies (Perlidae) and flat headed mayflies (Afronurus sp.);*
- *To maintain SASS scores within the range previously measured (except after major floods and during droughts);*
- *To maintain the diversity and abundance of fish species;*
- *To maintain flow-dependant fish species by ensuring that riffle areas remain perennial;*

- *To maintain secondary channels as nursery areas for fish, and;*
- *To maintain rooted banks and deep pools for species that need these habitats.*

High-flows

- *To maintain the natural magnitudes and durations of flow peaks through the system.*
- *To improve the overall macro-channel structure by ensuring a balance (dynamic equilibrium) between sediment deposition and sediment conveyance.*
- *To ensure that pools do not become sedimented.*
- *To prevent accumulation of sediments in the system by providing flushes several times per year.*
- *To maintain existing vegetation composition in riparian zones by maintaining the natural variability in flow fluctuations.*
- *To stimulate recruitment of key indicator species of riparian zone health and maintain a range of size classes of dominant riparian species in perennial channels.*
- *To discourage encroachment of additional exotic species and terrestrial species in the riparian zone by periodic flooding.*

Assurance Rules

Maintenance flows were set at 70% assurance for all sites. Droughts were set at the value of between 0 and 10% assurance.

Final Results

The final output from the EWR Specialist Meeting was a representative time series of monthly volumes, based on the assurance values specified for maintenance and drought conditions.

Confidence

Each specialist provided a confidence evaluation on a scale of 0 (no confidence) to 5 (high confidence) for their component for various parameters, with associated reasons. Parameters that were rated were: the EWR sites; the available data; ecological classification; low-flow results; and high-flow results.

ECOCLASSIFICATION RESULTS

Table C provides a summary of the results for each site and Resource Unit. From this it can be seen that the upstream areas are generally in good ecological condition(RUs A and B), the middle reaches are in moderate ecological condition (RUs C and M), while the lower reaches are in very poor condition (RUs D and E). The Gladdespruit (RU G), is in a very poor condition. The overall picture is thus one of a system that deteriorates in the lower reaches. The main reasons for the deterioration in conditions are summarised in Table B.

The Recommended Ecological Categories (RECs) ranged between Category B (small risk allowed) to Category D (large risk allowed). The REC was usually the same as the PES, except where the PES was highly degraded and an improvement was recommended (e.g., EWR Site K3).

The PES and overall EcoStatus for each site, and a summary of key drivers and responses, are summarised in Table B.

Table B. Summary of the Present Ecological Status (PES), and a description of the drivers and responses for each Resource Unit.

<table>
<tr><th>EWR site and PES</th><th>Summary of key drivers and responses</th></tr>
<tr><td>Komati River</td><td></td></tr>
<tr><td colspan="2">Resource Unit A (upstream of Nooitgedacht Dam)
No EWR site</td></tr>
<tr><td>
<table>
<tr><th>Driver Components</th><th>Component PES</th><th>Driver PES</th><th>ECOSTATUS PES</th></tr>
<tr><td>HYDROLOGY</td><td>A</td><td rowspan="3">A</td><td rowspan="7">B</td></tr>
<tr><td>GEOMORPH</td><td>B</td></tr>
<tr><td>WATER QUALITY</td><td>A</td></tr>
<tr><td>Response Components</td><td>Component PES</td><td>Instream PES</td></tr>
<tr><td>FISH</td><td>B</td><td rowspan="2">B</td></tr>
<tr><td>AQUATIC INVERTS</td><td>B</td></tr>
<tr><td>RIPARIAN VEG</td><td>B/C</td><td>B/C</td></tr>
</table>
</td><td>The Komati River upstream of Nooitgedacht Dam is generally in excellent ecological condition, but riparian vegetation is degraded through alien invasive plants, such as wattle.</td></tr>
<tr><td colspan="2">Resource Unit B (between Nooitgedacht and Vygeboom Dams)
K1 - Gevonden</td></tr>
<tr><td>
<table>
<tr><th>Driver Components</th><th>Component PES</th><th>Driver PES</th><th>ECOSTATUS PES</th></tr>
<tr><td>HYDROLOGY</td><td>C</td><td rowspan="3">C</td><td rowspan="7">B/C</td></tr>
<tr><td>GEOMORPH</td><td>C</td></tr>
<tr><td>WATER QUALITY</td><td>B</td></tr>
<tr><td>Response Components</td><td>Component PES</td><td>Instream PES</td></tr>
<tr><td>FISH</td><td>B/C</td><td rowspan="2">B</td></tr>
<tr><td>AQUATIC INVERTS</td><td>B</td></tr>
<tr><td>RIPARIAN VEG</td><td>C</td><td>C</td></tr>
</table>
</td><td>Although there is no cessation of flow at K1, the hydrology has changed significantly: Nooitgedacht Dam has not overtopped significantly since 1970s and so flood assurances have decreased, and this has affected the geomorphology. Furthermore, the dam does not make any compensatory releases, so low-flows have decreased. Forestry has also had an impact on low-flows. Water temperatures are likely to have increased due to reduced low-flows, and nutrients have increased due to trout dams and tourist developments.</td></tr>
<tr><td colspan="2">Komati River: Resource Unit C (downstream of Vygeboom Dam)
K2 – Kromdraai</td></tr>
<tr><td>
<table>
<tr><th>Driver Components</th><th>Component PES</th><th>Driver PES</th><th>ECOSTATUS PES</th></tr>
<tr><td>HYDROLOGY</td><td>C/D</td><td rowspan="3">C</td><td rowspan="7">C</td></tr>
<tr><td>GEOMORPH</td><td>C/D</td></tr>
<tr><td>WATER QUALITY</td><td>B/C</td></tr>
<tr><td>Response Components</td><td>Component PES</td><td>Instream PES</td></tr>
<tr><td>FISH</td><td>B/C</td><td rowspan="2">B/C</td></tr>
<tr><td>AQUATIC INVERTS</td><td>C</td></tr>
<tr><td>RIPARIAN VEG</td><td>C</td><td>C</td></tr>
</table>
</td><td>Although there is no cessation of flow at K2, the hydrology has changed significantly: Vygeboom Dam releases minimal water and has had moderate impacts on the floods. A weir upstream of K2 has also had small impacts. Aerial photographs suggest that the bed morphology has changed from sand-bed dominance in 1937, to bed-rock dominance in 2003. The main water quality issues are bacterial problems and some contamination from domestic washing powders. Groundwater is contaminated with nitrates due to poor sanitation in the area. Invertebrate taxa that require good water quality, and slow-flowing water, have disappeared. This is thought to reflect water quality problems. Of the 15 expected fish species, only eels were not collected.</td></tr>
</table>

Middle Komati River, Swaziland (downstream of Maguga Dam)
M1 - Silingani

Driver Components	Component PES	Driver PES	ECOSTATUS PES
HYDROLOGY	D	C	C
GEOMORPH	C		
WATER QUALITY	B/C		
Response Components	Component PES	Instream PES	
FISH	B/C	B/C	
AQUATIC INVERTS	B		
RIPARIAN VEG	D	D	

Maguga Dam has had a significant impact on this site, and instream habitat availability is impacted by dense growth of benthic diatoms possibly associated with the release of cold water. Maguga Dam is expected to impact negatively on geomorphology (sediment depletion) and associated instream habitat diversity, but these changes are not yet evident. Of the 29 species of indigenous fish expected at this site, 14 and 17 species were collected during surveys in 2003 and 2004. There has been a reduction in sensitive fish species. The invertebrate fauna has changed significantly since the completion of Maguga Dam, but there is no evidence to indicate that conditions have deteriorated. The riparian vegetation at the site is degraded, but in reasonable condition for the area as a whole.

Resource Unit D (Lower reaches)
K3-Tonga

Driver Components	Component PES	Driver PES	ECOSTATUS PES
HYDROLOGY	E	E	E
GEOMORPH	D/E		
WATER QUALITY	D		
Response Components	Component PES	Instream PES	
FISH	E/F	E	
AQUATIC INVERTS	E		
RIPARIAN VEG	D/E	D/E	

Ecological conditions at K3 are highly impacted by frequent and extended periods of flow cessation, cuased primarily by diversion of water at Tonga Weir. Clearing of bank vegetation and sand mining has reduced bank stabilisation and led to alien vegetation encroachment. The main water quality issues are nutrients (with associated benthoic algal blooms) and bacterial contamination and increased water temperatures and slight salinisation when the river stops flowing. Of the 31 species of indigenous fish expected, only seven were recorded in 2003. All flow-sensitive species have disaooeared and species sensitive to poor water quality have reduced in diversity and abundancre. Fish migration is severely impacted by the large numbers of weirs. Aquatic invertebrate data show that the fauna deteriorates significantly when flows drop, and all sensitive species had disappeared during low-flows in 2003.

Komati River. Resource Unit E
No EWR site

Driver Components	Component PES	Driver PES	ECOSTATUS PES
HYDROLOGY	E	E	E
GEOMORPH	E		
WATER QUALITY	D/E		
Response Components	Component PES	Instream PES	
FISH	D	E	
AQUATIC INVERTS	E		
RIPARIAN VEG	E	E	

As above, but with more weirs and sand-mining.

Tributaries

Gladdespruit - Resource Unit G

G1 - Vaalkop

Driver Components	Component PES	Driver PES	ECOSTATUS PES
HYDROLOGY	B	C	D
GEOMORPH	D		
WATER QUALITY	C		
Response Components	**Component PES**	**Instream PES**	
FISH	D	D	
AQUATIC INVERTS	D		
RIPARIAN VEG	D	D	

The main impacts in the Gladdespruit are related to (a) a reduction in low-flow due to forestry, (b) water quality problems due to acid mine drainage from old gold mines, sulphates and raw sewerage, (c) erosion and sedimentation, (d) alien invasives and (e) trout dams. Invertebrate species sensitive to water quality have disappeared. There has been a loss of migratory fish species. The riparian zone is characterised by loss of species richness, composition and structure, and abundance of alien invasive plants.

Teespruit - Resource Unit T

T1 - Teespruit

Driver Components	Component PES	Driver PES	ECOSTATUS PES
HYDROLOGY	B	C	C
GEOMORPH	C		
WATER QUALITY	C		
Response Components	**Component PES**	**Instream PES**	
FISH	B/C	C	
AQUATIC INVERTS	C		
RIPARIAN VEG	C	C	

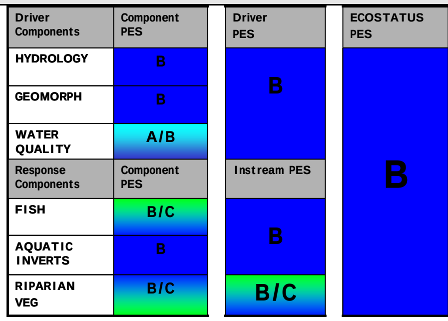
The hydrology and geomorphology of the Teespruit have been slightly impacted due to small-scale abstractions. The water quality is in good condition except for the lower section where there is a sewerage works with associated organic pollution. Of 15 fish species expected fish, 11 were collected in 2003. Some deep habitats are shallower than expected, and catadromous species were missing due to weirs downstream. There are no historical invertebrate data, but taxa that appear to be missing are those that are sensitive to poor quality water. However, a high diversity of blackflies (6 species) indicates that water quality is within acceptable limits for aquatic ecosystems. The vegetation has experienced a moderate change in abundance and structure, mainly due to encroachment of alien vegetation.

Seekoeispruit - Resource Unit S

Driver Components	Component PES	Driver PES	ECOSTATUS PES
HYDROLOGY	B	C/B	C
GEOMORPH	C		
WATER QUALITY	B/C		
Response Components	**Component PES**	**Instream PES**	
FISH	C	C	
AQUATIC INVERTS	C		
RIPARIAN VEG	C	C	

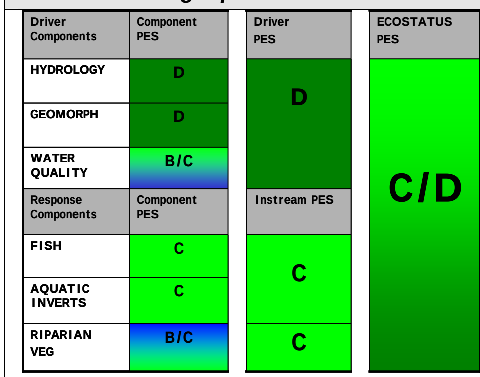
The Seekoeispruit is unregulated and so the hydrology is close to natural, with small impacts related to abstraction of low-flows. The riparian is invaded by alien vegetation (mostly wattle), and poor landuse practices have led to erosion and embeddedness of the stream bed. This has reduced habitat availability for fish and invertebrates. The main water quality issues are associated with a number of poorly functioning sewage works and general low level of sanitation throughout the catchment, particularly in the vicinity of Badplaas.

Lomati River. Resource Unit L (upstream of Driekoppies Dam)
No EWR site



The Lomati River upstream of Driekoppies Dam is in an excellent ecological condition. The main impacts are related to forestry activities in the upper reaches (sedimentation, alien vegetation etc), and subsistence agriculture within Swaziland.

Lomati River. Resource Unit M (Lower reaches)
L1 – Kleindoringkop



The ecosystem at L1 is fairly healthy, although there has been a major change from reference conditions. The geomorphology is greatly modified from natural from a fairly unstable mobile channel, with large sand banks to a vegetation-stabilized channel, with a negligible sand component. These changes are attributed largely to the impacts of Schoemans Dam. The vegetation is greatly modified from natural from a fairly sparsely vegetated channel to a channel with a significant woody vegetation component. The fish comprise a greatly altered community structure in which temperate species have replaced tropical species. The PES EcoStatus measured against the original (natural) reference condition is in a Category D. The PES EcoStatus measured against modified reference conditions which include; (a) temperate fish species rather than tropical, (b) more woody material, (c) more defined channel and (d) increased natural base flows for all months (especially in the dry season) were in a Category C/D.

Table B. EcoClassification Summary.

R.U.	Site	PES	Importance		Ecological Category		
			EIS	SI	Alt (up)	Alt (down)	REC
Komati River							
A	-	B	M	L	N/A	N/A	B
B	K1	B/C	H	M	B	C/D	B/C
C	K2	C	H	H	B	D	C
Maguga	M1	C	H	V.H	B	D	C
D	K3	E	M	V.H	N/A	N/A	D
E	-	E	M	V.H	N/A	N/A	D
Tributaries							
G	G1	D	L	L	C	N/A	D
S	-	C	M	M	N/A	N/A	C
T	T1	C	H	M	B	D	C
L	-	B	V.H	H	N/A	N/A	B
M	L1	C/D	H	H	N/A	N/A	C/D

Note: EWR site L1 has changed irreversibly from historical reference conditions and when evaluated as such the PES=D, but when evaluated against current (modified) reference conditions, the PES = C/D
N/A=not applicable; V.H. = very high; H = high; M = moderate; L = low.

EWR Scenario results
The flows recommended for the REC are summarised in Table D, and constituted between 12 and 37% of the nMAR. These values represent the limits of flow reduction to be used in yield models. The values are generally lower than a previous estimate of the EWR of the Komati River, conducted in 1997.

Table D. Summary Instream Flow Requirements for EWR sites in the Komati River Catchment, expressed as a percentage of the natural Mean Annual Runoff (nMAR) for the Recommended Ecological Categories (ECs).

EWR Site	REC	Maintenance low flows (%)	Drought low flows (%)	High flows (%)	Long-term mean of nMAR
K1	B/C	14.99	4.08	8.97	24.17
K2	C	8.53	2.8	8.22	14.63
M1	C	7.05	1.57	7.5	18.07
K3	D	19.78	8.6	6.18	28.79
G1	D	12.41	6.17	4.35	25.51
T1	C	18.89	8.22	15.46	36.54
L1	C/D	6.49	2.85	2.99	11.82

Confidence
A summary of confidence scores ifor each component s given in Table E. A large amount of historical data have been collected from the main Komati River, so confidence in the available biological data was generally high for the main river, and less so for the tributaries. The confidence in the low-flow hydraulics was generally high, but confidence in high flow hydraulics was low because the study was conducted during an extended dry period, which made it impossible to calibrate the hydraulics under high flow conditions. Confidence in the sites selected was high, with the notable exeption of EWR Site K3 (Tonga), which had been historically inundated by backup from a weir, and was reinundated during the course of the study. Confidence in the hydrology was moderate for most sites, with the notable exception EWR Site G1 (Gladdespruit), where confidence was low.

Table E. Summary of the confidence ratings regarding the classification, and determination of high and low flows. Scores: 0 = no confidence; 5 = very high confidence.

	EWR SITE	AVAILABLE DATA	ECOLOGICAL CLASSIF.	OUTPUT LOW FLOW	OUTPUT HIGH FLOW
Komati River					
EWR Site K1					
HYDROLOGY	n/a	3	3	n/a	n/a
HYDRAULICS	3	4/0=2	n/a	5	2
QUALITY	n/a	3	2	n/a	n/a

	EWR SITE	AVAILABLE DATA	ECOLOGICAL CLASSIF.	OUTPUT LOW FLOW	OUTPUT HIGH FLOW
GEOMORPH	3.5	3	3	4	3.5
RIP VEG	3	3	4	2	3
FISH	4	4	4	4	4
INVERT	4	4	4	4	4
EWR Site K2					
HYDROLOGY	n/a	3.5	3	n/a	n/a
HYDRAULICS	3	3/3=3	n/a	2.5	4
QUALITY	n/a	3	3	n/a	n/a
GEOMORPH	3.5	3	2.5	n/a	4
RIP VEG	4	3	4	n/a	3
FISH	4	4	4	4	4
INVERT	4	4	4	4	4
EWR Site M1					
HYDROLOGY	n/a	4	4	n/a	N/a
HYDRAULICS	3	2/3=3	N/a	2	3
QUALITY	n/a	1	2	n/a	n/a
GEOMORPH	n/a	2	3.5	n/a	3
RIP VEG	3	2	3	n/a	3
FISH	4	4	4	4	4
INVERT	4	5	4	4	4
EWR Site K3					
HYDROLOGY	n/a	3	3	n/a	N/a
HYDRAULICS	3	4/0=2	n/a	3	2
QUALITY	n/a	4.5	4	N/a	n/a
GEOMORPH	2	3	4	N/a	3.5
RIP VEG	3	3	4	n/a	3
FISH	4	4	4	3	5
INVERT	2	4	4	3	4
Tributaries					
EWR Site G1					
HYDROLOGY	n/a	2	3	n/a	n/a
HYDRAULICS	4	4/0=2	n/a	2.5	2.5
QUALITY	n/a	4	3	n/a	n/a
GEOMORPH	2	2.5	3	n/a	3
RIP VEG	4	3	4	n/a	3
FISH	4	4	4	n/a	3
INVERT	3	4	4	4	4
EWR site T1					
HYDROLOGY	n/a	3	3	n/a	n/a
HYDRAULICS	4	4/0=2	n/a	5	3
QUALITY	n/a	1	1	n/a	n/a
GEOMORPH	4	2	3	n/a	3.5
RIP VEG	3	3	4	n/a	3
FISH	4	4	4	4	3
INVERT	3	3	4	4	4
EWR site L1					
HYDROLOGY	n/a	3	3	n/a	n/a
HYDRAULICS	2	4/1=2.5	n/a	4	2
QUALITY	n/a	1	1	n/a	n/a
GEOMORPH	4.5	3	3.5	n/a	4

	EWR SITE	AVAILABLE DATA	ECOLOGICAL CLASSIF.	OUTPUT LOW FLOW	OUTPUT HIGH FLOW
RIP VEG	4	3	3	n/a	3
FISH	4	4	4	4	3
INVERT	3	3	3	3	3

Abbreviations

Amp	*Amphilius*
ASPT	Average Score Per Taxon
BBM	Building Block Methodology
Bano	*Barbus anoplus*
Blin	*Barbus lineomaculatus*
Bpol	*Barbus polylepis*
Chl	*Chiloglanis*
CEMA	*Chiloglanis emarginartus*
D: RDM	Directorate: Resource Directed Measures
DRIFT	Downstream Response to Imposed Flow Transformations
DWAF	Department of Water Affairs and Forestry
EC	Ecological Category
EIS	Ecological Importance and Sensitivity
EWR	Ecological Water Requirement
FD	Fast-Deep
FS	Fast -Shallow
GSM	Gravel, Sand & Mud
HFS-R	Habitat Flow Stressor Response
HIS	Habitat Suitability Index
IFR	Instream Flow Requirement
KOBWA	Komati Basin Water Authority
MAR	Mean Annual Runoff
MVIC	Marginal Vegetation-in-Current
MVOC	Marginal Vegetation-out-of-Current
nMAR	naturalised Mean Annual Runoff
NWA	National Water Act
Oper	*Opsaridium perengueyi*
PES	Present Ecological State
pMAR	present Mean Annual Runoff
REC	Recommended Ecological Category
RQO	Resource Quality Objective
RU	Resource Unit
RVI	Riparian Vegetation Index
SASS5	South African Scoring System (Version 5)
SD	Slow-Deep
SIC	Stones-in-Current
SOC	Stones-out-of-Current
SS	Slow-Shallow
TPTC	Tripartite Permanent Technical Committee
WP	Wetted Perimeter

Glossary

BIOTA	A collective term for all the organisms (plants, animals, fungi and bacteria) in an ecosystem.
BIOTOPE	The place in which a certain assemblage of organisms live.
CATADROMOUS	Moving from freshwater to the sea to breed.
GEOPHYTE	Perennial herbaceous plant with dormant parts (rhizomes, bulbs, tubers) underground.
HABITAT	The place in which a plant or animal lives. (See BIOTOPE.)
HYDRAULICS	The branch of science and technology concerned with the mechanics of fluids, especially liquids.
HYDROLOGY	Science dealing with properties, distribution and circulation of water in the biosphere.
INVERTEBRATE	An animal without a backbone - includes insects, snails, sponges, worms, crabs and shrimps.
LENTIC	Standing water.
LIMNOPHILIC	Open water.
MESOPHYTIC	Plants that prefer temperate climate with moderate soil moisture.
REFUGIA	An area where a population is maintained during unfavourable conditions.
RESERVE	The quantity and quality of water required (a) to satisfy basic human needs by securing a basic water supply, as prescribed under the Water Services Act, 1997 (Act No. 108 of 1997), for people who are now or who will, in the reasonably near future, be (i) relying upon; (ii) taking water from; or (iii) being supplied from, the relevant water resource; and (b) to protect aquatic ecosystems under the National Water Act, 1998 (Act No. 36 of 1998) in order to secure ecologically sustainable development and use of the relevant water resource. The Reserve refers to the modified EWR, where operational limitations and stakeholder consultation are taken into account.
RESOURCE UNIT	Stretches of river that are sufficiently ecologically distinct to warrant their own specification of Ecological Water Requirements.
RHEOPHILIC	Flow-dependent.
RIPARIAN HABITAT	The physical structure and associated vegetation of the areas associated with a watercourse which

	are commonly characterised by alluvial soils, and which are inundated or flooded to an extent and with a frequency sufficient to support vegetation of species with a composition and physical structure distinct from those of adjacent land areas.
RIPARIAN	Pertaining to the river bank.
SECTOR	A 5km stretch of river used to quantify Habitat Integrity.
TERRACE	Relic floodplain or valley floor deposits above the present river level representing a former floodplain level prior to incision.
XEROPHYTIC	Plants adapted to arid conditions.

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1. INTRODUCTION

1.1 BACKGROUND

The South African National Water Act (Act No. 36 of 1998) (NWA) is founded on the principle that National Government has overall responsibility for and authority over water resource management for the benefit of the public without compromising the current and future functioning of the natural environment. Chapter 3 of the NWA provides for the statutory protection of water resources through the Reserve for water resources. The legislation gives priority to water for the Reserve to meet both basic human needs and Ecological Water Requirement (EWR), as well as for strategic and international obligations.

The Directorate of Resource Directed Measures (D:RDM) is tasked with the responsibility of ensuring that the Reserve requirements, which have priority over other uses with the exception of strategic and international demands, are determined before license applications for water use can be processed. This is particularly so in stressed catchments, where the available water resources cannot meet the demand of all the users. There are several stressed catchments where applications for licensing have been received by the D: RDM.

The Komati River Catchment was identified by DWAF as a priority catchment for a comprehensive Reserve determination due to the high water demands for irrigation, afforestation and industry and rapidly increasing domestic water demands (DWAF 2004a, b). The water shortages experienced in the area have led to intense competition for the available water resources among user sectors. Planned extensions to irrigation have been put on hold and a substantial portion of the population in the catchment does not have access to basic level of services.

A number of studies point to the Komati River as a stressed system, particularly the lower reaches (TPTC 2002; DWAF 2002a; DWAF 2003a; DWAF 2004a). An overview of these studies is presented in DWAF's Internal Strategic Perspective, which highlights the need for the implementation of the Reserve in the upper Komati to meet the downstream Reserve needs and the need for compulsory licensing (DWAF 2004b). The overview suggests the possibility of delaying the implementation of the Reserve because of competing uses with ESKOM. The aforementioned reports emphasize the high demand by irrigation, especially new demands by emerging farmers.

Due to the high priority of the environmental issues in the region and the establishment of the Inkomati Catchment Management Agency in 2004, DWAF has identified the need to adopt an integrated catchment view by initiating a study to determine the comprehensive Reserve requirements of the Komati River Catchment. This approach will ensure that the individual rivers will not be viewed in the isolation, but in the context of the overall catchment. This will also facilitate the most efficient utilisation of the resources. This report forms part of this process and concerns the Ecological Water Requirement (EWR) Quantity component of the Ecological Reserve.

1.2 TERMS OF REFERENCE

The original Terms of Reference for this study were detailed in a report by DWAF, dated 28th November 2002. The Terms of Reference were modified slightly in the Inception Report ([1]DWAF 2004a), and in January 2005 further modifications were made to include Swaziland.

1.3 AIMS

1.3.1 Aims of this Study

The aims of this study were as follows:

- ***Ecological Water Requirement***: To recommend a comprehensive Ecological Water Requirement (EWR), for water quality and quantity, for various reaches of the Komati River system for the Recommended Ecological Category (REC), and alternative Ecological Categories (if applicable);

- ***Wetlands:*** To clarify the need for a wetlands study, based on a review of available information, focussing on the ecological importance of wetlands in the catchment and the links between wetlands, rivers and groundwater;

- ***Groundwater:*** To clarify the need for a groundwater study, based on a review of available information, focusing on the significance of groundwater to wetlands and surface flows and the importance of groundwater to current and potential users in the catchment, and;

- ***Capacity Building*****:** To train persons from previously disadvantaged communities in specific aspects of assessing Ecological Water Requirements.

1.3.2 Aims of this Report

This report forms part of the process of quantifying the EWR component of the Reserve for the water resources of the Komati River Catchment. The overall aim of this report was to record the proceedings of the Specialist Meetings and the recommendations made for the REC and the EWR (Quantity), referred to as the IFR component of the Ecological Reserve for selected sites of the Komati River Catchment. The specific aims of this report were as follows:

- ***Present Ecological State (PES):*** To define Reference Conditions and classify each Resource Unit in which EWR sites were selected, in terms of the PES of the main ecological drivers (hydrology, geomorphology and water quality) and ecological responses (riparian vegetation, aquatic invertebrates and fish), and to integrate the PES results of individual ecological components into an overall EcoStatus;

- ***Recommended Ecological Category (REC) and alternatives:*** To recommend an Ecological Category and alternative categories, based on the results of the PES, an assessment of the trends (changes) that are likely to take place assuming no change in current conditions, the Ecological Importance and Sensitivity (EIS), Socio-cultural Importance (SI), as well as an assessment of practicality of improving ecological conditions;

- ***Ecological Water Requirements:*** To recommend and motivate specific low and high flows for maintaining ecological conditions within a specific ecological category, and to present the results in the form of assurance rules for each selected EWR site for each month of the year and for each EC assessed, and;

- ***Confidence*****:** To indicate the confidence associated with the results generated for each EWR site.

1.4 STRUCTURE OF THIS REPORT

This report is structured into the following chapters:

Chapter 1: Introduction

This chapter.

Chapter 2: Study Area

Chapter 2 describes the study area and the sites selected.

Chapter 3: Approaches and Methods

Chapter 3 explains the overall approach followed during the Specialist Meetings and summarises the steps followed to provide the final flow recommendations for each EWR site. The sequential steps followed to provide the results prior to and during the Specialist Meetings are discussed.

Chapters 4 - 10: EWR Results

Chapters 4 to 10 present the results for each site.

Chapter 11: Conclusions

Chapter 11 presents key conclusions drawn from the Specialist Meetings.

Chapter 12: Recommendations

Chapter 12 makes recommendations regarding the EWR.

Chapter 13: References

References cited in the text.

Appendices

Detailed results and specialist reports are included in the appendices.

1.5 Previous Studies

Several studies have examined the EWR for various sections of the Komati River Catchment at various levels of resolution and these studies formed the basis for the present study. However, no study had assessed the EWR for the catchment as a whole. The following section summarises the methods and limitations of previous studies of EWR in the Komati Catchment.

1.5.1 Driekoppies Dam

Bruwer 1993: In 1993 the Tennant Method (Tennant 1976) of assessing EWRs was applied to various nodes along the lower Komati and Lomati Rivers as part of an initial assessment of the EWR downstream of the proposed Driekoppies Dam (Bruwer 1993). The Tennant Method is limited because it provides an annual total volume only and does not indicate how the flows should be allocated over an annual cycle.

Ninham Shand 1994: A reasonably detailed assessment of EWRs was undertaken as part of the environmental mitigation plan for Driekoppies Dam (Ninham Shand 1994). One site was selected in the Lomati River immediately downstream of Driekoppies Dam and two sites were selected in the Komati River downstream of the Lomati River confluence, but upstream of the Crocodile River. The main shortfalls of this study were the limited biological data collected and unreliable hydraulics.

Singh et al. 2003: A rapid assessment was made of the flow requirements immediately downstream of Driekoppies Dam in 2003 (Singh *et al.* 2003).

1.5.2 Maguga Dam

AfriDev et al. 1998b: A comprehensive assessment of EWRs in the Komati River between Maguga Dam and the Lomati River confluence was undertaken as part of the environmental mitigation plan for Maguga Dam in 1997 and 1998 (AfriDev *et al.* 1998a). The assessment was based on a comprehensive application of the Building Block Method, in which the Ecological Importance and Sensitivity, the Present Ecological State and the Desired Future State formed important components of the assessment (King and Louw 1998). Four sites were chosen as follows:

- EWR1: [M1] Silingani 1 (Swaziland)
- EWR2: Silingani 2 (Swaziland)
- EWR3: IYSIS Weir (Swaziland)
- EWR4: Tonga rapids (South Africa)

Baseline data on riparian vegetation and limited data on geomorphology were collected on one occasion, while detailed seasonal data were collected on aquatic invertebrates and fish. The main limitation of this study was that no alternative scenarios were considered.

1.5.3 National River Health Programme

The National River Health Programme has collected biomonitoring data at 19 sites in the catchment and the results were summarised in the Komati River State of the Environment Report (2001). These data provide a good indication of the current ecological condition of the rivers in the catchment and formed an important source of information for this study.

2. STUDY AREA

The Study Area for this project was originally defined by the D: RDM as the Komati River Catchment (X1) within South Africa. This area comprises two distinct sections: Komati West, upstream of Swaziland, and Komati North, downstream of Swaziland. The study focussed on the Komati River and main tributaries, namely: Lomati, Teespruit, Gladdespuit and Seekoeispruit (Figure 2-1). The Study Area was delineated into ten Resource Units prior to the selection of EWR sites. A detailed account of the ecological delineation of the Komati River is presented in AfriDev (2004 b). In January 2005 the Study Area was extended to include Swaziland. Resource Units were not defined for Swaziland during this study, but a detailed assessment of habitat integrity and ecological zonation undertaken as part of the Maguga Dam EWR study in 1997 identified two distinct zones: a Middleveld Zone upstream of Bhalekane Bridge and a Lowveld Zone downstream of the Bhalekane Bridge ([1]DWAF 2004 b). With the completion of Maguga Dam the area within Swaziland can therefore be divided into three Resource Units: 1) Upstream of Maguga Dam, 2) Maguga Dam to Bhalekane Bridge and 3) Bhalekane Bridge to Mananga. The area upstream of Maguga Dam is ecologically similar to Resource Unit C, while the area downstream of Bhalekane Bridge is similar to Resource Unit D. This means that by including Swaziland into the Study Area there is one additional Resource Unit, between Maguga Dam and Bhalekane Bridge.

2.1 SITES SELECTED

Seven sites were originally selected for assessment, but two became inundated during the course of the study because of the upgrading of weirs, and an additional site in Swaziland was included in January 2005 (Figure 2-1; Table 2-1). The process of selecting sites was based on an examination of river video footage taken during a helicopter survey in July 1997 and June 2003 and subsequent ground-truthing by a full team of specialists. A detailed description of the process of selecting sites and the sites selected is presented in the Resource Unit Report (DWAF 2004 b).

Table 2-1. Details of sites selected and the corresponding 5km Sector number and Resource Unit.

Site Name	River	Sector	Locality	Video track log date and time	Resource Unit
Komati River					
K1-Gevonden	Upper Komati	K21	25° 51'15.6"S; 30° 22' 35.9"E	25.06.2003 11h17m23s	**B**
K2-Kromdraai	Upper Komati	K45	26° 02'19.7"S; 31° 00'11.3"E	25.06.2003 15h48m02s	**C**
M1-Silingani	Middle Komati	n/a	26° 05.970'S: 31° 23.893'E	02.07.1997 10h50m50s	**Maguga**
K3-Tonga*	Lower Komati	LK32	25° 40'01.1"S 31° 48'04.8"E	02.07.1997 12h16h29	**D**
K3A-Tonga**	Lower Komati	LK32	25° 40'39.5"S 31° 47'26.0"E	02.07.1997 12h15h33	**D**
K4-Elsana*	Lower Komati	LK34	25° 38'33.6"S; 31° 48'54.8"E	26.06.2003 11h33m24s	**E**
K5-Lebombo**	Lower Komati	LK44	25°26'55.9"S; 31°57'28.2"E	26.06.2003 11h54m19s	**E**
Tributaries					
G1-Vaalkop	Gladdespruit	G4	25° 46'18.2"S 30° 37'37.8"E	25.06.2003 12h52m22s	**G**
T1-Teespruit	Teespruit	T8	26° 01'09.5"S; 30° 51'07.3"E	25.06.2003 14h52m12s	**T**
L1-Kleindoringkop	Lomati	L21	25° 38'58.0"S: 31° 37'23.5"E	Skipped in video due to tape change	**M**

** Discontinued due to inundation; **Selected for monitoring purposes only.*

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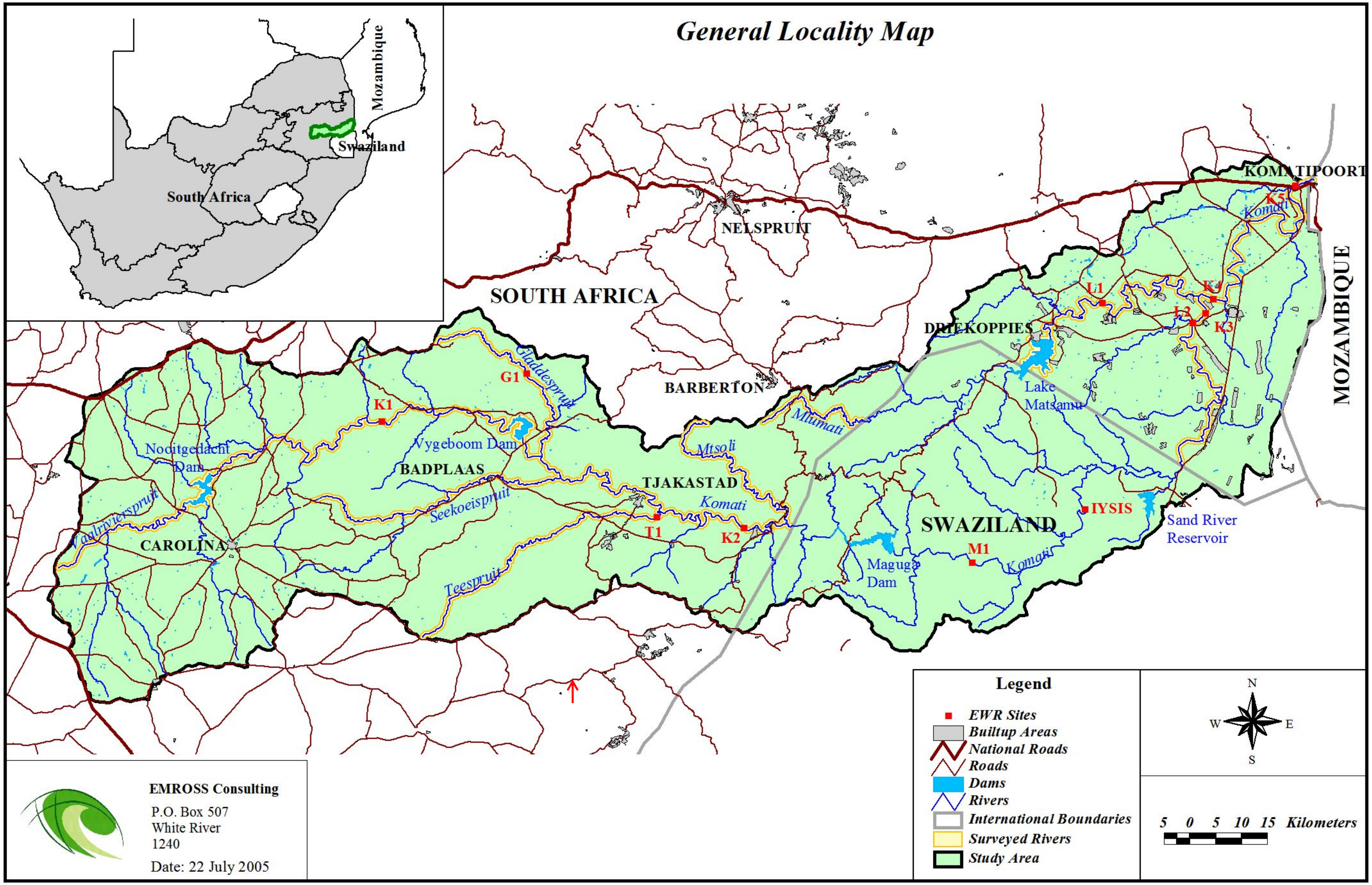


Figure 2-1. Map of the Komati River Catchment, showing major tributaries, dams, gauging weirs and EWR sites.

3. METHODS

This chapter explains the methods used in the study. The results for each component are detailed in subsequent chapters.

3.1 APPROACH

The approach to this study was based on the generic 8-step process used for the Thukela Reserve determination, illustrated in Figure 3.1 (DWAF 2004c). The main difference was that detailed socioeconomic assessments components and public participation activities were not undertaken during this study. This report refers to Steps 3 and 4 shown in Figure 3-1. Detailed methods are not repeated here as they are described in various documents and scientific journals, as referenced. Detailed information on which the flow recommendations were based, including the specialists reports, are included as appendices to this report.

3.2 DATA COLLECTION

3.2.1 Hydraulics

At each EWR site within South Africa one or more cross-sectional profiles were selected by the EWR team and surveyed by Mr Anthony Stephens in November 2003. Hydraulic data for EWR Site M1 in Swaziland was based on data collected as part of the Maguga Dam EWR study in 1997 (AfriDev *et al*.1998 a). The profiles were used as the basis for hydraulic modelling and discharge and corresponding water levels were recorded on five separate occasions to calibrate the profiles. At sites K1, K2 and L1 detailed spatial topographical data were collected and used to develop a two dimensional habitat model. The sites were surveyed by the Department of Water Affairs and Forestry: Directorate Geomatics in April 2004. Detailed results of the hydraulics assessment and habitat modelling are presented in Appendix A.

3.2.2 Geomorphology

Particle size distributions and other geomorphological data were collected at each EWR site within South Africa in August 2003. Geomorphological data for EWR Site M1 in Swaziland was based on data collected as part of the KOBWA EWR Monitoring Study in November 2003. Detailed results of the geomorphological assessment are presented in Appendix B.

3.2.3 Riparian Vegetation

Vegetation profiles were surveyed and basic environmental data were recorded during the initial site-selection visit in August 2003. Many plants were dormant at the time so an additional survey to update the preliminary species checklists was undertaken in April 2004. Data for EWR Site M1 in Swaziland was based on data collected as part of the KOBWA EWR Monitoring Study in November 2003 and again in November 2004. Detailed results are presented in Appendix C.

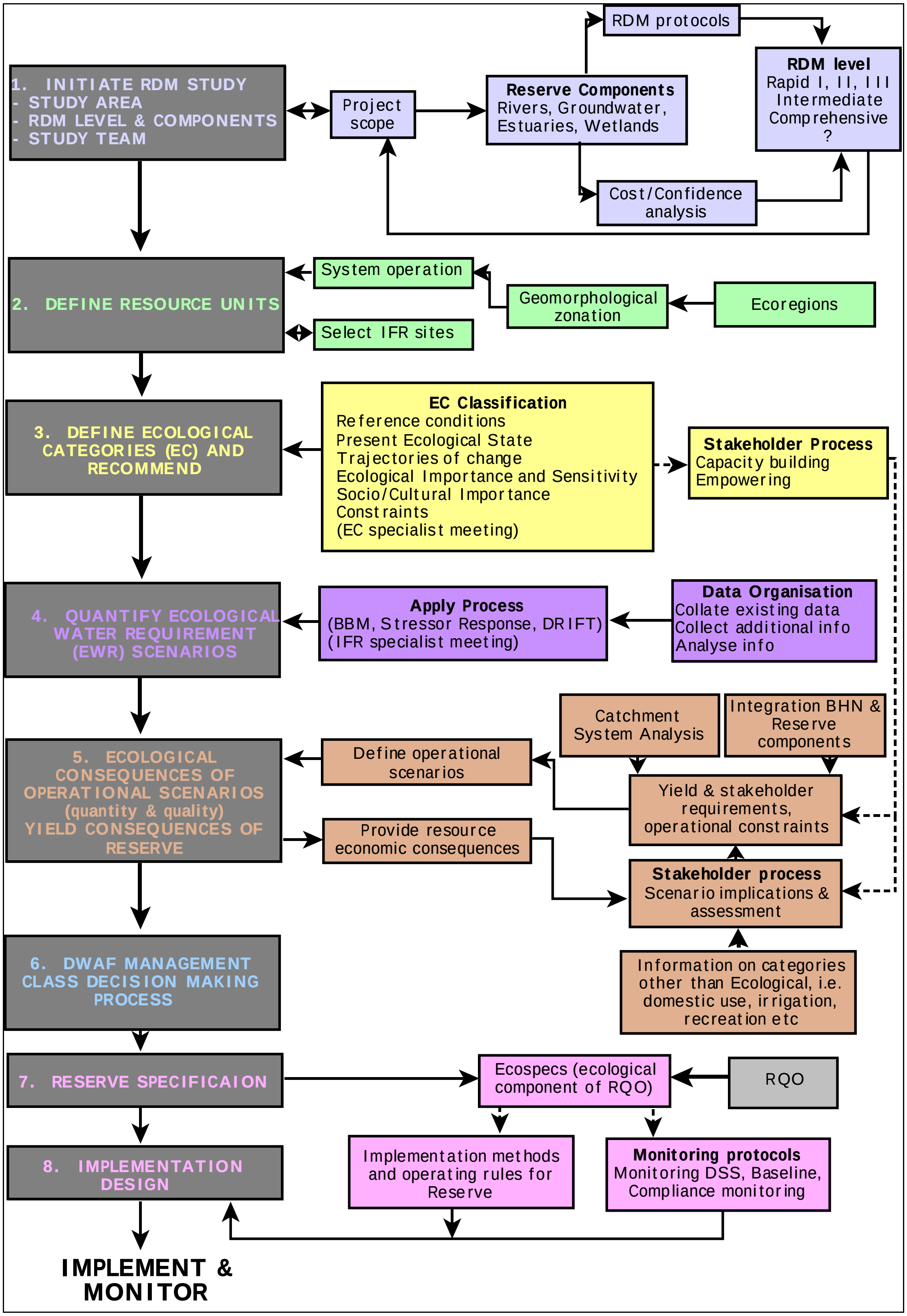


Figure 3-1. The generic 8-step Ecological Reserve Procedure (from DWAF 2003b).

3.2.4 Aquatic Invertebrates

Aquatic invertebrates were collected using the SASS5 method during the initial site-selection visit in August 2003. Additional data were collected in the lower Komati, including EWR Site M1 in Swaziland, as part of the KOBWA EWR Monitoring Study on four occasions in 2003 and 2004. Detailed results are presented in Appendix D.

3.2.5 Fish

Fish were sampled at each EWR site during the initial site-selection visit in August 2003. Additional data were collected in the lower Komati, including EWR Site M1 in Swaziland, as part of the KOBWA EWR Monitoring Study on two occasions in 2003 and 2004. Detailed results are presented in Appendix E and Appendix E1.

3.3 SPECIALIST MEETINGS

Two Specialist Meetings on the Komati River Catchment were held as follows:

- Meeting No 1
  Venue: Bundu Lodge, Nelspruit
  Dates: 25th to 29th October 2004
  EWR sites: K1, K2, K3, L1, T1, G1
- Meeting No 2
  Venue: CSIR, Pretoria
  Dates: 31st January to 1st February 2005
  Sites: M1 (Swaziland)

3.4 ECOCLASSIFICATION

Ecological Classification, or EcoClassification, refers to "the totality of the features and characteristics of a river and its riparian areas that bear upon its ability to support an appropriate natural flora and fauna and its capacity to provide a variety of goods and services" (Iversen *et al.* 2000). This ability relates directly to the capacity of the system to provide a variety of goods and services.

3.4.1 Reference Conditions

Prior to the Specialist Meetings a description of natural (reference) conditions was provided by each specialist component. This information was used to define the PES.

3.4.2 Present Ecological State (PES)

Prior to the Specialist Meetings the PES for the main habitat drivers (hydrology, geomorphology and water quality) and ecological responses (riparian vegetation, aquatic invertebrates and fish), were determined for each Resource Unit in which there was an EWR site. The methods were based on a rule-based system described in a user manual prepared by DWAF and the Water Research Commision (Kleynhans *et al*. 2005). Essentially the methods use a swing ranking system in which key components are ranked and weighted to provide consistent results. Standard Excel spreadsheets were used in the assessments. These methods are under various stages of development and the first draft of the manual, dated June 2004, was used in this study. The results of the rule-based models for each component were provided as Ecological Categories (ECs) ranging from Category A (*Natural*) to Category F (*Critically Modified*) (Figure 3-2). The categories represent a range along a continuum, so half categories (i.e. Category B/C) represent a condition at the border between Categories B and C (Figure 3-2).

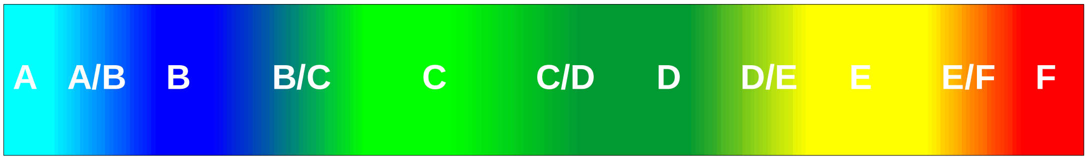


Figure 3-2. Illustration of the of Ecological Categories on a continuum, showing the colour-coding that was used throughout the study (DWAF 2004c).

3.4.3 Trends

Prior to the Specialist Meeting an assessment was made for each ecological component (geomorphology, riparian vegetation, aquatic invertebrates and fish) of Trends (i.e. change) that are likely to take place within each Resource Unit, assuming no change in current development conditions. A distinction was made between short-term trends (<5years) and long-term trends (>20yrs). The trends were classified as either stable (0), improving (+), or degrading (-). Results were presented at the Specialist Meetings and verified.

3.4.4 EcoStatus

Prior to the Specialist Meeting the EcoStatus of each Resource Unit was determined using the rule-based method described in detail in a user manual prepared by Kleynhans *et al.* (2005). These methods were still being tested and the first draft of the manual, dated June 2004, was used. Essentially the method integrates the PES for each component (fish, aquatic invertebrates, riparian vegetation, geomorphology and hydrology) in a consistent way, and in doing so, provides an assessment of the overall state, referred to as the "*EcoStatus".* The results were categorised in one of six categories, from Category A (*Natural*) to Category F (*Critically Modified*). The results of the aquatic invertebrates and fish were integrated to provide an overall assessment of instream ecological conditions. Detailed results are presented in Appendix F. Results were presented at the Specialist Meetings and verified.

3.5 IMPORTANCE

3.5.1 Ecological Importance and Sensitivity (EIS)

Prior to the Specialist Meeting an assessment was made of Ecological Importance and Sensitivity (EIS) of each Resource Unit in which there was an EWR site. Detailed results are presented in Appendix G. The assessment considered both natural and present day conditions and was based on the method developed and described by DWAF (1999). The method rates the following aspects of the biota and habitats on a scale of 0 (unimportant) to 4 (very important):

Biota

- Rare and endangered aquatic species
- Unique, endemic or isolated species or populations
- Presence of species that are intolerant or sensitive to changes in flow or flow related water quality changes
- Diversity of aquatic biota

Habitats

- Diversity of habitats types (i.e. pools, riffles, runs, rapids, waterfalls, riparian forests, etc).
- Presence of refugia
- Sensitivity (or fragility) of the system and its resilience (i.e. the ability to recover following disturbance) to changes in flow
- Sensitivity (or fragility) of the system and its resilience (i.e. the ability to recover following disturbance) to changes in water quality
- Importance as a migration corridor
- Importance as a conservation area (relevant to present conditions only)

3.5.2 Socio-cultural Importance

Prior to the Specialist Meetings an assessment was made of Socio-cultural Importance (SI) of each Resource Unit. Detailed results are presented in Appendix H. The method was based on a rapid method developed and described by Huggins (2003). The method rates the following aspects on a scale of 0 (unimportant) to 4 (very important).

Socio-cultural Importance

- People directly dependant on a healthy flowing river for water supplies
- People dependant on riparian plants for building, thatching and medicinal plants
- People dependant on the river for subsistence fishing
- People using the river for recreational purposes that requires ecologically healthy river

Cultural/Historical Values

- Sacred places on the river, and religious cultural events associated with the river
- Historical/archaeological sites on the river
- Special features and beauty spots
- General aesthetic value of the river
- Sense of place of those living proximate to the river

Conservation Aspects in a Social Context

- Potential for ecotourism
- Present recreation, and potential for recreation

3.6 RECOMMENDED AND ALTERNATIVE ECOLOGICAL CATEGORIES (ECs)

Following the above assessment of EcoStatus, motivated recommendations were made for a Recommended Ecological Category (REC) for each Resource Unit in which there was an EWR site. The REC was based on a combination of factors including PES, EIS, the Socio-cultural Importance, the ecological trends and the practical feasibility of implementing recommended changes (Figure 3-3). In some cases, particularly those of the upper EWR sites (K1 and K2) the REC was initially higher than the present state. However, in light of the current strategic demands, achieving an improvement was considered unlikely and so the overall PES (EcoStatus) category was accepted as the REC. The REC was accompanied by a number of alternative ECs for which flow scenarios were considered. These were guided by the rules as shown in Table 3-1.

Table 3-1. Guidelines for the range of alternative Ecological Categories (ECs) to be addressed (DWAF 2005).

PES	Alternative EC	
	Increase (Up)	Decrease (Down)
A	N/A	N/A
A/B	N/A	B/C
B	N/A	C
B/C	B	C/D
C	B	D
C/D	B/C	D
D	C	N/A
D/E	D	N/A
E	D	N/A
E/F	D	N/A
F	D	N/A

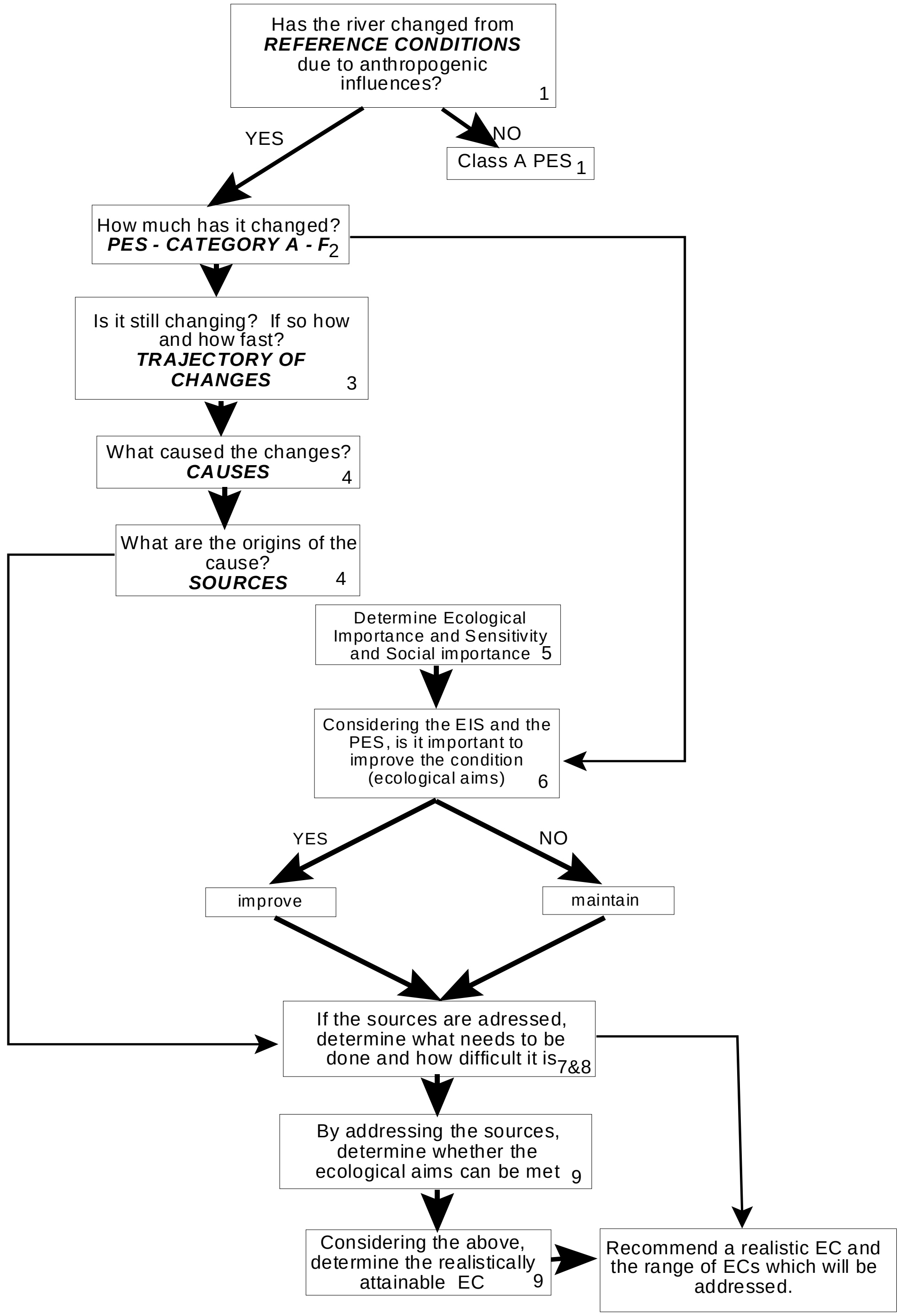


Figure 3-3. Flow diagram illustrating the information generated to determine the Recommended Ecological Category (DWAF 2005).

3.7 KEY MONTHS

Maintenance flows were determined for two ecologically important (key) months of the year. The key months were selected on the distribution of total flows in which the driest and wettest months were selected. Flows for the remaining months were interpolated from the shape of the natural seasonal hydrograph. The key months selected for this study were:

- ***September:*** a typical dry month, when the biota are most stressed due to low flows and higher water temperatures.
- ***February:*** a typical wet month.

3.8 RECOMMENDATIONS FOR LOW-FLOWS

Recommendations for low flows were determined for each EWR site using the Habitat Flow Stressor Response (HFSR) method (Hughes and O'Keeffe 2004; IWR Source-to-Sea 2004). This method was developed to address shortcomings in the Building Block Methodology (BBM). The basis of the method is the application of a Stress Index that describes the consequences of flow reduction to flow-dependent biota. The stressors, flow hydraulics and associated habitat changes, are related to biotic responses in terms of abundance, life stages and persistence. The definitions apply to instream fauna and were calibrated for organisms that would comprise flowing water for optimal habitat. Separate stress indices were determined for invertebrates and selected target fish species, and an Integrated Stress Curve was determined based on the most sensitive components. The stress indices were generated by examining the relationships between flows, habitat availability and biomonitoring survey results.

Fish (CJ Kleynhans)

Habitat suitabilities for selected target fish species were rated on the basis of expert knowledge and a simplified Habitat Suitability Index (HSI) calculated as proposed by Stuber *et al.* (1982). Target species were selected on the basis of their flow and depth preferences and requirements during different life-stages. This method makes use of the suitability of various habitat characteristics to fulfil the life-stage requirements of the selected target species (DWAF 2005). The suitability of the habitat (flow-depth class and cover) under various flow conditions were scored on a scale of 0 (*None*) to 5 (*Very High*) for each of the following:

- Breeding (B),
- Survival / abundance (S),
- Cover (C),
- Health (H),
- Water quality (only flow related aspects – temperature and oxygen concentration) (W)

The habitat suitability index for a particular flow was calculated as follows:

$$HSI = (B+S+C+H+W)/5$$

Where the assessment needed to be applied outside of the breeding season (dry season), the HSI was calculated by excluding suitability for breeding requirements, using the following equation:

$$HSI = (S+C+H+W)/4$$

The average HSI score was expressed as a proportion of 10 and then transformed (reversed) to relate a high score out of 10 to a low suitability, and vice versa. For example, 0 indicated completely suitable conditions while 10 indicated completely unsuitable conditions.

Invertebrates

The relation between flows and stress for aquatic invertebrates at each site was based on an assessment of the available hydraulic data, photographs of habitat availability at different flows, and expert knowledge of invertebrate fauna expected at each site. The assessment focused on identifying key flow-dependent specie(s), and critical habitats such as riffles and marginal vegetation. The first step in the process was to determine the flows at each site at which the stress index would be 0. Higher stresses were determined by anticipating the depths and velocities and associated flows at which remnants of the key species, or required habitats, would be present. Stresses would be caused by reductions in velocity, with corresponding increases in temperature, sedimentation, diatom growth on stones, exposure to predators, and possibilities of decreased oxygen concentrations, especially at night. The suitability of various habitats to aquatic invertebrates at various stress levels was then rated on a five-point scale, where 0=no habitat and 5=highly suitable. Particular attention was given to inflection points in graphs that plotted the relations between flow and key hydraulic parameters. The key hydraulic parameters (depth, velocity, wetted perimeter etc) associated with each stress were then specified.

Natural and Present-Day Stress Profiles (IWR Source-to-Sea (eds), 2004).

Once the stress indices (for low flows) had been identified for the components (fish and invertebrates), the numbers were tabled and the unidentified flow stresses interpolated. At any one flow, the component with the highest stress point represented the integrated stress curve. From this point on, all requirements were provided in terms of the integrated and not the component stresses. Specialists referred back to their component Stress Index to convert any one integrated stress value to their corresponding component stress value.

The modelled natural and present day monthly flow time series were converted to stress time series using the fish and invertebrate stress indices. The wet and dry season results were printed out and provided to specialists. Specialists then determined whether these represented the expected stress conditions under natural flow conditions. This, in essence, represents a hydrological check of the stress indices. The reason for this process is that the component stress indices have different flow-stress relationships. The integrated requirements were then set in terms of the percentage time for the different components and plotted on a duration graph (axis consisting of stress and a % time).

The interpretation of stress durations is complex as the discharge values decrease up the y-axis, as opposed to the standard flow duration graphs, in which discharge values increase up the y-axis. This difference is accommodated for in the step-wise procedure as explained below. The relationship between flow duration graphs, as used during the determination of flows during the application of the BBM process, and the stress duration graph is illustrated in Figure 3.4.

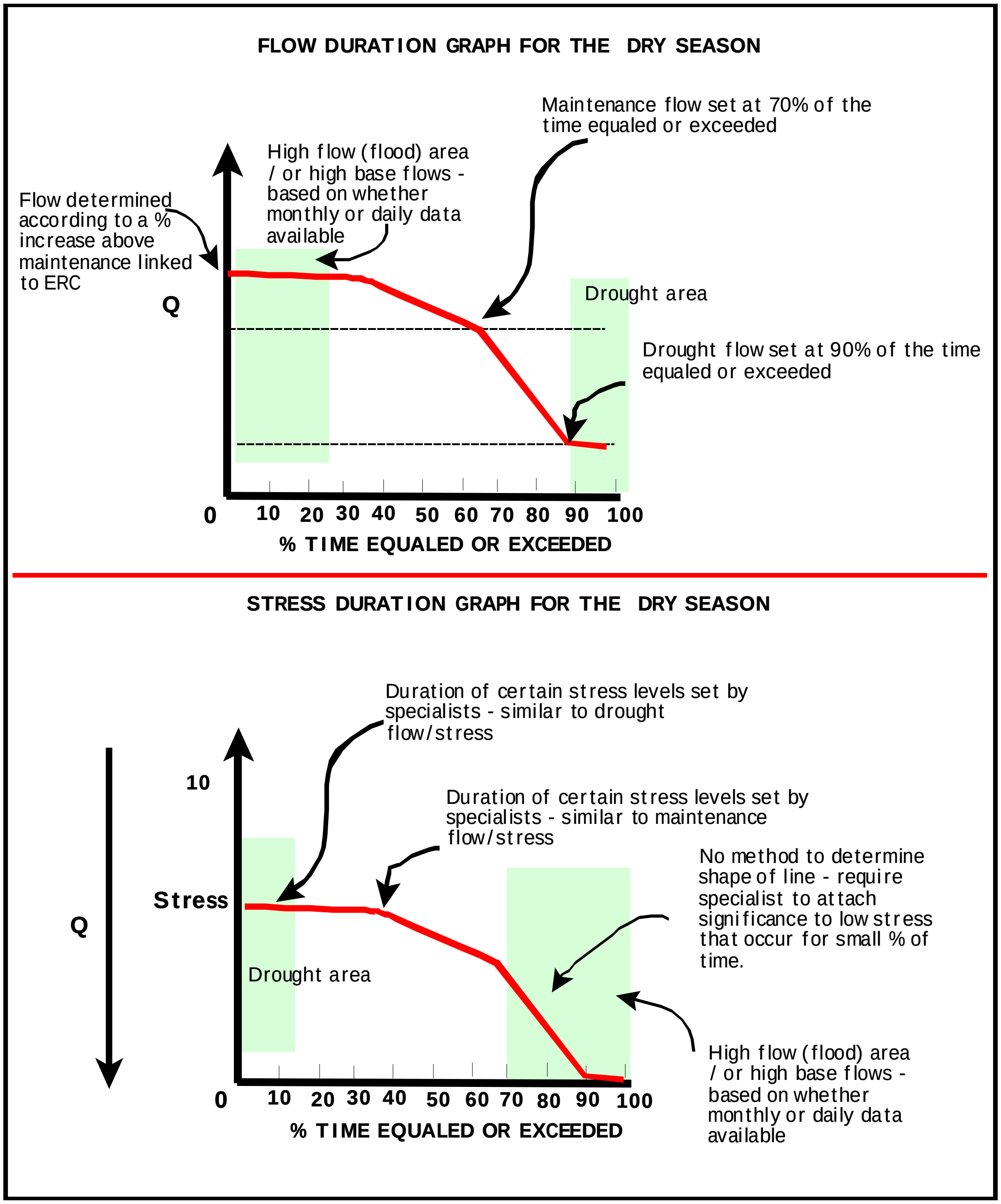


Figure 3-4. Comparison between flow duration and stress duration graphs (IWR Source-to-Sea (eds), 2004).

The stepwise procedure for recommending the low-flow EWR was as follows:

- Specialists determined the percentage time during which stress would be equalled or exceeded for each different season. The specialists were required to provide at least the maintenance stress (set according to assurances identified by the hydrologist) for both seasons, and the drought stress (at 10% assurance). Any additional points, which could provide more information regarding the shape of the curve, were also used. The information was documented in spreadsheets. This information was required for each component, for each EC for which a Reserve scenario was generated. Specialists used the definitions or objectives (set for the alternative ECs) to determine whether the stress would change under these conditions, or whether the stress remains the same and the duration changes.

- The stress (critical values) for the wet and dry season at specific percentage points were provided to the facilitator who tabled these on a flip chart and plotted them on a blank stress profile.
- The stress profile was then overlain with the natural stress profile, a modelled present day hydrology (or preferably observed gauged data if at all possible), and desktop estimated Reserves for each EC.
- The natural and present day (or observed) hydrology was used to determine whether the points recommended by specialists were realistic. The following basic rules were considered:
    - In a river where present flows are greater than natural (eg where the river is used as a conduit), recommendations could be greater than natural.
    - If specialists have identified the modified present flow regime as a problem for their component, and require a flow improvement for the component ecological condition, their points should fall between natural and present (ie closer to the natural than to the present flow).
    - If specialists identified the modified present flow regime as a reason for the PES, but the present state must be maintained, and there is no negative trajectory, points should fall beyond both the natural and present lines. If however there is a negative trajectory, improvement will be required to MAINTAIN, and therefore points can again fall between natural and present flows.
    - If specialists have identified that all the causes of the PES are non-flow related, points should not reflect any improvement of the present flow regime.
    - In a river where present flows are greater than natural, it is highly likely that the points would fall between present and natural, i.e. representing more flow than natural, but less than present.
- In general, the points plotted for the components representing the lowest stress at any time guided the shape of the recommended low flow. Outliers were investigated and if confidence associated with these recommendations was very low; these points were not used to shape the curves.
- The curve was then drawn in by hand. This hand-drawn line represents a band (of flow /stress requirements).
- The hydrologist then investigated which Desktop-generated curve most closely represented the recommended curve, and adjusted the hydrology to fit the hand-drawn curve.
- This curve was presented to the specialists, who indicated whether further manipulation is required or whether the curve represents their requirements adequately.

- The final generated curve was then presented graphically in the report.

At this point the low flow recommendations for each Reserve scenario were finalised and high flow recommendations were needed to enable the Reserve scenarios to be provided.

3.9 RECOMMENDATIONS FOR HIGH-FLOWS

The Downstream Response to Imposed Flow Transformation (DRIFT) method was used to determine high flow requirements (Brown and King 2000).

General

The following procedure was adopted with respect to the flood analyses undertaken for the EWR sites:

1. Statistical analysis of the flood peaks was done to determine a suitable relationship between flood peak discharge and catchment area for a range of return periods that could be used to estimate return period floods at each of the EWR sites under natural conditions. These values, in particular the 1:2 year return period flood, were used as a reference point for the floods at each of the sites.
2. Where daily present-day hydrological data were available these were analysed using the flood analysis options in DRIFT-HYDRO (Flood analysis in DRIFT-HYDRO). This included EWR sites K1, K2 and K3 (partially).
3. Where daily present-day hydrological data were not available, or were deemed to be unreliable, the present day flood daily averaged were estimated based on local knowledge about the water resource developments and the demands on those systems. This included EWR sites K3 (partially), L1, G1 and T1.
4. The flood data were summarized as follows:
    - 4.1. Four classes of intra-annual flood events calculated as:
      Class IV = (1:2 annual peak –10%) to (1:2 annual peak –10%)/2;
      Class III = (1:2 annual peak –10%)/2 to (1:2 annual peak –10%)/4
      Class II = (1:2 annual peak –10%)/4 to (1:2 annual peak –10%)/8
      Class I = (1:2 annual peak –10%)/8 to (1:2 annual peak –10%)/16.
    - 4.2. Daily average peaks for the 2, 5, 10 and 20 return period floods (although only the 2 and 5 return period floods subsequently were motivated for).
    - 4.3. For each size class, for present day conditions, the following additional information was provided, where possible:
        - average daily average peak;
        - duration;
        - frequency per annum (average and mode);
        - timing.
5. The summary naturalized and present day flood data for each site was presented to the geomorphological and vegetation specialists. These specialists were then tasked with the following:
    - 5.1. checking whether the estimated present day flood classes make sense in terms of the geomorphology and riparian vegetation, and if not adjust the size classes accordingly;

5.2. describe what each of the these flood classes are expected to achieve;
5.3. recommend the frequency of each size class flood to maintain:
- PES;
- one category down from PES;
- one category up from PES, where appropriate.

6. The summary naturalized and present day flood data for each site was presented to the macroinvertebrate and fish specialists. These specialists were then tasked with the following:
   6.1. checking the floods that had been recommended by the geomorphological and vegetation specialists;
   6.2. recommend additional floods, were appropriate to maintain:
      - PES;
      - one Category down from PES;
      - one Category up from PES, where appropriate.

Flood analysis in DRIFT-HYDRO

For each present-day daily hydrological record:

1. The high flow events were manually separated from the lowflow events using the 'Mark Events' routine in DRIFT-HYDRO. Low flows are visually distinguished from high flows using guidelines such as the rate of change of the slope of the daily hydrograph, or the discharge at which selected features of the channel become inundated.
2. Once a start and end day has been selected for an event, a linear interpolation is performed between them. For the days in between, any flow above the interpolated value is assigned to be 'flood flow' and any value below the line is assigned to 'low flows'. This procedure is repeated for all floods marked. Finally the separated time-series are written to file.
3. The high flow statistics are generated using the 'High Flow Stats' routine in DRIFT-HYDRO. The following information is generated for the high flows:
   - a list of all events in the hydrological record;
   - dates of occurrence, magnitude, duration, volume and days to peak for all floods on record;
   - four size classes of intra-annual floods, with:
     - average number of floods per year in each class;
     - average monthly distribution of floods in each class;
     - average magnitude, duration and volume for each size class;
   - magnitude, duration and volume of floods with return periods of 1:2, 1:5, 1:10 and 1:20 years.

3.10 FINAL RESULTS

The low flows and high flows were then incorporated into an integrated flow regime. The final output was EWR rules, presented as duration tables, were provided from the Desktop Model. The IFR assurance rules were documented in the report. Results were also provided as IFR tables (the .tab tables).

For Resource Units without EWR sites, the results were generated by extrapolation from either upstream or downstream EWR sites. As these results were extrapolated, they were of low confidence.

3.11 ASSURANCE

Maintenance flows were set at 70% assurance for all sites. Droughts occur in the region of 0 to 10% assurance.

3.12 CONFIDENCE

Each specialist provided a confidence evaluation on a scale of 0 (*No Confidence*) to 5 (*High Confidence*) for their component for various parameters, with associated reasons. The following aspects were rated:

- ***EWR Site:*** The confidence in the site for providing reasonable cues to set the EWR requirements;
- ***Available Data:*** The confidence in the available data, both historical and collected, and the ability to interpret the data to recommend flows accurately;
- ***Ecological Classification***: The confidence in all data that contributed to determining the PES and EC (i.e. Reference conditions, PES, trend, EIS, EC);
- ***Output Low Flows***: The confidence in the low flows that were recommended to achieve the component objectives. If the requirements for an individual component were superseded by another component, the final flow represents more flows than recommended and confidence would be high.
- ***Output High Flows:*** The confidence in the high flows that were recommended to achieve the component objectives. If the requirements for an individual component were superseded by another component, the final flow represents more flows than recommended and confidence would be high.

3.13 ASSUMPTIONS AND LIMITATIONS

Vegetation: The riparian vegetation responses model had not been tested and finalised when this study was conducted, and has not been incorporated in the formula to calculate EcoStatus.

Channel Geomorphology: The HFSR and DRIFT approaches assume that certain flows affect the channel morphology more than others. It is assumed that the identification of these critical flows and their incorporation into the modified flow regime will aid maintenance of the natural channel structure and diversity of physical biotopes.

Expert Opinion: The HSFR and DRIFT approaches recommend a range of flows that rely partly on the expert opinion of specialists, achieve the objectives set. Experts may differ in their recommendations and in the setting of objectives.

Critical Sites: An assumption underlying EWR site selection is that sites are sensitive to changes in flow. It is assumed that by providing water for the EWR sites, then the flow needs of the rest of the river will be met. For this reason, the sites selected are not necessarily representative of the river, but the choice of suitable EWR sites remains critical.

Site selection and the compromise between hydraulics and environmental informational needs: Logistical and financial constraints impose limitations on the number of sites that can be selected. Thus when sites are selected the informational needs for the hydraulic and ecological components need to be considered. Inevitably, this involves reaching a compromise in order to provide a reasonable hydraulic and environmental characterisation of the site.

Temporal Changes: The recommendations of the HFSR and DRIFT approaches are strongly contingent on the hydraulic parameters at the selected EWR sites. However, even for systems in equilibrium, river profiles are not static and are likely to vary, particularly after floods. An EWR is therefore unavoidably affected by the particular time in the drought-flood cycle that the bulk of the data are collected.

High Flows: Confidence in high flows was limited by the lack of accurate simulated daily present-day hydrology from L1, T1, G1 and there were doubts as to accuracy of the high flow data sets for K1, K2 and K3.

Large Floods: The HFSR and DRIFT approaches assume that larger floods (eg >1:3 year occurrence) will occur naturally from time to time, but these were not included in the EWR calculations. Large floods are vital for maintenance and resetting of the river, especially in geomorphological terms. If these flows were to be intercepted (e.g. by very large dams), the character of the river would change and the Reserve objectives would not be met.

Target Species: The HFSR and DRIFT approaches cater for the most flow-sensitive species or group of species in a river. The method assumes that if the flow-sensitive species are taken care of, other species that are not flow-sensitive, will be catered for as well.

Biodiversity: The HFSR and DRIFT approaches assume that the natural biota associated with a river is able to tolerate low-flow and high flow conditions that naturally occurred in the river from time to time. The modified flows are assumed to maximise the opportunities for the greatest number of naturally occurring taxa.

Flow criteria used are the most important: The HFSR and DRIFT approaches assumes that the maintenance of the natural biota and the natural functioning of a river is determined mainly by key components of the natural flow regime. Clearly, this is a simplification, as river ecosystems are highly complex and multivariate. It is therefore to be expected that other factors, such as inter- and intra-specific competition, and less obvious components of the flow regime, may also play significant roles.

4. EWR SITE K1 – GEVONDEN

4.1 ECOLOGICAL CATEGORIES

The PES for EWR Site K1 is summarised Table 4-1, and a description of the reference conditions, and PES for individual components is presented in Table 4-2.

Table 4-1. The PES for EWR Site K1.

Driver Components	Component PES	Driver PES	ECOSTATUS PES
HYDROLOGY	C	C	B/C
GEOMORPH	C		
WATER QUALITY	B		
Response Components	Component PES	Instream PES	
FISH	B/C	B	
AQUATIC INVERTS	B		
RIPARIAN VEG	C	C	

Table 4-2. Description of the PES categories for each habitat driver and biological response for EWR Site K1.

Category B = Largely Natural; Category B/C = Largely Natural to Moderately Modified and Category C= Moderately Modified.

Driver and responses	Reference conditions	PES	PES description
			Overall PES for Drivers Moderately Modified (Category C).
Hydrology	nMAR= 181 million m^3/a	C	pMAR= 128 million m^3/a EWR Site K1 on the Komati River lies some 70 km downstream of Nooitgedacht Dam. This dam has a relatively high capacity compared to the nMAR of its catchment (78.4 against 64 Mm^3). It will therefore have a significant effect on moderating flows through the dam. Nooitgedacht Dam controls 61% of the catchment area, but only 40% of the flow due to relatively high runoff from tributary catchments downstream of the dam. The main changes from natural are: • pMAR is 71% of nMAR; • 15% reduction at 70% exceedance • Delay of about 2 months in wet season • Moderate events 24% reduction at 50% exceedance • High flow events 46% reduction at 10% exceedance
Geomorphology	K1 is classified as an upper foothill site on account of its channel gradient of 0.007. The	C	Nooitgedacht Dam reduces effectiveness of intermediate floods and traps bed sediments. These changes have

Driver and responses	**Reference conditions**	**PES**	**PES description**
			Overall PES for Drivers Moderately Modified (Category C).
	expected reach type would be either plane bed, pool-riffle or pool rapid with a bed material dominated by cobble or bedrock and cobble. The channel lies within a V-shaped valley so there is little scope for lateral channel migration. The channel itself occupies a narrow channel floor. The development of secondary channels around cobble bars is a probable reference condition. These could be observed from the earliest aerial photographs.		caused the following changes in sediment inputs, riparian vegetation and channel structure. **Sediment inputs:** Dam impacts on coarse sediment inputs. Some coarsening of the bed material is evident. **Riparian Vegetation:** Riparian vegetation on the banks offers bank stability and protection. Examination of aerial photographs points to a spread of reeds onto instream features and into secondary channels. No evidence of changes to woody riparian vegetation. Reduced flows have led to reed encroachment and loss of secondary channels. **Channel structures** No impact.
Water Quality	The reference water quality at K1 would have been excellent with no potential land use activities cauing water quality changes.	**B**	Water quality is good despite Eskom water requirements and open-cast coal mining. Possible deterioration in bacterial contamination caused by septic tanks of tourism facilities.
			Overall Instream PES Largely Natural (Category B)
Riparian Vegetation	No exotic species present.	**C**	The main changes triggered by flow related causes (attenuation of intra-annual floods, streamflow reduction from increased abstraction) and non-flow related causes (upstream forestry and tourism activities (septic tanks affecting water quality), gravel road crossings, bank erosion, increased sedimentation, increased alien invasive plants).
Marginal zone: Sedgeland \ Reedbed on stream banks	• sidebars dominated by mesophytic grass species and sedges. • frequently inundated sidebars dominated by clumps of the reeds and the shrub *Salix mucronata*. • Other noteworthy plants include the medicinal geophyte *Crinum* sp.		• moderate increase in biomass of *Phragmites mauritianus* reeds. • moderate reduction in cover of mesophytic grasses such as *Ischaemum fasciculatum* and *Miscanthus junceus*; and of sedges such as *Cyperus marginatus* and *Schoenoplectus brachyceras* • small reduction of indigenous species of grasses and sedges and of the shrub *Salix mucronata*. • small change in overall species composition for example the presence of the naturalized exotic grass *Paspalum dilatatum*. • no significant change in vegetation structure.
Lower riparian zone: Shrubby Grassland on firm alluvial slopes	• mesophytic grasses provide the dominant ground cover. • return wetland seepage result in vegetation communities not wholly river-dependent. • mesophytic shrubs occur as scattered individuals. • presence of mesophytic trees such as *Ficus sur* and *Syzygium cordatum* • No terrestrial species present.		• moderate reduction in biomass (loss of trees species *Ficus sur* and *Syzygium cordatum*) • moderate reduction in cover of mesophytic grasses such as *Ischaemum fasciculatum* and *Imperata cylindrica* • moderate reduction in number of indigenous species such as *Ficus sur* and *Syzygium cordatum* as terrestrialisation occurs. • moderate change in overall species composition as terrestrial species and alien invader species (wattle) invade. • moderate reduction in structure due to replacement of riparian trees with terrestrial and invader species
Upper riparian zone: Open Woodland on firm alluvial slopes	• shallow, slightly clayey sandy soils on the right slope supporting typically riparian species as well as non-riparian species. • woodland structure maintained by regular seedling recruitment • good ground cover of grasses.		• Small reduction in biomass and overall species composition from terrestrialisation (loss of trees such as *Rhus gerarrdii*). • Small reduction in grass cover (replacement of mesophytic species by more xerophytic species). • Small reduction in number of indigenous species

Driver and responses	Reference conditions	PES	PES description
			Overall PES for Drivers Moderately Modified (Category C).
			• No significant change in vegetation structure
Fish	Eleven (11) species expected to occur under natural conditions.	**B/C**	Eleven species expected, 10 recently collected. Abundances were lower than expected. **Flow depth:** Lower abundance of fish dependant on fast deep habitats and species preferring slow flowing habitats with undercut banks and marginal vegetated areas. *Chiloglanis emarginatus* and *Barbus argenteus* absent from site. Slight improvement downstream near Gembsbokhoek Weir. **Flow Modification:** absence of *Anguilla mossambica* related to large impoundments preventing recolonization. Migration of fish effected by weirs and dams. Low abundance of flow dependant and moderately flow dependants. **Substrate:** Low abundance of fish dependant on substrate in fast deep habitats and species preferring fast flowing habitats as well as species preferring undercut banks and marginal vegetated areas. **Water Quality:** Many species also sensitive and moderately sensitive to changes.
Aquatic Invertebrates	There are no historical records of aquatic invertebrates in Resource Unit B prior to the construction of Nooitgedacht Dam. Taxa that are expected under reference conditions include Perlidae, Heptageniidae, Polymitarcidae and Prosopistomodatidae.	**B**	Confidence in the results was high. The main changes triggered by flow and non-flow related causes: • high abundances and diversity of baetid mayflies, stoneflies and Coleoptera. • Prosopistomatidae and Polymitarcyidae were encountered in the stones biotope. • functional feeding groups dominated by filterers and gathering collectors. • reduced abundance of taxa that require fast-flowing water and good quality, clear water. • increased numbers of tolerant taxa, such as *Baetis harrisoni.*

Additional tables providing scores for the individual driver components and biological responses (instream) and a summary of the EcoStatus are available in Appendix F.

4.2 TRENDS

The trend for aquatic invertebrates are considered stable under current development conditions, although increased tourism development in the area is likely to have a slightly detrimental impact on the river. Fish, vegetation (with future control of invasive wattle*)* and geomorphology are stable under current conditions. There has been sufficient time since the building of the Nooitgedacht Dam for structural changes in river bed to have already taken place.

4.3 IMPORTANCE

4.3.1 Ecological Importance and Sensitivity

The Ecological Importance and Sensitivity of Resource Unit B within the Komati Gorge was rated *Very High* under natural conditions and *High* under present conditions. The confidence for this assessment was high. The main determinants were the presence of the rare endangered fish *Chiloglanis bifurcus*, a bald ibis breeding colony and the presence of endemic fish species: *Chiloglanis emarginatus* and *Barbus argenteus.* Detailed results are presented in Appendix G.

4.3.2 Socio-cultural Importance

Resource Unit B was of *Moderate* Socio-cultural Importance. Landuse is characterised by commercial dryland agriculture, some irrigated agriculture, livestock grazing (mainly cattle), and localised ecotourism developments (fishing, walking, biking and birding). Population densities are very low. Direct dependence on the river for water supply and other harvestable resources is probably low, although there is likely to be significant commercial harvesting of medicinal herbs and tubers for sale in Gauteng. The Komati Gorge is spectacular and largely undeveloped, offering significant potential for further ecotourism development. San and other archaeological sites are present. Detailed results are presented in Appendix H.

4.4 RANGE OF ECOLOGICAL CATEGORIES

4.4.1 Recommended Ecological Category

The EIS (present) was rated as *High*, indicating that a higher category should be recommended. However, due to the strategic importance and scarcity of water it was considered unrealistic to recommend a higher category. Maintaining the river as a Category B/C would be adequate from an ecological point of view and the PES was accepted as the REC.

4.4.2 Alternative Ecological Categories

Two alternative Ecological Categories were considered: Category B and Category C/D. The conditions for achieving classes are given in Table 4-3 and summarised in Table 4-4.

Table 4-3. Summary of the conditions defining the alternative Ecological Categories for EWR Site K1.

Driver and responses	Alternative B	Alternative C/D
General	Category B conditions would comprise: (a) improved water quality (temperature decrease, increased oxygen), (b) increased flows, (c) a change in the proportion of *Salix* and reeds (i.e. less reeds) and (d) active secondary channels. Increased flows may open secondary channels, but would be unable to bring back previously lost fine sediments.	Category C/D conditions would comprise (a) less high flows due to increased dam abstraction, (b) deterioration in water quality (increase in temperature, decrease in oxygen), (c) a drop in low flows affecting tributaries, (d) increased reed encroachment, (e) narrower and embedded channel and (f) a decrease in flood assurances.
Geomorphology	Increased frequency of intermediate floods will improve chance for transport of a wider range of sediment classes, resulting in improved bed sorting and maintenance of channel plan form and geometry. Higher flows should help open up secondary channels if encroaching vegetation can	A reduction in intermediate floods would result in a localised reduction in channel width and further loss of secondary channels, possible loss of pool depth and tendency for embedded cobbles. Loss of width would be accelerated by encroaching vegetation

Driver and responses	Alternative B	Alternative C/D
	be uprooted by floods.	
Riparian Vegetation	Improvement within the Marginal zone: small increase in biomass of reeds and shrubs, a small reduction in vegetation cover of mesophytic grasses and of sedges. There would be no significant change in species richness, composition and vegetation structure. An improvement within the Lower Riparian Zone: small reduction in biomass and structure as a result of tree loss, a small reduction in cover of mesophytic grasses and number of indigenous species and a small change in species composition as naturalized exotics invade. Improvement within the Upper Riparian Zone: no significant change in vegetation abundance, cover, richness, composition and structure.	Marginal zone: a serious increase in biomass of reeds, large reduction in mesophytic grass and sedge cover, moderate reduction of indigenous species of grasses and sedges and possibly of the hydrophytic shrub *Salix mucronata* and the geophyte *Crinum* sp, moderate change in overall species composition and structure due to the introduction of exotic tree species. Lower Riparian Zone : moderate reduction in biomass from tree loss, moderate reduction in cover of mesophytic grasses, large reduction of indigenous mesophytic species, large change in overall species composition as terrestrial species and alien invader species invade and moderate reduction in structure due to replacement of riparian trees. Upper Riparian Zone: small reduction in biomass and structure due to terrestrialisation and depleted number of trees, moderate reduction in grass cover being replaced by more xerophytic species, small reduction in number of indigenous species, moderate change in overall species composition from terrestrialisation and invasion of ephemeral species and small reduction in vegetation structure.
Fish	Increased base flows would provide more habitats for flow dependant and moderately flow dependant species. This will also increase the abundance of available habitats for species dependant on fast deep and fast shallow conditions and provide more permanent habitat for species dependant on the availability of marginal vegetation and undercut banks.	Reduction in the abundance of species dependant on fast deep and fast shallow habitats. The species most affected will be those dependant on substrate and marginal vegetation with undercut banks as these habitats decrease. This will also reduce the suitability of available fast deep habitats (i.e. a loss of at least 2 species, *Chiloglanis emarginatus* and *Barbus argenteus).* It is also likely that *Amphilius uranoscopus* may be largely affected. This may also affect the available breeding habitats of yellowfish. An increase in temperatures and nutrients will decrease the abundance of species intolerant and moderately intolerant to water quality changes.
Aquatic Invertebrates	Category B may be easily achievable at EWR Site K1, which is maintained by tributary accruals. Aquatic invertebrates do not move up a category.	Taxa expected to disappear following more reduced low-flows and increased nutrients are Hydroptilidae, Elmidae, Helolidae, Dixidae, Athericidae, Perlidae and Psephenidae.

Driver Components	Component PES	Driver PES	ECOSTATUS PES
HYDROLOGY	B	B	B
GEOMORPH	C		
WATER QUALITY	B		
Response Components	**Component PES**	**Instream PES**	
FISH	B	B	
AQUATIC INVERTS	B		
RIPARIAN VEG	B	B	

Driver Components	Component PES	Driver PES	ECOSTATUS PES
HYDROLOGY	D	D	C/D
GEOMORPH	D		
WATER QUALITY	C		
Response Components	**Component PES**	**Instream PES**	
FISH	C/D	C	
AQUATIC INVERTS	C		
RIPARIAN VEG	D	D	

Table 4-4. Summary of the Alternative EcoStatus B and C/D for EWR Site K1.

The rule-based models for the individual components were run in a predictive manner and based on the above hypothetical scenarios, the matrixes that would be affected were changed. These spreadsheets with the changes indicated as different colours are included in the specialist appendices.

4.5 STRESS INDICES

Refer to Appendix I for the flow stress indices for the REC and alternative EC's for fish and aquatic invertebrates.

4.5.1 Stress Index: Fish

The rheophilic species selected was *Chiloglanis emarginatus* which is dependant on the presence of deep moderately fast flowing waters. The semi-rheophilic was *Labeobarbus polylepis* and the limnophilic species selected was *Barbus anoplus*. The rheophilic species was the most stressed under all the flow conditions (Table 4-5). With a flow of 2.66 m^3/s there is abundant fast deep habitat available and none of the life history requirements of *Chiloglanis emarginatus* are likely to be stressed. At a flow of 1.66 m^3/s there is a significant loss in the availability of fast deep habitats that will significantly affect breeding and to a lesser extent available habitat and suitable cover. At a flow of 1.0 m^3/s the availability of fast deep habitats is further reduced and breeding will be restricted to only a few areas. The availability of suitable cover will also further reduce the abundance of the species. At a flow of 0.25 m^3/s the species will only survive in limited numbers due to a lack of suitable habitat and this will also start to affect the quality of the water and the health of the fish. At a flow of 0.1 m^3/s no suitable fast deep habitats will be present.

Rheophilic species represents the highest stresses at any given flow and this was therefore used to generate the stress index.

Table 4-5. Stress table for rheophilic, semi-rheophilic and limnophilic fish species showing Habitat Suitability at EWR Site K1. CEMA=*Chiloglanis emarginatus*.

FLOW (CUMEC)	2.66	1.660	1.000	0.500	0.450	0.250	0.100	0.050	0
RELATIVE ABUNDANCE FLOW-DEPTH & COVER RATING: 0=NONE;1=RARE;2=SPARSE;3=MODERATE;4=ABUNDANT;5=VERY ABUNDANT)									
FAST DEEP	5	3.0	3.0	2.0	2.0	1.0	0.0	0.0	0
FAST SHALLOW	4.0	4.0	3.0	3.0	3.0	2.0	1.0	0.0	0
SLOW DEEP	3.0	3.0	3.0	2.0	2.0	2.0	1.0	0.0	0
SLOW SHALLOW	4.0	4.0	4.0	4.0	4.0	4.0	3.0	3.0	3
OVERALL HABITAT RESPONSE	**2**	**3**	**4**	**5**	**5**	**6**	**8**	**9**	**9**

SUITABILITY FOR DIFFERENT FISH REQUIREMENTS PER HABITAT GUILD									
RHEOPHILIC	**SPECIES:**								
	CEMA								
Breeding and early life-stages=	5.0	3.0	2.0	1.0	1.0	0.0	0.0	0.0	0
Survival /Abundance =	5.0	4.0	3.0	2.0	2.0	1.0	0.0	0.0	0
Cover =	5.0	4.0	3.0	2.0	2.0	1.0	0.0	0.0	0
Health and condition=	5.0	5.0	3.0	3.0	3.0	3.0	0.0	0.0	0
Water quality=	5.0	5.0	5.0	4.0	4.0	3.0	2.0	0.0	0
Rheophilic stress - (breeding requirements included)	**0**	**2**	**4**	**5**	**5**	**7**	**9**	**10**	**10**
SEMI-RHEOPHILIC	**SPECIES:**								
	Bpol								
Breeding and early life-stages=	5.0	4.0	3.0	2.0	2.0	0.0	0.0	0	
Survival /Abundance =	4.0	4.0	4.0	3.0	3.0	2.0	2.0	1	
Cover =	4.0	4.0	4.0	3.0	3.0	2.0	2.0	1	
Health and condition=	5.0	5.0	5.0	4.0	4.0	3.0	2.0	2	
Water quality=	5.0	5.0	5.0	4.0	4.0	3.0	2.0	2	
Semi-rheophilic stress - (breeding requirements included)	**1**	**1**	**2**	**4**	**4**	**6**	**7**	**8**	
LIMNOPHILIC	**SPECIES:**								
	Bano								
Breeding and early life-stages=	4.0	4.0	3.0	2.0	2.0	2.0	1.0	1	
Survival /Abundance =	4.0	4.0	3.0	3.0	3.0	3.0	2.0	2	
Cover =	4.0	4.0	3.0	3.0	3.0	2.0	2.0	2	
Health and condition=	5.0	5.0	5.0	5.0	5.0	3.0	3.0	1	
Water quality=	5.0	5.0	5.0	5.0	5.0	4.0	3.0	1	
Limnophilic stress (breeding requirements included)	**1**	**1**	**2**	**3**	**3**	**4**	**6**	**7**	
FLOW(CUMEC)	2.66	1.66	1.00	0.50	0.45	0.25	0.10	0.05	0.00
FLOW-DEPTH CONVERTED TO HABITAT RESPONSE (10=ALL FLOW-DEPTH CLASSES ABSENT (RIVER DRY); 0=FLOW-DEPTH *CLASSES OPTIMUM FOR SITE* ; 9=NO FLOW)									
Fast deep	0	4	4	6	6	8	10	10	10
Fast shallow	2	2	4	4	4	6	8	10	10
Slow deep	4	4	4	6	6	6	8	10	10
Slow shallow	2	2	2	2	2	2	4	4	4
OVERALL HABITAT RESPONSE	**2**	**3**	**4**	**5**	**5**	**6**	**8**	**9**	**9**

4.5.2 Stress Index: Aquatic Invertebrates

Optimum Flow rates: 0.3 and 0.6 m/s
Key Species: *Tricorythus* and *Neoperla spio*
Critical Habitats: Riffle

The relationships between aquatic invertebrate habitats, flows, stresses and associated biological responses at EWR Site K1 are detailed in Table 4-6. The critical factors that were used to determine the stress curve were the current speeds, overall species composition and an indicator species, *Neoperla spio*. During the field survey on 4th August 2003 the flow was 0.28 m^3/s and the rocks were covered in senescent algae that limited habitat suitability, and a habitat stress score of 6 was allocated. However, biomonitoring data showed that some flow-sensitive species were still present at these flows, so the biological response stress was reduced to 5.

Table 4-6. Stress Table – Flow Dependant Invertebrate at EWR Site K1.

Habitat Flow Response Index	HABITAT ABUNDANCE AND SUITABILITY					TOTAL	FLOW	HABITAT RESPONSE	HABITAT CHARACTERISTICS					BIOTIC RESPONSE	FLOW	SPECIES STRESS	INTEGRATED STRESS
	SIC	SOC	VIC	VOC	GSM				Max depth (m)	Avg depth (m)	Max vel (m/s)	Avg vel (m/s)	WP (m)				
0	**5**	**3**	**5**	**5**	**1**	**19**	**2.000**	All habitat in excess, very high quality: very fast, very deep, very wide wetted perimeter	0.42	0.24	1.2	0.39	22.75	All very abundant, all healthy, all species persist	**2.000**	**0**	**1.1**
1	**4**	**4**	**5**	**4**	**1**	**18**	**1.660**	All plentifull, high quality; fast, wide wetted perimeter	0.39	0.22	1.1	0.35	22	All abundant, all healthy, all species persist	**1.660**	**1**	**2.0**
2	**4**	**4**	**4**	**3**	**1**	**16**	**1.200**	Critical habitats sufficient; quality slightly reduced: fast, wetted perimeter slightly reduced	0.36	0.2	n/a	0.3	20.73	Slight reduction for sensitive rheophilic species, all healthy in some areas, all species persist	**-**	**2**	**3.0**
3	**4**	**4**	**3**	**3**	**1**	**15**	**0.930**	Reduced critical habitat, reduced critical quality; moderate velocity, fairly deep, wetted perimeter slightly/moderately reduced	0.34	0.19	n/a	0.26	19.9	Reduction for all rheophilic species; all healthy in limited areas; all species persist	**0.930**	**3**	**4.0**
4	**4**	**4**	**3**	**2**	**1**	**14**	**0.500**	Critical habitats limited; moderate quality: Moderate velocity, Some deep areas, Wide WP moderately reduced	0.3	0.17	0.55	0.19	17.2	Further reduction for all rheophilic species; all viable in limited areas, critical life stages of some sensitive rheophilic species at risk, all species persist	**0.500**	**4**	**4.8**
5	**3**	**5**	**2**	**2**	**1**	**13**	**0.410**	Critical habitat very reduced; moderate/ low quality; moderate/slow velocity, few deep areas wetted perimeter moderately/very reduced	0.28	0.16	0.4	0.16	16.5	Limited populations of all rheophilic species. Critical life-stages of sensitive rheophilic species at risk or non-viable; all species persist	**0.280**	**5**	**6.5**
6	**2**	**5**	**1**	**2**	**1**	**11**	**0.280**	Critical habitat residual. Low quality; Moderate/slow velocity.	0.26	0.15	0.35	0.13	15.4	Sensitive rheophilic species rare, critical stages of sensitive rheophilic species non-viable, and at risk for some less sensitive species. All species persisit in the short-term	**-**	**6**	**7.5**
7	**1**	**4**	**1**	**1**	**1**	**8**	**0.150**	No critical habitat, other habitats moderate quality; slow, narrow wetted perimeter	0.22	0.12	0.25	0.09	13.8	Most rheophilic species rare; All life-stages of sensitive rheophilic species at risk or non-viable. Most sensitive rheophilic species disappear	**0.150**	**7**	**8.2**
8	**1**	**4**	**0**	**0**	**1**	**6**	**0.050**	Flowing water habitats residual low quality: slow trickle, very narrow wetted perimeter	0.17	0.08	0.15	0.04	12.4	Remnant populations of some rheophilic species; all life stages of most rheophilic species at risk or non-viable, many rheophilic species disappear	**-**	**8**	**8.9**
9	**0**	**4**	**0**	**0**	**1**	**5**	**-**	Standing water habitats only, very low quality, no flow	0.04	0.02	n/a	0	2.2	Mostly pool dwellers; all life stages of most rheophilic species non-viable; most or all rheophilic species disappear	**0.050**	**9**	**9.9**
10	**0**	**0**	**0**	**0**	**0**	**0**	**-**	Only hyporheic refugia, no surface water	0	0	0	0	0	Only specialists persist, virtually no development.	**-**	**10**	**10.0**

1 SIC: Partially submerged hard substrate in current >0.1 m/s
2 SOC: Partially submerged hard substrate in current <0.1 m/s
3 VIC: Submerged vegetation (at least 2-3cm submerged) in current >0.1 m/s
4 VOC: Submerged vegetation (at least 2-3cm submerged) in current<0.1 m/s
5 GSM: Small particles submerged

4.5.3 Integrated Stress Curve

The individual component stresses are illustrated as well as the integrated stress line (black line) (Figure 4-1). Fish stress was consistently higher than invertebrate stress, so fish stress represents the integrated stress.

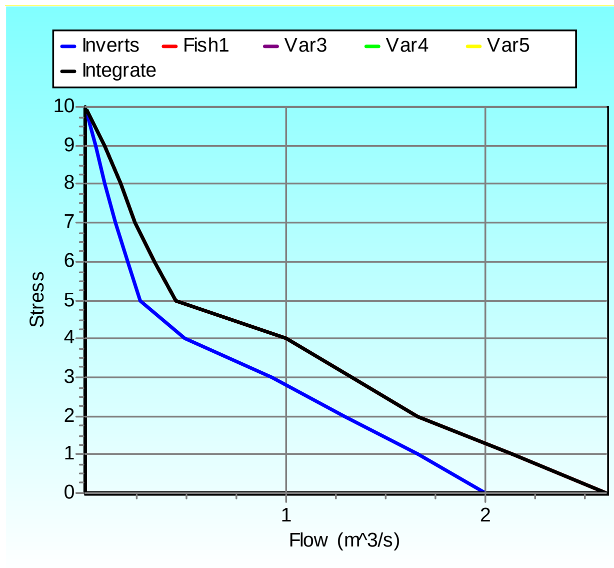
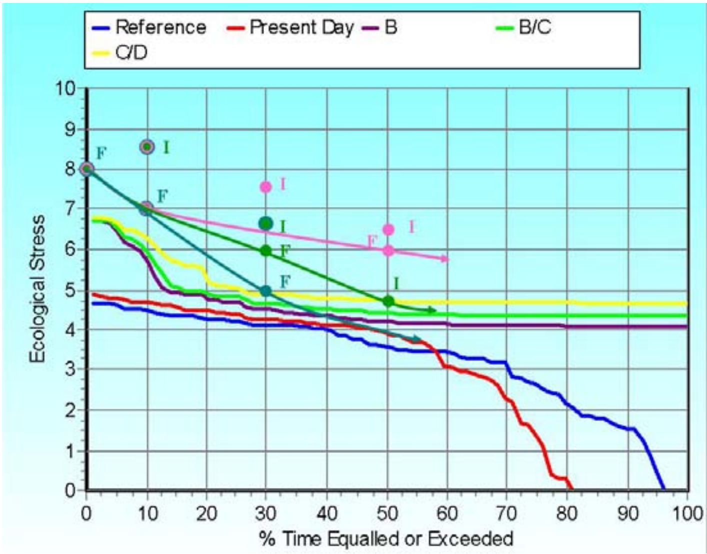


Figure 4-1. Index Stress Curves for EWR Site K1.

4.6 DETERMINATION OF EWR SCENARIOS

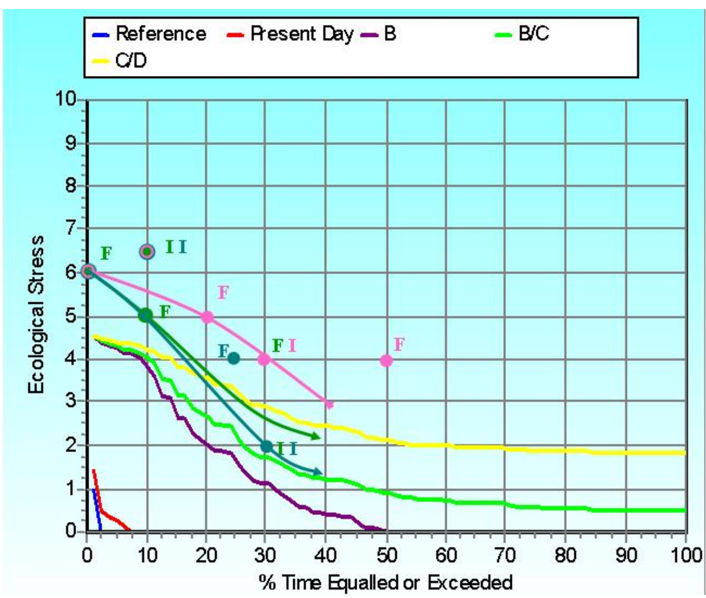
4.6.1 Low-Flow Requirements

The determined integrated stress index must now be used to identify required stress levels at specific durations for the wet and dry season. The requirements are illustrated in Figure 4-2.



Dry Season
Pink = C/D
Blue = B,
Dark Green = B/C

F = Fish
I = Invertebrates



Wet Season
Pink = C/D
Blue = B,
Dark Green = B/C

F = Fish
I = Invertebrates

Figure 4-2. EWR Site K1 – Stress duration curves for all scenarios.

4.6.2 Motivations: Fish, Invertebrates and Vegetation

The stress referred to in the motiations below refers to fish stress, not component stress.

FISH: DURATIONS AND MOTIVATIONS TO BE USED FOR DETERMINING STRESS REQUIREMENTS.
Indicator: *Chiloglanis emarginatus* **Fish:** This species is dependant on perennial flow in fast deep habitats and its requirements will cater for the other rheophilic species.
FISH STRESS REQUIREMENTS
DRY SEASON
DROUGHT: 10% at stress 7 will allow for low survival of the species in minimal available fast deep conditions. At lower flows fast deep conditions will no longer be present in the river. The stress level should never exceed 8 (0% of the time) otherwise the species could be lost.
MAINTENANCE B/C: Require good habitat for the dry season and stress of 6 can be tolerated for 30% of the time. **MAINTENANCE B:** Require good habitat for the dry season and stress of 5 can be tolerated for 30% of the time. **MAINTENANCE D:** Require moderate good habitat for the dry season and stress of 6 can be tolerated for 50% of the time.
WET SEASON
DROUGHT: 10%.at stress 5 will still allow spawning, but only with few fast deep sites with favourable habitat conditions. Relatively limited FD available but fragmented (patchy). A stress of 6 must never (0% of time) occur as this will only allow for minimal survival and no recruitment or breeding. At this point summer temperatures may also become problematic and oxygen levels in water may become critical.
MAINTENANCE B/C: Require good survival habitat and good to moderately good breeding habitat and recruitment. Therefore a stress of 4 can be tolerated for 30% of the time. **MAINTENANCE B:** Require good survival habitat and good to moderately good breeding habitat and recruitment. Therefore a stress of 4 can be tolerated for 25% of the time. **MAINTENANCE D:** Require moderate survival habitat for the species and moderate available breeding habitat and recruitment. Therefore a stress of 4 can be tolerated for 50% of the time.
General life history requirements *Chiloglanis emarginatus* ***Eggs:*** Margins of FD (>0.3 m, >0.3 m/s) gravel cobble substrate. October – January. >16°C Duration 7 days 3 - 30% ***Larva:*** Feeding and Growth: Nursery areas (>0.3 m, >0.2 m/s), Margins of FD, SS & overhanging vegetation. Duration larval period: 2 months. ***Juvenile:*** Feeding and Growth: Mostly FD and margins of SS (>0.30m deep >0.2 m/s). Cover: Cobbles & rocks overhanging vegetation. Duration 3-6 months. ***Adult:*** FD (>0.3 m, >0.3 m/s) gravel, cobble Substrate. Spawning season: October – January. Cue: increased temperature, flow and changes in water quality (e.g. conductivity).

The stress referred to in the motiations below refers to aquatic invertebrate stress, not component stress.

AQUATIC INVERTEBRATES: DURATIONS AND MOTIVATIONS TO BE USED FOR DETERMINING STRESS REQUIREMENTS
Indicator: *Neoperla spio* **Invertebrates**: The indicators are rheophilic species.
STRESS REQUIREMENTS FOR RECOMENDED EC
DRY SEASON
DROUGHT: +/-10%. Stress 7: Survival conditions. Flow more than a trickle must be maintained over the riffle, average depth 12 cm and average velocity 0.09 m/s.
MAINTENANCE B: 30%. Stress 5: Require good riffle habitat for the dry season. Average depth 15 cm and average velocity 0.13 m/s. Biomonitoring data collected at Stress level of 5 in August 2003 indicated a PES of Category B. These flows should be sufficient to maintain the high diversity of baetid mayflies, and populations of the stonefly *Neoperla spio,* Corixidae, Hydraenidae, Leptoceridae, Hydrophilidae, Simuliidae (mainly *Simulium medusaeforme*), Ancylidae, Planorbinae, Chironomidae, Sphaeriidae, Hemiptera and Coleoptera (Dytiscidae, Elmidae, Gyrinidae, Haliplidae, Hydraenidae, Hydrophilidae, Psephenidae). **MAINTENANCE C:** Reduced diversity of habitat conditions occurring more often. Drought: Stress 7 for dry season. Average depth 16 cm and average velocity 0.16 m/s. Stress 5 for wet season. Maintenance: Stress 6 for dry season and Stress 3 for the wet season: Average depth 19 cm and average velocity 0.26 m/s. Taxa expected to disappear following more reduced low-flows and increased nutrients are Hydroptilidae, Elmidae, Helolidae, Dixidae, Athericidae, Perlidae and Psephenidae.
OTHER: 50%. Stress 4: Require average depth 17 cm and average velocity 0.19 m/s.
WET SEASON
DROUGHT: +/- 10%. Stress 5: Require good riffle habitat for the dry season. Average depth 15 cm and average velocity 0.13 m/s.
MAINTENANCE : 30%. Stress 1: Ensure viability of riffle community. Average depth of 22 cm and average velocity of 0.36 m/s during the dry season to protect against high temperatures and low oxygen concentrations.

The low flow requirements set by fish and aquatic invertebrates were assessed for riparian vegetation.

RIPARIAN VEGETATION		
Flow	**Discharge (m^3/s)**	**Max flow depth (m)**
September drought	0.15	0.13
September maintenance	0.4	0.28
February drought	0.4	0.28
February maintenance	1.3	0.37
A prolonged drought flow (> 2 weeks) in September may prove detrimental to grassland and sedgeland vegetation of seasonal bars in the marginal zone. It may also detrimentally affect shrubs such as *Salix mucronata* in the lower riparian zone. Therefore it may be important to provide at least one dry season fresher (in August) in such an instance.		

4.6.3 Final Low Flow Requirements

Adjustments to the Desktop Reserve Model requirements were made to fit the specialist requirements as shown in Tables 4.7 to 4.9.

Table 4-7. EWR K1 - Maintenance and drought low flows (EC = B).

Month	Desktop (m^3/s)		Modified (m^3/s)		Ratio (Mod/Desk)	
	Maintenance low flows	Drought low flows	Maintenance low flows	Drought low flows	Maintenance low flows	Drought low flows
Jan	1.965	0.577	1.500	0.280	76%	49%
Feb	2.453	0.713	1.900	0.350	77%	49%
Mar	2.024	0.593	1.500	0.320	74%	54%
Apr	1.810	0.537	1.250	0.275	69%	51%
May	1.507	0.454	1.000	0.230	66%	51%
Jun	1.271	0.392	0.800	0.210	63%	54%
Jul	0.963	0.308	0.600	0.180	62%	58%
Aug	0.822	0.270	0.547	0.170	67%	63%
Sep	0.788	0.263	0.523	0.165	66%	63%
Oct	0.839	0.275	0.550	0.170	66%	62%
Nov	1.216	0.378	0.900	0.210	74%	56%
Dec	1.563	0.469	1.200	0.260	77%	55%

Table 4-8. EWR K1 – Maintenance and drought flows (REC = BC).

Month	Desktop		Modified		Ratio (Mod/Desk)	
	Maintenance low flows	Drought low flows	Maintenance low flows	Drought low flows	Maintenance low flows	Drought low flows
Jan	1.561	0.577	1.300	0.280	83%	49%
Feb	1.945	0.713	1.450	0.350	75%	49%
Mar	1.608	0.593	1.400	0.320	87%	54%
Apr	1.442	0.537	1.200	0.275	83%	51%
May	1.206	0.454	0.920	0.230	76%	51%
Jun	1.024	0.392	0.675	0.210	66%	54%
Jul	0.784	0.308	0.490	0.180	63%	58%
Aug	0.675	0.270	0.380	0.170	56%	63%
Sep	0.649	0.263	0.400	0.165	62%	63%
Oct	0.687	0.275	0.440	0.170	64%	62%
Nov	0.981	0.378	0.718	0.210	73%	56%
Dec	1.249	0.469	1.000	0.260	80%	55%

Table 4-9. EWR K1 – Maintenance and drought flows (EC = CD).

Month	Desktop		Modified		Ratio (Mod/Desk)	
	Maintenance low flows	Drought low flows	Maintenance low flows	Drought low flows	Maintenance low flows	Drought low flows
Jan	0.857	0.577	0.570	0.280	67%	49%
Feb	1.063	0.713	0.700	0.350	66%	49%
Mar	0.882	0.593	0.650	0.320	74%	54%

Apr	0.796	0.537	0.600	0.275	75%	51%
May	0.670	0.454	0.500	0.230	75%	51%
Jun	0.576	0.392	0.400	0.210	69%	54%
Jul	0.448	0.308	0.280	0.180	63%	58%
Aug	0.391	0.240	0.230	0.170	59%	71%
Sep	0.378	0.263	0.220	0.165	58%	63%
Oct	0.398	0.275	0.230	0.170	58%	62%
Nov	0.553	0.378	0.360	0.210	65%	56%
Dec	0.693	0.469	0.500	0.270	72%	58%

The final curves for EWR Site K1 are shown in Figure 4-3 and Figure 4-4.

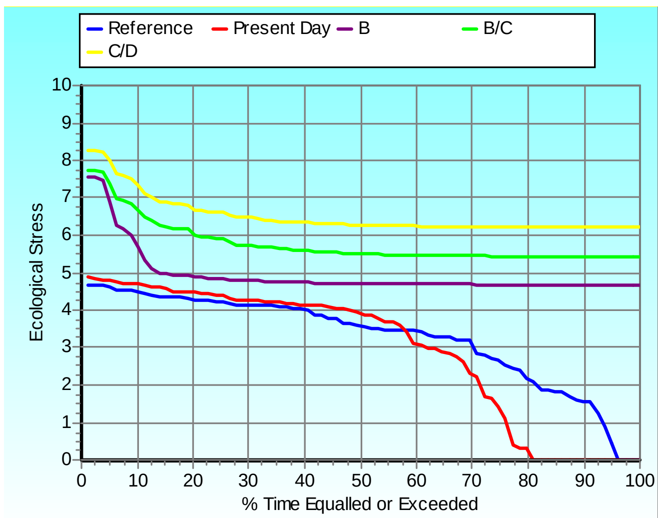


Figure 4-3. Final Stress Duration Curve for reference conditions, present day and categories B, B/C and C/D for the dry season (September) at EWR Site K1.

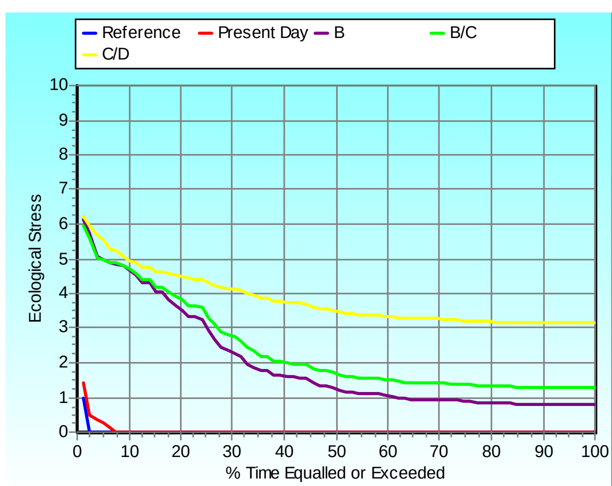


Figure 4-4. Final Stress Duration Curve for reference conditions, present day and categories B, B/C and C/D for wet season (February) at EWR Site K1.

4.6.4 High Flow Requirements

The functions for each Flood Class are described in spreadsheets. A summary of the flood class ranges and recommended number of high flow events required for each EC is provided in Table 4-7 below. Additional flood class motivations are detailed in Appendix J.

4.7 FINAL RESULTS

The final EWR results for the recommended and alternative categories are summarised below (Table 4-10 – Table 4.16) and detailed results are presented in Appendix K.

Table 4-10. Flood class parameters and recommended number of high flow events required for each EC – EWR Site K1.

Note: *Timing: 1 = January; 12 = December
P = present, A = absent

EC = B/C	Flood parameters			NUMBER OF EVENTS					FINAL		Discussion of changes	
FLOOD CLASSES	Range	Range Average	Duration (days)	Geom No.	Veg No.	Invert No.	Fish No.	MIN	No.	*Timing	Primary	Secondary
Class 1	2.25-5.00	3.6	2.0	3.0	3.0	3.0	3.0	3.0	3.0	5-8	Fish: Migrations, breeding and recruitment. It is essential that marginal vegetation in one of these events are inundated for 4—5 days which will allow the fish larvae in at least one event to become free swimming and reduce losses due to drying of eggs. Early Class II floods willalso address this need.	Inverts: To maintain clear surfaces in SIC and prevent embeddedness that leads to reduced species diversity.· To maintain productivity by providing relevant cue for emergence or for breeding.· To maintain species diversity by ensuring temporal diversity of flows
Class 2	5.00-11.10	7.3	3.0	1.5	2.0			2.0	2.0	11-5	Geom. Sorting of fine bedload	Veg. Maintain vegetation of lower riparian zone. Inundate key species such as *Salix mucronata, Rhus gerarrdii, Miscanthus junceus.* Seed dispersal and germination of key species such as *Salix mucronata* .
Class 3	11.10-22.00	15.5	4.0	0.5	1.0			1.0	1.0	11-5	Veg. Maintain vegetation of lower riparian zone. Inundate key species such as *Salix mucronata, Rhus gerarrdii, Miscanthus junceus.* Seed dispersal and germination of key species such as *Rhus gerarrdi, Salix mucronata* .	Geom: Starts to move cobble10% of sand transport, 2% gravel transport. Sand and gravel transport, bed sorting.
Class 4	22.00-44.41	29.9	5.0	0.5	0.6			0.6	1:2	11-5	Veg. Facilitate seed dispersal of key species. Transported sediments provide substrate for germination of key species. Prevent reed encroachment in marginal zone. Maintain habitat diversity. Control terrestrialisation. Remove debris.	Geom: Important flow range for transport of medium size sediment; should also get into secondary channels
1:2	49.3		7.0	1:2					1:2	Any	Geom: Effective discharge for sediment transport and preventing vegetation encroachment.	General habitat maintenance.
1:5	81.9		7.0	1:5					-	-	Geom: Overtops banks, Upper limit of effective stream power; some cobble movement. Active entrainment of cobble, bed sorting, inhibit vegetation encroachment.	General habitat maintenance.
1:10	139.2		8.0	1:10					-	-	Important that water resource developments are not operated a flood control devices - the large floods are beneficial to riverine ecosystems.	General habitat maintenance.
1:20	151.9		8.0	1:20					-	-		

EC = B	Flood parameters			NUMBER OF EVENTS							Discussion of changes	
									FINAL			
FLOOD CLASSES	Range	Range Average	Duration (days)	Geom No.	Veg No.	Invert No.	Fish No.	MIN	No.	*Timing	Primary	Secondary
Class 1	2.25-5.00	3.6	4.0	3.0	4.0	4.0	3.0	4.0	4.0	5-8	Fish: Duration increased for fish: Migrations, breeding and recruitment. It is essential that marginal vegetation in these events are inundated for 4—5 days which will allow the fish larvae to become free swimming and reduce losses due to drying of eggs.. Presently these floods are only 2 days which will partly explain the low abundance of species breeding in marginal vegetation. Early Class II floods willalso address this need.	Inverts: See folr B/C - just fewer floods.
Class 2	5.00-11.10	7.3	3.0	1.5	3.5			3.5	3.5	11-5	Veg.	To maintain some of the historical sediment transport patterns
Class 3	11.10-22.00	15.5	4.0	0.5	1.5			1.5	2.0	11-5	Geom: Sand and gravel transport, bed sorting.	Veg. Maintain vegetation of lower riparian zone. Inundate key species such as *Salix mucronata, Rhus gerarrdii, Miscanthus junceus*. Seed dispersal and germination of key species such as *Rhus gerarrdi, Salix mucronata* .
Class 4	22.00-44.41	29.9	5.0	1.5	1.0			1.5	1.0	11-5	Geom: To maintain some of the historical sediment transport potential.	Veg. Facilitate seed dispersal of key speciesTransported sediments provide substrate for germination of key species. Prevent reed encroachment in marginal zone.Maintain habitat diversity. Control terrestrialisation. Remove debris.
1:2	49.3	-	7.0	1.0				1.0	1:1	11-5	Geom: Effective discharge for sediment transport and preventing vegetation encroachment	General habitat maintenance.
1:10	81.9	-	7.0	1:10					1:10	Any	Geom: Open up secondary channels.	General habitat maintenance.
1:20	139.2	-	8.0	1:20					n/a	n/a	Important that water resource developments are not operated a flood control devices - the large floods are beneficial to riverine ecosystems.	General habitat maintenance.
1:50	151.9	-	8.0	1:50					n/a	n/a		

EC = C/D	Flood parameters			NUMBER OF EVENTS					FINAL		Discussion of changes	
FLOOD CLASSES	Range	Range Average	Duration (days)	**Geom No.**	**Veg No.**	**Invert No.**	**Fish No.**	**MIN**	**No.**	***Timing**	**Primary**	**Secondary**
Class 1	2.25-5.00	3.6	2.0	2.0	2.0	2.0	3.0	3.0	3.0	5-8	Fish: Migrations, breeding and recruitment. It is essential that marginal vegetation in one of these events are inundated for 4—5 days which will allow the fish larvae in at least one event to become free swimming and reduce losses due to drying of eggs. Early Class II floods willalso address this need.	Inverts: Flush out senescent algae and fines and provide cue for breeding or emergence. To maintain productivity by providing relevant cue for emergence or for breeding.· To maintain species diversity by ensuring temporal diversity of flows.
Class 2	5.00-11.10	7.3	3.0	1.0	1.0			1.0	1.0	11-5	Geom: Sand and gravel transport -5 % total sand transport, low % gravel transportinundates gravel bar. Sorting of fine bedload.	Veg. Maintain vegetation of lower riparian zone. Inundate key species such as *Salix mucronata, Rhus gerarrdii, Miscanthus junceus.* Seed dispersal and germination of key species such as *Salix mucronata* .
Class 3	11.10-22.00	15.5	4.0	0.5	0.5			0.5	1:2	11-5	Geom: Starts to move cobble10% of sand transport, 2% gravel transport. Sand and gravel transport, bed sorting.	Veg. Maintain vegetation of lower riparian zone. Inundate key species such as *Salix mucronata, Rhus gerarrdii, Miscanthus junceus.* Seed dispersal and germination of key species such as *Rhus gerarrdi, Salix mucronata* .
Class 4	22.00-44.41	29.9	5.0	0.5	0.2			0.5	1:2	11-5	Geom: Important flow range for transport of medium size sediment; should also get into secondary channels	Veg. Facilitate seed dispersal of key species. Transported sediments provide substrate for germination of key species. Prevent reed encroachment in marginal zone.Maintain habitat diversity. Control terrestrialisation. Remove debris.
1:2	49.3	-	7.0	1:3				0.0	1:3	11-5	Geom: Effective discharge for sediment transport and preventing vegetation encroachment	General habitat maintenance.
1:10	81.9	-	7.0	1:5					-	-	Geom. Moves small cobble; 17% of sand transport; 8% gravel transport;upper level close to lower limit if bankfull. Important flow range for transport of medium size sediment; should also get into secondary channels.	General habitat maintenance.
1:20	139.2	-	8.0	1:10					-	-	Important that water resource developments are not operated a flood control devices - the large floods are beneficial to riverine ecosystems.	General habitat maintenance.
1:50	151.9	-	8.0	1:20					-	-		

Table 4-11. EWR Summary Table for EWR Site K1 for REC: B/C.

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	VOL ($X10^6$ m^3)	nMAR%
EWR SITE K1: EMC = B/C														
LOW FLOWS														
MAINTENANCE LOW FLOWS (m^3/s)[1]	0.4	0.7	1.0	1.3	1.7	1.4	1.2	1.0	0.7	0.5	0.4	0.3	**27.149**	**14.99**
DROUGHT LOW FLOWS (m^3/s)	0.2	0.2	0.3	0.3	0.4	0.3	0.3	0.2	0.2	0.2	0.2	0.2	**7.39**	**4.08**
HIGH FLOWS														
FLOOD (daily average: m^3/s)	-	-	7.3	15	1)29.9 2)50.0	-	7.3	3.6	-	3.6	-	3.6	**16.254**	**8.97**
Duration (in days)	-	-	3	4	1) 5 2) 5	-	3	1	-	1	-	1		
Return period (years)	-	-	1:1	1:1	1) 1:2 2) 1:2[2]	-	1:1	1:1	-	1:1	-	1:1		
LONG-TERM MEAN													**43.793**	**24.17**

[1] Figures rounded-off to the nearest one decimal place.
[2] Alternating years

Table 4-12. EWR Summary Table for EWR Site K1 for Alternative EC: B.

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	VOL ($X10^6$ m^3)	nMAR%
EWR SITE K1: EMC = B														
LOW FLOWS														
MAINTENANCE LOW FLOWS Q m^3/s [3]	0.55	0.9	1.2	1.5	1.9	1.5	1.3	1.0	0.8	0.6	0.6	0.5	**32.071**	**17.70**
DROUGHT LOW FLOWS (m^3/s)	0.2	0.2	0.3	0.3	0.4	0.3	0.3	0.2	0.2	0.2	0.2	0.2	**7.388**	**4.08**
HIGH FLOWS														
FLOOD (daily average: m^3/s)	-	7.5	7.5	15	1)29.9 2)50.0	15	7.5	3.6	3.6	3.6	3.6	-	**22.452**	**12.39**
Duration (in days)	-	3	3	4	1) 5 2) 5	4	3	1	1	1	1	-		
Return period (years)	-	1:1	1:1	1:1	1) 1:1 2) 1:2	1:1	1:1	1:1	1:1	1:1	1:1	-		
LONG-TERM MEAN													**52.99**	**29.25**

[3] Figures rounded-off to the nearest one decimal place.

Table 4-13. EWR Summary Table for Alternative EC: C/D.

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	VOL ($X10^6$ m^3)	nMAR%
EWR SITE K1: EMC = C/D.														
LOW FLOWS														
MAINTENANCE LOW FLOWS (m^3/s)[4]	0.2	0.4	0.5	0.7	0.9	0.7	0.6	0.5	0.4	0.3	0.2	0.2	**13.72**	**7.57**
DROUGHT LOW FLOWS (m^3/s)	0.2	0.2	0.3	0.3	0.4	0.3	0.3	0.2	0.2	0.2	0.2	0.2	**7.388**	**4.08**
HIGH FLOWS														
FLOOD (daily average: m^3/s)	-	-	7.3	15.5	1)29.9 2)50.0	-	-	3.6	-	3.6	-	3.6	**9.976**	**5.34**
Duration (in days)	-	-	3	4	1) 5 2) 5	-	-	1	-	1	-	1		
Return period (years)	-	-	1:1	1:2	1) 1:2 2) 1:3	-	-	1:1	-	1:1	-	1:1		
LONG-TERM MEAN													***28.768***	***15.88***

[4] Figures rounded-off to the nearest one decimal place.

Table 4-14. EWR rule table for REC: B/C

Desktop Version 2, Printed on 31/01/2005
Summary of EWR rule curves for : EWR K1 Monthly Nat EWR K1
Determination based on defined BBM Table with site specific assurance rules.
Regional Type : E.Escarp   REC = B/C

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

This EWR rule table can be used in combination with the natural duration curves below for implementation.

Reserve flows without High Flows

Month	**10%**	**20%**	**30%**	**40%**	**50%**	**60%**	**70%**	**80%**	**90%**	**99%**
Oct	0.855	0.853	0.847	0.833	0.806	0.756	0.673	0.550	0.401	0.290
Nov	1.221	1.217	1.206	1.184	1.143	1.068	0.945	0.767	0.557	0.399
Dec	1.554	1.548	1.534	1.505	1.450	1.352	1.193	0.965	0.696	0.496
Jan	1.943	1.933	1.913	1.873	1.800	1.673	1.471	1.186	0.855	0.610
Feb	2.420	2.411	2.388	2.342	2.256	2.102	1.851	1.493	1.070	0.755
Mar	2.001	1.995	1.977	1.940	1.871	1.746	1.540	1.244	0.891	0.628
Apr	1.795	1.791	1.776	1.746	1.687	1.580	1.399	1.132	0.811	0.569
May	1.501	1.499	1.488	1.465	1.419	1.333	1.185	0.962	0.688	0.481
Jun	1.274	1.273	1.265	1.246	1.209	1.137	1.014	0.825	0.592	0.415
Jul	0.976	0.976	0.970	0.957	0.931	0.879	0.787	0.644	0.464	0.326
Aug	0.840	0.840	0.834	0.822	0.798	0.752	0.672	0.550	0.399	0.285
Sep	0.808	0.807	0.801	0.789	0.765	0.720	0.643	0.527	0.385	0.277

Natural Duration curves

Oct	3.663	2.823	2.180	1.822	1.534	1.378	1.131	1.004	0.855	0.631
Nov	15.174	9.282	5.069	3.839	3.295	2.982	2.608	2.346	1.574	0.849
Dec	21.599	16.708	13.575	7.284	5.653	4.865	4.510	3.543	2.561	1.501
Jan	29.279	19.052	16.588	9.285	7.523	6.276	5.234	4.719	3.584	2.434
Feb	36.611	21.036	14.261	9.268	6.184	5.671	5.204	4.588	4.088	2.732
Mar	19.355	10.588	7.150	5.570	4.895	4.208	3.883	3.551	3.002	2.386
Apr	8.322	5.868	4.950	4.394	4.062	3.808	3.472	2.870	2.404	1.779
May	5.074	4.170	3.476	3.230	2.983	2.647	2.292	2.109	1.680	1.023
Jun	3.461	3.063	2.623	2.269	2.033	1.836	1.725	1.451	1.258	0.903
Jul	2.614	1.983	1.800	1.613	1.508	1.378	1.146	1.019	0.922	0.709
Aug	2.009	1.613	1.437	1.277	1.142	1.075	0.986	0.896	0.810	0.676
Sep	1.879	1.636	1.377	1.196	1.146	1.038	0.930	0.860	0.752	0.637

Total Reserve Flows

	% Points									
Month	**10%**	**20%**	**30%**	**40%**	**50%**	**60%**	**70%**	**80%**	**90%**	**99%**
Oct	0.855	0.853	0.847	0.833	0.806	0.756	0.673	0.550	0.401	0.290
Nov	1.221	1.217	1.206	1.184	1.143	1.068	0.945	0.767	0.557	0.399
Dec	1.554	1.548	1.534	1.505	1.450	1.352	1.193	0.965	0.696	0.496
Jan	1.943	1.933	1.913	1.873	1.800	1.673	1.471	1.186	0.855	0.610
Feb	2.420	2.411	2.388	2.342	2.256	2.102	1.851	1.493	1.070	0.755
Mar	2.001	1.995	1.977	1.940	1.871	1.746	1.540	1.244	0.891	0.628
Apr	1.795	1.791	1.776	1.746	1.687	1.580	1.399	1.132	0.811	0.569
May	1.501	1.499	1.488	1.465	1.419	1.333	1.185	0.962	0.688	0.481
Jun	1.274	1.273	1.265	1.246	1.209	1.137	1.014	0.825	0.592	0.415
Jul	0.976	0.976	0.970	0.957	0.931	0.879	0.787	0.644	0.464	0.326
Aug	0.840	0.840	0.834	0.822	0.798	0.752	0.672	0.550	0.399	0.285
Sep	0.808	0.807	0.801	0.789	0.765	0.720	0.643	0.527	0.385	0.277

Table 4-15. EWR rule table for EC: B

Desktop Version 2, Printed on 31/01/2005
Summary of EWR rule curves for : EWR K1 Monthly Nat EWR K1
Determination based on defined BBM Table with site specific assurance rules.
Regional Type : E.Escarp EC = B

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

This EWR rule table can be used in combination with the natural duration curves below for implementation.

Reserve flows without High Flows

Month	**10%**	**20%**	**30%**	**40%**	**50%**	**60%**	**70%**	**80%**	**90%**	**99%**
Oct	1.002	1.000	0.992	0.974	0.940	0.878	0.773	0.619	0.433	0.293
Nov	1.452	1.447	1.434	1.406	1.353	1.257	1.101	0.874	0.606	0.405
Dec	1.867	1.859	1.840	1.803	1.732	1.606	1.401	1.107	0.761	0.504
Jan	2.347	2.334	2.308	2.257	2.162	1.998	1.736	1.366	0.937	0.620
Feb	2.930	2.918	2.888	2.828	2.716	2.516	2.191	1.725	1.176	0.768
Mar	2.417	2.409	2.386	2.338	2.248	2.086	1.820	1.436	0.979	0.638
Apr	2.162	2.157	2.138	2.099	2.023	1.884	1.650	1.306	0.891	0.578
May	1.800	1.798	1.784	1.754	1.695	1.584	1.393	1.107	0.755	0.489
Jun	1.518	1.517	1.506	1.482	1.434	1.343	1.185	0.945	0.647	0.421
Jul	1.150	1.150	1.143	1.127	1.094	1.028	0.912	0.732	0.505	0.330
Aug	0.982	0.981	0.974	0.959	0.929	0.871	0.771	0.619	0.432	0.288
Sep	0.941	0.940	0.933	0.918	0.888	0.832	0.736	0.592	0.415	0.280

Total Reserve Flows

	% Points									
Month	**10%**	**20%**	**30%**	**40%**	**50%**	**60%**	**70%**	**80%**	**90%**	**99%**
Oct	1.002	1.000	0.992	0.974	0.940	0.878	0.773	0.619	0.433	0.293
Nov	1.452	1.447	1.434	1.406	1.353	1.257	1.101	0.874	0.606	0.405
Dec	1.867	1.859	1.840	1.803	1.732	1.606	1.401	1.107	0.761	0.504
Jan	2.347	2.334	2.308	2.257	2.162	1.998	1.736	1.366	0.937	0.620
Feb	2.930	2.918	2.888	2.828	2.716	2.516	2.191	1.725	1.176	0.768
Mar	2.417	2.409	2.386	2.338	2.248	2.086	1.820	1.436	0.979	0.638
Apr	2.162	2.157	2.138	2.099	2.023	1.884	1.650	1.306	0.891	0.578
May	1.800	1.798	1.784	1.754	1.695	1.584	1.393	1.107	0.755	0.489
Jun	1.518	1.517	1.506	1.482	1.434	1.343	1.185	0.945	0.647	0.421
Jul	1.150	1.150	1.143	1.127	1.094	1.028	0.912	0.732	0.505	0.330
Aug	0.982	0.981	0.974	0.959	0.929	0.871	0.771	0.619	0.432	0.288
Sep	0.941	0.940	0.933	0.918	0.888	0.832	0.736	0.592	0.415	0.280

Table 4-16. EWR rule table for EC: C/D

Desktop Version 2, Printed on 31/01/2005
Summary of EWR rule curves for : EWR K1 Monthly Nat EWR K1
Determination based on defined BBM Table with site specific assurance rules.
Regional Type : E.Escarp EC = C/D

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

This EWR rule table can be used in combination with the natural duration curves below for implementation.

Reserve flows without High Flows

Month	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	0.654	0.653	0.649	0.640	0.622	0.589	0.535	0.454	0.358	0.285
Nov	0.909	0.907	0.900	0.886	0.860	0.813	0.735	0.623	0.490	0.391
Dec	1.139	1.136	1.127	1.109	1.074	1.014	0.916	0.775	0.609	0.486
Jan	1.409	1.403	1.391	1.367	1.322	1.245	1.122	0.948	0.746	0.597
Feb	1.747	1.742	1.728	1.700	1.648	1.554	1.403	1.185	0.929	0.739
Mar	1.450	1.446	1.435	1.413	1.370	1.294	1.170	0.989	0.774	0.614
Apr	1.309	1.306	1.297	1.279	1.243	1.177	1.066	0.902	0.705	0.557
May	1.101	1.100	1.094	1.079	1.051	0.998	0.906	0.768	0.599	0.471
Jun	0.947	0.946	0.941	0.929	0.906	0.861	0.783	0.664	0.518	0.406
Jul	0.737	0.737	0.733	0.725	0.708	0.674	0.615	0.524	0.408	0.319
Aug	0.643	0.642	0.639	0.631	0.615	0.585	0.533	0.453	0.355	0.280
Sep	0.621	0.621	0.617	0.609	0.594	0.564	0.513	0.437	0.343	0.272

Total Reserve Flows

	% Points									
Month	**10%**	**20%**	**30%**	**40%**	**50%**	**60%**	**70%**	**80%**	**90%**	**99%**
Oct	0.654	0.653	0.649	0.640	0.622	0.589	0.535	0.454	0.358	0.285
Nov	0.909	0.907	0.900	0.886	0.860	0.813	0.735	0.623	0.490	0.391
Dec	1.139	1.136	1.127	1.109	1.074	1.014	0.916	0.775	0.609	0.486
Jan	1.409	1.403	1.391	1.367	1.322	1.245	1.122	0.948	0.746	0.597
Feb	1.747	1.742	1.728	1.700	1.648	1.554	1.403	1.185	0.929	0.739
Mar	1.450	1.446	1.435	1.413	1.370	1.294	1.170	0.989	0.774	0.614
Apr	1.309	1.306	1.297	1.279	1.243	1.177	1.066	0.902	0.705	0.557
May	1.101	1.100	1.094	1.079	1.051	0.998	0.906	0.768	0.599	0.471
Jun	0.947	0.946	0.941	0.929	0.906	0.861	0.783	0.664	0.518	0.406
Jul	0.737	0.737	0.733	0.725	0.708	0.674	0.615	0.524	0.408	0.319
Aug	0.643	0.642	0.639	0.631	0.615	0.585	0.533	0.453	0.355	0.280
Sep	0.621	0.621	0.617	0.609	0.594	0.564	0.513	0.437	0.343	0.272

4.8 CONFIDENCE

The confidence was evaluated according to a score of 0-5 with zero reflecting 'no confidence' and 5 reflecting 'very high' confidence (Table 4-16).

Given the level of information, the specialists were moderately to highly confident of their results. The moderate confidence outcome reflects the general lack of monitoring and calibration data for the Ecological Reserve.

Table 4-17. Confidence Ratings for EWR Site K1.

	EWR SITE	**AVAILABLE DATA**	**ECOLOGICAL CLASSIF.**	**OUTPUT LOW FL**	**OUTPUT HIGH FL**
HYDROLOGY		3	3		
	Confidence is fairly high on the accuracy of the simulation of observed (historic) flows. The simulation is based on calibrations done a number of years ago and is a reasonable representation of the time series in terms of the range of flows. The low flows are slightly higher based on nature of calibration.				
HYDRAULICS	3	4/0=2		5	2
	Measured flows in the range 0.25 to 2.66m^3/s. Recommended low-flows for the PES (B/C) in the range 0.25 to 1.5m^3/s (ie. within measured range), and high flows in the range 3.6-30 (within year) to 49-152 (1:2-1:20) (ie. all high flows above measured values).				
QUALITY		3	2		
	Water quality data used from DWAF monitoring programme at monitoring point X1H033Q01 (1983 – 1999). Confidence in the data is medium (3) as the sample number was small. No temperature, dissolved oxygen and turbidity data available. EC confidence in data was low due to limited data being available and no temperature, dissolved oxygen, chlorophyll and turbidity data availabl				
GEOMORPH	3.5	3	3	4	3.5
	Long-term photos at small scale, post dam hydrology data only. Moderate confidence in prediction of how dam would affect geomorphological processes; some indication of plan form change from aerial photographs, no knowledge of previous bed conditions. Reasonable morphological clues that are in accordance with sediment transport predictions. Problem to balance potential armouring impacts against prevention of vegetation encroachment. **GENERAL COMMENT ON CONFIDENCE IN FLOOD REQUIREMENTS** The key indicators for flood requirements are channel morphology and bed mobility under different discharges. It is assumed that the shape of the channel cross-section represents an adjustment to flows of a given magnitude and frequency. There appears to be a strong association between Class I floods and a low level in-channel bench; the upper range of Class IV floods is associated with the top of the active channel bank and Class V floods overtop the channel on to the flood zone. Class VI floods are often associated with a higher terrace. These assumptions are based on field observation and established empirical relationships.				
RIP VEG	3	3	4	2	3

	EWR site: Generally a good site but wetland seepage from left bank and rock outcrop on right bank are disadvantages. **Available data:** Vegetation profile studied twice (once in winter and once in Autumn). Previous status of vegetation unknown. **Ecological classification:** Confirmed by RVI analysis. **Output low flow:** Recommendations not tested. **Output high flow:** Recommendations match current situation.				
FISH	4	4	4	4	4
	Confidence in available data is moderately high because historic data goes back to 1960's and also 1970/80's. Several surveys have been conducted in this Resource Unit over last three years, specifically looking at the status of the species used to set the stress response. Moderately high confidence in EC based on the available data and several recent surveys conducted during last 3 years in this Resource Unit. The site is representative of the Resource Unit and also represents close to the best conditions in this Resource Unit. Confidence in low flows was based on the available hydraulic and fish information; hence it was possible to set realistic flows in terms of its stress and availability of critical habitat for indicator species. Confidence in high flows was based on our understanding of the species in this Resource Unit, fish mainly needs Class 1 floods in terms of breeding and migrations. Also confident that floods asked for by others will more than cater for the needs of the fish.				
INVERT	4	4	4	4	4
	Moderate diversity of biotopes present, but with highly suitable SIC and SOC. Absent biotopes include bedrock and aquatic vegetation and poor MVIC, MVOC, gravel and sand. Rocks with senescent algae limit habitat suitability. Data were available for 26 SASS samples recorded at 12 sampling sites within this Resource Unit, of which two samples were colleted during this study, so confidence in the available was high. Information available was suitable for evaluation as required. For September the levels set exceeded what was considered necessary for invertebrates for most of the time, while in February the levels set were slightly lower, but the difference was considered insignificant.				

5. EWR SITE K2 – KROMDRAAI

5.1 ECOLOGICAL CATEGORIES

The PES for EWR Site K2 is summarised Table 5-1, and a description of the reference conditions, and PES for individual components is presented in Table 5-2.

Table 5-1. The PES for EWR Site K2.

Driver Components	Component PES	Driver PES	ECOSTATUS PES
HYDROLOGY	C/D	C	C
GEOMORPH	C/D		
WATER QUALITY	B/C		
Response Components	**Component PES**	**Instream PES**	
FISH	B/C	B/C	
AQUATIC INVERTS	C		
RIPARIAN VEG	C	c	

Table 5-2. Description of the PES categories for each habitat driver and biological response for EWR Site K2.

Category B = Largely Natural; Category B/C = Largely Natural to Moderately Modified; C= Moderately Modified; C/D= Moderately to Largely Modified.

Driver and responses	Reference conditions	PES	PES description
			Overall PES for Drivers Moderately Modified (Category C).
Hydrology	nMAR= 527 million m^3/a	C/D	pMAR= 305 million m^3/a EWR Site K2 lies 70 km downstream of Vygeboom Dam - and has similar capacity to Nooitgedacht Dam, but much smaller percentage of the MAR (78 vs 266 Mm^3). The dam controls 57% of catchment area, which produces 47% of the nMAR at EWR Site K2. No cessation of flow but small changes in seasonality, and moderate impacts on floods. The main changes from natural conditions are: • pMAR is 58% of nMAR; 57% reduction at 70% exceedance • Present day flows are slightly higher in Aug & Sep • Moderate events are 45% reduced at 50% exceedance • High flow events are 28% reduced at 10% exceedance
Geomorphology	K2 is classified as an upper foothill site on account of its channel gradient of 0.0067. The expected reach type would be either plane bed, pool-riffle or pool rapid with a bed	C/D.	Aggregate effects of Vygeboom and Nooitgedacht Dam upstream. These have caused following changes in sediment inputs, riparian vegetation and channel structure. **Sediment inputs:** Evidence of coarsening of bed material.

	material dominated by cobble or bedrock and cobble. There is a flood plain present on the left hand side of the river. Secondary flood channels would probably have crossed this flood plain, serving to bring water, sediment and nutrients to the riparian zone.		Tributaries downstream of Vygeboom Dam bring in significant amounts of sediment. Locally, increased channel sedimentation will occur in response to reduced stream power. **Riparian Vegetation:** Good bank stability from woody vegetation on the flood zone, macro-channel banks and widespread reed growth. Aerial photographs - evidence of localised channel narrowing due to reed growth, but not at site itself. See below **Channel structures:** Bridge upstream of K2, but small localised effect on channel morphology.
Water Quality	The water quality of K2 would have been improved in a reference condition due to the impacts of Vygeboom Dam being negated. The water quality improvements, compared to PES, include no temperature changes in the impoundment and an improved water quality upstream in the Komati, Seeikoespruit and Teespruit Rivers. The water quality will would have been in a higher B category.	**B/C**	Groundwater contaminated with nitrates due to poor sanitation in area and bacterial problems. However, the main issue is bacteria. and surprisingly few hemipterans despite their hardiness. This is thought to be due to the domestic washing powders possibly brought in from Tjakastad.
			Overall Instream PES Moderately to Largely Modified (Category B/C).
Riparian Vegetation	No exotic species present.	**C**	Main changes triggered by flow-related causes (attenuation of intra-annual floods, reduced low flows) and non-flow related causes (erosion and sedimentation from overgrazing & agriculture, terrestrialisation, alien plant invasion, reed encroachment, groundwater pollution).
Marginal zone: Grassland / Reedbed on stream banks	• annual flood benches dominated by grass species and sedges. • Presence of waterside fern *Amelopteris prolifera*. • Narrow lateral channels dominated by clumps of reed, shrubs and sedges.		• moderate increase in biomass & cover of reeds, grasses, forbs and sedges. • moderate reduction in number of indigenous species (grasses and sedges) • moderate change in structure due to extensive spread of *Phragmites mauritianus* reeds. • moderate change in overall species composition. • presence of naturalized exotic species *Verbena bonariensis* and *Ageratum houstianum*.
Lower riparian zone: Open Woodland on firm alluvial plains	• grasses provide the dominant ground cover on the firm alluvial flood plain. • Mesophytic trees and shrubs occur as scattered individuals. • Terrestrial species not present.		• moderate increase in biomass from *Phragmites mauritianus* reed encroachment. • moderate increase in vegetation cover (grasses and shrubs). • small reduction of indigenous species from terrestrialisation and encroachment. • small change in species composition from terrestrial invader species. • small change in structure due to encroachment by *Phragmites mauritianus* and high density of *Sesbania sesban*ia
Upper riparian zone: Closed Woodland on firm colluvial slopes	• clayey, silty fine/medium sands of hillslopes support relic riparian species and mostly non-riparian species. • woodland structure maintained by regular seedling recruitment of such species. good ground cover of grasses		• small increase in biomass due to encroachment by alien invaders. • change in overall species composition from terrestrialisation and encroachment of certain ephemeral and alien species. • small change in structure
Fish	Fifteen (15) species expected to occur under natural conditions.	**B/C**	Fifteen species expected, 14 recently collected. **Flow depth:** Lower abundance of fish fauna dependant on fast deep habitats (*Chiloglanis emarginatus* and *Barbus argenteus*) and of species preferring slow flowing habitats with undercut banks and marginal vegetated areas **Flow Modification:** Migration of fish effected by weirs and dams; *Anguilla mossambica* absent; flow dependant and moderately flow dependants lower in abundance. **Substrate:** Significantly lower abundance of fish

			dependant on substrate in fast deep habitats. Noted: three weirs redundant and can be removed.
Aquatic Invertebrates	Under natural conditions there would be a higher abundance of taxa such as Hydropsychidae, Caenidae and Tricorythidae and those that require good water quality.	C	Confidence in results was high. The main changes triggered by flow and non-flow related causes (see above). • characterised by presence of freshwater sponges (Porifera). • High numbers of *Neoperla spio*, Heptageniidae, Leptoceridae, Elmidae, Corixidae, Leptophlebiidae, Philopotamidae, Hirudinea, Polymitarcidae, Spaeriidae and Corbiculidae. • 6 species of blackfly indicating river in good condition. • disappearance of taxa that require good water quality, and slow-flowing water • scarce = Hydropsychidae, Caenidae and Tricorythidae. • few hemipterans despite hardiness • functional feeding groups represented were predators, gathering collectors, filtering collectors, and scrapers.

Additional tables providing scores for the individual driver components and biological responses (instream) and a summary of the EcoStatus are available in Appendix F.

5.2 TRENDS

The trends for aquatic invertebrates, vegetation and geomorphology are considered stable under current development and Vygeboom Dam management conditions. The impacts on geomorphology from the Vygeboom Dam have been in place for over 30 years.

5.3 IMPORTANCE

5.3.1 Ecological Importance and Sensitivity

The Ecological Importance and Sensitivity of Resource Unit C within the Somgimvelo provincial reserve was considered to be *High* both under natural and present conditions. The confidence for this assessment was high. The main determinants were the diversity of habitats (although it was noted that there are few backwaters and cascades), the presence of the endangered *Chiloglanis bifurcus*, hippopotamus (*Hippopotamus amphibious*), African finfoot (*Podica senegalensis*), Half-collared kingfisher (*Alcedo semitorquata*), the rare Striped Flufftail (*Sarothrura affinis*), vulnerable South African Python (*Python natalensis*), the presence of endemic fish species*;. C. emarginatus* and *Barbus argenteus* and the Yellow-striped reed frog (*Hyperolius semidiscus*). The high importance of the area for conservation (Songimvelo Reserve, Nkomazi Wilderness Area and Transboundary Park) was also considered important at a national level. Detailed results are presented in Appendix G.

5.3.2 Socio-cultural Importance

The area was considered of *High* Socio-cultural Importance. Landuse in Resource Unit C is dominated by wilderness and poor, densely-populated rural areas. The Nkomazi Wilderness Area is a proclaimed National Heritage area. Population densities and dependence on the river are variable. Activities include harvesting of riparian timber (mainly wattle) for fuelwood and subsistence market gardening.

Historically, the Resource Unit shows remnants of early and middle stone-age occupation, early and late iron-age settlement and occupation of the Nguni people. It contains among the oldest rock formations in the world (3700 million years old), some of the oldest sea floor fossils and evidence of the oldest and largest meteorite impact on earth. Efforts are underway to make this a World Heritage Site. Detailed results are presented in Appendix H.

5.4 RANGE OF ECOLOGICAL CATEGORIES

5.4.1 Recommended Ecological Category

The EIS (present) and socio-cultural importance are *High*, indicating that a higher category should be recommended. There is potential for improvement of the local catchment conditions through changing land-use as a large portion of this Resource Unit has been bought for the Inkomazi Wilderness Area and it is likely that deleterious farming practices will be reduced. Erosion can be minimised through rehabilitation. As improvement can be achieved by non-flow measures, it was concluded that the PES Category C was recommended on account of the strategic importance of water in this catchment.

The operation of Vygeboom Dam can definitely be addressed so as to reinstate variability into the system. Currently there is a constant release between 400 – 600 l/s. Limited freshes are introduced from the adjoining Seekoeispruit and small tributaries deliver large amounts of sediment locally into the main channel. Coupled with reduced flow, this increases the likelihood of localised channel narrowing and fining of bed sediments.

5.4.2 Alternative Ecological Categories

Two alternative Ecological Categories were considered (Category B and D). Initial running of the model achieved a Category B/C (82%). However, vegetation achieved a high Category B (88%) so it was decided that the Alternative up falls in a Category B instead. The conditions for achieving alternative categories are given in Table 5-3 and summarised in Table 5-4.

Table 5-3. Summary of the conditions defining the alternative Ecological Categories.

Driver and responses	Alternative B	Alternative D
General	Category B conditions would comprise: (a) an increase in low flows, (b) improved sanitation, (c) rehabilitation of dongas, (d) a changed operation of dam to reinstate variability, release from dam to include some freshes, limited freshes introduced from adjoining tributaries), (e) reinstatement of moderate floods to prevent reed encroachment and channel narrowing, and (f) removal of redundant weir to improve fish migration. However, improvement for geomorphology is difficult because, despite increased flows, sediment would still be trapped behind the dam wall.	Category D conditions would comprise less low flows, a decrease in freshes and moderate flows, a change in water quality (increased nutrients, less dissolved oxygen, algal growth, water temperature increase in slow shallow habitats), increase in reeds, narrowing of channel, increased embedded cobbles, reduction of vegetation diversity, increase in alien vegetation and sedimentation of pools.
Geomorphology	Increased frequency of intermediate floods will improve transport of a wider range of sediment classes, resulting in improved bed sorting and	Further reduction of intermediate floods with no catchment rehabilitation (dongas) will lead to increased deposition of sand and fine gravels. Predicted morphological changes

Driver and responses	Alternative B	Alternative D
	maintenance of channel plan form and geometry. Higher floods should inhibit encroachment of vegetation onto lateral bars. The impact of the upstream weir and bridge will remain the same	include the extension of lateral bars and their stabilization by vegetation, decreased depth of pools and some loss of open cobble habitat. Bed sorting will decrease. The impact of the weir and bridge remains the same.
Riparian Vegetation	Improvement within the marginal zone (Grassland \ Reedbed on stream banks): small increase in biomass and cover of reeds affecting vegetation structure, a small reduction in number of indigenous species of grasses and sedges and a small change in overall species composition, such as the naturalized exotic species *Verbena bonariensis* . An improvement within the lower riparian zone (Open Woodland on firm alluvial plains): small increase in biomass as a result of reed encroachment, small increase in cover of grasses, a small reduction of indigenous species from terrestrialisation and encroachment. An improvement within the upper riparian zone: no significant change in abundance, cover, structure and species richness, a small change in overall species composition as terrestrialisation and alien invasives set in.	Marginal zone: large increase in reeds and grass cover, a large reduction in indigenous species of grasses, sedges, the mesophytic tree *Combretum erythrophyllum*, the hydrophytic herb *Commelina banghalensis,* and the fern *Amelopteris prolifera* and a large change in overall species composition and vegetation structure. The cover-abundance of *Periscaria attenuata* and *Verbena bonariensis* may also increase. Lower riparian zone: large decrease in reeds due to terrestrialisation, a large decrease in grass and shrub cover, a moderate reduction of indigenous species as terrestrialisation and encroachment occurs, a moderate change in overall species composition and structure. Upper riparian zone: moderate reduction in grass cover, species richness and biomass due to encroachment by alien invaders, a moderate change in overall species composition as terrestrialisation and invasives sets in and a small change in vegetation structure.
Fish	Increased base flows establishing more habitats, particularly for species dependant on fast deep and fast shallow conditions. Reduction in slow-shallow habitats will reduce the risk of critical water temperatures. Conditions in riffles, mainly for flow dependant and moderately flow dependant species will improve and increase species abundance and provide more permanent habitat for species dependant on the availability of marginal vegetation and undercut banks. The removal of three redundant weirs will re-establish fish movement between Maguga and Vygeboom Dams.	Reduction of flows will decrease the frequency of occurrence of most species, especially the abundance of species dependant on fast deep and fast shallow habitats. A reduction in habitat suitability will affect those dependant, or moderately dependant, on perennial flow, substrate and marginal vegetation / undercut banks and reduce suitability of available fast deep habitats and may also affect the available breeding of yellowfish. Increase in temperatures and nutrients due to reduced flows will decrease the abundance of species intolerant and moderately intolerant of water quality changes. Reduced flows can result in a loss of at least 2 species (*Chiloglanis emarginatus* and *Barbus argenteus*), and it is likely that *Amphilius uranoscopus* may be largely affected.
Aquatic Invertebrates	Taxa expected to re-appear: Hydrachnellidae (Water Mites), *Tricorythus* sp., Prosopistomatidae (Water specs), *Elassoneuria trimeniana, Centroptiloides bifasciata,* Naucoridae (Creeping water bugs), Corixidae (Water boatmen), Gerridae (Water striders), *Hydropsyche* sp., *Hydropsyche longifurca, Macrostemum capensis,* Polymorphanisus, Hydroptilidae, Haliplidae (Crawling Water Beetles), Hydraenidae (Minute Moss Beetles), Hydrophilidae (Water Scavenger Beetles), *Simulium vorax,* Ancylidae and *Gyraulus costulatus.*	Taxa expected to disappear following more reduced low-flows and increased nutrients: Porifera (Sponges), Perlidae, Leptophlebiidae (Prongills), Polymitarcyidae (Pale Burrowers), Tricorythidae (Stout crawlers), Heptageniidae (Flathead mayflies), *Afroptilum sudafricanum, Pseudocloeon bellus, Pseudocloeon latus, Psuedopannata maculosum,* Chlorolestidae, *Amphipsyche scottae,* Elmidae (Riffle Beetles), Psephenidae (Water Pennies), Tipulidae (Crane Flies), *Simulium alcocki, Simulium cervicornutum, Simulium lumbwanum, Simulium rotundum* and Corbiculidae.

Table 5-4. Summary of the Alternative EcoStatus B and D for EWR Site K2.

Driver Components	Component PES	Driver PES	ECOSTATUS PES
HYDROLOGY	B	B	B
GEOMORPH	B/C		
WATER QUALITY	B		
Response Components	Component PES	Instream PES	
FISH	B	B	
AQUATIC INVERTS	B		
RIPARIAN VEG	B	B	

Driver Components	Component PES	Driver PES	ECOSTATUS PES
HYDROLOGY	D	D	D
GEOMORPH	D		
WATER QUALITY	C/D		
Response Components	Component PES	Instream PES	
FISH	C/D	C/D	
AQUATIC INVERTS	D		
RIPARIAN VEG	D	D	

The rule-based models for the individual components were run in a predictive manner and based on the above hypothetical scenarios, the matrixes that would be affected were changed. These spreadsheets with the changes indicated as different colours are included in the specialist appendices.

5.5 STRESS INDICES

Refer to Appendix I for the flow stress indices for the REC and alternative EC's for fish and aquatic invertebrates.

5.5.1 Stress Index: Fish

The rheophilic species selected was *C. emarginatus* which is dependant on the presence of deep, moderately fast-flowing waters. The semi-rheophilic was *Labeobarbus marequensis*. The rhepohilic species was the most stressed under all the flow conditions (Table 5-5).

With a flow of 5.5 m^3/s there is abundant fast deep habitat available and none of the life history requirements of *C. emarginatus* are likely to be stressed. At a flow of 2.2 m^3/s there is a significant loss in the availability of fast deep habitats that will significantly affect breeding and to a lesser extent available habitat and suitable cover. At a flow of 1.5 m^3/s the availability of fast deep habitats is further reduced and breeding will be restricted to only a few areas. The availability of suitable cover will also further reduce the abundance of the species. With the majority of available habitat being slow and shallow at a flow of 0.5m^3/s species numbers will be limited due to a lack of suitable habitat and deteriorating water quality And increased water temperatures. At a flow of 0.1 m^3/sno suitable fast, deep habitats will be present.

Rheophilic species represents the highest stresses at any given flow and this was therefore used to generate the stress index.

Table 5-5. Stress table for rheophilic fish species showing Habitat Suitability at EWR Site K2.

FLOW (CUMEC)	7.50	5.500	2.200	1.920	1.520	0.500	0.100	0.000
RELATIVE ABUNDANCE FLOW-DEPTH & COVER RATING: 0=NONE;1=RARE;2=SPARSE;3=MODERATE;4=ABUNDANT;5=VERY ABUNDANT)								
FAST DEEP	5	4.0	3.0	3.0	2.0	1.0	0.0	0.0
FAST SHALLOW	2.0	2.0	2.0	3.0	3.0	2.0	1.0	0.0
SLOW DEEP	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
SLOW SHALLOW	3.0	3.0	3.0	3.0	3.0	4.0	3.0	2.0
SUITABILITY FOR DIFFERENT FISH REQUIREMENTS PER HABITAT GUILD								
RHEOPHILIC	**SPECIES:**							
	CEMA							
Breeding and early life-stages=	5.0	5.0	4.0	3.0	1.0	0.0	0.0	0.0
Survival /Abundance =	5.0	5.0	4.0	4.0	3.0	2.0	0.0	0.0
Cover =	5.0	5.0	4.0	4.0	3.0	1.0	0.0	0.0
Health and condition=	5.0	5.0	5.0	5.0	4.0	3.0	0.0	0.0
Water quality=	5.0	5.0	5.0	5.0	4.0	2.0	0.0	0.0
Rheophilic stress - (breeding requirements included)	**0**	**0**	**1**	**2**	**4**	**7**	**10**	**10**

FLOW (CUMEC)	7.50	5.50	2.20	1.92	1.52	0.50	0.10	0.00	0.00
FLOW-DEPTH CONVERTED TO HABITAT RESPONSE (10=ALL FLOW-DEPTH CLASSES ABSENT (RIVER DRY); 0=FLOW-DEPTH *CLASSES OPTIMUM FOR SITE* ; 9=NO FLOW)									
Fast deep	0	2	4	4	6	8	10	10	10
Fast shallow	6	6	6	4	4	6	8	10	10
Slow deep	0	0	0	0	0	0	0	0	10
Slow shallow	4	4	4	4	4	2	4	6	10
OVERALL HABITAT RESPONSE	**3**	**3**	**4**	**3**	**4**	**4**	**6**	**7**	**10**

5.5.2 Stress Index: Aquatic Invertebrates

Optimum Flow rates: 0.3 and 0.6 m/s
Key Species: *Neoperla spio*
Critical Habitats: Riffle

The relationships between aquatic invertebrate habitats, flows, stresses and associated biological responses at EWR Site K1 are detailed in Table 5-6.

The critical factors that were used to determine the stress curve were the current speeds and overall species composition. During the field survey on 5th August 2003 the flow was 1.9 m^3/s, and a habitat stress score of 3 was allocated. However, biomonitoring data showed that many flow-sensitive species were still present at these flows, and so the biological response stress was reduced to 2.

Table 5-6. Stress Table – Flow Dependant Invertebrate at EWR Site K2.

Habitat Flow Response Index	HABITAT ABUNDANCE AND SUITABILITY					TOTAL	FLOW	HABITAT RESPONSE	HABITAT CHARACTERISTICS					BIOTIC RESPONSE	FLOW	SPECIES STRESS	INTEGRATED STRESS
	SIC	SOC	VIC	VOC	GSM				Max depth (m)	Avg depth (m)	Max vel (m/s)	Avg vel (m/s)	WP (m)				
0	5	0	5	5	2	17	5.500	All habitat in excess, very high quality: very fast, very deep, very wide wetted perimeter	0.72	0.41	1.4	0.5	28	All very abundant, all healthy, all species persist	5.500	0	0.0
1	4	1	4	5	2	16	3.700	All plentifull, high quality; fast, wide wetted perimeter	0.64	0.35		0.43	26.68	All abundant, all healthy, all species persist	3.000	1	1.0
2	3	3	3	4	2	15	2.200	Critical habitats sufficient; quality slightly reduced: fast, wetted perimeter slightly reduced	0.54	0.28		0.35	23.9	Slight reduction for sensitive rheophilic species, all healthy in some areas, all species persist	1.900	2	2.0
3	3	3	3	3	2	14	1.900	Reduced critical habitat, reduced critical quality; moderate velocity, fairly deep, wetted perimeter slightly/moderately reduced	0.52	0.26	1.0	0.33	23.56	Reduction for all rheophilic species; all healthy in limited areas; all species persist	-	3	4.0
4	3	3	3	2	2	13	1.500	Critical habitats limited; moderate quality: Moderate velocity, Some deep areas, Wide WP moderately reduced	0.48	0.23		0.3	22.49	Further reduction for all rheophilic species; all viable in limited areas, critical life stages of some sensitive rheophilic species at risk, all species persist	1.000	4	5.5
5	3	3	2	2	2	12	1.000	Critical habitat very reduced; moderate/ low quality; moderate/slow velocity, few deep areas wetted perimeter moderately/very reduced	0.42	0.19		0.27	20.79	Limited populations of all rheophilic species. Critical life-stages of sensitive rheophilic species at risk or non-viable; all species persist	-	5	6.2
6	2	2	1	1	2	8	0.500	Critical habitat residual. Low quality; Moderate/slow velocity.	0.34	0.13	0.7	0.23	17.65	Sensitive rheophilic species rare, critical stages of sensitive rheophilic species non-viable, and at risk for some less sensitive species. All species persisit in the short-term	0.500	6	7.0
7	2	2	1	1	2	8	0.200	No critical habitat, other habitats moderate quality; slow, narrow wetted perimeter	0.25	0.1		0.2	10.89	Most rheophilic species rare; All life-stages of sensitive rheophilic species at risk or non-viable. Most sensitive rheophilic species disappear	-	7	8.5
8	1	2	0	1	1	5	0.050	Flowing water habitats residual low quality: slow trickle, very narrow wetted perimeter	0.16	0.06	0.4	0.14	5.62	Remnant populations of some rheophilic species; all life stages of most rheophilic species at risk or non-viable, many rheophilic species disappear	0.050	8	9.8
9	0	1	0	0	1	2	-	Standing water habitats only, very low quality, no flow	0.02	0.01		0.02	0.46	Mostly pool dwellers; all life stages of most rheophilic species non-viable; most or all rheophilic species disappear	-	9	9.9
10	0	0	0	0	0	0	-	Only hyporheic refugia, no surface water	0	0	0	0	0	Only specialists persist, virtually no development.	-	10	10.0

1 SIC: Partially submerged hard substrate in current >0.1 m/s
2 SOC: Partially submerged hard substrate in current <0.1 m/s
3 VIC: Submerged vegetation (at least 2-3cm submerged) in current >0.1 m/s
4 VOC: Submerged vegetation (at least 2-3cm submerged) in current<0.1 m/s
5 GSM: Small particles submerged

5.5.3 Integrated Stress Curve

The individual component stresses are illustrated as well as the integrated stress line (black line) (Figure 5-1).

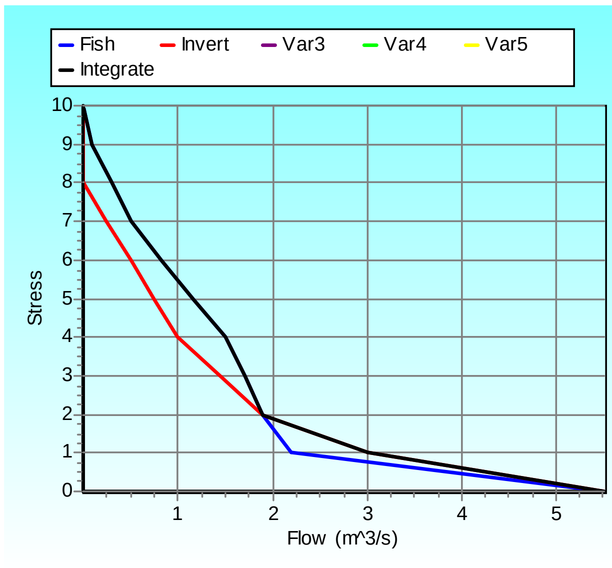
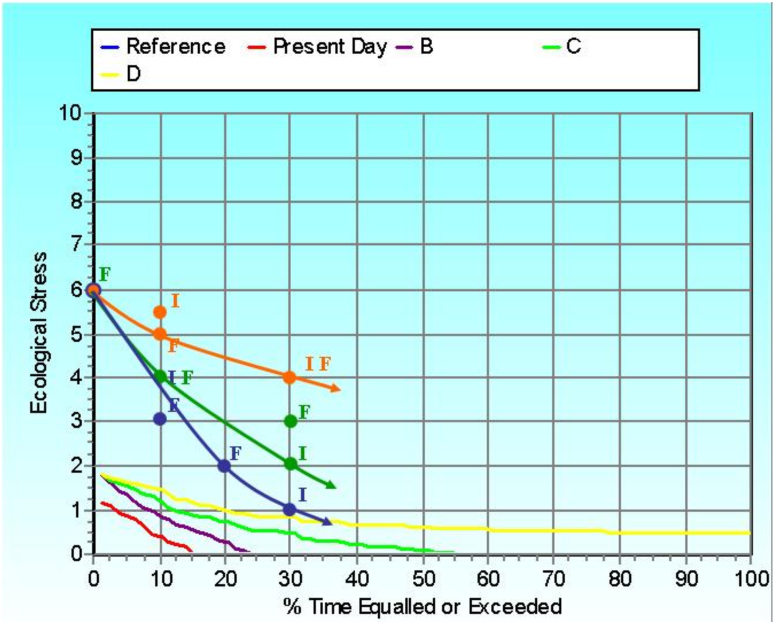


Figure 5-1. Index Stress Curves for EWR Site K2.

5.6 DETERMINATION OF EWR SCENARIOS

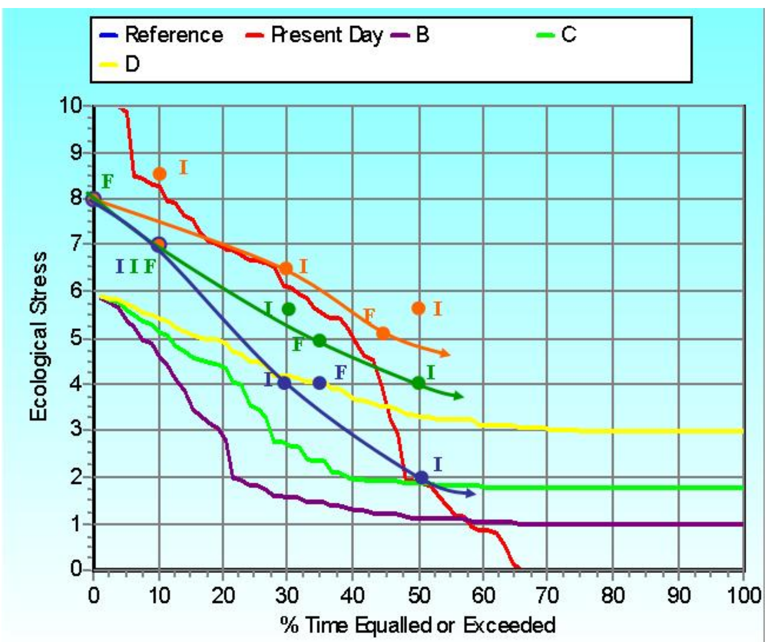
5.6.1 Low-Flow Requirements

The determined integrated stress index must now be used to identify required stress levels at specific durations for the wet and dry month / season. The requirements are illustrated in Figure 5-2.



Wet Season
Orange = D,
Blue = B,
Dark Green = C

F = Fish
I = Invertebrates



Dry Season
Orange = D,
Blue = B,
Dark Green = C

F = Fish
I = Invertebrates

Figure 5-2. EWR Site K2 – Stress duration curves for all scenarios[5].

[5] There was no ecological stress under reference conditions, so the line for reference conditions does not show in the graph above.

5.6.2 Motivations: Fish and Invertebrates.

The stress referred to in the motiations below refers to fish stress, not component stress.

FISH: DURATIONS AND MOTIVATIONS TO BE USED FOR DETERMINING STRESS REQUIREMENTS.
Indicator: *C. emarginatus* The indicator is one of the rheophilic species. The most sensitive being *C. emarginatus* was selected, which is dependant on perennial flow in fast deep habitats.
STRESS REQUIREMENTS
DRY SEASON
DROUGHT: A 10% at stress 7 will allow for low survival of the species in minimal available fast deep conditions. At lower flows fast deep conditions will no longer be present in the river. The stress level should never exceed 8 (0% of the time) otherwise the species could be lost.
MAINTENANCE: **B/C:** Require good habitat for the dry season and stress of 6 can be tolerated for 30% of the time. **MAINTENANCE B:** Require good habitat for the dry season and stress of 5 can be tolerated for 30% of the time. **MAINTENANCE D:** Require moderate good habitat for the dry season and stress of 6 can be tolerated for 50% of the time.
WET SEASON
DROUGHT: 10%.at stress 5 will still allow spawning, but only with few fast deep sites with favourable habitat conditions. Relatively limited FD available but fragmented (patchy). A stress of 6 must never (0% of time) occur as this will only allow for minimal survival and no recruitment or breeding. At this point summer temperatures may also become problematic and oxygen levels in water may become critical.
MAINTENANCE B/C: Require good survival habitat and good to moderately good breeding habitat and recruitment. Therefore a stress of 4 can be tolerated for 30% of the time. **MAINTENANCE B:** Require good survival habitat and good to moderately good breeding habitat and recruitment. Therefore a stress of 4 can be tolerated for 25% of the time. **MAINTENANCE D:** Require moderate survival habitat for the species and moderate available breeding habitat and recruitment. Therefore a stress of 4 can be tolerated for 50% of the time.
General life history requirements : *C. emarginatus* *Eggs:* Margins of FD (>0.3 m, >0.3 m/s) gravel cobble substrate. October – January. >16°C Duration 7 days 3 - 30% *Larva:* Feeding and Growth: Nursery areas (>0.3 m, >0.2 m/s), Margins of FD, SS & overhanging vegetation. Duration larval period: 2 months. *Juvenile:* Feeding and Growth: Mostly FD and margins of SS (>0.30m deep >0.2 m/s). Cover: Cobbles & rocks overhanging vegetation. Duration 3-6 months. *Adult:* FD (>0.3 m, >0.3 m/s) gravel, cobble Substrate. Spawning season: October – January. Cue: increased temperature, flow and changes in water quality (e.g. conductivity).

The stress referred to in the motiations below refers to aquatic invertebrate stress, not component stress.

AQUATIC INVERTEBRATES: DURATIONS AND MOTIVATIONS TO BE USED FOR DETERMINING STRESS REQUIREMENTS
Indicator: *Neoperla spio* The indicators are rheophilic species.
STRESS REQUIREMENTS FOR RECOMENDED EC
DRY SEASON
DROUGHT: +/-10%. Stress 6: Survival conditions. Ensure refuge habitats for taxa such as Philopotamidae, Hirudinea, Sphaeriidae and Corbiculidae. Flow more than a trickle must be maintained over the riffle, to protect against high temperatures and low oxygen concentrations. These flows should be sufficient to maintain populations of Heptageniidae and the phoretic blackfly, *Simulium lumbwanum*, whose larvae are found attached exclusively to Heptageniidae.
MAINTENANCE C: 0%. Stress 4: Require good riffle habitat for the dry season. Average depth 19 cm and average velocity 0.27 m/s. Biomonitoring data collected at Stress level of 2 in August 2003 indicated a PES of Category C, suggesting that the main cause of deterioration in aquatic assemblages is not flow related. **MAINTENANCE D:** For Category D a Stress of 4 was assigned for maintenance conditions. Sensitive taxa expected to disappear include *Neoperla spio,* Tricorythidae, Psephenidae, Heptageniidae and Polymitarcidae. **MAINTENANCE B:** For Category B a Stress of 3 was assigned for the maintenance conditions for the dry season. This should be sufficient to maintain sensitive taxa such as Hydrachnellidae (Water Mites), *Tricorythus* sp., Prosopistomatidae (Water specs), *Elassoneuria trimeniana, Centroptiloides bifasciata,* Naucoridae (Creeping water bugs), Corixidae (Water boatmen), Gerridae (Water striders), *Hydropsyche* sp., *Hydropsyche longifurca, Macrostemum capensis,* Polymorphanisus, Hydroptilidae, Haliplidae (Crawling Water Beetles), Hydraenidae (Minute Moss Beetles), Hydrophilidae (Water Scavenger Beetles), *Simulium vorax,* Ancylidae and *Gyraulus costulatus.*
OTHER: 50%. Stress 3:
WET SEASON
DROUGHT: +/- 10%. Stress 3: Require good riffle habitat for the dry season. Average depth 23cm and average velocity 0.3 m/s.
MAINTENANCE C: 30%. Stress 2: Ensure viability of riffle community. Average depth of 26 cm and average velocity of 0.33 m/s . A stress of 1 was assigned for improved conditions (Category B), while a stress of 3 was assigned for deteriorated conditions (Category D). **MAINTENANCE D:** For the wet season a stress of 4 was assigned for the drought, while a stress of 3 was assigned for maintenance conditions. Sensitive taxa expected to disappear include *Neoperla spio,* Tricorythidae, Psephenidae, Heptageniidae and Polymitarcidae. **MAINTENANCE B:** For Category B a Stress of 1 was assigned for maintenance flows during the wet season. This should be sufficient to maintain sensitive taxa such as Hydrachnellidae (Water Mites), *Tricorythus* sp., Prosopistomatidae (Water specs), *Elassoneuria trimeniana, Centroptiloides bifasciata,* Naucoridae (Creeping water bugs), Corixidae (Water boatmen), Gerridae (Water striders), *Hydropsyche sp*., *Hydropsyche longifurca, Macrostemum capensis,* Polymorphanisus, Hydroptilidae, Haliplidae (Crawling Water Beetles), Hydraenidae (Minute Moss Beetles), Hydrophilidae (Water Scavenger Beetles), *Simulium vorax,* Ancylidae and *Gyraulus costulatus.*

OTHER: 50%. Stress 2: Require average depth 26 cm and average velocity 0.33 m/s.

The low flow requirements set by fish and aquatic invertebrates were assessed for riparian vegetation.

RIPARIAN VEGETATION		
Flow	**Discharge (m^3/s)**	**Max flow depth (m)**
September drought	0.5	0.34
September maintenance		
February drought		
March maintenance	1.5	0.48
Acceptable for riparian vegetation.		

5.6.3 Final Low Flow Requirements

Present Day Lowflows: Monthly vs Observed and Present Day data

The pattern of flows in the present day monthly flow sequence used to generate the stress-duration curves for EWR Site K2 did not agree with:

- the observed records from X1H036 and X1H001;
- the daily simulated flows generated by Prof. Denis Hughes;
- the specialists opinion of the flow regime that had resulted in PES at EWR Site K2;

This was particularly true for the two extremes of the curve, which indicated prolonged periods of, on the one hand, very high base flows (low stress) and on the other, zero flows (high stress; Figure 5-3).

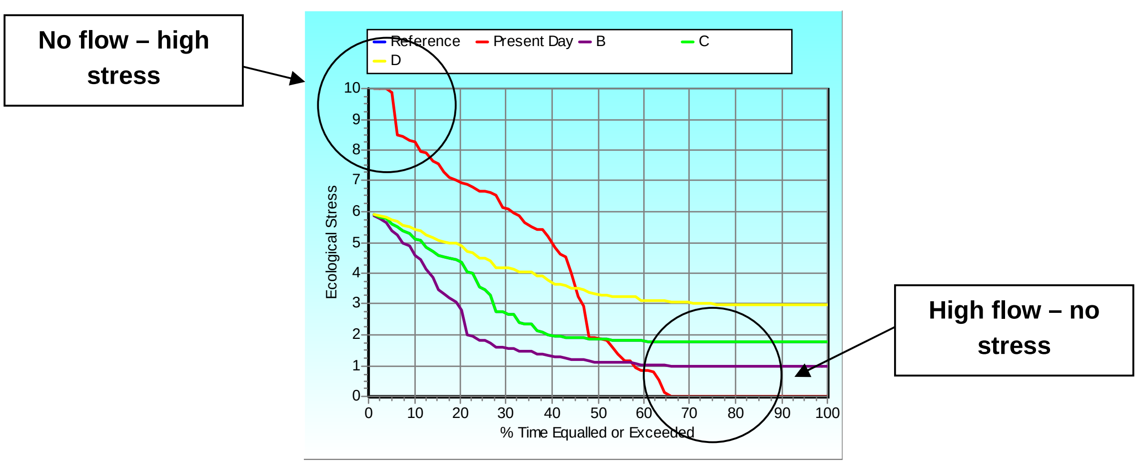


Figure 5-3. Stress curves generated using present day monthly flow sequence for EWR Site K2 (red); and the stress curves for B (purple). C (green) and D (yellow) from the Desktop Model.

In addition, it was unclear whether the rules used to simulate flows at EWR Site K2, had been implemented at the site.

There was unanimous agreement among the facilitators, the hydrologist and the biophysical specialists that the observed and daily, simulated flow records gave a more accurate picture of the actual situation at the site, i.e., the flow regime currently maintaining a Category C river. The present day stress curve could therefore not guide the setting of required stresses. Furthermore, there was general consensus that the present day simulated monthly flow regime would not maintain a C category river at EWR Site K2.

Adjustments to the Desktop Reserve Model requirements were made to fit the specialist requirements as shown in Tables 5.7 to 5.9.

Table 5-7. EWR K2 - Maintenance and drought low flows (EC = B).

Month	Desktop (m^3/s)		Modified (m^3/s)		Ratio (Mod/Desk)	
	Maintenance low flows	Drought low flows	Maintenance low flows	Drought low flows	Maintenance low flows	Drought low flows
Jan	5.781	1.721	3.700	0.650	64%	38%
Feb	7.288	2.145	4.200	0.800	58%	37%
MAR	6.166	1.825	3.900	0.700	63%	38%
Apr	5.614	1.682	3.650	0.600	65%	36%
May	4.728	1.437	3.200	0.500	68%	35%
Jun	4.083	1.268	2.700	0.400	66%	32%
Jul	3.150	1.012	2.100	0.350	67%	35%
Aug	2.686	0.886	1.800	0.300	67%	34%
Sep	2.553	0.856	1.731	0.257	68%	30%
Oct	2.646	0.876	1.800	0.263	68%	30%
Nov	3.556	1.126	2.400	0.338	67%	30%
Dec	4.523	1.382	3.100	0.480	69%	35%

Table 5-8. EWR K2 – Maintenance and drought flows (REC = C).

Month	Desktop		Modified		Ratio (Mod/Desk)	
	Maintenance low flows	Drought low flows	Maintenance low flows	Drought low flows	Maintenance low flows	Drought low flows
Jan	3.309	1.721	1.700	0.650	51%	38%
Feb	4.148	2.145	1.750	0.800	42%	37%
Mar	3.519	1.825	1.700	0.700	48%	38%
Apr	3.223	1.682	1.600	0.600	50%	36%
May	2.735	1.437	1.500	0.500	55%	35%
Jun	2.388	1.268	1.400	0.400	59%	32%
Jul	1.874	1.012	1.300	0.350	69%	35%
Aug	1.621	0.886	1.200	0.300	74%	34%
Sep	1.553	0.856	1.039	0.257	67%	30%
Oct	1.599	0.876	1.150	0.263	72%	30%
Nov	2.100	1.126	1.300	0.338	62%	30%
Dec	2.623	1.382	1.500	0.480	57%	35%

Table 5-9. EWR K2 – Maintenance and drought flows (EC = D).

Month	Desktop		Modified		Ratio (Mod/Desk)	
	Maintenance low flows	Drought low flows	Maintenance low flows	Drought low flows	Maintenance low flows	Drought low flows
Jan	1.721	1.721	0.800	0.650	46%	38%
Feb	2.145	2.145	0.830	0.800	39%	37%
Mar	1.825	1.825	0.800	0.700	44%	38%
Apr	1.682	1.682	0.700	0.600	42%	36%
May	1.437	1.437	0.650	0.500	45%	35%
Jun	1.268	1.268	0.600	0.400	47%	32%
Jul	1.012	1.012	0.550	0.350	54%	35%
Aug	0.886	0.886	0.510	0.300	58%	34%
Sep	0.856	0.856	0.497	0.257	58%	30%
Oct	0.876	0.876	0.505	0.263	58%	30%
Nov	1.126	1.126	0.600	0.338	53%	30%
Dec	1.382	1.382	0.720	0.480	52%	35%

The low flow recommendations for each reserve scenario were finalised (Figure 5-4 and Figure 5-5).

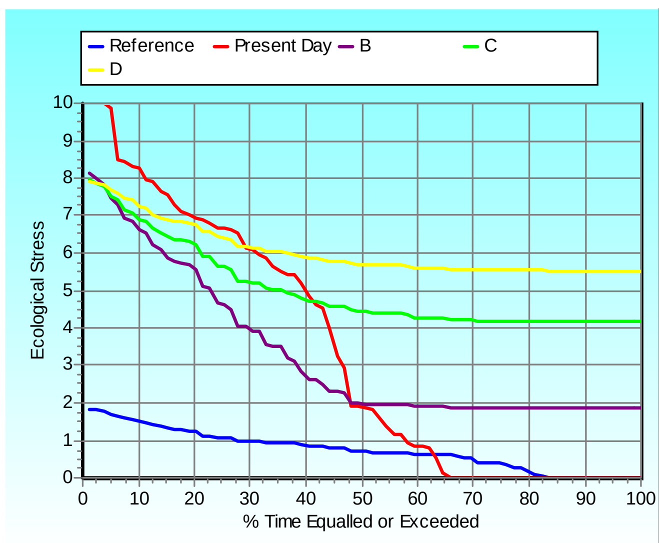


Figure 5-4. Final Stress Duration Curve for Reference conditions, present day and categories B, C and D for the dry season (September) at EWR Site K2.

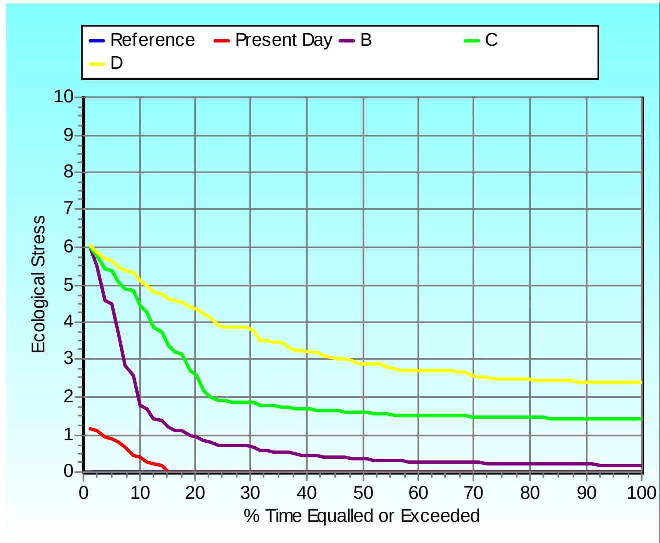


Figure 5-5. Final Stress Duration Curve for Reference conditions, present day and categories B, C and D for wet season (February) at EWR Site K2.

5.6.4 High Flow Requirements

The functions for each Flood Class are described in spreadsheets. A summary of the flood class ranges and recommended number of high flow events required for each EC is provided in Table 5-10 below. Additional flood class motivations are detailed in Appendix J.

Table 5-10. Flood class parameters and recommended number of high flow events required for each EC – EWR Site K2.

Note: *Timing: 1 = January; 12 = December
P = present, A = absent

EC = C	Flood parameters			NUMBER OF EVENTS					FINAL		Discussion of changes	
FLOOD CLASSES	Range	Range Average	Duration (days)	Geom No.	Veg No.	Invert No.	Fish No.	MIN	No.	*Timing	Primary	Secondary
Class 1	4.8-9.71	7.3	2.0	2.0	2.0	3.0	3.0	3.0	3.0	4-9	Inverts:	Fish:
Class 2	9.71-19.42	14.0	5.0	1.0	2.0			2.0	2.0	11-4	Veg. Periodic recharge of lower riparian slopes:· To inundate key species such as *Salix mucronata* and *Cyperus marginatus* · To saturate rooting zone of species such as *Ficus sycomorus* and *Combretum erythrophyllum* · To inundate key species of seasonal channels· To prevent reed encroachment in marginal zone	Geom. Transport sand and gravel, inundate in-channel bench. Retain some of natural variability.
Class 3	19.42-38.84	28.1	5.0	2.0	2.0			2.0	2.0	11-4	Geom. Intermediate functions to Classes I and III. Retain variability of flows.	Veg. Periodic recharge of lower riparian slopes:· To inundate key species such as *Salix mucronata* and *Cyperus marginatus.* To saturate rooting zone of species such as *Ficus sycomorus* and *Combretum erythrophyllum.* To inundate key species of seasonal channels· To prevent reed encroachment in marginal zone. ·
Class 4	38.84-77.86	55.0	6.0	1.0	1.0			1.0	1.0	11-4	Geom: Maintain present channel geometry and bed sorting . Inundate flood plain and secondary channels, effective discharge for sediment transport – coarse gravels & limited cobble movement.	Veg. Facilitate seed dispersal of key species of lower riparian zone (eg. *Combretum erythrophyllum* and *Ficus sycomorus*)Transported sediments provide substrate for germination of key species. Maintain habitat diversity. Control terrestrialisation of lower riparian zone. Remove debris and scour seasonal channels.
1:2	86.46	-		P				P	1:2		Geom. Channel maintenance.	None.
1:5	158.83	-						0.0				
1:10	189.6	-						0.0				
1:20	382.16	-						0.0				

EC = B	Flood parameters			NUMBER OF EVENTS							Discussion of changes	
									FINAL			
FLOOD CLASSES	Range	Range Average	Duration (days)	**Geom No.**	**Veg No.**	**Invert No.**	**Fish No.**	**MIN**	**No.**	***Timing**	Primary	Secondary
Class 1	4.8-9.71	7.3	4.0	3.0	4.0	4.0	3.0	4.0	4.0	4-9	Veg. Periodic recharge of banks in marginal zone: · To inundate key species such as fern Amelopteris prolifera· To maintain good cover of grasses (eg. Ischaemum fasciculatum· To reduce proliferation of naturalised exotics such as Ageratum houstianum and Verbena bonariensis	Inverts. As for EC C, but increased number of events.
Class 2	9.71-19.42	14.0	5.0		3.0			3.0	3.0	11-4	Veg. Periodic recharge of lower riparian slopes:· To inundate key species such as *Salix mucronata* and *Cyperus marginatus* · To saturate rooting zone of species such as *Ficus sycomorus* and *Combretum erythrophyllum*· To inundate key species of seasonal channels· To prevent reed encroachment in marginal zone. · To reduce proliferation of naturalised exotic grass *Paspalum dilatatum* .	None.
Class 3	19.42-38.84	28.1	5.0		3.0			3.0	3.0	11-4	Veg. Periodic recharge of lower riparian slopes:· To saturate rooting zone of species such as *Ficus sycomorus* and *Combretum erythrophyllum* · To inundate key species of seasonal channels· To prevent reed encroachment in marginal zone· To reduce proliferation of naturalised exotic grass *Paspalum dilatatum* .	General habitat maintenance.
Class 4	38.84-77.86	55.0	6.0		2.0			2.0	2.0	11-4	Veg. Facilitate seed dispersal of key species of lower riparian zone (eg. *Combretum erythrophyllum* and *Ficus sycomorus*). Transported sediments provide substrate for germination of key speciesIncrease habitat diversity. Control terrestrialisation. Remove debris and scour seasonal channels.	General habitat maintenance.
1:2	86.46	-		P				P	1:2	-	Geom. Channel maintenance.	General habitat maintenance.
1:5	158.83	-						0.0	-	-	Cannot be managed.	General habitat maintenance.
1:10	189.6	-						0.0	-	-		
1:20	382.16	-						0.0	-	-		

EC = D	Flood parameters			NUMBER OF EVENTS					FINAL		Discussion of changes	
FLOOD CLASSES	Range	Range Average	Duration (days)	Geom No.	Veg No.	Invert No.	Fish No.	MIN	No.	*Timing	Primary	Secondary
Class 1	4.8-9.71	7.3	2.0	1.0	0.0	2.0	2.0	2.0	2.0	11-4	Inverts: · Flush out senescent algae and fines and provide cue for breeding or emergence.· Provide sufficient current speed to discourage bilharzias snail populations.· To maintain clear surfaces in SIC and prevent embeddedness that leads to reduced species diversity.· To maintain productivity by providing relevant cue for emergence or for breeding.· To maintain species diversity by ensuring temporal diversity of flows. · There are presently three Class 1 floods passing and the PES for invertebrates is Category C.	Fish:
Class 2	9.71-19.42	14.0	5.0	0.0	1.0			1.0	1.0	11-4	Veg. · Reeds already severely encroached into marginal zone· Salix mucronata already displaced	None.
Class 3	19.42-38.84	28.1	5.0	2.0	0.5			2.0	2.0	11-4	Geom. Maintain some channel geometry and bed sorting . Inundate flood plain and secondary channels, effective discharge for sediment transport – coarse gravels & limited cobble movement.	Veg.
Class 4	38.84-77.86	55.0	6.0	0.5				0.5	1:2	11-4	Retention of some of intermediate floods, but at a reduced frequency from C.	None.
1:2	86.46							A	1:5	-	Geom. Channel maintenance.	
1:5	158.83							0.0	-	-		General habitat maintenance.
1:10	189.6							0.0	-	-		
1:20	382.16							0.0	-	-		

5.7 FINAL RESULTS

The final EWR results for the recommended and alternative categories are summarised below (Tables 5-11 to 5-16) and the detailed results are presented in Appendix K.

Table 5-11. EWR Summary Table for EWR Site K2 for Recomended Ecological Category: C.

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	VOL ($X10^6$ m^3)	nMAR %
EWR SITE K2: EMC = C.														
LOW FLOWS														
MAINTENANCE LOW FLOWS (m^3/s)[6]	1.2	1.3	1.5	1.7	1.8	1.7	1.6	1.5	1.4	1.3	1.2	1.0	**44.990**	**8.53%**
DROUGHT LOW FLOWS (m^3/s)	*0.3*	*0.3*	*0.5*	*0.7*	*0.8*	*0.7*	*0.6*	*0.5*	*0.4*	*0.4*	*0.3*	*0.3*	***14.756***	***2.8***
HIGH FLOWS														
FLOOD (daily average: m^3/s)	7.3	14.0	14.0	28.0	1)28.0 2)86.5	55	7.3	-	-	-	-	7.3	**43.315**	**8.22**
Duration (in days)	2	5	5	5	1) 5 2) 6	6	2	-	-	-	-	2		
Return period (years)	1:1	1:1	1:1	1:1	1) 1:1 2) 1.2	1:1	1:1	-	-	-	-	1:1		
LONG-TERM MEAN													***77.108***	***14.63***

[6] Figures rounded-off to the nearest one decimal place.

Table 5-12. EWR Summary Table for EWR Site K2 for Alternative EC: B.

	OCT	**NOV**	**DEC**	**JAN**	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEP**	**VOL ($X10^6$ m^3)**	**nMAR %**
EWR SITE K2: EMC = B.														
LOW FLOWS														
MAINTENANCE LOW FLOWS (m^3/s)[7]	1.8	2.4	3.1	3.7	4.2	3.9	3.7	3.2	2.7	2.1	1.8	1.7	**89.824**	**17.04**
DROUGHT LOW FLOWS (m^3/s)	*0.3*	*0.3*	*0.5*	*0.7*	*0.8*	*0.7*	*0.6*	*0.5*	*0.4*	*0.4*	*0.3*	*0.3*	***14.756***	***2.8***
HIGH FLOWS														
FLOOD (daily average: m^3/s)	7.3	14.0	1)14.0 2)28.0	1)14.0 2)28.0	1)28.0 2)55.0 3)86.5	55	7.3	7.3	-	-		7.3	**65.391**	**12.40**
Duration (in days)	2	5	1) 5 2) 5	1) 5 2) 5	1) 5 2) 6 3) 6	6	2	2	-	-		2		
Return period (years)	1:1	1:1	1) 1:1 2) 1:1	1) 1:1 2) 1:1	1) 1:1 2) 1.1 3) 1:2	1:1	1:1	1:1	-	-		1:1		
LONG-TERM MEAN													***149.39***	***28.34***

[7] Figures rounded-off to the nearest one decimal place.

Table 5-13. EWR Summary Table for EWR Site K2 for Alternative EC: D.

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	VOL ($X10^6$ m^3)	nMAR%
EWR SITE K2: EMC =D.														
LOW FLOWS														
MAINTENANCE LOW FLOWS (m^3/s)[8]	0.5	0.6	0.7	0.8	0.8	0.8	0.7	0.7	0.6	0.6	0.5	0.5	**20.263**	**3.86**
DROUGHT LOW *FLOWS (m^3/s)*	*0.3*	*0.3*	*0.5*	*0.7*	*0.8*	*0.7*	*0.6*	*0.5*	*0.4*	*0.4*	*0.3*	*0.3*	***14.756***	***2.8***
HIGH FLOWS														
FLOOD (daily average: m^3/s)	7.3	-	14.0	28.0	1)28.0 2)86.5	55	7.3	-	-	-	-	-	**22.282**	**4.23**
Duration (in days)	2	-	5	5	1) 5 2) 6	6	2	-	-	-	-	-		
Return period (years)	1:1	-	1:1	1:1	1) 1:1 2) 1.5	1:2	1:1	-	-	-	-	-		
LONG-TERM MEAN													***57.549***	***10.92***

[8] Figures rounded-off to the nearest one decimal place.

Table 5-14. EWR rule table for recommended REC: C

Desktop Version 2, Printed on 31/01/2005
Summary of EWR rule curves for : EWR K2 Generic Name
Determination based on defined BBM Table with site specific assurance rules.
Regional Type : E.Escarp   REC = C

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

This EWR rule table can be used in combination with the natural duration curves below for implementation

Reserve flows without High Flows

Month	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	1.602	1.597	1.582	1.550	1.487	1.373	1.180	0.896	0.554	0.297
Nov	1.811	1.804	1.785	1.747	1.674	1.543	1.329	1.018	0.650	0.375
Dec	2.090	2.081	2.059	2.016	1.934	1.789	1.553	1.215	0.816	0.520
Jan	2.369	2.357	2.331	2.282	2.190	2.030	1.775	1.417	1.000	0.692
Feb	2.527	2.519	2.503	2.474	2.419	2.319	2.144	1.850	1.395	0.883
Mar	2.369	2.362	2.340	2.297	2.215	2.066	1.823	1.471	1.054	0.742
Apr	2.230	2.225	2.206	2.167	2.091	1.951	1.717	1.371	0.955	0.641
May	2.090	2.087	2.071	2.036	1.966	1.835	1.610	1.271	0.856	0.541
Jun	1.950	1.948	1.933	1.901	1.835	1.710	1.492	1.161	0.752	0.440
Jul	1.811	1.811	1.798	1.771	1.712	1.599	1.398	1.085	0.691	0.388
Aug	1.671	1.670	1.657	1.628	1.569	1.458	1.266	0.973	0.611	0.335
Sep	1.447	1.445	1.433	1.407	1.354	1.256	1.088	0.834	0.523	0.288

Natural Duration curves

Oct	11.499	8.766	6.463	5.462	4.831	4.320	3.622	3.248	2.830	2.158
Nov	44.826	19.687	15.069	10.829	9.753	8.816	8.021	6.470	5.243	2.766
Dec	54.099	48.073	30.724	21.229	17.425	14.602	12.784	10.786	8.083	4.346
Jan	83.102	59.633	49.683	30.249	23.156	17.174	15.464	13.833	10.588	8.009
Feb	117.026	63.951	45.606	29.183	18.395	17.324	16.055	14.120	12.430	9.057
Mar	56.649	35.036	24.037	16.383	14.796	13.404	12.168	11.078	9.394	7.975
Apr	26.339	17.187	15.444	13.777	12.905	12.118	10.818	9.263	7.940	6.227
May	15.218	12.690	11.302	10.652	9.543	8.625	7.669	6.769	5.821	3.659
Jun	10.829	9.726	8.457	7.423	6.694	6.026	5.687	4.830	4.321	3.029
Jul	8.322	6.321	5.768	5.354	4.895	4.506	3.797	3.371	3.106	2.371
Aug	6.362	5.354	4.559	4.211	3.831	3.521	3.252	2.976	2.707	2.296
Sep	6.111	5.320	4.468	3.904	3.773	3.353	3.079	2.894	2.485	2.095

Total Reserve Flows

	% Points									
Month	**10%**	**20%**	**30%**	**40%**	**50%**	**60%**	**70%**	**80%**	**90%**	**99%**
Oct	1.995	1.990	1.970	1.930	1.850	1.704	1.460	1.100	0.666	0.339
Nov	3.130	3.118	3.084	3.014	2.882	2.644	2.253	1.688	1.017	0.515
Dec	3.367	3.352	3.314	3.240	3.098	2.848	2.440	1.856	1.168	0.656
Jan	6.527	5.961	5.466	5.013	4.552	3.781	3.243	2.484	1.604	0.953
Feb	15.053	13.385	11.958	10.705	9.522	7.540	6.442	4.867	3.011	1.630
Mar	11.501	10.288	9.245	8.327	7.451	5.978	5.123	3.884	2.414	1.317
Apr	2.636	2.630	2.607	2.559	2.466	2.294	2.006	1.581	1.070	0.685
May	2.090	2.087	2.071	2.036	1.966	1.835	1.610	1.271	0.856	0.541
Jun	1.950	1.948	1.933	1.901	1.835	1.710	1.492	1.161	0.752	0.440
Jul	1.811	1.811	1.798	1.771	1.712	1.599	1.398	1.085	0.691	0.388
Aug	1.671	1.670	1.657	1.628	1.569	1.458	1.266	0.973	0.611	0.335
Sep	1.854	1.851	1.835	1.801	1.732	1.603	1.382	1.049	0.641	0.331

Table 5-15. EWR rule table for EC: B

Desktop Version 2, Printed on 31/01/2005
Summary of EWR rule curves for : EWR K2 Generic Name
Determination based on defined BBM Table with site specific assurance rules.
Regional Type : E.Escarp EC = B

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

This EWR rule table can be used in combination with the natural duration curves below for implementation.

Reserve flows without High Flows

Month	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	2.148	2.142	2.121	2.076	1.987	1.826	1.555	1.155	0.673	0.311
Nov	2.864	2.852	2.820	2.755	2.630	2.406	2.038	1.505	0.873	0.401
Dec	3.700	3.682	3.639	3.553	3.389	3.098	2.627	1.950	1.153	0.560
Jan	4.416	4.389	4.334	4.225	4.023	3.673	3.116	2.330	1.417	0.742
Feb	5.013	4.996	4.957	4.884	4.750	4.508	4.080	3.362	2.253	1.003
Mar	4.655	4.637	4.586	4.484	4.288	3.937	3.361	2.527	1.538	0.799
Apr	4.356	4.345	4.301	4.212	4.036	3.714	3.174	2.378	1.417	0.695
May	3.819	3.813	3.779	3.707	3.561	3.286	2.817	2.109	1.242	0.585
Jun	3.222	3.219	3.192	3.133	3.012	2.784	2.388	1.785	1.040	0.473
Jul	2.506	2.506	2.488	2.447	2.361	2.194	1.897	1.435	0.853	0.407
Aug	2.148	2.146	2.128	2.090	2.011	1.861	1.602	1.207	0.719	0.348
Sep	2.066	2.063	2.044	2.004	1.925	1.775	1.519	1.134	0.662	0.303

Total Reserve Flows

	% Points									
Month	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	2.509	2.502	2.476	2.424	2.320	2.130	1.812	1.343	0.777	0.352
Nov	4.074	4.057	4.011	3.917	3.737	3.416	2.888	2.123	1.216	0.539
Dec	7.212	7.177	7.091	6.919	6.593	6.014	5.075	3.728	2.141	0.960
Jan	10.653	9.795	9.036	8.321	7.566	6.299	5.317	3.931	2.323	1.133
Feb	27.650	24.630	22.035	19.742	17.548	13.869	11.724	8.648	5.025	2.328
Mar	13.786	12.563	11.491	10.514	9.525	7.849	6.660	4.940	2.898	1.374
Apr	4.729	4.716	4.669	4.571	4.380	4.029	3.440	2.572	1.525	0.738
May	4.180	4.173	4.136	4.056	3.896	3.594	3.078	2.301	1.349	0.627
Jun	3.222	3.219	3.192	3.133	3.012	2.784	2.388	1.785	1.040	0.473
Jul	2.506	2.506	2.488	2.447	2.361	2.194	1.897	1.435	0.853	0.407
Aug	2.148	2.146	2.128	2.090	2.011	1.861	1.602	1.207	0.719	0.348
Sep	2.438	2.435	2.413	2.366	2.271	2.094	1.790	1.332	0.771	0.346

Table 5-16. EWR rule table for EC: D

Desktop Version 2, Printed on 31/01/2005
Summary of EWR rule curves for : EWR K2 Generic Name
Determination based on defined BBM Table with site specific assurance rules.
Regional Type : E.Escarp   EC = D

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

This EWR rule table can be used in combination with the natural duration curves below for implementation.

Reserve flows without High Flows

Month	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	1.005	1.003	0.994	0.977	0.942	0.878	0.772	0.614	0.425	0.282
Nov	1.195	1.191	1.180	1.158	1.115	1.039	0.914	0.734	0.519	0.359
Dec	1.434	1.429	1.416	1.390	1.342	1.256	1.116	0.916	0.679	0.504
Jan	1.594	1.587	1.573	1.546	1.496	1.408	1.268	1.071	0.842	0.673
Feb	1.820	1.815	1.806	1.788	1.756	1.697	1.594	1.420	1.152	0.849
Mar	1.594	1.590	1.579	1.556	1.511	1.432	1.302	1.113	0.889	0.722
Apr	1.395	1.392	1.383	1.364	1.327	1.259	1.145	0.976	0.773	0.620
May	1.295	1.294	1.285	1.268	1.233	1.167	1.055	0.885	0.678	0.520
Jun	1.195	1.194	1.186	1.170	1.136	1.072	0.960	0.790	0.580	0.421
Jul	1.095	1.095	1.089	1.075	1.045	0.987	0.885	0.725	0.524	0.370
Aug	1.015	1.015	1.008	0.993	0.962	0.904	0.804	0.651	0.462	0.319
Sep	0.989	0.988	0.981	0.965	0.932	0.872	0.768	0.612	0.421	0.276

Total Reserve Flows

	% Points									
Month	**10%**	**20%**	**30%**	**40%**	**50%**	**60%**	**70%**	**80%**	**90%**	**99%**
Oct	1.497	1.493	1.479	1.451	1.395	1.292	1.119	0.864	0.557	0.326
Nov	1.195	1.191	1.180	1.158	1.115	1.039	0.914	0.734	0.519	0.359
Dec	3.030	3.017	2.984	2.918	2.794	2.574	2.216	1.702	1.098	0.647
Jan	5.752	5.191	4.708	4.277	3.858	3.159	2.735	2.139	1.446	0.934
Feb	9.584	8.551	7.666	6.891	6.160	4.937	4.263	3.298	2.160	1.314
Mar	6.077	5.481	4.968	4.516	4.082	3.352	2.921	2.298	1.557	1.005
Apr	1.903	1.899	1.884	1.854	1.795	1.686	1.504	1.235	0.910	0.666
May	1.295	1.294	1.285	1.268	1.233	1.167	1.055	0.885	0.678	0.520
Jun	1.195	1.194	1.186	1.170	1.136	1.072	0.960	0.790	0.580	0.421
Jul	1.095	1.095	1.089	1.075	1.045	0.987	0.885	0.725	0.524	0.370
Aug	1.015	1.015	1.008	0.993	0.962	0.904	0.804	0.651	0.462	0.319
Sep	0.989	0.988	0.981	0.965	0.932	0.872	0.768	0.612	0.421	0.276

5.8 CONFIDENCE

The confidence was evaluated according to a score of 0-5, where 0 = 'no confidence' and 5 = 'very high' confidence (Table 5-17).

Table 5-17. Confidence Ratings for EWR Site K2.

	EWR SITE	AVAILABLE DATA	ECOLOGICAL CLASSIF.	OUTPUT LOW FL	OUTPUT HIGH FL
HYDROLOGY		3.5	3		
	Confidence is fairly high on the accuracy of the simulation of observed (historic) flows. The simulation is based on calibrations done a number of years ago and is a reasonable representation of the time series in terms of the range of flows. The low flows are slightly higher based on nature of calibration.				
HYDRAULICS	3	3/3=3		2.5	4
	Measured flows in the range 1.9 to 62.7m^3/s. Recommended low-flows for the PES (C) in the range 0.5 to 2.2m^3/s (ie. largely below lowest ,measured value), and high flows in the range 7.3-55 (within year) (ie. within measured range) to 86-382 (1:2-1:20) (ie. above measured values but reasonable estimates of flow resistance and energy slope for hydraulic modelling).				
QUALITY		3	3		
	Water quality data used from DWAF monitoring programme at monitoring point XH001Q01 (1977-2004). Confidence is the data is medium (3). No temperature, dissolved oxygen and turbidity data available. EC confidence in data was medium despite no temperature, dissolved oxygen, chlorophyll and turbidity data available				
GEOMORPH	3.5	3	2.5	n/a	4
	Long-term photos at small scale, good quality post dam hydrology data only. Site visit and some recce of local catchment. Low / moderate confidence in prediction of how dam would affect geomorphological processes; some indication of plan form change from aerial photographs, no knowledge of previous bed conditions. Good morphological clues for present day features; theoretical uncertainties over bed load transport predictions and effect of changing number of events.				
RIP VEG	4	3	4	n/a	3
	EWR site: A good site **Available data:** Vegetation profile studied twice (once in winter and once in Autumn). Previous status of vegetation unknown. **Ecological classification:** Confirmed by RVI analysis **Output low flow:** Recommendations not tested **Output high flow:** Recommendations match current situation				
FISH	4	4	4	4	4

	Confidence in available data is moderately high because historic data goes back as far as the 1960's and also 1970 /80's. Several surveys has been conducted in this Resource Unit over last three years, specifically looking at the status of the species used to set the stress response (*C. emarginatus*). Moderately high confidence in EC based on the available data and several recent surveys conducted during last 3 years in this Resource Unit. Moderately high confidence in EWR site is as the site provided good indications of the abundance of critical habitat required by indicator species under different flows and could be used to set stress. Moderately high confidence in low flows based on the available hydraulic and fish information hence it was possible to set realistic flows in terms of its stress and availability of critical habitat for indicator species. Moderately high confidence in high flows based on understanding of the species in this Resource Unit, fish mainly has a need of Class 1 floods in terms of breeding and migrations. Also confident that floods asked for by the other components will be able to cater for the needs of the fish.				
INVERT	4	4	4	4	4
	High diversity of biotopes present: Highly suitable SIC, MVIC, MVOC and aquatic vegetation; Suitable SOC and gravel. Moderate sand. Absent biotopes included bedrock and mud. Data were available for 28 SASS samples recorded at 12 sampling sites within this Resource Unit, so confidence in the results was high. Information available was suitable for evaluation as required. Low flows: The invertebrate requirements were close to or at levels set. High flows: The invertebrate requirements were close to or at levels set.				

6. EWR SITE K3 – TONGA

6.1 ECOLOGICAL CATEGORIES

The PES for EWR Site K3 is summarised Table 6-1, and a description of the reference conditions, and PES for individual components is presented in Table 6-2.

Table 6-1. The PES for EWR Site K3.

Driver Components	Component PES	Driver PES	ECOSTATUS PES
HYDROLOGY	E	E	E
GEOMORPH	D/E		
WATER QUALITY	D		
Response Components	Component PES	Instream PES	
FISH	E/F	E	
AQUATIC INVERTS	E		
RIPARIAN VEG	D/E	D/E	

Table 6-2. Description of the PES categories for each habitat driver and biological response for EWR Site K3.

Category B/C = Largely Natural to Moderately Modified; D= Largely Modified; D/E= Largely Modified to Seriously Modified; E= Seriously Modified and E/F= Seriously to Critically Modified.

Driver and responses	Reference conditions	PES	PES description
			Overall PES for Drivers Seriously Modified (Category E).
Hydrology	nMAR= 1016 million m^3/a	**E**	pMAR= 385 million m^3/a with Maguga Dam. EWR Site K3 lies 65 km below Maguga Dam which was completed early in 2002. Maguga Dam has a capacity of 302 mill cubic metres and controls 77% of the catchment of K3 and 76% of the MAR at this site. The system model set up by KOBWA was used in this case, but it is important to note that the operating rules are not all relevant as the system is currently operated differently. The main changes from natural conditions include the following: • Low flows reduction of 5% (70% exceedence) which is quite significant. • Present MAR is 38% of the nMAR • Definitely does stop flowing here. • Seasonality changed from 7 months to 3 months. • Moderate events removed as a result of dams and increased abstraction • High flows/ floods are reduced.
Geomorphology	K3 is classified as a lower foothill site on account of its channel gradient of 0.0021. Its gradient puts it close to a lowland river. The expected reach type would be an alluvial regime channel with a bed material	**D/E**	Maguga Dam is likely to have a moderate to large ***future*** effect on geomorphological processes at EWR Site K3. Given the short time since completion it is unlikely that these impacts will as yet be manifested in terms of morphological change.These have caused following

	dominated by gravel and sand. The bed would generally be highly mobile, forming mid-channel bars within a braided configuration. Multiple flood channels associated with a flood plain would be characteristic of this site. Stable substrate to support vegetation would be restricted to the channel margins, banks and islands. Marginal vegetation would be an important habitat.		changes in sediment inputs, riparian vegetation and channel structure. **Sediment inputs:** impacted to a moderate extent by catchment erosion within Swaziland, but weirs will have mitigated this to some extent. **Riparian Vegetation:** aerial photographs indicate a loss of woody vegetation from the river banks, but an increase on the flood plain. Vegetation provides a patchy cover on the banks and along the channel margins, giving moderate protection against erosion. Scattered reeds occur on the channel bed and a ground layer has colonised in-stream bars. There has been a large impact on the riparian vegetation, which can be attributed to clearing by the local population. **Channel structure:** this reach is impacted by a number of large weirs causing removal of finer sediments, exposure of bedrock and exaggeration of rapid morphological features. There is evidence that K3 may be inundated at high flows. The impact of channel obstruction is rated as large. **Channel morphology:** nature of cross-section indicates that there may have been channel incision, causing floods to be concentrated in the main channel and de-linking the active channel from the flood plain. The cause of this is not known, but could be the result of sediment depletion. Failure of the downstream weir during the 2000 floods may have increased incision.
Water Quality	The reference condition water quality conditions at K3 would have been improved due to the impacts of Maguga and Driekoppies Dams as well as removal from IYSIS canal being negated. The water quality improvements, compared to PES, include no temperature changes in the impoundment and an improved water quality upstream in the Komati, Seeikoespruit and Teespruit Rivers. The current water quality problems such as nutrient enrichment (phosphates, nitrates, nitrites, ammonia), filamentous algae on rocks, higher salinity values (electrical conductivity) and microbiological contamination would not have been an issue under reference conditions.	**D**	The main changes from natural conditions include increased nutrients, bacterial contamination, temperature change and slight salinisation when the river stops flowing.
			Overall Instream PES Seriously Modified (Category E)
Riparian Vegetation	No exotic species present.	**D/E**	The main changes triggered by flow related causes (attenuation of floods caused by dams and weirs, reduced low flows, deterioration in water quality) and non-flow related causes (erosion and sedimentation from overgrazing and agriculture, terrestrialisation, cultivation of riparian zones, alien plant invasion, sand and coal mining, use of poisons to catch fish and deforestation).
Marginal zone: Reedbed on banks of incised main channel	• Intermittent clumps of trees (*Syzygium* species, *Breonadia salicina*) and reeds in main channel, with sedges (*Cyperus* species) and grasses occupying open areas. • The mesophytic herb *Commelina benghalensis* and fern *Amelopteris prolifera* would be present. • Alien invader species would be absent.		• Large decrease of reeds due to harvesting and/or unsuitable substrate • demise of large *Syzygium* cf. *guineense* trees • Moderate reduction of indigenous grasses and sedges due to encroachment by the annual grass *Sorghum bicolor* • Moderate change in overall species composition for example the presence of the exotic species *Flaveria bidentis*. • Moderate change in structure due to loss of *Syzygium*

			cf. *guineense* trees and reeds.
Lower riparian zone : Shrubland / Relic reedbed on loose sand terraces	• Trees and shrubs such as *Ficus sycomorus, Ficus capreifolia, Phyllanthus reticulatus* and *Nuxia oppositifolia* would occur in a mosaic of closed and open-canopy woodland. • *Phragmites mauritianus* and *Typha capensis* would be dominant at margins of seasonal pools and secondary channels. • Terrestrial species would not be dominant, and alien invader species would be absent.		• Large decrease in reeds and some tree species as a result of terrestrialisation and cultivation. • Large reduction of indigenous species due to terrestrialisation and alien-species encroachment • Serious change in overall species composition and structure due to thinning of reeds and alien encroachment.
Upper riparian zone: Open Woodland on firm colluvial slopes	• The colluvial hillslopes would support mostly 'non-riparian' tree species (*Diospyros mespiliformis, Trichilia emetica, Combretum imberbe*). • Good ground cover of grasses such as *Themeda triandra* and *Panicum maximum*. • No alien invasive species present.		• Large reduction in the number of indigenous species, vegetation cover, structure and biomass due to deforestation. • Large change in overall species composition due to deforestation and invasion by alien species.
Fish	The available background information indicates that this site contained about 31, both temperate and more tropical species. It is most likely that tropical species such as *Hydrocynus vittatus* and *Brycinus imberi* historically occurred at this site and that eurotopic (flow requirement for at least a part of their life cycle) and limnophilic (no dependence on flow) species dominated the fish assemblage. Most of the expected species under reference conditions at this site is considered eurytopic indicating that they have a flow requirement for at least part of their life cycle	**E/F**	31 (temperate and tropical species) expected, 27 recently collected. **Flow depth:** Absence of species preferring fast flowing habitats. **Flow Modification:** Absence (or low abundance) of flow dependant and moderately flow dependant fish species. Loss of four species (*Barbus eutaenia, Opsaridium peringueyi, Chiloglanis pretoriae* and *C. swierstrai*) (rheophilic). All other categories also severely affected. Migration of fish severely effected by weirs and dams **Cover:** Disappearance of fish fauna dependant on substrate in fast habitats All other categories also severely affected. Lower abundance of species preferring fast flowing habitats as well as species preferring undercut banks and marginal vegetated areas Absence of *Petrocephalus wesselsi* and *Marcusenius macrolepidotus* which have specific habitat requirements, favouring the shelter of root wads and undercut banks **Water Quality:** Sensitive and moderately sensitive species are absent. All other categories severely affected. Temperature, nutrients and salinity are the most critical aspects
Aquatic Invertebrates	Based on the available data it is likely that SASS5 scores under pristine conditions at K3 are likely to have been consistently >180 and ASPT>6.5. The SASS5 TPC scores for K3 and K4 and are defined as the lowest SASS5 equivalent scores that were recorded at Tonga in 1997 and 1998, before the construction of Maguga Dam (ie, <142 and ASPT<5.1).	**E**	The main changes triggered by flow and non-flow related causes (see above). • high abundance of the gastropod snails *Biomphalaria pfefferi* and *Melanoides tuberculata.* • general absence of Heptageniidae, Tricorythidae and Hydropsychidae. • blackfly fauna dominated by one highly tolerant species*: Simulium adersi.* • Absence of freshwater shrimps *Caridina nilotica* and Tricorythidae. • Significantly lower diversity and abundance of case-building caddisflies. • All sensitive species have disappeared and our surviving in Lomati River (adjacent- refuge).

Additional tables providing scores for the individual driver components and biological responses (instream) and a summary of the EcoStatus are available in Appendix F.

6.2 TRENDS

Available data indicate conclusively that the ecological conditions for aquatic invertebrates within this Resource Unit deteriorated rapidly under current development conditions. The site will continue to degrade from the impacts caused by the recently constructed Maguga Dam and weir, thus placing geomorphology also on a negative trend. Considering that current management of releases from upstream impoundments is not likely to change, and considering that it would be difficult to control deforestation and cultivation in the riparian zone, the trend for vegetation is considered to be negative. Under current conditions, the PES for vegetation is expected to drop to a Category E in the short term (<5 yrs) and to a Category F in the long term (>20yrs). Until the operating rules for Maguga Dam are known, it is difficult to predict the trend for fish, but it is most likely negative. If there is a steady release and more water reaching the site, there could be an improvement. Hydropower and a balancing weir are to be constructed further affecting the ecological conditions.

6.3 IMPORTANCE

6.3.1 Ecological Importance and Sensitivity

The Ecological Importance and Sensitivity of Resource Unit D within the provincial reserve was considered *Very High* under natural conditions and *Moderate* under present conditions. The confidence for this assessments was *High.* The main determinants were the diversity of habitats, the presence of the indeterminate Black Coucal, the rare Little Bittern (*Ixobrychus minutes*), the vulnerable Eurasian Bittern (*Botaurus stellaris)*, the rare White-crowned plover (*Vanellus albiceps*), Barred minnow *(Opsaridium perengueyi)*, the hippopotamus (*Hippopotamus amphibious)*, the endangered crocodile (*Crocodylus niloticus)*, the endemic *Macrobrachium*, *Machadorythus* mayfly, tigerfish (*Hydrocynus vittatus*) (historically), intolerant species to flow (*Chiloglanis pretoriae, Opsaridium perengueyi*), species richness (27 species) and the importance as a migration corridor for eels, *Macrobracium* and local breeding migrations of fish and birds. Detailed results are presented in Appendix G.

6.3.2 Socio-cultural Importance

The area was considered to be of a *Very High* Socio-cultural Importance. Landuse of Resource Unit D is characterised by commercial subsistence agriculture and irrigated sugarcane. Population densities are very high. The use of natural resources for generating income is a very important component to household economy, particularly among women, who weave baskets and sleeping mats, and collect wild vegetables and fruits. These resources are also used for dietary and medicinal purposes and for building, fencing, firewood and wood carving. Besides bathing and swimming, certain sects, such as the Red Gown Zionists, use the river for Baptism and other rituals, including weddings. However, respondents stated that this is no longer possible because of the low level in the river, and the Red Gown must now “wait for the rains”. People in the vicinity look to Maguga and Driekoppies Dams to restore flow levels. Detailed results are presented in Appendix H.

6.4 RANGE OF ECOLOGICAL CATEGORIES

6.4.1 Recommended Ecological Category

The EIS (present) was moderate and the socio-cultural importance *Very High*. Considering that the PES is Seriously Modified (Category E) it was suggested that a higher Category (D) be recommended. Category D will help achieve a better level of sustainability. To improve the state of this Resource Unit to a Category D the following should be addressed:

- flow related issues (dam operation, weirs etc)
- importance of the river in delivering certain goods and services to the surrounding communities
- management of the entire catchment
- water quality

The Recommended Ecological Category was considered (Category D). The conditions for achieving this are given in Table 6-3 and summarised in Table 6-4.

Table 6-3. Summary of the conditions defining the Recommended Ecological Category.

Driver and responses	Recommended category
General	In general, the REC D conditions would comprise: (a) improved baseflows, (b) reduced irrigation return flows, (c) improved riparian zone acting as a buffer, (d) controlled deforestation, cultivation and grazing in riparian zone and (e) reduced fragmentation and inundation (from weirs). Geomorphology would improve (Category D). It is noted that backfill from the Driekoppies weir causes death of trees along the riparian zone.
Geomorphology	Remain in a Category D***,*** as the EcoStatus cannot be raised above a D, however, the score would be improved from 40 to 50. This will be achieved by improving the riparian vegetation (implies protection of the riparian zone). The impact of weirs and upstream dams cannot be decreased due to the effect on sediment storage. Channel incision is not reversible.
Riparian Vegetation	Improvement within the Marginal zone: moderate decrease in biomass of *Phragmites mauritianus* reeds due to harvesting and/or unsuitable substrate; demise of large *Syzygium* cf*. guineense* trees due to inundation from Nel weir back-up, moderate decrease in cover of reeds and of large trees, increased cover of hydrophytic annual grass, small reduction in number of indigenous species of grasses and sedges as a result of competition from *Sorghum bicolour*, small change in overall species composition and the presence of exotic species, small change in structure due to loss of *Syzygium* cf. *guineense* trees and reeds. An improvement within the Lower Riparian Zone: moderate decrease in number of indigenous species, moderate decrease in biomass and cover of reeds and some tree species as a result of terrestrialisation and cultivation, large change in overall species composition as alien invader species invade and a large change in structure due to thinning of reeds and encroachment by alien invader species. Improvement within the Upper Riparian Zone: moderate reduction in biomass and cover due to deforestation of tree species for construction and firewood, moderate, moderate reduction in number of indigenous species due to deforestation, moderate change in overall species composition due to deforestation and invasion by alien species and a large change in structure due to deforestation.
Fish	Increased base flows would establish more habitats, particularly for species dependant on fast deep and fast shallow conditions. This will create conditions in riffles for flow dependant and moderately flow dependant species and allow some re-colonization. Increased base flow will create some habitat on substrate in fast flowing waters and will provide more permanent habitat for species dependant on the availability of marginal vegetation, root wads and undercut banks. More base flows will reduce slow shallow habitats and reduce the risk of critical water temperatures, nutrient build-up and reduced oxygen improving conditions in all categories. Improving migration will greatly enhance recolonisation.
Aquatic Invertebrates	Category D should be moderately easy to implement because it would simply require that the river remains perennial.

Table 6-4. Summary of the Recommended Ecological Category D for EWR Site K3.

Driver Components	Component PES	Driver PES	ECOSTATUS PES
HYDROLOGY	D	D	D
GEOMORPH	D		
WATER QUALITY	D		
Response Components	Component PES	Instream PES	
FISH	D	D	
AQUATIC INVERTS	D		
RIPARIAN VEG	D	D	

6.4.2 Alternative Ecological Categories

No alternative ecological categories were considered as establishing the REC Category D was regarded as a priority.

The rule-based models for the individual components were run in a predictive manner and based on the above hypothetical scenario, the matrix that would be affected were changed. These spreadsheets with the changes indicated as different colours are included in the specialist appendices.

6.5 Stress Indices

Refer to Appendix I for the flow stress indices for the REC for fish and aquatic invertebrates.

6.5.1 Stress Index: Fish

The rheophilic species selected was *Chiloglanis pretoriae* which is dependant on the presence of moderately fast flowing waters (fast shallow & fast deep). The semi-rheophilic species selected was *Labeobarbus marequensis*. The rheohilic species was the most stressed under all flow conditions (Table 6-5).

With a flow of 4 m^3/s there is abundant fast habitat available and none of the life history requirements of *Chiloglanis pretoriae* are likely to be stressed. At a flow of 2.7 m^3/s there is still moderate availability of fast habitats but most rifles tend to become quite shallow. This will significantly affect breeding and to a lesser extent available habitat and suitable cover. At a flow of 1.7 m^3/s the availability of fast habitats is further reduced and breeding will be restricted to only a few areas. The availability of suitable cover will reduce affecting the abundance of the species. At a flow of 0.5 m^3/s the species will only survive in limited numbers due to a lack of suitable habitat. This flow will also start to affect water quality (increased temperature, decreased oxygen, change in nutrient and salinity levels) and the health of the fish because the majority of available habitat is slow shallow. At a flow of 0.1 m^3/s, no suitable fast flowing habitats are present and the species may be lost.

Rheophilic species represents the highest stresses at any given flow and this was therefore used to generate the stress index.

Table 6-5. Stress table for rheophilic fish species showing Habitat Suitability at EWR Site K3.

FLOW (CUMEC)	6.60	4.000	2.700	2.000	1.700	1.000	0.500	0.290	0.030	0
RELATIVE ABUNDANCE FLOW-DEPTH & COVER RATING: 0=NONE;1=RARE;2=SPARSE;3=MODERATE;4=ABUNDANT;5=VERY ABUNDANT)										
FAST DEEP	4	3.0	3.0	2.0	2.0	1.0	0.0	0.0	0.0	0
FAST SHALLOW	2.0	2.0	2.0	2.0	2.0	2.0	1.0	1.0	0.0	0
SLOW DEEP	3.0	3.0	3.0	3.0	3.0	3.0	2.0	2.0	1.0	1
SLOW SHALLOW	3.0	3.0	4.0	4.0	4.0	5.0	5.0	5.0	3.0	2
RHEOPHILIC	**SPECIES:**									
	Cpre									
Breeding and early life-stages=	5.0	5.0	4.0	3.0	2.0	1.0	1.0	0.0	0.0	
Survival /Abundance =	5.0	5.0	4.0	3.0	2.0	2.0	1.0	1.0	0.0	
Cover =	5.0	5.0	4.0	4.0	3.0	2.0	1.0	1.0	0.0	
Health and condition=	5.0	5.0	5.0	4.0	3.0	2.0	2.0	1.0	0.0	
Water quality=	5.0	5.0	5.0	4.0	3.0	2.0	2.0	1.0	0.0	
Rheophilic stress - (breeding requirements included)	**0**	**0**	**1**	**3**	**5**	**6**	**7**	**8**	**10**	**10**
FLOW (CUMEC)	6.60	4.00	2.70	2.00	1.70	1.00	0.50	0.29		0.00
FLOW-DEPTH CONVERTED TO HABITAT RESPONSE (10=ALL FLOW-DEPTH CLASSES ABSENT (RIVER DRY); 0=FLOW-DEPTH *CLASSES OPTIMUM FOR SITE* ; 9=NO FLOW)										
Fast deep	2	4	4	6	6	8	10	10		10
Fast shallow	6	6	6	6	6	6	8	8		10
Slow deep	4	4	4	4	4	4	6	6		8
Slow shallow	4	4	2	2	2	0	0	0		6
OVERALL HABITAT RESPONSE	**4**	**5**	**4**	**5**	**5**	**5**	**6**	**6**		**9**

6.5.2 Stress Index: Aquatic Invertebrates

Optimum Flow rates: 0.3 and 0.6 m/s
Key Species: Tricorythus
Critical Habitats: Riffle

The relationships between aquatic invertebrate habitats, flows, stresses and associated biological responses at EWR Site K1 are detailed in Table 6-6.

The critical factors that were used to determine the stress curve were the current speeds and overall species composition. During the field survey on 8th August 2003 the flow was 0.29 m^3/s, and a habitat stress score of 7 was allocated. The substrate was covered in filamentous algae that reduced habitat suitability significantly. However, biomonitoring data showed that flow-sensitive species were absent at these flows and so the biological response stress at this flow was increased to 8. Biomonitoring data collected a few kilometres upstream at the Tonga Rapids in July 1997, when the flow was 3.3 m^3/s, indicated a healthy invertebrate fauna (ASPT 7.3) which equated to a stress of 3.

Table 6-6. Stress Table – Flow Dependant Invertebrate at EWR Site K3.

Habitat Flow Response Index	HABITAT ABUNDANCE AND SUITABILITY					TOTAL	FLOW	HABITAT RESPONSE	HABITAT CHARACTERISTICS					BIOTIC RESPONSE	FLOW	SPECIES STRESS	INTEGRATED STRESS
	SIC	SOC	VIC	VOC	GSM				Max depth (m)	Avg depth (m)	Max vel (m/s)	Avg vel (m/s)	WP (m)				
0	**5**	**4**	**5**	**5**	**3**	**22**	**6.600**	All habitat in excess, very high quality: very fast, very deep, very wide wetted perimeter	0.74	0.49	1.1	0.38	37.62	All very abundant, all healthy, all species persist	**5.000**	**0**	**0**
1	**4**	**4**	**5**	**5**	**3**	**21**	**5.000**	All plentifull, high quality; fast, wide wetted perimeter	64	0.40	1.1	0.36	36.89	All abundant, all healthy, all species persist	**4.000**	**1**	**1**
2	**4**	**4**	**4**	**5**	**3**	**20**	**4.000**	Critical habitats sufficient; quality slightly reduced: fast, wetted perimeter slightly reduced	0.57	0.34	1.0	0.34	36.00	Slight reduction for sensitive rheophilic species, all healthy in some areas, all species persist	**3.600**	**2**	**2**
3	**4**	**4**	**3**	**5**	**3**	**19**	**3.600**	Reduced critical habitat, reduced critical quality; moderate velocity, fairly deep, wetted perimeter slightly/moderately reduced	0.56	0.33		0.32	35.87	Reduction for all rheophilic species; all healthy in limited areas; all species persist		**3**	**3**
4	**3**	**4**	**3**	**5**	**3**	**18**	**3.100**	Critical habitats limited; moderate quality: Moderate velocity, Some deep areas, Wide WP moderately reduced	0.54	0.31		0.29	35.47	Further reduction for all rheophilic species; all viable in limited areas, critical life stages of some sensitive rheophilic species at risk, all species persist	**3.100**	**4**	**4**
5	**3**	**4**	**3**	**5**	**2**	**17**	**2.700**	Critical habitat very reduced; moderate/ low quality; moderate/slow velocity, few deep areas wetted perimeter moderately/very reduced	0.52	0.30	0.75	0.26	35.04	Limited populations of all rheophilic species. Critical life-stages of sensitive rheophilic species at risk or non-viable; all species persist	**2.700**	**5**	**5**
6	**2**	**4**	**2**	**5**	**2**	**15**	**1.700**	Critical habitat residual. Low quality; Moderate/slow velocity.	0.48	0.27	0.65	0.21	34.08	Sensitive rheophilic species rare, critical stages of sensitive rheophilic species non-viable, and at risk for some less sensitive species. All species persisit in the short-term	**1.700**	**6**	**6**
7	**2**	**3**	**2**	**5**	**2**	**14**	**0.290**	No critical habitat, other habitats moderate quality; slow, narrow wetted perimeter	0.32	0.14	0.25	0.08	28.74	Most rheophilic species rare; All life-stages of sensitive rheophilic species at risk or non-viable. Most sensitive rheophilic species disappear	**-**	**7**	**7**
8	**1**	**3**	**1**	**2**	**2**	**9**	**0.030**	Flowing water habitats residual low quality: slow trickle, very narrow wetted perimeter	0.2	0.08	0.1	0.03	15.8	Remnant populations of some rheophilic species; all life stages of most rheophilic species at risk or non-viable, many rheophilic species disappear	**0.290**	**8**	**8**
9	**0**	**1**	**0**	**1**	**1**	**3**	**-**	Standing water habitats only, very low quality, no flow	0.06	0.02	0	0	1.86	Mostly pool dwellers; all life stages of most rheophilic species non-viable; most or all rheophilic species disappear	**-**	**9**	**9**
10	**0**	**0**	**0**	**0**	**0**	**0**	**-**	Only hyporheic refugia, no surface water	0	0	0	0	0	Only specialists persist, virtually no development.	**-**	**10**	**10**

1 SIC: Partially submerged hard substrate in current >0.1 m/s
2 SOC: Partially submerged hard substrate in current <0.1 m/s
3 VIC: Submerged vegetation (at least 2-3cm submerged) in current >0.1 m/s
4 VOC: Submerged vegetation (at least 2-3cm submerged) in current<0.1 m/s
5 GSM: Small particles submerged

6.5.3 Integrated Stress Curve

The individual component stresses are illustrated as well as the integrated stress line (black line) (Figure 6-1).

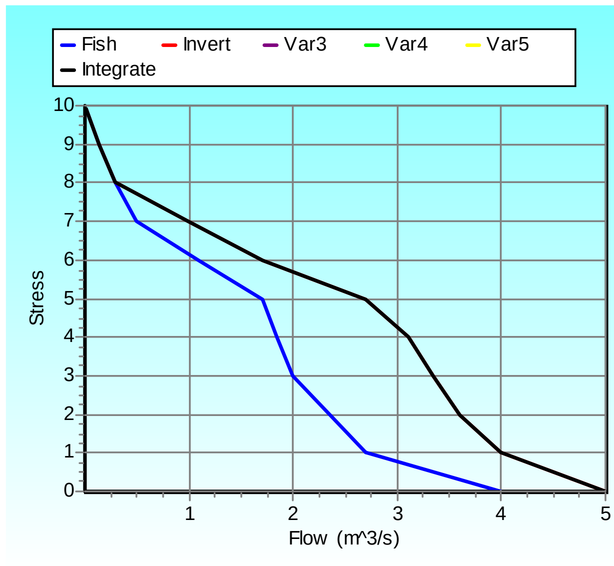
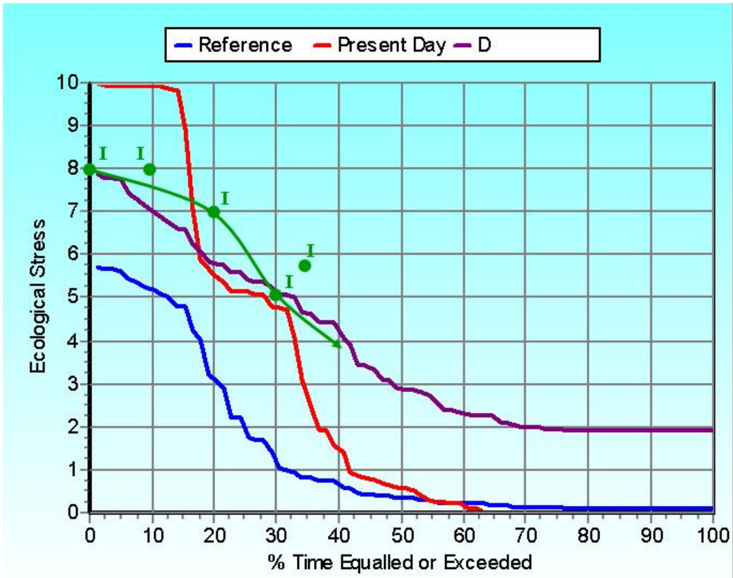


Figure 6-1. Index Stress Curves for EWR Site K3.

6.6 DETERMINATION OF EWR SCENARIOS

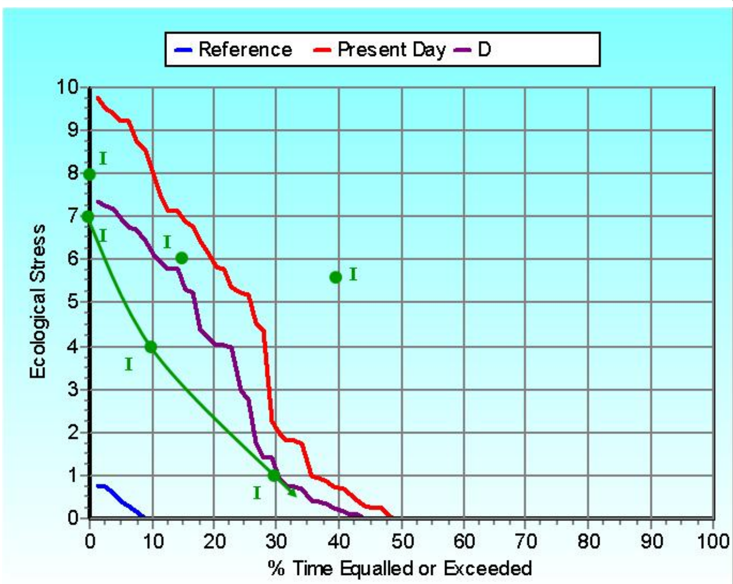
6.6.1 Low-Flow Requirements

The determined integrated stress index must now be used to identify required stress levels at specific durations for the wet and dry month / season. The requirements are illustrated in Figure 6-2.



Dry Season
Dark Green = D

I = Invertebrates



Wet Season
Dark Green = D

I = Invertebrates

Figure 6-2. EWR Site K3 – Stress duration curves for all scenarios.

6.6.2 Motivations: Fish and Invertebrate

The stress referred to in the motiations below refers to fish stress, not component stress.

FISH: DURATIONS AND MOTIVATIONS TO BE USED FOR DETERMINING STRESS REQUIREMENTS.
Indicator: *Chiloglanis pretoriae* The most sensitive rheophilic species is *Chiloglanis pretoriae* and was the selected indicator. This species is dependant on perennial flow in fast deep habitats and its requirements will cater for other rheophilic species.
STRESS REQUIREMENTS FOR THE REC
DRY SEASON

DROUGHT: 12% at stress 6 (IS = 6.9) will allow for low survival of the species in minimal available fast deep conditions. At lower flows fast deep conditions will no longer be present in the river. The stress level should never exceed 8 (0% of the time) otherwise the species could be lost.
MAINTENANCE D: Require moderate habitat for the dry season and stress of 4 (IS=5.9) can be tolerated for 22% of the time.
WET SEASON
DROUGHT: 20%.at stress 5 (IS=6) will still allow limited spawning, but only with few fast flowing sites with favourable habitat conditions. Relatively sparse FD available. A stress of 6 (IS= 6.9) must never (0% of time) occur as this will only allow for minimal survival and no recruitment or breeding. At this point summer temperatures may also become problematic and oxygen levels in water may become critical.
MAINTENANCE D: Require moderate survival habitat for the species and moderate available breeding habitat and recruitment. Therefore a stress of 4 (IS=5.7) can be tolerated for 40% of the time.
General life history requirements *Chiloglanis pretoraie* *Eggs:* Margins of FS (<0.3 m, >0.3 m/s) gravel cobble substrate. October – January. >16°C Duration 7 days 3 - 30% *Larva:* Feeding and Growth: Nursery areas (<0.3 m, >0.2 m/s), Margins ofSS & overhanging vegetation. Duration larval period: 2 months. *Juvenile:* Feeding and Growth: Mostly FS and margins of SS (<0.30m deep >0.2 m/s). Cover: Cobbles & rocks overhanging vegetation. Duration 3-6 months. *Adult:* FD and FS (<0.3 m, >0.3 m/s) gravel, cobble Substrate. Spawning season: October – January. Cue: increased temperature, flow and changes in water quality (e.g. conductivity).

The stress referred to in the motiations below refers to aquatic invertebrate stress, not component stress.

AQUATIC INVERTEBRATES: DURATIONS AND MOTIVATIONS TO BE USED FOR DETERMINING STRESS REQUIREMENTS
Indicator: *Tricorythus* sp. The indicators are rheophilic species.
STRESS REQUIREMENTS FOR RECOMENDED EC
DRY SEASON)
DROUGHT: +/-10%. Stress 8: Survival conditions. Ensure refuge habitats for taxa such as Turbellaria and *Cloeoen excisum.* Flow more than a trickle must be maintained over the riffle, to protect against high temperatures and low oxygen concentrations. The river should never stop flowing as this eliminates many taxa and significantly reduces biodiversity. The main cause of deterioration in present aquatic assemblages is related to zero flows and very low flows, and associated proliferation of benthic algae.
MAINTENANCE D: 30%. Stress 4: Require good riffle habitat for the dry season. Ensure sufficient current velocity (average 0.29 m/s) for flow-dependent taxa such as *Simulium alcocki, Cheumatopsyche afra* and Philopotamidae. Discourage bilharzia snails (*Bulinus africanus* and *Biomphalaria pfeifferi*), mosquitoes (Culicidae) and excessive numbers of Thiaridae which are associated with warm water temperatures at low flows. Provide sufficient flows for maintenance of freshwater shrimps (Atyidae).
WET SEASON
DROUGHT: +/- 10%. Stress 6: Require riffle habitat to ensure sufficient current velocity (average 0.21m/s) for flow-dependent taxa such as *Pseudocloeon glaucum.*
MAINTENANCE D: 30%. Stress 1: Ensure sufficient current velocity (average 0.36 m/s) for flow-dependent taxa such as *Simulium hargreavesi, Simulium damnosum* and C*heumatopsyche afra*, which would be expected for a Category D. Discourage bilharzia snails (*Bulinus africanus* and *Biomphalaria pfeifferi*) and mosquitoes (Culicidae) and excessive numbers of Thiaridae. Ensure that stones in current habitats are kept free of benthic

algae.

The low flow requirements set by fish and aquatic invertebrates were assessed for riparian vegetation.

RIPARIAN VEGETATION		
Flow	**Discharge (m^3/s)**	**Max flow depth (m)**
September drought	0.32	0.32
September maintenance	2.7	0.52
February drought	1.5	0.46
February maintenance	4.0	0.57
Acceptable for riparian vegetation.		

6.6.3 Final Low Flow Requirements

Adjustments to the Desktop Reserve Model requirements were made to fit the specialist requirements as shown in Tables 6.7.

Table 6-7. EWR K3 - Maintenance and drought low flows (REC = D).

Month	Desktop (m^3/s)		Modified (m^3/s)		Ratio (Mod/Desk)	
	Maintenance low flows	Drought low flows	Maintenance low flows	Drought low flows	Maintenance low flows	Drought low flows
Jan	3.308	3.308	2.600	0.589	79%	18%
Feb	4.183	4.183	3.000	0.700	72%	17%
Mar	3.728	3.728	2.900	0.664	78%	18%
Apr	3.510	3.510	2.700	0.624	77%	18%
May	3.035	3.035	2.450	0.540	81%	18%
Jun	2.755	2.755	2.200	0.490	80%	18%
Jul	2.291	2.291	1.950	0.408	85%	18%
Aug	2.029	2.029	1.870	0.361	92%	18%
Sep	1.950	1.950	1.832	0.347	94%	18%
Oct	1.932	1.932	1.818	0.344	94%	18%
Nov	2.323	2.323	1.900	0.450	82%	19%
Dec	2.713	2.713	2.100	0.550	77%	20%

The final curves for EWR 1 are shown in The low flow recommendations for each reserve scenario were finalised (Figure 6-3 and Figure 6-4).

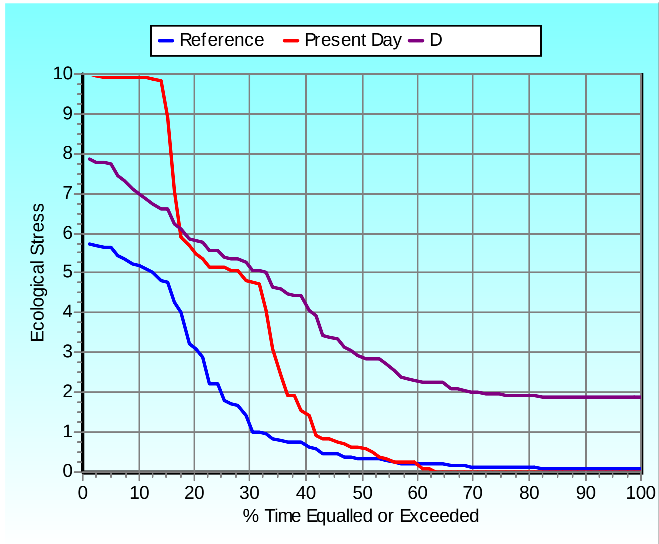


Figure 6-3. Final Stress Duration Curve for reference conditions, present day and category D for the dry season (September) at EWR Site K3.

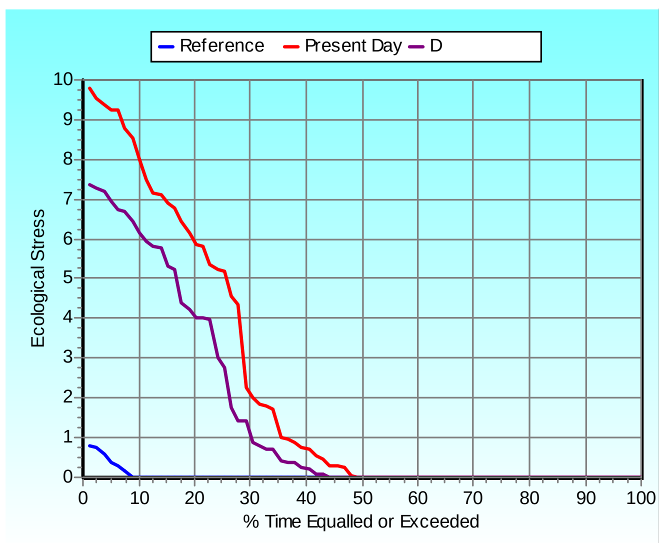


Figure 6-4. Final Stress Duration Curve for reference conditions, present day and category D for wet season (February) at EWR Site K3.

6.6.4 High Flow Requirements

The functions for each Flood Class are described in spreadsheets. A summary of the flood class ranges and recommended number of high flow events required for the REC is provided in Table 6-8 below. Flood class motivations are detailed in Appendix J.

Table 6-8. Flood class parameters and recommended number of high flow events required for the REC – EWR Site K3.

Note: *Timing: 1 = January; 12 = December
P = present, A = absent

EC = D	Flood parameters			NUMBER OF EVENTS					FINAL		Discussion of changes	
FLOOD CLASSES	Range	Range Average	Duration (days)	Geom No.	Veg No.	Invert No.	Fish No.	MIN	No.	*Timing	Primary	Secondary
Class 1	8-16	11.9	2.0	2.0	2.0	2.0	3.0	3.0	3.0	3-11	Fish: Mainly for the Inundation of marginal vegetated areas for spawning. There is also a requirement for cleaning of the remaining sections of gravel/cobble beds for riffle spawning. This flow are mainly to create spawning areas for tropical species in backwaters, secondary channels and in marginal vegetation. These floods will also cater for the gravel spawners and for limited available spawning sites for yellowfish in terms of depth in riffles. It is important for more than one event to activate backwaters (nursery areas) and create opportunities for fish fry enter the mainstream and reduce losses due to drying of backwaters before fry can re-enter.. Most of the fish are serial spawners and need more than one opportunity per annum to ensure that sufficient recruitment do take place.	Inverts: · Flush out benthic algae and fines and provide cue for breeding or emergence.· Provide sufficient current speed to discourage bilharzia and Thiaridae snail populations.· To maintain productivity by providing relevant cue for emergence or for breeding and upstream migration of freshwater prawns (Macrobrachium spp.)· To maintain species diversity by ensuring temporal diversity of flows. · There are presently about two Class 1 floods passing this site. Although the PES for invertebrates is Category E, this is attributed to zero and low flows rather than an absence of freshets. The observed flow records at X1H003 indicate that freshets are still passing the system, despite the presence of Maguga Dam. This indicates that the present day freshets are entering the system downstream of Maguga Dam.
Class 2	16-32	24.1	5.0	2.0	2.0			2.0	2.0	11-4	Geom: Maintain variability for D. Movement of fine gravels.	Veg: Maintenance of Geomorphology as Class D will cater for vegetation
Class 3	32-63	46.4	6.0	2.0	2.0			2.0	2.0	11-4	Geom: Maintain variability for D. Fine gravel transport.	eg: Maintenance of Geomorphology as Class D will cater for vegetation
Class 4	63-126	84.1	7.0	1.0	1.0			1.0	1.0	11-4	Geom: Maintain variability for D. Medium gravel transport.	eg: Maintenance of Geomorphology as Class D will cater for vegetation
1:2	140	-	8.0	P				P	1:2	Any	Geom: Maintain channel geometry and Bed sorting. Key discharge for geomorphological processes.	General habitat maintenance.
1:5	307	-	12.0						-	-	See 1:10.	General habitat maintenance.
1:10	457	-	12.0	P				P	-	-	Fish: Required to inundate floodplains in Moz., which stimulates large recolonisation migrations. Was nat 1:5 - c. 800 cumecs. - now require c. 1:10.	Geom: These floods would also now be the only ones that would inundate the 'now' raised detatched floodplain at site K3. Although there is some evidence to suggest that they are periodically inundated by backfill from the weir downstream.
1:20	663	-	12.0						-	-	Cannot be released.	General habitat maintenance.
Important Note:	There is a 1:5 to 1:10 year requirement for a large flood to inundate floodplains in Mozambique, which will allow huge numbers of fish, especially tropical species such as *Labeo* spp, *Barbus* spp., *tigerfish* (*Hydrocynus, Micralestes* and *Brycinus*) and *Mesobola* to re-enter the river and trigger massive upstream recolonization migrations. These migrations are essential to replenish fish stocks in Komati River and for maintaining genetic diversity in the system. Current attenuations of these flood events as a result of upstream development are threatening this phenomenon.											

6.7 FINAL RESULTS

The final EWR results for the recommended category is summarised below (Table 6-9 to 6.10) and the detailed results are presented in Appendix K.

Table 6-9. EWR Summary Table for EWR Site K3 for Recomended Ecological Category: D.

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	VOL ($X10^6$ m^3)	nMAR%
EWR SITE K3: EMC =D.														
LOW FLOWS														
MAINTENANCE LOW FLOWS (m^3/s)	1.8	1.9	2.1	2.6	3.0	2.9	2.7	2.5	2.2	2.0	1.9	1.8	**71.650**	**7.05**
DROUGHT LOW FLOWS (m^3/s)	*0.3*	*0.5*	*0.6*	*0.6*	*0.7*	*0.7*	*0.6*	*0.5*	*0.5*	*0.4*	*0.4*	*0.3*	***15.927***	***1.57***
HIGH FLOWS														
FLOOD (daily average: m^3/s)	11.9	24.1	24.1	46.5	46.5	1)84.1 2)140	11.9	-	-	-	-	11.9	**76.188**	**7.50**
Duration (in days)	2	5	5	6	6	1) 7 2) 8	2	-	-	-	-	2		
Return period (years)	1:1	1:1	1:1	1:1	1:1	1) 1:1 2) 1.2	1:1	-	-	-	-	1:1		
LONG-TERM MEAN													***183.681***	***18.07***

Table 6-10. EWR rule table for REC: D

Desktop Version 2, Printed on 28/11/2004
Summary of EWR rule curves for : EWR K3 Monthly Nat EWR K3
Determination based on defined BBM Table with site specific assurance rules.
Regional Type : E.Escarp REC = D

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

This EWR rule table can be used in combination with the natural duration curves below for implementation.

Reserve flows without High Flows

Month	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	3.615	3.605	3.568	3.490	3.337	3.056	2.586	1.892	1.056	0.427
Nov	3.779	3.764	3.721	3.635	3.470	3.175	2.690	1.988	1.155	0.533
Dec	4.177	4.157	4.109	4.011	3.827	3.500	2.968	2.206	1.308	0.640
Jan	5.171	5.138	5.071	4.939	4.694	4.269	3.592	2.637	1.529	0.710
Feb	5.967	5.938	5.867	5.726	5.458	4.983	4.211	3.105	1.801	0.830
Mar	5.768	5.744	5.679	5.547	5.294	4.841	4.098	3.022	1.745	0.791
Apr	5.370	5.355	5.301	5.188	4.966	4.559	3.876	2.870	1.657	0.744
May	4.873	4.865	4.821	4.726	4.535	4.177	3.564	2.641	1.509	0.651
Jun	4.376	4.371	4.333	4.252	4.087	3.772	3.227	2.397	1.371	0.591
Jul	3.878	3.878	3.849	3.783	3.645	3.375	2.897	2.154	1.218	0.499
Aug	3.719	3.715	3.682	3.612	3.469	3.197	2.726	2.009	1.123	0.448
Sep	3.643	3.637	3.604	3.531	3.386	3.114	2.648	1.945	1.084	0.432

Natural Duration curves

Oct	22.435	17.992	13.430	11.264	10.140	8.643	7.941	7.269	6.261	4.954
Nov	59.313	39.063	29.444	23.677	19.564	17.940	16.574	14.788	9.306	6.327
Dec	86.526	69.598	57.400	40.961	33.942	29.204	25.258	21.244	16.805	7.228
Jan	132.098	92.047	73.723	60.357	46.924	35.850	31.829	27.225	22.555	18.399
Feb	246.532	134.970	76.120	55.915	44.267	34.487	31.130	26.939	23.822	19.610
Mar	129.600	71.024	52.737	39.397	31.892	29.794	26.449	22.185	17.955	15.252
Apr	60.544	38.873	32.971	29.672	27.832	25.829	23.681	19.267	15.694	12.018
May	29.686	24.854	22.390	21.050	20.288	18.160	16.566	14.303	12.593	8.695
Jun	23.472	19.583	16.682	15.961	15.251	13.978	12.647	11.134	9.468	6.501
Jul	18.705	14.755	13.381	11.884	11.126	10.559	9.468	8.580	7.389	5.190
Aug	14.397	12.254	10.977	9.845	9.353	8.531	7.796	7.247	6.470	4.887
Sep	15.448	11.335	9.857	9.182	8.850	7.982	7.438	6.686	5.826	5.150

Total Reserve Flows

	% Points									
Month	**10%**	**20%**	**30%**	**40%**	**50%**	**60%**	**70%**	**80%**	**90%**	**99%**
Oct	4.417	4.404	4.358	4.262	4.074	3.730	3.152	2.300	1.272	0.499
Nov	6.618	6.590	6.514	6.360	6.064	5.533	4.662	3.402	1.906	0.789
Dec	6.925	6.891	6.808	6.642	6.327	5.768	4.861	3.561	2.028	0.887
Jan	12.875	11.816	10.880	9.999	9.071	7.513	6.311	4.616	2.648	1.193
Feb	14.496	13.338	12.311	11.348	10.334	8.616	7.269	5.337	3.061	1.367
Mar	35.319	31.394	28.024	25.060	22.241	17.501	14.775	10.830	6.148	2.652
Apr	6.198	6.181	6.117	5.986	5.728	5.255	4.461	3.291	1.880	0.819
May	4.873	4.865	4.821	4.726	4.535	4.177	3.564	2.641	1.509	0.651
Jun	4.376	4.371	4.333	4.252	4.087	3.772	3.227	2.397	1.371	0.591
Jul	3.878	3.878	3.849	3.783	3.645	3.375	2.897	2.154	1.218	0.499
Aug	3.719	3.715	3.682	3.612	3.469	3.197	2.726	2.009	1.123	0.448
Sep	4.471	4.464	4.422	4.333	4.154	3.818	3.242	2.375	1.313	0.507

6.8 CONFIDENCE

The confidence was evaluated according to a score of 0-5 with zero reflecting 'no confidence' and 5 reflecting 'very high' confidence (Table 6-11).

Table 6-11. Confidence Ratings for EWR Site K3.

	EWR SITE	AVAILABLE DATA	ECOLOGICAL CLASSIF.	OUTPUT LOW FL	OUTPUT HIGH FL
HYDROLOGY		3	3		
	Confidence is fairly high on the accuracy of the simulation of observed (historic) flows. The simulation is based on calibrations done a number of years ago and is a reasonable representation of the time series in terms of the range of flows. The low flows are slightly higher based on nature of calibration.				
HYDRAULICS	3	4/0=2		3	2
	Measured flows in the range 0.031 to 6.6m^3/s. Recommended low-flows for a Category D (PES=E) in the range 0.29 to 4.0m^3/s (ie. within measured range – but concern regarding backup from the raised downstream weir), and high flows in the range 12-84 (within year) to 140-663 (1:2-1:20) (ie. above measured values and concern regarding backup from raised downstream weir).				
QUALITY		4.5	4		
	Water quality data used from DWAF monitoring programme at monitoring point X1H003Q01 (1977 – 2005). No temperature, dissolved oxygen and turbidity data available. Confidence is the data is a high. EC confidence in data was medium to high (long data base of 28 years) due to limited data being available and no temperature, dissolved oxygen, chlorophyll and turbidity data available				
GEOMORPH	2	3	4	N/A	3.5
	Long-term photos at small scale, post dam hydrology data only. Site visit by specialist. Clear evidence of degradation based on upstream impacts and condition of the site. Uncertainty about impact of downstream weir on flood levels; some evidence that channel incision has caused de-linking form floodplain.				
RIP VEG	3	3	4	N/A	3
	EWR site: A good site, but badly degraded (main channel deeply incised, and relic channels desiccated) **Available data:** Vegetation profile studied twice (once in winter and once in Autumn). Previous status of vegetation unknown. **Ecological classification:** Confirmed by RVI analysis **Output low flow:** Recommendations not tested **Output high flow:** Recommendations match current situation				
FISH	4	4	4	3	5

	Confidence in available data is moderately high because historic data goes back as far as the 1960's and pre Maguga Dam surveys. Several surveys has been conducted in this Resource Unit over last three years. Moderately high confidence in the EC based on the available data and several recent surveys conducted during last 3 years in this Resource Unit. Moderately high confidence in the site provided good indications of the abundance of critical habitat required by indicator species under different flows and could be used to set stress. Moderately high confidence in low flows based on the available hydraulic data and fish info it was possible to set realistic flows in terms of its stress and availability of critical habitat for indicator species. Moderately high confidence in high flows based on our understanding of the species in this Resource Unit, fish has a need of Class 1 floods in terms of breeding and migrations. There is a requirement for a large flood to inundate floodplains in Mozambique which will allow important massive upstream recolonization migrations. Only moderately confident that floods asked for by others will cater for the latter.				
INVERT	2	4	4	3	4
	Moderate biotopes present: Highly suitable sand; Suitable SIC, SOC, MVIC, MVOC and gravel. Absent biotopes include bedrock and mud. Abundance of benthic algae limits habitat availability. Data were available for 13 SASS samples recorded at 4 sampling sites within this Resource Unit, so confidence in the results was high. Information available was suitable for EcoClassification evaluation as required, although conditions are variable over time. The invertebrate requirements are the critical requirements (low flows), and the influence of water quality reduced confidence in predictions. The invertebrate requirements for high flows are being met by the requirements of fish.				

7. EWR SITE G1 – VAALKOP

7.1 ECOLOGICAL CATEGORIES

The PES for EWR Site G1 is summarised in Table 7-1, and a description of the reference conditions, and PES for individual components is presented in Table 7-2.

Table 7-1. The PES for EWR Site G1.

Driver Components	Component PES	Driver PES	ECOSTATUS PES
HYDROLOGY	B	C	D
GEOMORPH	D		
WATER QUALITY	C		
Response Components	Component PES	Instream PES	
FISH	D	D	
AQUATIC INVERTS	D		
RIPARIAN VEG	D	D	

Note: Without considering riparian vegetation, the EcoStatus model results in a Category C/D. If riparian vegetation is taken into account (which is in a Category D), the PES is more likely to be a Category D with potential for improvement as Working for Water should be clearing alien invasive species from the area.

Table 7-2. Description of the PES categories for each habitat driver and biological response for EWR Site G1.

Category B = Largely Natural; C= Moderately Modified and Category D = Largely Modified.

Driver and responses	Reference conditions	PES	PES description
			Overall PES for Drivers Moderately Modified (Category C).
Hydrology	nMAR= 18.4 million m^3/a	**B**	pMAR= 12.6 million m^3/a The main changes from natural conditions are seen in the reduction of low and moderate flows due mainly to forestry and the removal of medium floods due to upstream trout dams. Seasonality has not changed from natural conditions. The river doesn't stop flowing (i.e. no zero flows). The main changes from natural conditions are: • pMAR is 69% of nMAR; 35% reduction at 70% exceedance • Seasonal index almost identical • Moderate flows: 27% reduction at 50% exceedance • High flows: 23% reduction at 10% exceedance
Geomorphology	G1 is classified as an upper foothill site on account of its channel gradient of 0.0067. The valley floor is characterised by a flood plain so the reference condition would	**D**	Catchment land use changes are considered to have had a small effect on geomorphological effectiveness of floods at EWR Site G1. EWR Site G1 is not impacted by upstream impoundments, but the event hydrology is likely

	probably be a meandering channel with a pool-riffle sequence comprised of coarse gravels or cobble. Bank erosion would occur naturally on the outer bends of meanders.		to have been effected by land use changes within the catchment. Likely that the magnitude of flood events with a high recurrence interval may have increased. These have caused following changes in sediment inputs, riparian vegetation and channel structure. **Sediment inputs:** Moderate increase in terms of sediment input from forest roads, other dirt roads, mining and upstream bank erosion. There is a significant proportion of sand and fine gravels in the bed material. **Riparian Vegetation:**. By 1997 the river corridor was heavily infested with black wattle and the upper catchment was extensively afforested. By the time of the site visit in November 2003 the black wattle had been cleared. There is widespread field evidence that black wattle is associated with incised channels and it is likely that some of the bank steepening observed at G1 can be attributed to this. The present vegetation cover affords some bank stability with a continuous ground layer on the active channel banks. Locally bank erosion of steep channel banks is evident. Continuous reeds protect the channel margins. The rating for riparian vegetation impacts at G1 is large. **Channel structures:** none
Water Quality	The reference water quality of the Gladdespruit would not have been impacted by upstream afforestration and mining. The water quality variable that would be improved are turbidity, salts and electrical conductivity and a reduction in sulphates, an increase in pH and decrease in metal concentrations.	**C**	The change from natural conditions have been caused by afforestation and mining (gold) activities. Mamry village is a source of raw sewerage affecting water quality. Sulphates were not recorded at the site, but were previously noted from the air.
			Overall Instream PES Largely Modified (Category D)
Riparian Vegetation	No exotic species present.	**D**	The main changes triggered by flow related causes (attenuation of intra-annual floods caused by upstream trout dams, streamflow reduction caused by forestry plantations) and non-flow related causes (upstream forestry and mining activities, seepage of acid mine water from abandoned gold mines gravel road crossings, increased sedimentation, disturbance form forestry activities (logging, burning, grazing), organic pollution from Mamre, alien plant invasion).
Marginal zone: Sedgy Grassland on stream banks	• Annual flood benches would support sedge clumps (Schoenoplectus brachyceras) and shrubs such as Cliffortia species in loose silty sand / mud at water's edge. • Mesophytic grasses such as Leersia hexandra and Panicum hymeniochilum would form a continuous sward on the annual flood bench • The upper limit of the marginal zone would support tree ferns (Cyathea dregei), and mesophytic forbs such as Senecio inaequidens. • Perched lateral channels would be dominated by grass species such as Imperata cylindrica in dry phases, and by Typha capensis and Periscaria attenuata in wet phases. • Naturalised exotic species would not be present.		• small reduction in biomass of reeds, marginal sedges and tree ferns probably as a result of channel incision. • small reduction in cover of mesophytic grasses. • moderate reduction of indigenous species of grasses, sedges and shrubs • moderate change in overall species composition, • presence of the naturalized exotic grass *Paspalum dilatatum*. • small reduction in structure due to fewer tree ferns and shrubs
Lower riparian zone: Open Woodland on	• Large mesophytic tree species such as *Combretum erythrophyllum* would occur on this alluvial floodplain.		• large reduction in biomass as a result of losing trees and shrubs (presumably because of past invasion by alien species (Wattle and Bugweed).

firm alluvial plain	• Smaller trees and shrubs such as *Dais cotinifolia, Leucosidea sericea* and *Buddleja salviifolia* would also be represented. • The grass layer would be dominated by species such as *Cynodon dactylon* with good cover. • Typically terrestrial species, naturalised exotic species, and alien invasive tree species would not occur.		• large reduction in cover of grasses due to shading by alien invaders • serious reduction of indigenous species and other mesophytic shrubs and forbs as a result of terrestrialisation and past invasion by alien species. • serious change in overall species composition since terrestrial and alien species invade. • serious reduction in structure due to replacement of woody riparian species such as with terrestrial and invader species (wattle)
Upper riparian zone: Gallery forest on Hillslope / Scrub forest on firm alluvial terrace	• The colluvial slopes and alluvial terraces would host gallery forest on the right bank and a scrubby type of riparian forest on the left bank. • Typical large tree species common to both banks would be *Rhus* species, whilst typical understorey shrubs would include *Euclea crispa* and *Diospyros lycioides*. • In the herb layer grasses such as *Setaria megaphylla,* ferns such as *Cheilanthes viridis,* and suffrutices such as *Rumex sagittatus* would be typical. • There would be no alien invasive species present.		• moderate increase in biomass as a result of invasion of understorey by Wattle Granadilla, Bugweed) and Rubus sp. • moderate reduction in herbaceous cover as a result of invasion • large reduction of indigenous forest species • large change in overall species composition as a result of invasion • moderate change due to alien-plant invasion but recruitment of large canopy species still evident.
Fish	Eleven (11) species expected to occur under natural conditions. Abundance of species preferring slow flowing habitats with undercut banks with marginal vegetated areas (*Barbus anoplus, Tilapia sparrmanii* and *Pseudocrenilabrus philander*). The presence of catadromous species (migrates to sea to breed) *Anguilla mossambica*, other migratory species such as *Barbus argenteus, Labeobarbus marequensis* and *Labeobarbus polylepis* and *Chiloglanis emarginatus*.	**C**	Eleven species expected, 5 recently collected. **Flow depth:** Fish preferring fast flowing habitats absent. Low abundance of species preferring slow flowing habitats with undercut banks and marginal vegetated areas. Historic record for *Chiloglanis emarginatus* in this river and its absence may be related to the absence of connectivity with mainstream and a reduction of flow and subsequent loss of habitat as a result. **Flow Modification:** Absence of *Anguilla mossambica* due to impoundments downstream and no connectivity with the mainstream, preventing recolonization. Absence of migratory species and fish species dependant on permanent flow. **Substrate:** Low abundance of fish preferring substrate in fast flowing habitats and preferring undercut banks and marginal vegetated areas. **Water Quality:** Many species sensitive and moderately sensitive to water quality changes.
Aquatic Invertebrates	Taxa found under natural conditions would include Hydrachnellidae, Perlidae, Heptageniidae, Blephariceridae, Tricorythidae, Protoneuridae, Calopterygidae, Naucoridae, Hydraenidae, Psephenidae, *Simulium vorax* and Athericidae.	**D**	Confidence in the results was high. The main changes triggered by flow and non-flow related causes (see above). • characterised by a very low diversity but generally high numbers of Baetidae, Hydropsychidae, Corixidae and Chironomidae • absence or low abundance of Tricorythidae, Heptageniidae, Gastropoda and Coenagrionidae • functional feeding groups were most often dominated by predators and gathering collectors • Reduction in the suitability of instream habitats • the development of yellow boy (*Sphaericus natans*) (restricted to a short stretch of river downstream of Mamre) • Reduction of aquatic biota sensitive to changes in water quality

Additional tables providing scores for the individual driver components and biological responses (instream) and a summary of the EcoStatus are available in Appendix F.

7.2 TRENDS

The aquatic invertebrate conditions are considered stable under current development conditions, and may improve following the upgrading of the Mamre sanitation system in 2004. Fish are considered stable. Geomorphology is on a negative trend. Channel instability will continue; but may be reversed with continued clearing of wattles and careful follow-up.

The trends for vegetation could be either stable or negative depending on management of alien plant invasions. Despite the recent clearing of wattle in the Lower Riparian Zone, recruitment is still taking place, and if alien plant invasions are left unchecked, the current condition of riparian vegetation is likely to decline, in which case the trend would be negative. Conversely, if alien invasions are consistently managed, the trend could become stable. Assuming current conditions, the predictions regarding PES for vegetation will remain Largely Modified (Category D) in the short-term (<5years) but will deteriorate to Largely to Seriously Modified (Category D/E) in the long terms (>20 years).

7.3 IMPORTANCE

7.3.1 Ecological Importance and Sensitivity

The Ecological Importance and Sensitivity of this Resource Unit G within the provincial reserve was considered high under natural conditions and low under present conditions. The confidence for this assessment was high. The main determinants were the presence of two flow-dependent fish species (*Chiloglanis pretoriensis, Amphilius uranoscopus*), the sensitivity to flow changes and flow related water quality changes. Detailed results are presented in Appendix G.

7.3.2 Socio-cultural Importance

The area was considered of low Socio-cultural Importance. Landuse in Resource Unit G is dominated by pine plantations, mining, trout farms and extensive cattle grazing. A small portion near the confluence with the Komati River is used for irrigated agriculture. Residents in the forestry village of Mamre source their water from a tributary of the Gladdespruit, while trout lodges are supplied by boreholes. The direct dependency on the Gladdespruit for potable water and subsistence economic activities is negligible, as most people in the area are formally employed. There are some abandoned gold mines and associated buildings that would have historical value. Detailed results are presented in Appendix H.

7.4 RANGE OF ECOLOGICAL CATEGORIES

7.4.1 Recommended Ecological Category

The Ecological Importance and Sensitivity (present) was low and the Socio-cultural Importance low, therefore the PES Category D was accepted as the REC.

7.4.2 Alternative Ecological Categories

One alternative Ecological Category was considered (Category C) as it is not ecologically viable to go below a Category D. The conditions for achieving this Category are given in Table 7-3 and summarised in Table 7-4.

Table 7-3. Summary of the conditions defining the alternative Ecological Category.

Driver and responses	Alternative C
General	Category C conditions would comprise: (a) improved Mamre village sewerage disposal, (b) better fire-erosion control, (c) monitoring of acid mine drainage from abandoned gold mines, (d) limited trout dams, (e) a fishway on weir, (f) management (stabilise) road crossings to control sediment inputs and (g) continued clearing of alien vegetation in the rest of the Resource Unit.
Geomorphology	Depends on erosion control in the catchment, paying particular attention to dirt roads that connect to the stream network. Continued clearing of black wattle from the riparian zone, with adequate follow up to prevent re-establishment. After initial destabilisation, stream banks can be left to recover as long as event flows meet the requirements of the Ecological Reserve.
Riparian Vegetation	Improvement within the Marginal Zone: no significant change in vegetation abundance and cover, a small reduction in number of indigenous species of grasses and sedges, a small change in overall species composition, the presence of the naturalized exotic grass *Paspalum dilatatum* and a small reduction in structure due to fewer tree ferns and shrubs. An improvement within the Lower Riparian Zone: moderate reduction in biomass as a result of losing shrubs, a moderate reduction in grass cover and indigenous species due to terrestrialisation and past invasion by alien species, a moderate change in overall species composition since terrestrial species and alien invader species invaded the zone and moderate reduction in structure due to replacement of woody riparian species. Improvement within the Upper Riparian Zone: small increase in biomass, a small reduction in herbaceous cover, a moderate reduction of indigenous forest species, a moderate change in overall species composition and a small change in structure.
Fish	Increased baseflows would re-establish fish migrations allowing some of the migratory species to periodically recolonize the river. All migratory species presently absent. A fishway on the Friesland weir would connect the Gladdespruit with the mainstream Komati River during flood events and may provide opportunity for species migration. Improved water quality is also important. The diversity and abundance of species dependant on fast flowing (fast shallow and fast deep) and slow flowing habitats will also increase. Higher diversity of fish dependant on permanent flow will be present if migratory species re-establish. Species dependant on pools (water column) will have the opportunity to re-establish in the river and species dependant on rocky substrate may increase. Fish movement within the will improve diversity of fish closer towards the reference condition.
Aquatic Invertebrates	Additional taxa that are likely to be found under improved conditions are Gerridae (Water striders), Veliidae (Broad-shouldered water striders), Tabanidae (Horse Flies), Coenagrionidae, Muscidae, Naucoridae (Creeping water bugs), Hydrachnellidae (Water Mites), Tricorythidae (Stout crawlers) and Perlidae.

Driver Components	Component PES	Driver PES	ECOSTATUS PES
HYDROLOGY	B	B	C
GEOMORPH	C		
WATER QUALITY	B		
Response Components	Component PES	Instream PES	
FISH	C	C	
AQUATIC INVERTS	C		
RIPARIAN VEG	C	C	

Table 7-4. Summary of the Alternative EcoStatus C for EWR Site G1.

The rule-based models for the individual components were run in a predictive manner and based on the above hypothetical scenario, the matrixes that would be affected were changed. These spreadsheets with the changes indicated as different colours are included in the specialist appendices.

7.5 STRESS INDICES

Refer to Appendix I for the flow stress indices for the REC and alternative EC for fish and aquatic invertebrates.

7.5.1 Stress Index: Fish

The rheophilic species selected was *Chiloglanis pretoriae* which is dependant on the presence of moderately fast flowing waters. The semi-rheophilic was *Barbus anoplus*. The rheophilic species was the most stressed under all the flow conditions (Table 7-5).

With a flow of 1 m^3/s there is abundant fast habitat available and none of the life history requirements of *Chiloglanis pretoriae* are likely to be stressed. At a flow of 0.32 m^3/s there is a significant loss in the availability of fast habitats that will significantly affect breeding and to a lesser extent available habitat and suitable cover. At a flow of 0.27 m^3/s the availability of fast deep habitats is further reduced and breeding will be restricted to only a few areas. The availability of suitable cover will also further reduce the abundance of the species. At a flow of 0.5 m^3/s the species will only survive in limited numbers due to a lack of suitable fast flowing habitats. Water quality will also be affected at this flow further affecting the health of fish. At a flow of 0.01 m^3/s no suitable fast flowing habitats will be present and causing species loss.

Rheophilic species represents the highest stresses at any given flow and this was therefore used to generate the stress index.

Table 7-5. Stress table for rheophilic fish species showing Habitat Suitability at EWR Site G1.

FLOW (CUMEC)	1.68	1.320	1.000	0.320	0.270	0.100	0.050	0.010	0.000
RELATIVE ABUNDANCE FLOW-DEPTH & COVER RATING: 0=NONE;1=RARE;2=SPARSE;3=MODERATE;4=ABUNDANT;5=VERY ABUNDANT)									
FAST DEEP	5	4.0	3.0	2.0	2.0	1.0	0.0	0.0	0.0
FAST SHALLOW	2.0	3.0	4.0	3.0	2.0	1.0	1.0	0.0	0.0
SLOW DEEP	1.0	2.0	2.0	3.0	3.0	2.0	2.0	2.0	1.0
SLOW SHALLOW	2.0	2.0	2.0	4.0	4.0	5.0	4.0	3.0	2.0
SUITABILITY FOR DIFFERENT FISH REQUIREMENTS PER HABITAT GUILD									
RHEOPHILIC	**SPECIES:**								
	Cpre								
Breeding and early life-stages=	5.0	5.0	5.0	3.0	1.0	0.0	0.0	0.0	0.0
Survival /Abundance =	5.0	5.0	5.0	4.0	3.0	2.0	1.0	0.0	
Cover =	5.0	5.0	5.0	4.0	3.0	2.0	1.0	0.0	
Health and condition=	5.0	5.0	5.0	5.0	4.0	3.0	2.0	0.0	
Water quality=	5.0	5.0	5.0	5.0	4.0	3.0	2.0	0.0	
Rheophilic stress - (breeding requirements included)	**0**	**0**	**0**	**2**	**4**	**6**	**8**	**10**	**10**
FLOW (CUMEC)	1.68	1.32	1.00	0.32	0.27		0.05	0.01	0.00
FLOW-DEPTH CONVERTED TO HABITAT RESPONSE (10=ALL FLOW-DEPTH CLASSES ABSENT (RIVER DRY); 0=FLOW-DEPTH *CLASSES OPTIMUM FOR SITE* ; 9=NO FLOW)									
Fast deep	0	2	4	6	6	8	10	10	10
Fast shallow	6	4	2	4	6	8	8	10	10
Slow deep	8	6	6	4	4	6	6	6	8
Slow shallow	6	6	6	2	2	0	2	4	6
OVERALL HABITAT RESPONSE	**5**	**5**	**5**	**4**	**5**	**6**	**7**	**8**	**9**

7.5.2 Stress Index: Aquatic Invertebrates

Optimum Flow rates: 0.3 and 0.6 m/s
Key Species: *Centroptiloides bifasciata*
Critical Habitats: Riffle

The relationships between aquatic invertebrate habitats, flows, stresses and associated biological responses at EWR Site G1 are detailed in Table 7-6. The critical factors that were used to determine the stress curve were the current speeds, overall species composition and an indicator species *Centroptiloides bifasciata* and Psephenidae. During the field survey on 4th August 2003 the flow was 0.27 m^3/s and a habitat stress score of 5 was allocated. Biomonitoring data showed that there were limited populations of flow-sensitive species and so the biological response stress was also rated as 2.

Table 7-6. Stress Table – Flow Dependant Invertebrate at EWR Site G1.

Habitat Flow Response Index	HABITAT ABUNDANCE AND SUITABILITY					TOTAL	FLOW	HABITAT RESPONSE	HABITAT CHARACTERISTICS					BIOTIC RESPONSE	FLOW	SPECIES STRESS	INTEGRATED STRESS
	SIC	SOC	VIC	VOC	GSM				Max depth (m)	Avg depth (m)	Max vel (m/s)	Avg vel (m/s)	WP (m)				
0	5	3	5	5	3	21	1.320	All habitat in excess, very high quality: very fast, very deep, very wide wetted perimeter	0.54	0.35	1.7	0.6	6.62	All very abundant, all healthy, all species persist	1.000	0	0
1	5	3	4	5	3	20	1.000	All plentifull, high quality; fast, wide wetted perimeter	0.53	0.33	1.4	0.5	6.5	All abundant, all healthy, all species persist	-	1	1
2	5	3	4	4	3	19	0.760	Critical habitats sufficient; quality slightly reduced: fast, wetted perimeter slightly reduced	0.48	0.3	1	0.41	6.42	Slight reduction for sensitive rheophilic species, all healthy in some areas, all species persist	0.760	2	2
3	4	3	3	4	3	17	0.500	Reduced critical habitat, reduced critical quality; moderate velocity, fairly deep, wetted perimeter slightly/moderately reduced	0.44	0.27		0.31	6.28	Reduction for all rheophilic species; all healthy in limited areas; all species persist	0.500	3	3
4	3	4	3	3	3	16	0.320	Critical habitats limited; moderate quality: Moderate velocity, Some deep areas, Wide WP moderately reduced	0.4	0.23	0.7	0.23	6.15	Further reduction for all rheophilic species; all viable in limited areas, critical life stages of some sensitive rheophilic species at risk, all species persist	0.320	4	4
5	3	4	2	3	3	15	0.270	Critical habitat very reduced; moderate/ low quality; moderate/slow velocity, few deep areas wetted perimeter moderately/very reduced	0.38	0.21	0.6	0.2	6.08	Limited populations of all rheophilic species. Critical life-stages of sensitive rheophilic species at risk or non-viable; all species persist	0.270	5	5
6	2	3	1	2	2	10	0.110	Critical habitat residual. Low quality; Moderate/slow velocity.	0.32	0.17		0.12	5.59	Sensitive rheophilic species rare, critical stages of sensitive rheophilic species non-viable, and at risk for some less sensitive species. All species persisit in the short-term	0.110	6	6
7	1	2	0	1	2	6	0.050	No critical habitat, other habitats moderate quality; slow, narrow wetted perimeter	0.27	0.14	0.2	0.08	4.8	Most rheophilic species rare; All life-stages of sensitive rheophilic species at risk or non-viable. Most sensitive rheophilic species disappear	-	7	7
8	1	1	0	1	1	4	0.004	Flowing water habitats residual low quality: slow trickle, very narrow wetted perimeter	0.16	0.09		0.02	2.83	Remnant populations of some rheophilic species; all life stages of most rheophilic species at risk or non-viable, many rheophilic species	0.050	8	8
9	0	1	0	1	1	3	-	Standing water habitats only, very low quality, no flow	0.1	0.06	0	0	2.02	Mostly pool dwellers; all life stages of most rheophilic species non-viable; most or all rheophilic species disappear	0.004	9	9
10	0	0	0	0	0	0	-	Only hyporheic refugia, no surface water	0	0	0	0	0	Only specialists persist, virtually no development.	-	10	10

1 SIC: Partially submerged hard substrate in current >0.1 m/s
2 SOC: Partially submerged hard substrate in current <0.1 m/s
3 VIC: Submerged vegetation (at least 2-3cm submerged) in current >0.1 m/s
4 VOC: Submerged vegetation (at least 2-3cm submerged) in current<0.1 m/s
5 GSM: Small particles submerged

7.5.3 Integrated Stress Curve

The individual component stresses are illustrated as well as the integrated stress line (black line) (Figure 7-1).

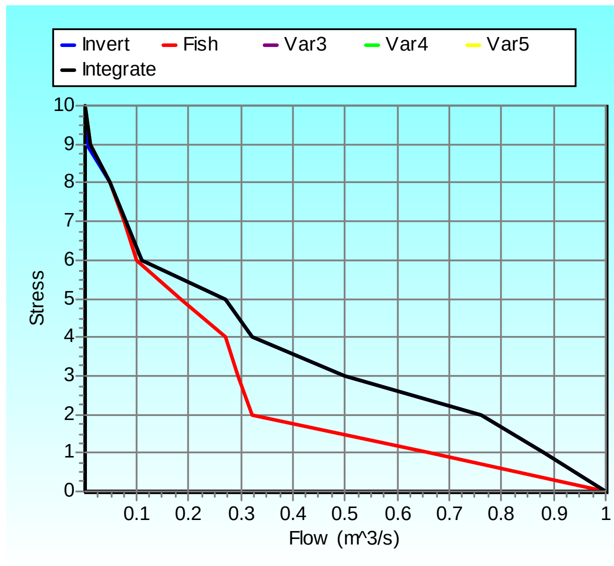


Figure 7-1. Index Stress Curves for EWR Site G1.

7.6 DETERMINATION OF EWR SCENARIOS

7.6.1 Low-Flow Requirements

The determined integrated stress index must now be used to identify required stress levels at specific durations for the wet and dry month / season. The requirements are illustrated in Figure 7-2.

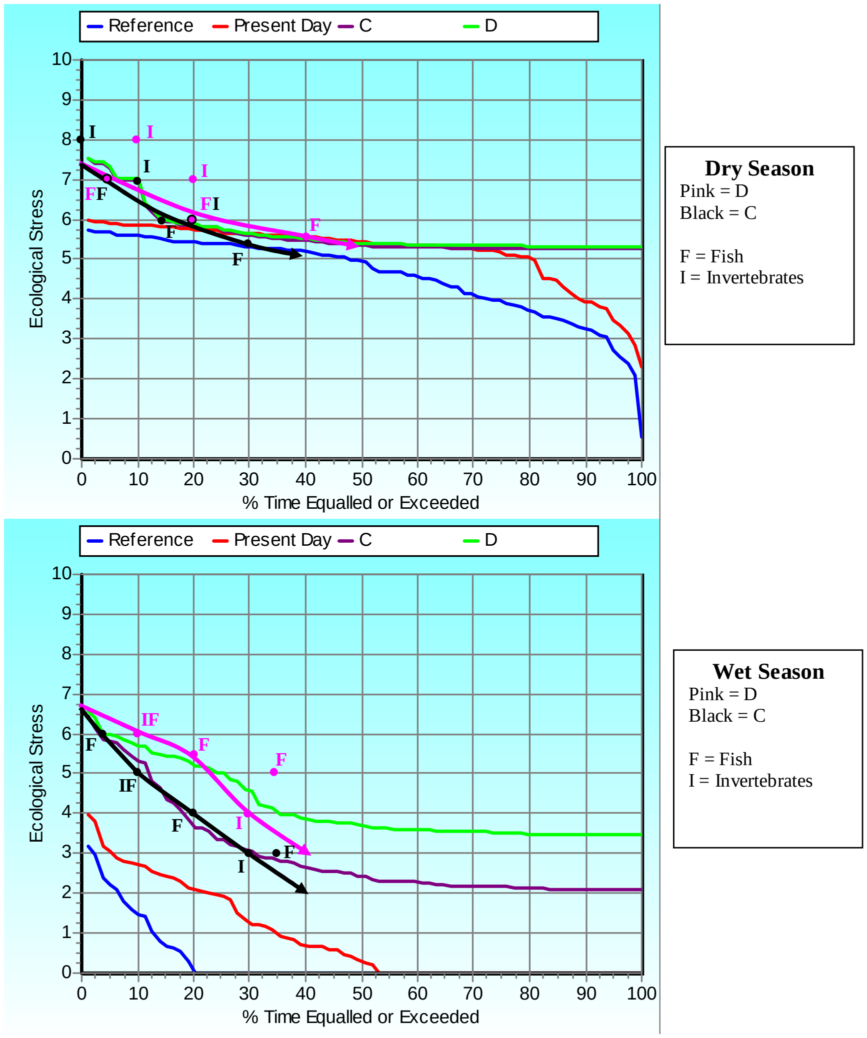


Figure 7-2. EWR Site G1 – Stress duration curves for all scenarios.

7.6.2 Motivations: Fish and Invertebrate

The stress referred to in the motiations below refers to fish stress, not component stress.

FISH: DURATIONS AND MOTIVATIONS TO BE USED FOR DETERMINING STRESS REQUIREMENTS.
Indicator: *Chiloglanis pretoriae* The most sensitive and abundant rheophilic species was selected as indicator. This species is dependant on perennial flow in fast deep habitats and its requirements will cater for the other rheophilic species.
STRESS REQUIREMENTS
DRY SEASON
DROUGHT: 5% at stress 7 will allow for low survival of the species in minimal available fast deep conditions. At lower flows fast deep conditions will no longer be present in the river. The stress level should never exceed 8 (0% of the time) otherwise the species could be lost.
MAINTENANCE D: Require moderate good habitat for the dry season and stress of 5 can be tolerated for 40%

of the time.
MAINTENANCE C: Require good habitat for the dry season and stress of 5 can be tolerated for 30% of the time.

WET SEASON

DROUGHT: 5%.at stress 6 will still allow spawning, but only with few fast sites with favourable habitat conditions. Relatively limited FS available but fragmented (patchy). A stress of 7 must never (0% of time) occur as this will only allow for minimal survival and no recruitment or breeding. At this point summer temperatures may also become problematic and oxygen levels in water may become critical.

MAINTENANCE D: Require moderate good survival habitat and moderately good breeding habitat and recruitment. Therefore a stress of 4 can be tolerated for 35% a stress of 5 for 20% of the time.

MAINTENANCE C: Require good survival habitat and good breeding habitat and recruitment. Therefore a stress of 4 can be tolerated for 20% and a stress of 5 for 10% of the time.

General life history requirements
Chiloglanis pretoriae
Eggs: Margins of FS (<0.3 m, >0.3 m/s) gravel cobble substrate. October – January. >16°C Duration 7 days 3 - 30%
Larva: Feeding and Growth: Nursery areas (<0.3 m, >0.2 m/s), Margins of SS & overhanging vegetation. Duration larval period: 2 months.
Juvenile: Feeding and Growth: Mostly FS and margins of SS (<0.30m deep >0.2 m/s). Cover: Cobbles & rocks overhanging vegetation. Duration 3-6 months.
Adult: FD and FS (<0.3 m, >0.3 m/s) gravel, cobble Substrate. Spawning season: October – January. Cue: increased temperature, flow and changes in water quality (e.g. conductivity).

The stress referred to in the motiations below refers to aquatic invertebrate stress, not component stress.

AQUATIC INVERTEBRATES: DURATIONS AND MOTIVATIONS TO BE USED FOR DETERMINING STRESS REQUIREMENTS

Indicator: *Centroptiloides bifasciata*
The indicators are rheophilic species.

STRESS REQUIREMENTS FOR RECOMENDED EC

DRY SEASON

DROUGHT: +/-10%. Stress 8: Survival conditions. Ensure refuge habitats for taxa such as Turbellaria. Flow more than a trickle must be maintained over the riffle, to protect against high temperatures and low oxygen concentrations. The river should never stop flowing as this eliminates many taxa and significantly reduces biodiversity.

MAINTENANCE D: 30%. Stress 7: Ensure sufficient depth (15cm) and current velocity (average 0.1m/s) for flow-dependent taxa such as *Cheumatopsyche afra*.

MAINTENANCE C: A Stress of 6 was assigned for the maintenance conditions for the dry season. The same diversity of habitat conditions are present, but occurring more often. Taxa expected are Gerridae (Water striders), Veliidae (Broad-shouldered water striders), Tabanidae (Horse Flies), Coenagrionidae, Muscidae, Naucoridae (Creeping water bugs), Hydrachnellidae (Water Mites), Tricorythidae (Stout crawlers) and Perlidae.

WET SEASON

DROUGHT: +/- 10%. Stress 6: Require riffle habitat to ensure sufficient current velocity (average 0.12 m/s) for flow-dependent taxa such as Leptophlebiidae.

MAINTENANCE D: 30%. Stress 4: Ensure sufficient current velocity (average 0.2 m/s) for flow-dependent taxa such as *Simulium hargreavesi, Simulium damnosum* and C*heumatopsyche afra.* Photographs taken of the site in August and November 2003 showed that there would be sufficient habitats available at a flow of 0.27m^3/s. **MAINTENANCE C:** A Stress of 3 was assigned for maintenance flows during the wet season. The same diversity of habitat conditions are present, but occurring more often. Taxa expected are Gerridae (Water striders), Veliidae (Broad-shouldered water striders), Tabanidae (Horse Flies), Coenagrionidae, Muscidae, Naucoridae (Creeping water bugs), Hydrachnellidae (Water Mites), Tricorythidae (Stout crawlers) and Perlidae.

The low flow requirements set by fish and aquatic invertebrates were assessed for riparian vegetation.

RIPARIAN VEGETATION		
Flow	**Discharge (m^3/s)**	**Max flow depth (m)**
September drought	0.08	0.23
September maintenance	0.27	0.31
February drought	0.1	0.24
February maintenance	0.32	0.32
Acceptable for riparian vegetation provided that drought flows do not occur more than 5% of the time, and not in consecutive years.		

7.6.3 Final Low Flow Requirements

The modelled monthly time series originally used for EWR Site G1 appeared to be providing dry season low flows that were considerably lower than those that had been measured at the site in the previous dry season, which was in a drought year (2003). Subsequent investigation of the data yielded the following:

- dry season lowflows not compatible with the biological information at the site
- the flood calculations (which were calculated independently of the modelled monthly time series) indicated that the low flows in both wet and dry season was being underestimated by at least 1 cumec in dry season, and similar (1.5 cumecs) in the wet season
- WR90 data provided a MAR for the quaternary catchment (X11J) of 52 MCM against 18 MCM estimated using the modelled monthly time series.

This led to the assumption that the data used in the modelled monthly time series had been incorrectly scaled relative to the actual runoff contribution at EWR Site G1. To correct this the following procedure was undertaken:

- the proportional contribution to X11J MAR upstream of the site was calculated using the rainfall procedure in SPATSIM, which allows calculation of the MAR for a fraction of the quaternary, using rainfall information for that quaternary;
- the modelled monthly time series was then rescaled to arrive at the MAR to that predicted by SPATSIM.

Adjustments to the Desktop Reserve Model requirements were made to fit the specialist requirements as shown in Tables 7-7 and 7-8.

Table 7-7. EWR G1 - Maintenance and drought low flows (EC = C).

Month	Desktop (m^3/s)		Modified (m^3/s)		Ratio (Mod/Desk)	
	Maintenance low flows	Drought low flows	Maintenance low flows	Drought low flows	Maintenance low flows	Drought low flows
Jan	0.238	0.124	0.400	0.085	168%	69%
Feb	0.296	0.153	0.530	0.090	179%	59%
Mar	0.254	0.132	0.420	0.085	165%	64%
Apr	0.235	0.123	0.340	0.080	145%	65%
May	0.197	0.104	0.280	0.075	142%	72%
Jun	0.174	0.092	0.250	0.070	144%	76%
Jul	0.137	0.074	0.200	0.068	146%	92%
Aug	0.119	0.065	0.170	0.065	143%	100%
Sep	0.113	0.063	0.163	0.063	144%	100%
Oct	0.116	0.063	0.170	0.063	147%	100%
Nov	0.148	0.080	0.215	0.068	145%	85%
Dec	0.186	0.098	0.270	0.075	145%	77%

Table 7-8. EWR G1 – Maintenance and drought flows (REC = D).

Month	Desktop		Modified		Ratio (Mod/Desk)	
	Maintenance low flows	Drought low flows	Maintenance low flows	Drought low flows	Maintenance low flows	Drought low flows
Jan	0.124	0.124	0.180	0.085	145%	69%
Feb	0.153	0.153	0.210	0.090	137%	59%
Mar	0.132	0.132	0.190	0.085	144%	64%
Apr	0.123	0.123	0.180	0.080	146%	65%
May	0.104	0.104	0.160	0.075	154%	72%
Jun	0.092	0.092	0.143	0.070	155%	76%
Jul	0.074	0.074	0.120	0.068	162%	92%
Aug	0.065	0.065	0.110	0.065	169%	100%
Sep	0.063	0.063	0.109	0.063	173%	100%
Oct	0.063	0.063	0.109	0.063	173%	100%
Nov	0.080	0.080	0.125	0.068	156%	85%
Dec	0.098	0.098	0.150	0.075	153%	77%

The low flow recommendations for each reserve scenario were finalised (Figure 7-3 and Figure 7-4).

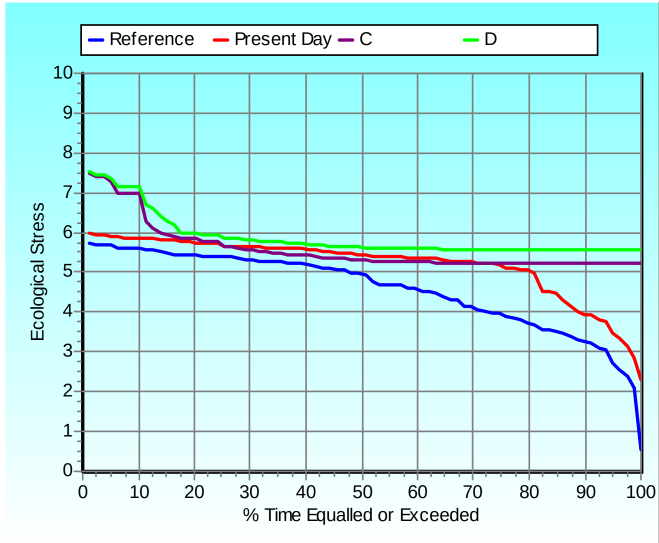


Figure 7-3. Final Stress Duration Curve for reference conditions, present day and categories C and D for the dry season (September) at EWR Site G1.

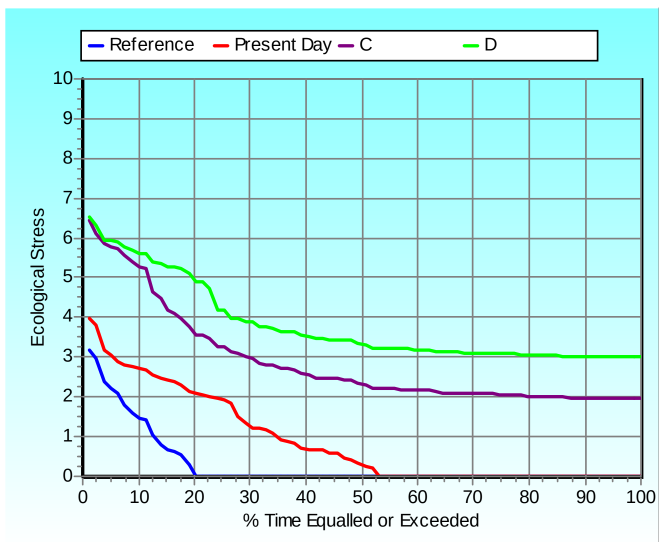


Figure 7-4. Final Stress Duration Curve for reference conditions, present day and categories C and D for wet season (February) at EWR Site G1.

7.6.4 High Flow Requirements

The functions for each Flood Class are described in spreadsheets. A summary of the flood class ranges and recommended number of high flow events required for each EC is provided in Table 7-7 below.Flood class motivations are detailed in Appendix J.

7.7 FINAL RESULTS

The final EWR results for the recommended and alternative categories are summarised below (Table 7-9 to Table 7-13) and the detailed results are presented in Appendix K.

Table 7-9. Flood class parameters and recommended number of high flow events required for each EC – EWR Site G1.

Note: *Timing: 1 = January; 12 = December
P = present, A = absent

EC = D	Flood parameters			NUMBER OF EVENTS					FINAL		Discussion of changes	
FLOOD CLASSES	Range	Range Average	Duration (days)	Geom No.	Veg No.	Invert No.	Fish No.	MIN	No.	*Timing	Primary	Secondary
Class 1	0.4-0.8	0.6	1.0	1.0	2.0	2.0		2.0	2.0	3-11	Inverts: · To maintain species diversity by ensuring temporal diversity of flows. · Two events per annum should be sufficient to provide breeding cues for a Category D and C.	Veg. Maintain vegetation of marginal zone. Prevent terrestrialisation. Inundate key species such as sedge *Schoenoplectus brachyceras* .
Class 2	0.8-1.6	1.2	1.0	2.0	2.0	2.0	1.0	2.0	2.0	11-4	Inverts:. · Provide cue for breeding or emergence.	Geom.
Class 3	1.6-3.2	2.4	2.0	2.0	2.0			2.0	2.0	11-4	Geom. Bed material transport. Add variability, sort bed material.	Veg. Provide essential variability in the flow regime. Maintain vegetation of marginal zone. Prevent terrestrialisation. Inundate key species such as sedge *Schoenoplectus brachyceras* .
Class 4	3.2-6.3	4.8	3.0	0.5	0.5			0.5	0.5	11-4	Geom. Channel maintenance flood for channel geometry and sediment transport. Normally approximates to annual flood under natural conditions.	Veg. Provide essential variability in the flow regime. Maintain vegetation of marginal zone. Inundate key species such as tree fern *Cyathea dregei.* Facilitate seed dispersal of key species such as *Cyathea dregei, Senecio inaequidens.* Transported sediments provide substrate for germination of key species. Control terrestrialisation.Saturate rooting zone of tree species such as *Combretum erythrophyllum* in lower riparian zone.
1:2	7	-	5.0		0.3			P	1:2		Geom. Overtops banks on to flood bench, deposition on flooded area. Reduce below natural frequency	General habitat maintenance.
1:5	30	-							-	-	Important that water resource developments are not operated a flood control devices - the large floods are beneficial to riverine ecosystems.	Cannot be released.
1:10	60	-						P	-	-		
1:20	103	-							-	-		

EC = C	Flood parameters			NUMBER OF EVENTS							Discussion of changes	
									FINAL			
FLOOD CLASSES	Range	Range Average	Duration (days)	Geom No.	Veg No.	Invert No.	Fish No.	MIN	No.	*Timing	Primary	Secondary
Class 1	0.4-0.8	0.6	1.0	3.0	2.0	2.0		3.0	2.0	3-11	Geom. Inundates in-channel bench, some transport of fine to medium gravel. Retain some variability.	Inverts:. · To maintain species diversity by ensuring temporal diversity of flows. · Two events per annum should be sufficient to provide breeding cues for a Category D and C.
Class 2	0.8-1.6	1.2	1.0	2.0	3.0	2.0	2.0	3.0	3.0	11-4	Veg.	Inverts:. · Provide cue for breeding or emergence.
Class 3	1.6-3.2	2.4	2.0	2.0	2.0			2.0	2.0	11-4	Geom. Bed material transport. Add variability, sort bed material.	Veg. Provide essential variability in the flow regime. Maintain vegetation of marginal zone. Prevent terrestrialisationInundate key species such as sedge *Schoenoplectus brachyceras* . Promote spread of indigenous grasses such as *Leersia hexandra* and *Panicum hymeniochilum* .
Class 4	3.2-6.3	4.8	3.0	1.0	1.0			1.0	1.0	11-4	Geom. Channel maintenance flood for channel geometry and sediment transport. Normally approximates to annual flood under natural conitions.	Veg. Provide essential variability in the flow regime. Maintain vegetation of marginal zone. Inundate key species such as tree fern *Cyathea dregei.* Facilitate seed dispersal of key species such as *Cyathea dregei, Senecio inaequidens* . Transported sediments provide substrate for germination of key species. Control terrestrialisation. Saturate rooting zone of tree species such as *Combretum erythrophyllum, Buddleja salviifolia, Leucosidea sericea* and *Dais cotinifolia* in lower riparian zone.
1:2	7	-	5.0		1.0			P	1:2	Any	Geom. Overtops banks on to flood bench, deposition on flooded area. Retain natural frequency for key geomorphological flow.	None.
1:5	30	-							-	-		
1:10	60	-							-	-		
1:20	103	-							-	-	Cannot be managed.	Cannot be managed.

Table 7-10. EWR Summary Table for EWR Site G1 for REC: D.

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	VOL ($X10^6$ m^3)	nMAR%
EWR SITE G1: EMC =D.														
LOW FLOWS														
MAINTENANCE LOW FLOWS (m^3/s)[9]	0.1	0.1	0.2	0.2	0.2	0.2	0.2	0.2	0.1	0.1	0.1	0.1	**4.681**	**12.41**
LOW FLOWS (m^3/s)	*0.1*	*0.1*	*0.1*	*0.1*	*0.1*	*0.1*	*0.1*	*0.1*	*0.1*	*0.1*	*0.1*	*0.1*	***2.328***	***6.17***
HIGH FLOWS														
FLOOD (daily average m^3/s)	-	1.2	1.2	2.4	1)2.4 2)3.5 3)7.0	-	0.6	-	-	-	-	0.6	**1.642**	**4.35**
Duration (in days)	-	1	1	2	1) 2 2) 3 3) 5	-	1	-	-	-	-	1		
Return period (years)	-	1:1	1:1	1:1	1) 1:1 2) 1.2[10] 3) 1.2	-	1:1	-	-	-	-	1:1		
LONG-TERM MEAN													***9.624***	***25.51***

[9] Figures rounded-off to the nearest one decimal place.
[10] Alternating with 3).

Table 7-11. EWR Summary Table for EWR Site G1 for Alternative EC: C.

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	VOL ($X10^6$ m^3)	nMAR%
EWR SITE G1: EMC =C.														
LOW FLOWS														
MAINTENANCE LOW FLOWS (m^3/s)[11]	0.2	0.2	0.3	0.4	0.5	0.4	0.3	0.3	0.3	0.2	0.2	0.2	**8.907**	**23.61**
DROUGHT LOW FLOWS (m^3/s)	*0.1*	*0.1*	*0.1*	*0.1*	*0.1*	*0.1*	*0.1*	*0.1*	*0.1*	*0.1*	*0.1*	*0.1*	***2.328***	***6.17***
HIGH FLOWS														
FLOOD (daily average: m^3/s)	-	1.2	1.2	1)1.2 2)2.4	1)2.4 2)4.8 3)7.0	-	0.6	-	-	-	-	0.6	**2.488**	**6.60**
Duration (in days)	-	1	1	1) 1 2) 2	1) 2 2) 3 3) 5	-	1	-	-	-	-	1		
Return period (years)		1:1	1:1	1) 1:1 2) 1.1	1) 1:1 2) 1.1 3) 1:2		1:1					1:1		
LONG-TERM MEAN													***12.45***	***33.00***

11 Figures rounded-off to the nearest one decimal place.

Table 7-12. EWR rule table for REC: D.

Desktop Version 2, Printed on 31/01/2005
Summary of EWR rule curves for : EWR G1 Generic Name
Determination based on defined BBM Table with site specific assurance rules.
Regional Type : E.Escarp   REC = D

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

This EWR rule table can be used in combination with the natural duration curves below for implementation.

Reserve flows without High Flows

Month	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	0.217	0.217	0.215	0.211	0.204	0.191	0.169	0.136	0.097	0.067
Nov	0.249	0.248	0.246	0.241	0.232	0.216	0.190	0.152	0.106	0.073
Dec	0.299	0.297	0.294	0.288	0.277	0.257	0.224	0.177	0.122	0.081
Jan	0.358	0.356	0.352	0.344	0.330	0.304	0.264	0.207	0.141	0.092
Feb	0.418	0.416	0.412	0.403	0.386	0.357	0.309	0.240	0.159	0.098
Mar	0.378	0.377	0.373	0.365	0.351	0.325	0.282	0.220	0.147	0.092
Apr	0.358	0.357	0.354	0.348	0.335	0.311	0.271	0.212	0.141	0.087
May	0.318	0.318	0.316	0.310	0.299	0.279	0.245	0.193	0.129	0.081
Jun	0.285	0.284	0.282	0.278	0.269	0.251	0.221	0.175	0.119	0.076
Jul	0.239	0.239	0.237	0.234	0.227	0.214	0.191	0.154	0.108	0.072
Aug	0.219	0.219	0.217	0.214	0.208	0.195	0.173	0.141	0.100	0.069
Sep	0.217	0.217	0.215	0.212	0.205	0.192	0.171	0.138	0.097	0.067

Natural Duration curves

Oct	0.762	0.560	0.474	0.396	0.355	0.291	0.269	0.239	0.202	0.168
Nov	2.735	1.308	0.868	0.768	0.718	0.625	0.567	0.463	0.382	0.212
Dec	3.887	3.412	2.479	1.456	1.262	1.027	0.833	0.784	0.586	0.310
Jan	6.366	4.264	3.539	2.326	1.699	1.232	1.086	0.844	0.765	0.594
Feb	8.647	4.592	3.476	2.025	1.397	1.257	1.124	1.004	0.831	0.508
Mar	4.387	2.744	1.785	1.232	1.094	0.974	0.885	0.840	0.668	0.437
Apr	2.025	1.208	1.157	1.030	0.957	0.876	0.802	0.702	0.602	0.343
May	1.045	0.892	0.825	0.769	0.698	0.605	0.553	0.508	0.441	0.273
Jun	0.806	0.710	0.598	0.559	0.509	0.444	0.405	0.351	0.309	0.204
Jul	0.624	0.467	0.426	0.392	0.370	0.343	0.287	0.258	0.220	0.149
Aug	0.482	0.399	0.340	0.302	0.287	0.265	0.235	0.228	0.194	0.146
Sep	0.463	0.374	0.316	0.293	0.274	0.247	0.224	0.204	0.177	0.158

Total Reserve Flows

	% Points									
Month	**10%**	**20%**	**30%**	**40%**	**50%**	**60%**	**70%**	**80%**	**90%**	**99%**
Oct	0.217	0.217	0.215	0.211	0.204	0.191	0.169	0.136	0.097	0.067
Nov	0.309	0.307	0.304	0.298	0.287	0.266	0.231	0.181	0.122	0.078
Dec	0.356	0.355	0.351	0.344	0.330	0.304	0.264	0.206	0.137	0.086
Jan	0.569	0.539	0.511	0.483	0.449	0.393	0.338	0.261	0.171	0.105
Feb	1.475	1.333	1.210	1.100	0.991	0.807	0.688	0.516	0.315	0.165
Mar	0.378	0.377	0.373	0.365	0.351	0.325	0.282	0.220	0.147	0.092
Apr	0.388	0.387	0.384	0.376	0.362	0.336	0.292	0.227	0.149	0.090
May	0.318	0.318	0.316	0.310	0.299	0.279	0.245	0.193	0.129	0.081
Jun	0.285	0.284	0.282	0.278	0.269	0.251	0.221	0.175	0.119	0.076
Jul	0.239	0.239	0.237	0.234	0.227	0.214	0.191	0.154	0.108	0.072
Aug	0.219	0.219	0.217	0.214	0.208	0.195	0.173	0.141	0.100	0.069
Sep	0.247	0.247	0.245	0.241	0.233	0.218	0.192	0.153	0.106	0.070

Table 7-13. EWR rule table for EC: C

Desktop Version 2, Printed on 12/11/2004
Summary of EWR rule curves for : EWR G1 Generic Name
Determination based on defined BBM Table with site specific assurance rules.
Regional Type : E.Escarp   EC = C

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

This EWR rule table can be used in combination with the natural duration curves below for implementation.

Reserve flows without High Flows

Month	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	0.237	0.236	0.234	0.230	0.222	0.207	0.182	0.145	0.101	0.067
Nov	0.300	0.298	0.296	0.290	0.278	0.258	0.224	0.175	0.117	0.074
Dec	0.376	0.374	0.370	0.362	0.347	0.320	0.276	0.212	0.138	0.082
Jan	0.557	0.554	0.547	0.533	0.508	0.464	0.394	0.295	0.181	0.097
Feb	0.738	0.734	0.726	0.708	0.675	0.617	0.522	0.386	0.225	0.106
Mar	0.585	0.583	0.576	0.563	0.538	0.494	0.421	0.316	0.191	0.097
Apr	0.474	0.472	0.468	0.458	0.440	0.406	0.350	0.266	0.166	0.090
May	0.390	0.389	0.386	0.379	0.365	0.339	0.295	0.228	0.145	0.083
Jun	0.348	0.348	0.345	0.339	0.328	0.305	0.266	0.207	0.133	0.077
Jul	0.279	0.279	0.277	0.273	0.264	0.248	0.219	0.174	0.117	0.074
Aug	0.237	0.237	0.235	0.231	0.224	0.210	0.186	0.149	0.104	0.069
Sep	0.227	0.227	0.225	0.222	0.214	0.201	0.178	0.143	0.100	0.067

Total Reserve Flows

Month	% Points 10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	0.237	0.236	0.234	0.230	0.222	0.207	0.182	0.145	0.101	0.067
Nov	0.347	0.346	0.342	0.335	0.322	0.297	0.257	0.199	0.130	0.079
Dec	0.422	0.420	0.416	0.407	0.389	0.358	0.308	0.236	0.151	0.087
Jan	0.843	0.801	0.762	0.721	0.670	0.584	0.495	0.369	0.223	0.114
Feb	2.170	1.977	1.807	1.652	1.397	1.227	1.035	0.761	0.437	0.196
Mar	0.585	0.583	0.576	0.563	0.538	0.494	0.421	0.316	0.191	0.097
Apr	0.497	0.496	0.491	0.481	0.462	0.426	0.367	0.279	0.172	0.093
May	0.390	0.389	0.386	0.379	0.365	0.339	0.295	0.228	0.145	0.083
Jun	0.348	0.348	0.345	0.339	0.328	0.305	0.266	0.207	0.133	0.077
Jul	0.279	0.279	0.277	0.273	0.264	0.248	0.219	0.174	0.117	0.074
Aug	0.237	0.237	0.235	0.231	0.224	0.210	0.186	0.149	0.104	0.069
Sep	0.251	0.251	0.249	0.245	0.237	0.221	0.195	0.155	0.107	0.070

7.8 CONFIDENCE

The confidence is evaluated according to a score of 0-5 with zero reflecting 'no confidence' and 5 reflecting 'very high' confidence (Table 7-14).

Table 7-14. Confidence Ratings for EWR Site G1.

	EWR SITE	AVAILABLE DATA	ECOLOGICAL CLASSIF.	OUTPUT LOW FL	OUTPUT HIGH FL
HYDROLOGY		2	3		
	Confidence is fairly high on the accuracy of the simulation of observed (historic) flows. The simulation is based on calibrations done a number of years ago and is a reasonable representation of the time series in terms of the range of flows. The low flows are slightly higher based on nature of calibration.				
HYDRAULICS	4	4/0=2		2.5	2.5
	Measured flows in the range 0.27 to 1.68m^3/s. Recommended low-flows for the PES (D) in the range 0.08 to 0.32m^3/s, and high flows in the range 0.6-4.8 (within year) (ie. slightly above measured range) and 7-103 (1:2-1:20) (ie. above highest measured value).				
QUALITY		4	3		
	Water quality data used from DWAF monitoring programme at monitoring point X1H019Q01 (1977-1996). Confidence in the data was high (4). EC confidence in data was medium(19 years data). No temperature, dissolved oxygen, chlorophyll and turbidity data available				
GEOMORPH	2	2.5	3	N/A	3
	Long-term photos at small scale, poor quality of hydrology data. Site visit by specialist at high flows, no visit to higher catchment or extended reach. Low to moderate confidence for sediment input status, better for in-reach riparian vegetation. Reasonable morphological clues, but problem estimating sediment transport at lower discharges. **GENERAL COMMENT ON CONFIDENCE IN FLOOD REQUIREMENTS** (same as EWR Site K3)				
RIP VEG	4	3	4	n/a	3
	EWR site: A good site, but highly degraded **Available data:** Vegetation profile studied twice (once in winter and once in Autumn). **Ecological classification:** Confirmed by RVI analysis. **Output low flow:** Recommendations not tested **Output high flow:** Recommendations match current situation				
FISH	4	4	4	3	3

	Confidence in available data is moderate because historic data goes back as far as the 1960's and 1970/80 surveys. A few surveys have been conducted in this Resource Unit over last three years. Moderate confidence in EC based on the available data and a few recent surveys conducted during last 3 years in this Resource Unit. Moderately high confidence in EWR site as the site provided good indications of the abundance of critical habitat required by indicator species and the sensitivity of this habitat under different flows and could be used to set stress. Moderately high confidence in low flows based on the available hydraulic data and fish info it was possible to set realistic flows in terms of its stress and availability of critical habitat for indicator species. Moderately high confidence in high flows based on our understanding of the species and hydraulics in this Resource Unit, fish has a need of Class II floods in terms of breeding and migrations. The Class I floods will not be sufficient to support spawning in the vegetation. The temperate fish do not have any other specific flood requirements that will not be catered for by others.				
INVERT	3	4	4	4	4
	High diversity of biotopes present: Highly suitable SOC, gravel and mud; Suitable SIC and MVOC; Moderate MVIC; Poor bedrock. Data were available for 21 SASS samples recorded at 13 sampling sites (including tributaries) within this Resource Unit, so confidence in the results was high. Information available was suitable for evaluation as required. The invertebrate requirements are being met for low flows. The invertebrate requirements for high flows are met by those of the fish.				

8. EWR SITE T1 – TEESPRUIT

8.1 ECOLOGICAL CATEGORIES

The PES for EWR site T1 is summarised Table 8-1, and a description of the reference conditions, and PES for individual components is presented in Table 8-2.

Table 8-1. The PES for EWR site T1.

Driver Components	Component PES	Driver PES	ECOSTATUS PES
HYDROLOGY	B	C	C
GEOMORPH	C		
WATER QUALITY	C		
Response Components	Component PES	Instream PES	
FISH	B/C	C	
AQUATIC INVERTS	C		
RIPARIAN VEG	C	C	

Table 8-2. Description of the PES categories for each habitat driver and biological response for EWR site T1.

Category B = Largely Natural; Category B/C= Largely Natural to Moderately Modified and C= Moderately Modified.

Driver and responses	Reference conditions	PES	PES description
			Overall PES for Drivers Moderately Modified (Category C).
Hydrology	nMAR= 60.6 million m^3/a	**B**	pMAR= 48.6 million m^3/a • pMAR is 80% of nMAR ; 23% reduction at 70% exceedance • Perennial • No significant change in seasonality • Moderate events: 22% reduction at 50% exceedance • High flow events: 20% reduction at 10% exceedance
Geomorphology	T1 is classified as an upper foothill site on account of its channel gradient of 0.0065. The expected reach type would be either plane bed, pool-riffle or pool rapid with a bed material dominated by cobble or bedrock and cobble. The river channel lies within a narrow flood zone between alternating hill slopes so is semi-confined. There is some potential for the development of secondary channels.	**C**	T1 is not impacted by upstream impoundments, but the event hydrology is likely to have been effected by land use changes within the catchment such as extensive semi-formal settlements with associated catchment hardening and dirt roads. Catchment land use changes are considered to have had a small to moderate effect on geomorphological processes. These have caused following changes in sediment inputs, riparian vegetation and channel structure. **Sediment inputs**: Small to moderate increase in terms of sediment input. There are a significant proportion of sand and fine gravels in the bed material at this site.

			Riparian Vegetation: Vegetation appears to be in good condition, but according to the vegetation specialist there is evidence of changes in cover and structure. A good vegetation cover on the banks provides a high level of protection against erosion along most of the banks. The rating for riparian vegetation impacts is therefore given as small. **Channel structures**: No impact
Water Quality	The reference condition water quality would not have been impacted by upstream production of nutrients, microbiological or turbidity.	**C**	The main change from reference conditions is an increase in nutrients and bacterial contamination from point and non-point sources of sewerage.
			Overall Instream PES Moderately Modified (Category C).
Riparian Vegetation	No exotic species present.	**C**	The main changes are triggered by flow related causes (reduced low flows from upstream abstractions) and non-flow related causes (erosion from upstream grazing, organic pollution from a poorly operated sewage works and non-point sources of organic pollution from poor sanitation facilities, agriculture and mining).
Marginal zone: Reedbed on sandy floodplain and banks	• Annual floodplains would be dominated by mesophytic trees and shrubs such as *Combretum erythrophyllum* and *Sesbania sesban* in an open canopy. • Grass species such as *Cynodon dactylon, Ischaemum fasciculatum* and *Panicum maximum* would dominate the field layer. • Clumps of *Phragmites* reeds and scattered sedges would occur at water's edge. • Lateral channels would also host the grass species *Miscantheus junceus* and the medicinal tree species *Catha edulis*. • Naturalised exotic species and alien invader species would not be present.		• Small decrease in cover and biomass of trees such as *Combretum erythrophyllum* and *Ficus sur* and *Phragmites* reeds as a result of reduced low flows and poor recruitment. • Moderate decrease in number of indigenous species • Moderate change in overall species composition as a result of invasion by species such as *Senna occidentalis* and *Sesbania punicea.* • Small change in structure due to invasion by species such as *Senna occidentalis* and *Sesbania punicea,* and poor recruitment of trees such as *Ficus sur.*
Lower riparian zone: Woodland on loose sand terraces	• On firm alluvial terraces, the woodland would be open, with mesophytic grasses such as *Bothriochloa insculpta* dominating the field layer and trees such as *Combretum erythrophyllum* dominating the tree layer. • On loose sands, tree cover of species such as *Combretum erythrophyllum, Morella serrata* and *Catha edulis* would be denser, and *Panicum maximum* would be one of the dominant grasses. • Other noteworthy plants would include the medicinal geophyte *Dietes iridioides*. • Terrestrial species and alien invader species would not occur in this zone.		• Small decrease in biomass and cover • Moderate decrease in number of indigenous species due to invasion by alien tree species such as *Acacia mearnsii* and *Melia azederach* • Moderate change in overall species composition due to invasion by alien tree species such as *Acacia mearnsii* and *Melia azederach* • Small change in structure due to poor recruitment of species such as *Cliffortia strobulifera* and *Morella serrata*
Upper riparian zone: Open Woodland on firm alluvial terraces and colluvial slopes	• The colluvial hillslopes would support mostly non-riparian tree species (eg. *Pavetta edentula and Aloe marlothii*) in an open woodland structure (right bank). • The alluvial terrace (left bank) would support mostly 'non-riparian trees' (eg. *Acacia robusta, Celtis africana*), with a field layer of grasses such as *Themeda triandra* and *Panicum maximum*). • There would be no alien invasive species present.		• Small reduction in biomass and cover due to deforestation on firm alluvial terraces • Small reduction in number of indigenous species due to deforestation on firm alluvial terraces. • Small change in overall species composition due to deforestation and invasion of alien species (*Acacia mearnsii*) on firm alluvial terraces • Small change in structure due to poor recruitment of indigenous species (*Acacia robusta, Celtis africana*) on firm alluvial terraces
Fish	Fifteen (15) species expected to occur under natural conditions. Presencde of *Anguilla moss*	**B/C**	Fifteen species expected, 11 was recently collected. **Flow depth:** Very low abundance of fish fauna

			dependant on fast deep habitats (*Chiloglanis emarginatus* and *Barbus argenteus*). Lower abundance of species preferring slow flowing habitats with undercut banks and marginal vegetated areas (*Barbus anoplus, Tilapia sparrmanii* and *Pseudocrenilabrus philander*). **Flow Modification:** Absence of *Anguilla mossambica* due to a large number of impoundments downstream preventing recolonization. Migration of fish has also been effected by weirs and dams in mainstream. Lower abundance of flow dependant and moderately flow dependant species **Substrate:** Low abundance or absence of fish fauna dependant on substrate in fast deep habitats. Species preferring undercut banks and marginal vegetated areas (*Barbus anoplus, Tilapia sparrmanii* and *Pseudocrenilabrus philander*) were lower than expected. **Water Quality:** Species affected is sensitive and moderately sensitive to changes.
Aquatic Invertebrates	There are no known reference data available on aquatic invertebrates in the Teespruit. Common taxa that are expected under natural conditions include Baetidae, Perlidae, Heptageniidae, Elmidae and Leptophlebiidae.	**C**	Confidence in the results was moderate. The main changes triggered by flow and non-flow related causes. The fauna was characterised by high abundances of Baetidae (*Baetis harrisoni*), Chironomidae, Veliidae and Simuliidae (mostly *Simulium medusaeforme* and *S. hargreaves*i), and absence of Ancylidae and Tricorythidae. Six species of blackflies, namely *Simulium medusaeforme, S. bequaerti, S. alckocki, S. damnosum, S. hargreaves*i and S. *rotundum,* were recorded at EWR site T1 on one site visit alone, indicating that the river is in reasonable good condition. The abundance of tolerant species (*S. medusaeforme* and *S. hargreavesi*), indicate organic enrichment.

Additional tables providing scores for the individual driver components and biological responses (instream) and a summary of the EcoStatus are available in Appendix F.

8.2 TRENDS

Under current conditions the trends for vegetation, invertebrates and geomorphology are considered to be stable for both the short and long-term.

8.3 IMPORTANCE

8.3.1 Ecological Importance and Sensitivity

The Ecological Importance and Sensitivity of Resource Unit T within the provincial reserve was considered *High* under natural and present conditions. The confidence for this assessment was high. The main determinants were the presence of endangered *C. emarginatus* and the presence of two flow-dependent fish species (*Chiloglanis* and *Amphilius uranoscopus*). Detailed results are presented in Appendix G.

8.3.2 Socio-cultural Importance

The area was considered of *Moderate* Socio-cultural Importance. Landuse is characterised by small-scale commercial and subsistence dryland farming and livestock grazing (mainly cattle). There are also small patches of irrigated agriculture. There are large areas of degraded, unimproved grasslands, with associated problems of soil erosion and exotic vegetation encroachment probably remnants of commercial agriculture. Direct dependence on river for water supply is likely to be fairly high, as houses are generally scattered. The river is important for washing of clothes, and it is likely that the river is also important for swimming. Moderate levels of natural resource harvesting are probable, including fuelwood, and river sand for building. There are almost certainly moderate to high levels of harvesting of medicinal herbs and tubers. Detailed results are presented in Appendix H.

8.4 RANGE OF ECOLOGICAL CATEGORIES

8.4.1 Recommended Ecological Category

The EIS (present) was *High* and the Socio-cultural Importance *Moderate*, indicating that a higher Category should be recommended. However, the PES was accepted as the REC, as maintaining the river as a Category C would be adequate from an ecological point of view.

8.4.2 Alternative Ecological Categories

Two alternative Ecological Categories were considered (Category B and Category D). The conditions for achieving classes are given in Table 8-3 and summarised in Table 8-4.

Table 8-3. Summary of the conditions defining the alternative Ecological Categories for EWR Site T1.

Driver and responses	Alternative B	Alternative D
General	Category B conditions would comprise: (a) improved sanitation in the catchment, (b) establishing protected riparian buffer zones, (c) a reduction of peri-urban development, (d) better management, (e) reduced overgrazing, (f) alien clearing in the riparian zone and (g) an increase in dry season low flows.	Category D conditions would comprise: (a) reduced base flows, (b) continued degradation of riparian vegetation, (c) an increase in catchment erosion (e.g. through cultivation and peri-urban development) and (d) deforestation of riparian zone.
Geomorphology	An improved ecostatus could be achieved through controlling erosion and peri-urban runoff form the catchment, and improving bank stability through removal of aliens.	Increased invasion by alien vegetation would deplete cover and structure and increase protection against bank erosion. Increased catchment erosion and storm runoff from peri-urban areas would increase sediment inputs into channel.
Riparian Vegetation	Improvement within the Marginal Zone: Small decrease in biomass and cover, a small decrease in number of indigenous species, a small change in overall species composition and a small change in structure. An improvement within the Lower Riparian Zone: No significant change in biomass and cover, a small decrease in number of indigenous species, a small change in overall species composition and a small change in structure. Improvement within the Upper Riparian Zone: No	Marginal Zone: A moderate decrease in biomass, cover and indigenous species and a moderate change in overall species composition and structure. Lower Riparian Zone: A moderate reduction in biomass and cover, a large decrease in number of indigenous species, a large change in overall species composition and a moderate change in structure. Upper Riparian Zone: A small reduction in biomass and cover, a moderate reduction in number of indigenous species., a moderate change in overall species composition and a small change in structure.

Driver and responses	Alternative B	Alternative D
	significant change in biomass and cover, a small reduction in number of indigenous species, a small change in overall species composition and structure.	
Fish	A slight increase in base flow, water quality and a decrease in sediment inputs would provide reduced imbedded cobbles and gravel as well as sedimentation of pools and backwaters. This will provide more habitats for moderately flow dependant species and for species dependant on fast deep and slow deep habitat conditions. Furthermore, it will provide more permanent habitat for species dependant on the availability of marginal vegetation and undercut banks as well as substrate in fast flowing sections of the river.	Reduction in the abundance of species dependant on fast deep and fast shallow habitats. Species dependant or moderately dependant on perennial flow will be mostly affected due to reduced flow and decreased suitable riffle habitats from sedimentation. Pools will reduce in depth and effect species dependent on water column. Species most affected are those dependant on substrate and marginal vegetation / undercut banks. This will also reduce the suitability of available fast deep habitat. Increase in temperatures and a change in temperatures dominating slow shallow habitats will decrease the abundance of species intolerant and moderately intolerant of water quality changes. Reduced flows can result in a loss of at least 2 species (*Chiloglanis emarginatus* and *Barbus argenteus*). Likely that *Amphilius uranoscopus* may be largely affected. This will also lead to a decrease in the abundance of several other species.
Aquatic Invertebrates	Taxa expected to appear are Hirudinea (Leeches), Potamonidae (Crabs), Perlidae (Stoneflies), Tricorythidae (Stout crawlers), Chlorocyphidae, Hydroptilidae, Helodidae, Planorbidae and Physidae.	Taxa expected to disappear are Turbellaria (flatworms), Leptophlebiidae (Prongills), *Pseudocloeon glaucum*, *Psuedopannata maculosa*, *Amphipsyche scottae*, Leptoceridae, Philopotamidae, Pyralidae, Elmidae (Riffle Beetles), Psephenidae (Water Pennies), Tipulidae (Crane Flies), *Simulium alcocki*, *Simulium bequaerti*, *Simulium rotundum*, and Athericidae/Rhagionidae.

Table 8-4. Summary of the Alternative EcoStatus B and D for EWR site T1.

Driver Components	Component PES	Driver PES	ECOSTATUS PES
HYDROLOGY	B	B	B
GEOMORPH	B		
WATER QUALITY	B		
Response Components	**Component PES**	**Instream PES**	
FISH	B	B	
AQUATIC INVERTS	B		
RIPARIAN VEG	B	B	

Driver Components	Component PES	Driver PES	ECOSTATUS PES
HYDROLOGY	C	D	D
GEOMORPH	D		
WATER QUALITY	C/D		
Response Components	**Component PES**	**Instream PES**	
FISH	C/D	D	
AQUATIC INVERTS	D		
RIPARIAN VEG	D	D	

The rule-based models for the individual components were run in a predictive manner and based on the above hypothetical scenarios, the matrixes that would be affected were changed. These spreadsheets with the changes indicated as different colours are included in the specialist appendices.

8.5 STRESS INDICES

Refer to Appendix I for the flow stress indices for the REC and alternative EC's for fish and aquatic invertebrates.

8.5.1 Stress Index: Fish

The rheophilic species selected was *Chiloglanis emarginatus* which is dependant on the presence of deep moderately fast flowing waters and *Chiloglanis pretoriae* which is dependant on fast shallows. The former rheophilic species was the most stressed under all the flow conditions (Table 8-5). It may be that conditions may not always be good for this species and they may have recolonised from the Komati River.

With a flow of 2.0 m^3/s there is abundant fast deep habitat available and none of the life history requirements of *Chiloglanis emarginatus* are likely to be stressed. At a flow of 1.68 m^3/s and 0.92 m^3/s there is a significant loss in the availability of fast deep habitats that will significantly affect breeding and to a lesser extent available habitat and suitable cover. At a flow of 0.32 m^3/s the availability of fast deep habitats is further reduced and breeding will be restricted to only a few areas. The availability of suitable cover will also reduce abundance of the species. At a flow of 0.12 m^3/s the species will only survive in limited numbers due to a lack of suitable habitat. With a slow shallow habitat water temperature increases thus affecting water quality and consequently the health of fish. At a flow of 0.05 m^3/s no suitable fast deep habitats are present.

Rheophilic species represents the highest stresses at any given flow and this was therefore used to generate the stress index.

Table 8-5. Stress table for rheophilic fish species showing Habitat Suitability at EWR site T1.

FLOW (CUMEC)	3.25	2.000	1.640	0.920	0.320	0.120	0.050	0.010	0.000
RELATIVE ABUNDANCE FLOW-DEPTH & COVER RATING: 0=NONE;1=RARE;2=SPARSE;3=MODERATE;4=ABUNDANT;5=VERY ABUNDANT)									
FAST DEEP	4	4.0	3.0	3.0	2.0	1.0	0.0	0.0	0.0
FAST SHALLOW	3.0	3.0	3.0	3.0	3.0	2.0	1.0	0.0	0.0
SLOW DEEP	2.0	2.0	2.0	2.0	2.0	1.0	0.0	0.0	0.0
SLOW SHALLOW	2.0	2.0	2.0	2.0	3.0	3.0	2.0	2.0	2.0
RHEOPHILIC 1	**SPECIES:**								
	Cema								
Breeding and early life-stages=	5.0	5.0	3.0	2.0	1.0	0.0	0.0		
Survival /Abundance =	5.0	5.0	4.0	4.0	2.0	1.0	0.0		
Cover =	5.0	5.0	4.0	3.0	2.0	1.0	0.0		
Health and condition=	5.0	5.0	5.0	4.0	3.0	2.0	0.0		
Water quality=	5.0	5.0	5.0	4.0	3.0	2.0	0.0		
Rheophilic stress - (breeding requirements included)	**0**	**0**	**2**	**3**	**6**	**8**	**10**	**10**	**10**

RHEOPHILIC 2	**SPECIES:**							
	Cpre							
Breeding and early life-stages=	5.0	5.0	4.0	3.0	2.0	1.0	0.0	0
Survival /Abundance =	5.0	5.0	5.0	5.0	4.0	2.0	1.0	0
Cover =	5.0	5.0	5.0	5.0	4.0	2.0	1.0	0
Health and condition=	5.0	5.0	5.0	5.0	5.0	3.0	1.0	0
Water quality=	5.0	5.0	5.0	5.0	5.0	3.0	1.0	0
Semi-rheophilic stress - (breeding requirements included)	**0**	**0**	**0**	**1**	**2**	**6**	**8**	**10**
FLOW (CUMEC)	3.25	2.00	1.64	0.92	0.32	0.12	0.05	0.01
FLOW-DEPTH CONVERTED TO HABITAT RESPONSE (10=ALL FLOW-DEPTH CLASSES ABSENT (RIVER DRY); 0=FLOW-DEPTH *CLASSES OPTIMUM FOR SITE* ; 9=NO FLOW)								
Fast deep	2	2	4	4	6	8	10	10
Fast shallow	4	4	4	4	4	6	8	10
Slow deep	6	6	6	6	6	8	10	10
Slow shallow	6	6	6	6	4	4	6	6
OVERALL HABITAT RESPONSE	**5**	**5**	**5**	**5**	**5**	**7**	**9**	**9**

8.5.2 Stress Index: Aquatic Invertebrates

Optimum Flow rates: 0.3 and 0.6 m/s
Key Species: *Amphipsyche scottae*
Critical Habitats: Riffle & marginal vegetation

The relationships between aquatic invertebrate habitats, flows, stresses and associated biological responses at EWR site T1 are detailed in Table 8-6. The critical factors used to determine the stress curve were the current speeds and overall species composition. During the field survey on 5th August 2003 the flow was 0.12 m^3/s, and a habitat stress score of 5 was allocated. Biomonitoring data showed that flow-sensitive species at this flow were rare, and no change was made to the biological stress allocated.

Table 8-6. Stress Table – Flow Dependant Invertebrate at EWR site T1.

Habitat Flow Response Index	HABITAT ABUNDANCE AND SUITABILITY					TOTAL	FLOW	HABITAT RESPONSE	HABITAT CHARACTERISTICS					BIOTIC RESPONSE	FLOW	SPECIES STRESS	INTEGRATED STRESS
	SIC	SOC	VIC	VOC	GSM				Max depth (m)	Avg depth (m)	Max vel (m/s)	Avg vel (m/s)	WP (m)				
0	**5**	**2**	**5**	**5**	**3**	**20**	**2.000**	All habitat in excess, very high quality: very fast, very deep, very wide wetted perimeter	0.63	0.32	1	0.60	12.2	All very abundant, all healthy, all species persist	**1.640**	**0**	**2.0**
1	**5**	**2**	**4**	**5**	**3**	**19**	**1.640**	All plentifull, high quality; fast, wide wetted perimeter	0.6	0.31	0.9	0.53	11.82	All abundant, all healthy, all species persist	**-**	**1**	**2.3**
2	**4**	**2**	**4**	**5**	**3**	**18**	**0.920**	Critical habitats sufficient; quality slightly reduced: fast, wetted perimeter slightly reduced	0.52	0.27	0.8	0.37	10.26	Slight reduction for sensitive rheophilic species, all healthy in some areas, all species persist	**-**	**2**	**2.7**
3	**3**	**3**	**3**	**4**	**3**	**16**	**0.500**	Reduced critical habitat, reduced critical quality; moderate velocity, fairly deep, wetted perimeter slightly/moderately reduced	0.46	0.25	0.7	0.27	8.97	Reduction for all rheophilic species; all healthy in limited areas; all species persist	**0.920**	**3**	**3.0**
4	**3**	**3**	**3**	**3**	**3**	**15**	**0.220**	Critical habitats limited; moderate quality: Moderate velocity, Some deep areas, Wide WP moderately reduced	0.38	0.21		0.16	7.21	Further reduction for all rheophilic species; all viable in limited areas, critical life stages of some sensitive rheophilic species at risk, all species persist	**0.500**	**4**	**5.0**
5	**3**	**3**	**2**	**3**	**3**	**14**	**0.120**	Critical habitat very reduced; moderate/ low quality; moderate/slow velocity, few deep areas wetted perimeter moderately/very reduced	0.34	0.18	0.35	0.12	6.42	Limited populations of all rheophilic species. Critical life-stages of sensitive rheophilic species at risk or non-viable; all species persist	**0.120**	**5**	**8.2**
6	**2**	**2**	**1**	**2**	**3**	**10**	**0.050**	Critical habitat residual. Low quality; Moderate/slow velocity.	0.28	0.17	0.2	0.07	4.69	Sensitive rheophilic species rare, critical stages of sensitive rheophilic species non-viable, and at risk for some less sensitive species. All species persisit in the short-term	**-**	**6**	**8.9**
7	**1**	**2**	**0**	**1**	**2**	**6**	**0.010**	No critical habitat, other habitats moderate quality; slow, narrow wetted perimeter	0.19	0.1	0.05	0.02	4.2	Most rheophilic species rare; All life-stages of sensitive rheophilic species at risk or non-viable. Most sensitive rheophilic species disappear	**0.050**	**7**	**9.2**
8	**1**	**1**	**0**	**1**	**2**	**5**	**0.005**	Flowing water habitats residual low quality: slow trickle, very narrow wetted perimeter	0.16	0.07		0.02	4.00	Remnant populations of some rheophilic species; all life stages of most rheophilic species at risk or non-viable, many rheophilic species disappear	**-**	**8**	**9.6**
9	**0**	**1**	**0**	**1**	**2**	**4**	**-**	Standing water habitats only, very low quality, no flow	0.08	0.03		0	1.78	Mostly pool dwellers; all life stages of most rheophilic species non-viable; most or all rheophilic species disappear	**0.010**	**9**	**9.9**
10	**0**	**0**	**0**	**0**	**0**	**0**	**-**	Only hyporheic refugia, no surface water	0	0	0	0	0	Only specialists persist, virtually no development.	**-**	**10**	**10.0**

* Estimate of the site

** Findings after calibration

1 SIC: Partially submerged hard substrate in current >0.1 m/s

2 SOC: Partially submerged hard substrate in current <0.1 m/s

3 MVIC: Submerged vegetation (at least 2-3cm submerged) in current >0.1 m/s

4 MVOC: Submerged vegetation (at least 2-3cm submerged) in current<0.1 m/s

5 GS pool: Gravel/sand/pool

8.5.3 Integrated Stress Curve

The individual component stresses are illustrated as well as the integrated stress line (black line) (Figure 8-1).

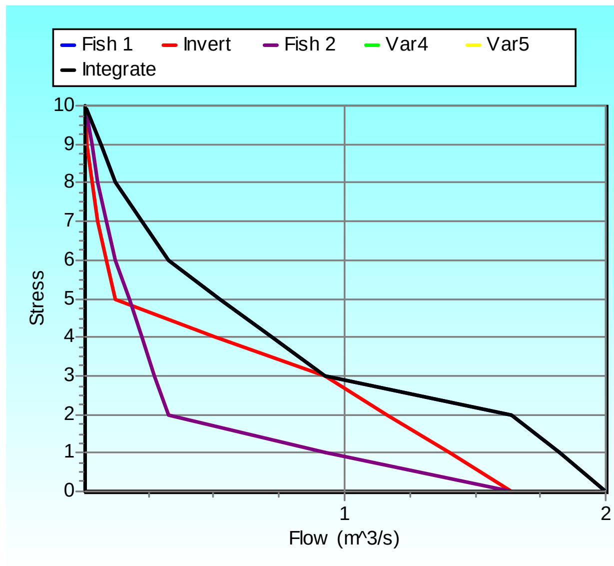


Figure 8-1. Index Stress Curves for EWR site T1.

8.6 DETERMINATION OF EWR SCENARIOS

8.6.1 Low-Flow Requirements

The determined integrated stress index must now be used to identify required stress levels at specific durations for the wet and dry month / season. The requirements are illustrated in Figure 8-2.

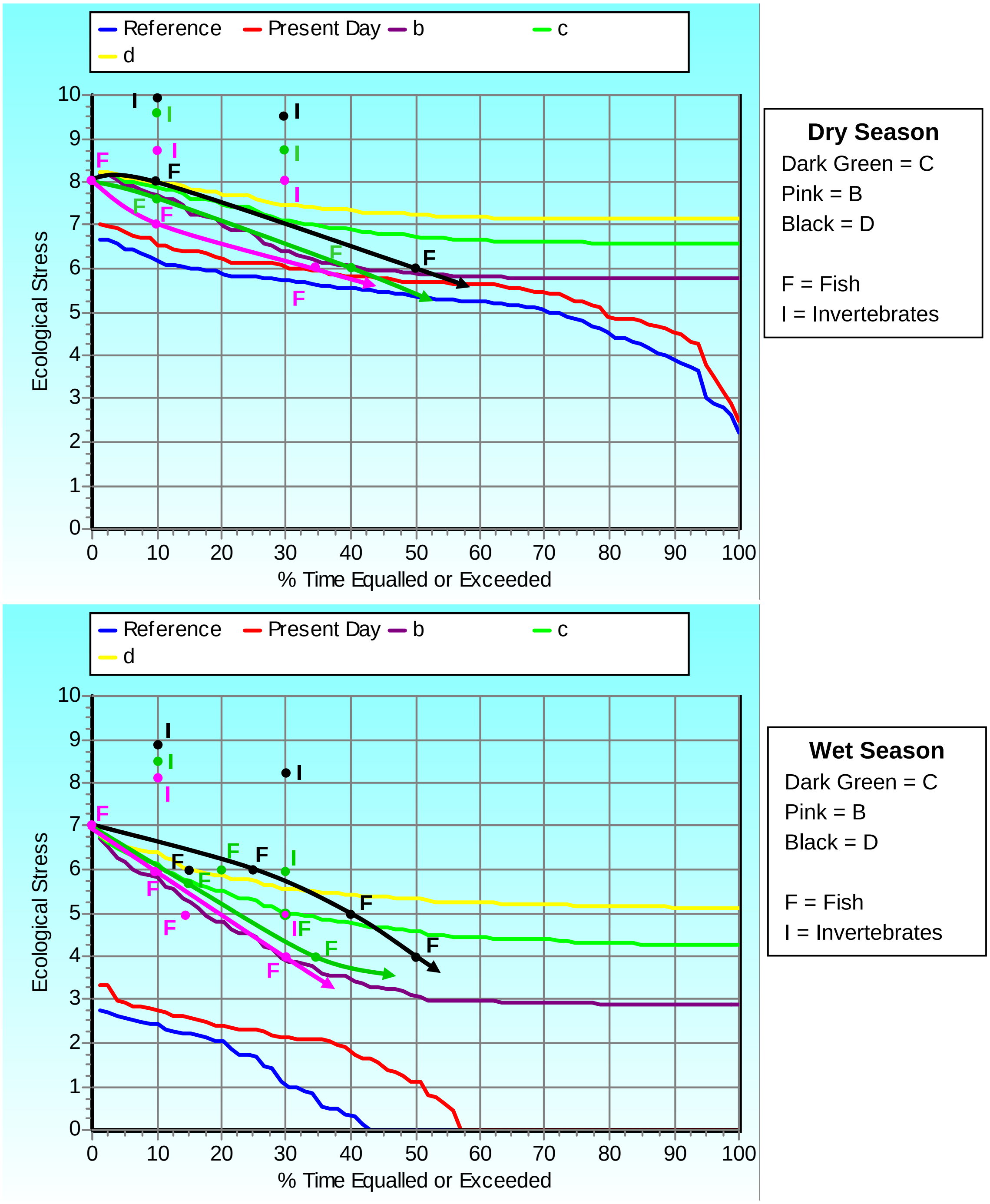


Figure 8-2. EWR site T1 – Stress duration curves for all scenarios.

8.6.2 Motivations: Fish and Invertebrate

The stress referred to in the motiations below refers to fish stress, not component stress.

FISH: DURATIONS AND MOTIVATIONS TO BE USED FOR DETERMINING STRESS REQUIREMENTS.
Indicator: *Chiloglanis emarginatus* The most sensitive rheophilic species was selected as the indicator. This species is dependant on perennial flow in fast deep habitats and its requirements will cater for the other rheophilic species.
DRY SEASON
DROUGHT: 10% at stress 7 will allow for low survival of the species in minimal available fast deep conditions. At lower flows fast deep conditions will no longer be present in the river. The stress level should never exceed 8 (0% of the time) otherwise the species could be lost.
MAINTENANCE B/C: Require good habitat for the dry season and stress of 6 can be tolerated for 40% of the time. This will allow some survival and low abundance. **MAINTENANCE B:** Require good habitat for the dry season and stress of 6 can be tolerated for 35% of the time. This will allow moderate survival and moderate abundance. **MAINTENANCE D:** Require good habitat allowing some survival and very low abundance for the dry season and stress of 6 can be tolerated for 50% of the time.
WET SEASON
DROUGHT: 20% at stress 6 will still allow limited spawning, but only with few fast deep sites with favourable habitat conditions. Relatively limited FD available but fragmented (patchy). Reducing the period to 10% will slightly improve the spawning and recruitment and an increase in the period to 20% will significantly spawning and recruitment. A stress of 7 must never (0% of time) occur as this will only allow for minimal survival and no recruitment or breeding. At this point summer temperatures may also become problematic and oxygen levels in water may become critical, especially with the inputs of nutrients.
MAINTENANCE B/C: Comprise good survival habitat and good to moderately good breeding habitat and moderate recruitment. Therefore a stress of 6.5 can be tolerated for 20% and 4.8 (see comments on stresstable) for 30% of the time. **MAINTENANCE B**: Comprise good survival habitat and increased good to moderately good breeding habitat and good recruitment. Therefore a stress of 6 can be tolerated for 15% and 5 for 20% of the time. **MAINTENANCE D:** Require moderate to low survival habitat for the species and limited available breeding habitat and low recruitment. Therefore a stress of 6 can be tolerated for 25% and 5 for 45% of the time.
General life history requirements *Chiloglanis emarginatus* *Eggs:* Margins of FD (>0.3 m, >0.3 m/s) gravel cobble substrate. October – January. >16°C Duration 7 days 3 - 30% *Larva:* Feeding and Growth: Nursery areas (>0.3 m, >0.2 m/s), Margins of FD, SS & overhanging vegetation. Duration larval period: 2 months. *Juvenile:* Feeding and Growth: Mostly FD and margins of SS (>0.30m deep >0.2 m/s). Cover: Cobbles & rocks overhanging vegetation. Duration 3-6 months. *Adult:* FD (>0.3 m, >0.3 m/s) gravel, cobble Substrate. Spawning season: October – January. Cue: increased temperature, flow and changes in water quality (e.g. conductivity).

The stress referred to in the motiations below refers to aquatic invertebrate stress, not component stress.

AQUATIC INVERTEBRATES: DURATIONS AND MOTIVATIONS TO BE USED FOR DETERMINING STRESS REQUIREMENTS
Indicator: *Amphipsyche scottae* The indicators are rheophilic species.

STRESS REQUIREMENTS FOR RECOMENDED EC
DRY SEASON
DROUGHT: +/-10%. Stress 6: Survival conditions. Ensure refuge habitats for taxa such as Turbellaria. Flow more than a trickle must be maintained over the riffle, to protect against high temperatures and low oxygen concentrations. The river should never stop flowing as this eliminates many taxa and significantly reduces biodiversity. Photographs taken of the site in August 2003, when the flow was 0.12m^3/s, showed that there would be sufficient habitats available for maintenance conditions. Ensure refuge habitats for taxa such as Hydroptilidae, Hirudinea, Tricorythidae, Chlorocyphidae, *Centroptiloides bifasciata,* Perlidae, Helodidae, *Centroptilum* sp. and *Polymorphanisus.*
MAINTENANCE B/C: 30%. Stress 5.5: Ensure sufficient current velocity (average 0.5 m/s) for flow-dependent taxa such as *Cheumatopsyche afra*, Heptageniidae, *Pseudocloeon glaucum.* **MAINTENANCE B**: 30%. Stress 4: Ensure sufficient current velocity (average 0.35m/s) for flow-dependent taxa such as *Cheumatopsyche afra*, Heptageniidae and *Pseudocloeon glaucum.*
WET SEASON
DROUGHT: +/- 10%. Stress 5.5: Require riffle habitat to ensure sufficient current velocity (average 0.17 m/s) for flow-dependent taxa such as Leptophlebiidae.
MAINTENANCE B/C: 30%. Stress 4.5: Photographs taken of the site in May 2004, when the flow was 0.32m^3/s, showed that there would be sufficient habitats available for maintenance conditions for Category C. Conditions should be suitable for the maintenance of taxa such as Athericidae, Leptoceridae, Ancylidae, *Simulium rotundum, Simulium alcocki,* Philopotamidae, Psephenidae, *Amphipsyche scotta*e and Leptophlebiidae and Elmidae. **MAINTENANCE B**: 30%. Stress 4: Taxa expected to appear for Hirudinea (Leeches), Potamonidae (Crabs), Perlidae (Stoneflies), Tricorythidae (Stout crawlers), Chlorocyphidae, Hydroptilidae, Helodidae, Planorbidae and Physidae. **MAINTENANCE D**: 30%. Stress 7:

The low flow requirements set by fish and aquatic invertebrates were assessed for riparian vegetation.

RIPARIAN VEGETATION		
Flow	**Discharge (m^3/s)**	**Max flow depth (m)**
September drought	0.16	0.36
September maintenance	0.28	0.40
February drought	0.29	0.41
February maintenance	0.6	0.48
Acceptable for riparian vegetation.		

8.6.3 Final Low Flow Requirements

Adjustments to the Desktop Reserve Model requirements were made to fit the specialist requirements as shown in Tables 8-7 to 8-9.

Table 8-7. EWR T1 - Maintenance and drought low flows (EC = B).

Month	Desktop (m^3/s)		Modified (m^3/s)		Ratio (Mod/Desk)	
	Maintenance low flows	Drought low flows	Maintenance low flows	Drought low flows	Maintenance low flows	Drought low flows
Jan	0.663	0.198	0.600	0.200	90%	101%
Feb	0.839	0.248	0.750	0.250	89%	101%
Mar	0.719	0.213	0.680	0.220	95%	103%
Apr	0.659	0.198	0.610	0.200	93%	101%
May	0.559	0.170	0.550	0.180	98%	106%
Jun	0.487	0.152	0.470	0.160	97%	105%
Jul	0.380	0.122	0.400	0.145	105%	119%
Aug	0.324	0.107	0.353	0.138	109%	129%
Sep	0.307	0.103	0.334	0.136	109%	132%
Oct	0.314	0.104	0.340	0.136	108%	131%
Nov	0.407	0.130	0.400	0.150	98%	115%
Dec	0.514	0.158	0.500	0.170	97%	108%

Table 8-8. EWR T1 – Maintenance and drought flows (REC = C).

Month	Desktop		Modified		Ratio (Mod/Desk)	
	Maintenance low flows	Drought low flows	Maintenance low flows	Drought low flows	Maintenance low flows	Drought low flows
Jan	0.379	0.198	0.470	0.200	124%	101%
Feb	0.478	0.248	0.550	0.250	115%	101%
Mar	0.410	0.213	0.500	0.213	122%	100%
Apr	0.378	0.198	0.450	0.200	119%	101%
May	0.323	0.170	0.400	0.170	124%	100%
Jun	0.285	0.152	0.350	0.150	123%	99%
Jul	0.226	0.122	0.280	0.120	124%	98%
Aug	0.195	0.107	0.240	0.110	123%	103%
Sep	0.187	0.103	0.220	0.100	118%	97%
Oct	0.190	0.104	0.235	0.100	124%	96%
Nov	0.241	0.130	0.295	0.130	122%	100%
Dec	0.298	0.158	0.380	0.160	128%	101%

Table 8-9. EWR T1 – Maintenance and drought flows (EC = D).

Month	Desktop		Modified		Ratio (Mod/Desk)	
	Maintenance low flows	Drought low flows	Maintenance low flows	Drought low flows	Maintenance low flows	Drought low flows
Jan	0.198	0.198	0.198	0.200	100%	101%
Feb	0.248	0.248	0.248	0.250	100%	101%
Mar	0.213	0.213	0.213	0.213	100%	100%
Apr	0.198	0.198	0.198	0.200	100%	101%
May	0.170	0.170	0.170	0.170	100%	100%
Jun	0.152	0.152	0.152	0.150	100%	99%
Jul	0.122	0.122	0.122	0.120	100%	98%
Aug	0.107	0.107	0.107	0.110	100%	103%
Sep	0.103	0.103	0.103	0.100	100%	97%

Oct	0.104	0.104	0.104	0.100	100%	96%
Nov	0.130	0.130	0.130	0.130	100%	100%
Dec	0.158	0.158	0.158	0.160	100%	101%

The final curves for EWR 1 are shown in The low flow recommendations for each reserve scenario were finalised (Figure 8-3 and Figure 8-4).

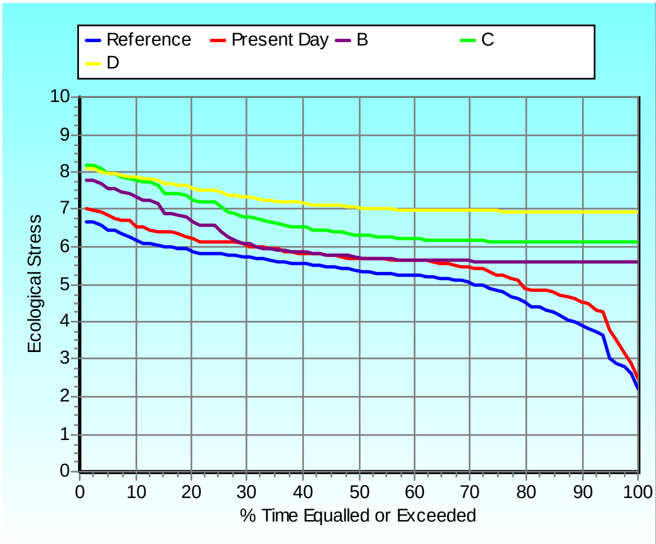


Figure 8-3. Final Stress Duration Curve for Reference conditions, present day and categories B, C and D for the dry season (September) at EWR site T1.

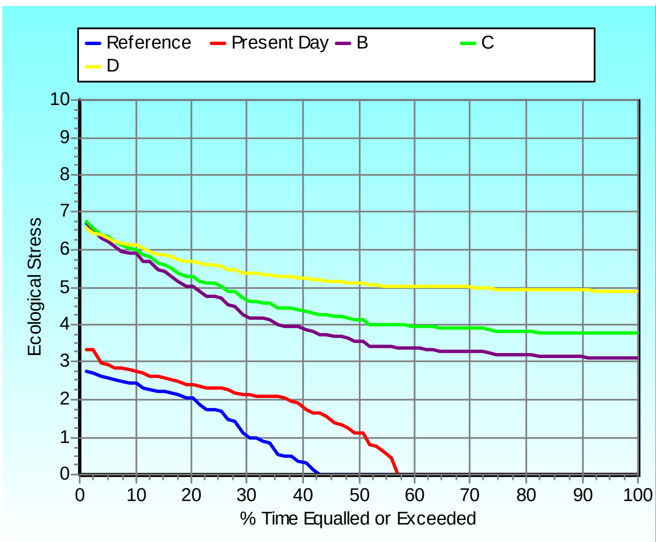


Figure 8-4. Final Stress Duration Curve for Reference conditions, present day and categories B, C and D for wet season (February) at EWR site T1.

8.6.4 High Flow Requirements

The functions for each Flood Class are described in spreadsheets. A summary of the flood class ranges and recommended number of high flow events required for each EC is provided in Table 8-7 below. Flood class motivations are detailed in Appendix J.

8.7 FINAL RESULTS

The final EWR results for the recommended and alternative categories are summarised below (Table 8-10 to Table 8-15) and the detailed results are presented in Appendix K.

Table 8-10. Flood class parameters and recommended number of high flow events required for each EC – EWR site T1.

Note: *Timing: 1 = January; 12 = December
P = present, A = absent

EC = C	Flood parameters			NUMBER OF EVENTS					FINAL		Discussion of changes	
FLOOD CLASSES	Range	Range Average	Duration (days)	Geom No.	Veg No.	Invert No.	Fish No.	MIN	No.	*Timing	Primary	Secondary
Class 1	1.7-3.3	2.5	1.0	1.0	2.0	3.0	1.0	3.0	3.0	3-11	Inverts: · Flush out benthic algae and fines· Provide sufficient current speed to discourage bilharzias snails. · Three events per annum should be sufficient to discourage unnaturally high populations of undesirable species and flush out fines.	Fish. Mainly for the Inundation of marginal vegetated areas for spawning. There is also a requirement for cleaning of gravel/ cobble beds for riffle spawning Important for local migrations, breeding and recruitment. It is important for more than one event to activate backwaters marginal vegetated and nursery areas. It is essential that marginal vegetation and or backwaters in this event is inundated for 4—5 days which will allow the fish larvae to become free swimming and reduce losses due to drying of eggs and fry and ensure some annual recruitment.
Class 2	3.3-6.5	4.9	2.0	2.0	2.0			2.0	2.0	11-4	Geom. Bed material transport and sorting. Retain some variability.	Fish / inverts / veg: Retain some flow variability.
Class 3	6.5-13	9.8	3.0	1.0	2.0			2.0	2.0	11-4		
Class 4	13-26	19.5	4.0	0.7	0.5			0.7	0.7	11-4	Geom. Channel maintenance flood for channel geometry and sediment transport.	None.
1:2	29	-	5.0	P				P	1:3		Geom. Overtops banks on to flood bench, deposition on flooded area. Small reduction relative to natural frequency for key geomorphological flow.	General habitat maintenance.
1:5	107	-							-	-	Important that water resource developments are not operated a flood control devices - the large floods are beneficial to riverine ecosystems.	Cannot be released.
1:10	196	-							-	-		
1:20	317	-							-	-		

EC = B	Flood parameters			NUMBER OF EVENTS							Discussion of changes	
									FINAL			
FLOOD CLASSES	Range	Range Average	Duration (days)	**Geom No.**	**Veg No.**	**Invert No.**	**Fish No.**	**MIN**	**No.**	***Timing**	Primary	Secondary
Class 1	1.7-3.3	2.5	1.0	1.0	4.0	4.0	2.0	4.0	4.0	3-11	Inverts: · Flush out benthic algae and fines· Provide sufficient current speed to discourage bilharzias snails. · Three events per annum should be sufficient to discourage unnaturally high populations of undesirable species and flush out fines. Increased needed for variability for B category. Veg. Prevent terrestrialisation. Soil moisture needed for fringing grasses at end of dormancy Inundate key species such as *Morella serrataInundate* seasonal channels.	Fish. Mainly for the Inundation of marginal vegetated areas for spawning. There is also a requirement for cleaning of gravel/ cobble beds for riffle spawning. Important for local migrations, breeding and recruitment. It is important for more than one event to activate backwaters marginal vegetated and nursery areas. It is essential that marginal vegetation and or backwaters in these events are inundated for 4—5 days which will allow the fish larvae to become free swimming and reduce losses due to drying of eggs and fry. Most of the fish are serial spawners and need more than one opportunity per annum to ensure that sufficient recruitment do take place
Class 2	3.3-6.5	4.9	2.0	3.0	4.0			4.0	3.0	11-4	Geom. Bed material transport and sorting. Retain some variability.	Fish / inverts / veg: Retain some flow variability.
Class 3	6.5-13	9.8	3.0	2.0	4.0			4.0	2.0	11-4		
Class 4	13-26	19.5	4.0	1.0	1.0			1.0	1.0	11-4	Geom. Channel maintenance flood for channel geometry and sediment transport. Normally approximates to annual flood under natural conditions.	General habitat maintenance.
1:2	29	-	5.0	P				P	1:2		Geom. Overtops banks on to flood bench, deposition on flooded area. Retain natural frequency for key geomorphological flow.	General habitat maintenance.
1:5	107	-	-						-	-	Overtop terrace and resetting bed	
1:10	196	-	-						-	-	Important that water resource developments are not operated a flood control devices - the large floods are beneficial to riverine ecosystems.	Cannot be released.
1:20	317	-	-						-	-		

EC = D	Flood parameters			NUMBER OF EVENTS							Discussion of changes	
									FINAL			
FLOOD CLASSES	Range	Range Average	Duration (days)	**Geom No.**	**Veg No.**	**Invert No.**	**Fish No.**	**MIN**	**No.**	***Timing**	Primary	Secondary
Class 1	1.7-3.3	2.5	1.0	1.0	1.0	2.0	1.0	2.0	2.0	3-11	Inverts: · Flush out benthic algae and fines· Provide sufficient current speed to discourage bilharzias snails. · Two events per annum should be sufficient for a D category.	Fish. Mainly for the Inundation of marginal vegetated areas for spawning. There is also a requirement for cleaning of gravel/ cobble beds for riffle spawning Important for local migrations, breeding and recruitment. It is important for more than one event to activate backwaters marginal vegetated and nursery areas. It is essential that marginal vegetation and or backwaters in this event is inundated for 4—5 days which will allow the fish larvae to become free swimming and reduce losses due to drying of eggs and fry and ensure some annual recruitment.
Class 2	3.3-6.5	4.9	2.0	2.0	1.0			2.0	2.0	11-4	Geom. Bed material transport and sorting. Retain some variability.	Fish / inverts / veg: Retain some flow variability.
Class 3	6.5-13	9.8	3.0	2.0	1.0			2.0	2.0	11-4		
Class 4	13-26	19.5	4.0	0.5	0.5			0.5	0.5	11-4	Geom. Channel maintenance flood for channel geometry and sediment transport. Normally approximates to annual flood under natural conditions, alternate with 1:3 flood.	General habitat maintenance.
1:2	29	-	5.0	P				P	1:3		Geom. Overtops banks on to flood bench, deposition on flooded area. Infrequent high magnitude events important for resetting bed and maintaining upper riparian zone habitat.	General habitat maintenance.
1:5	107	-							-	-	Important that water resource developments are not operated a flood control devices - the large floods are beneficial to riverine ecosystems.	Cannot be released.
1:10	196	-							-	-		
1:20	317	-							-	-		

Table 8-11. EWR Summary Table for EWR site T1 for REC: C.

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	VOL ($X10^6$ m^3)	nMAR%
EWR SITE T1: EMC =C.														
LOW FLOWS														
MAINTENANCE LOW FLOWS (m^3/s)	0.2	0.3	0.4	0.5	0.6	0.5	0.5	0.4	0.4	0.3	0.2	0.2	**11.448**	**18.89**
DROUGHT LOW FLOWS (m^3/s)	*0.1*	*0.1*	*0.2*	*0.2*	*0.3*	*0.2*	*0.2*	*0.2*	*0.2*	*0.1*	*0.1*	*0.1*	***4.982***	***8.22***
HIGH FLOWS														
FLOOD (daily average m^3/s)	2.5	4.9	4.9	9.8	1)9.8 2)19.5 3)29.9		2.5					2.5	**9.370**	**15.46**
Duration (in days)	1	2	2	3	1) 3 2) 4 3) 5		1					1		
Return period (years)	1:1	1:1	1:1	1:1	1) 1:1 2) 1:1:5 3) 1:3		1:1					1:1		
LONG-TERM MEAN													***22.139***	***36.54***

Table 8-12. EWR Summary Table for EWR site T1 for EC: B.

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	VOL ($X10^6$ m^3)	nMAR%
EWR SITE T1: EMC =B.														
LOW FLOWS														
MAINTENANCE LOW FLOWS (m^3/s)	0.3	0.4	0.5	0.6	0.8	0.7	0.6	0.6	0.5	0.4	0.4	0.3	**15.684**	**25.88**
DROUGHT LOW FLOWS (m^3/s)	*0.1*	*0.2*	*0.2*	*0.2*	*0.3*	*0.2*	*0.2*	*0.2*	*0.2*	*0.1*	*0.1*	*0.1*	***5.464***	***9.02***
HIGH FLOWS														
FLOOD (daily average: m^3/s)	2.5	4.9	1)4.9 2)9.8	1)4.9 2)9.8	19.5	1)2.5 2)29.9	2.5					2.5	**12.345**	**20.37**
Duration (in days)	1	2	1) 2 2) 3	1) 2 2) 3	4	1) 1 2) 5	1					1		
Return period (years)	1:1	1:1	1) 1:1 2) 1.1	1) 1:1 2) 1.1	1:1	1) 1:1 2) 1.2	1:1					1:1		
LONG-TERM MEAN													***27.438***	***45.28***

Table 8-13. EWR Summary Table for EWR site T1 for EC: D.

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	VOL ($X10^6$ m^3)	nMAR%
EWR SITE T1: EMC =D.														
LOW FLOWS														
MAINTENANCE LOW FLOWS (m^3/s)	0.1	0.1	0.2	0.2	0.3	0.2	0.2	0.2	0.2	0.1	0.1	0.1	**4.982**	**8.22**
DROUGHT LOW FLOWS (m^3/s)	*0.1*	*0.1*	*0.2*	*0.2*	*0.3*	*0.2*	*0.2*	*0.2*	*0.2*	*0.1*	*0.1*	*0.1*	***4.982***	***8.22***
FLOOD (daily average: m^3/s)		4.9	4.9	9.8	1)9.8 2)19.5 3)29.9		2.5					2.5	**8.446**	**13.94**
Duration (in days)		2	2	3	1) 3 2) 4 3) 5		1					1		
Return period (years)		1:1	1:1	1:1	1) 1:1 2) 1:2 3) 1:3		1:1					1:1		
LONG-TERM MEAN													***17.511***	***28.9***

Table 8-14. EWR rule table for REC: C

Desktop Version 2, Printed on 06/12/2004
Summary of EWR rule curves for : EWR T1 Monthly Nat EWR T1
Determination based on defined BBM Table with site specific assurance rules.
Regional Type : E.Escarp REC = C

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

This EWR rule table can be used in combination with the natural duration curves below for implementation.

Reserve flows without High Flows

Month	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	0.328	0.327	0.324	0.319	0.308	0.289	0.256	0.208	0.150	0.106
Nov	0.411	0.410	0.406	0.399	0.385	0.360	0.319	0.260	0.190	0.137
Dec	0.530	0.528	0.523	0.513	0.494	0.461	0.406	0.329	0.237	0.169
Jan	0.655	0.652	0.645	0.632	0.608	0.565	0.498	0.403	0.293	0.211
Feb	0.767	0.764	0.757	0.743	0.717	0.670	0.595	0.486	0.358	0.263
Mar	0.697	0.695	0.689	0.676	0.652	0.609	0.539	0.437	0.315	0.225
Apr	0.627	0.626	0.621	0.611	0.591	0.554	0.493	0.402	0.293	0.211
May	0.558	0.557	0.553	0.544	0.527	0.495	0.440	0.358	0.257	0.180
Jun	0.488	0.487	0.484	0.477	0.463	0.435	0.388	0.316	0.227	0.159
Jul	0.390	0.390	0.388	0.383	0.372	0.351	0.314	0.256	0.183	0.127
Aug	0.335	0.334	0.332	0.327	0.318	0.300	0.268	0.220	0.161	0.116
Sep	0.307	0.306	0.304	0.300	0.291	0.274	0.244	0.200	0.146	0.105

Natural Duration curves

Oct	1.221	0.978	0.762	0.653	0.582	0.478	0.444	0.392	0.336	0.265
Nov	4.379	2.064	1.566	1.254	1.150	1.003	0.938	0.795	0.613	0.340
Dec	6.078	4.954	3.405	2.292	1.781	1.632	1.404	1.269	0.952	0.497
Jan	9.648	6.825	5.414	3.592	2.714	1.975	1.800	1.635	1.232	0.952
Feb	13.835	7.350	5.564	3.245	2.125	2.013	1.823	1.666	1.447	1.124
Mar	6.116	4.391	2.852	1.934	1.729	1.557	1.415	1.344	1.098	0.963
Apr	3.241	1.933	1.813	1.644	1.543	1.474	1.285	1.123	0.965	0.745
May	1.755	1.542	1.340	1.273	1.154	1.023	0.915	0.814	0.717	0.478
Jun	1.319	1.154	1.019	0.899	0.814	0.725	0.667	0.598	0.536	0.378
Jul	0.997	0.777	0.706	0.653	0.601	0.556	0.459	0.429	0.392	0.299
Aug	0.773	0.661	0.553	0.515	0.467	0.426	0.399	0.362	0.336	0.284
Sep	0.752	0.644	0.521	0.471	0.455	0.417	0.378	0.355	0.313	0.255

Total Reserve Flows

Month	% Points 10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	0.424	0.423	0.419	0.412	0.397	0.370	0.324	0.257	0.177	0.116
Nov	0.684	0.682	0.675	0.661	0.635	0.588	0.510	0.398	0.265	0.166
Dec	0.794	0.790	0.782	0.766	0.735	0.679	0.590	0.461	0.310	0.197
Jan	1.760	1.610	1.479	1.358	1.236	1.031	0.888	0.687	0.453	0.280
Feb	5.594	4.952	4.404	3.245	2.125	2.013	1.823	1.666	1.071	0.566
Mar	0.697	0.695	0.689	0.676	0.652	0.609	0.539	0.437	0.315	0.225
Apr	0.727	0.725	0.719	0.707	0.683	0.638	0.564	0.454	0.321	0.221
May	0.558	0.557	0.553	0.544	0.527	0.495	0.440	0.358	0.257	0.180
Jun	0.488	0.487	0.484	0.477	0.463	0.435	0.388	0.316	0.227	0.159
Jul	0.390	0.390	0.388	0.383	0.372	0.351	0.314	0.256	0.183	0.127
Aug	0.335	0.334	0.332	0.327	0.318	0.300	0.268	0.220	0.161	0.116
Sep	0.406	0.406	0.403	0.396	0.383	0.358	0.316	0.253	0.175	0.116

Table 8-15. EWR rule table for EC: B

Desktop Version 2, Printed on 06/12/2004
Summary of EWR rule curves for : EWR T1 Monthly Nat EWR T1
Determination based on defined BBM Table with site specific assurance rules.
Regional Type : E.Escarp EC = B

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

This EWR rule table can be used in combination with the natural duration curves below for implementation.

Reserve flows without High Flows

Month	**10%**	**20%**	**30%**	**40%**	**50%**	**60%**	**70%**	**80%**	**90%**	**99%**
Oct	0.406	0.405	0.402	0.396	0.383	0.360	0.321	0.264	0.195	0.143
Nov	0.478	0.476	0.472	0.464	0.448	0.418	0.371	0.302	0.219	0.158
Dec	0.597	0.595	0.589	0.578	0.556	0.517	0.455	0.365	0.259	0.181
Jan	0.717	0.713	0.705	0.690	0.663	0.615	0.538	0.430	0.305	0.213
Feb	0.896	0.892	0.884	0.866	0.834	0.775	0.681	0.545	0.385	0.266
Mar	0.812	0.810	0.802	0.787	0.757	0.705	0.618	0.494	0.345	0.235
Apr	0.729	0.727	0.721	0.708	0.684	0.638	0.562	0.450	0.315	0.213
May	0.657	0.656	0.651	0.641	0.620	0.580	0.513	0.411	0.287	0.192
Jun	0.561	0.561	0.557	0.549	0.532	0.499	0.443	0.357	0.251	0.170
Jul	0.478	0.478	0.475	0.469	0.456	0.430	0.384	0.313	0.223	0.154
Aug	0.422	0.421	0.419	0.413	0.401	0.378	0.338	0.277	0.202	0.145
Sep	0.399	0.399	0.396	0.390	0.379	0.357	0.320	0.264	0.195	0.143

Total Reserve Flows

Month	% Points **10%**	**20%**	**30%**	**40%**	**50%**	**60%**	**70%**	**80%**	**90%**	**99%**
Oct	0.495	0.493	0.489	0.481	0.465	0.435	0.384	0.310	0.220	0.153
Nov	0.728	0.725	0.718	0.704	0.677	0.627	0.546	0.429	0.290	0.187
Dec	1.479	1.472	1.456	1.423	1.360	1.250	1.070	0.811	0.507	0.281
Jan	2.282	2.070	1.886	1.719	1.552	1.274	1.091	0.833	0.533	0.311
Feb	3.736	3.357	3.030	2.739	2.125	1.985	1.699	1.288	0.805	0.445
Mar	3.167	2.854	2.583	1.934	1.729	1.557	1.415	1.116	0.696	0.383
Apr	0.820	0.818	0.811	0.796	0.768	0.715	0.627	0.498	0.341	0.224
May	0.657	0.656	0.651	0.641	0.620	0.580	0.513	0.411	0.287	0.192
Jun	0.561	0.561	0.557	0.549	0.532	0.499	0.443	0.357	0.251	0.170
Jul	0.478	0.478	0.475	0.469	0.456	0.430	0.384	0.313	0.223	0.154
Aug	0.422	0.421	0.419	0.413	0.401	0.378	0.338	0.277	0.202	0.145
Sep	0.490	0.490	0.486	0.471	0.455	0.417	0.378	0.312	0.222	0.153

Table 8-16. EWR rule table for EC: D

Desktop Version 2, Printed on 06/12/2004
Summary of EWR rule curves for : EWR T1 Monthly Nat EWR T1
Determination based on defined BBM Table with site specific assurance rules.
Regional Type : E.Escarp   EC = D

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

This EWR rule table can be used in combination with the natural duration curves below for implementation.

Reserve flows without High Flows

Month	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	0.207	0.207	0.206	0.203	0.198	0.189	0.174	0.151	0.123	0.103
Nov	0.259	0.259	0.257	0.254	0.247	0.236	0.217	0.190	0.157	0.133
Dec	0.315	0.314	0.312	0.308	0.300	0.286	0.263	0.231	0.192	0.164
Jan	0.395	0.393	0.390	0.385	0.374	0.356	0.328	0.287	0.240	0.205
Feb	0.494	0.493	0.490	0.483	0.471	0.449	0.413	0.362	0.301	0.256
Mar	0.425	0.424	0.421	0.416	0.405	0.386	0.355	0.311	0.258	0.218
Apr	0.395	0.394	0.392	0.387	0.378	0.361	0.333	0.292	0.242	0.205
May	0.339	0.339	0.337	0.333	0.326	0.312	0.288	0.252	0.208	0.174
Jun	0.303	0.303	0.301	0.298	0.292	0.279	0.258	0.225	0.185	0.154
Jul	0.243	0.243	0.242	0.240	0.235	0.225	0.208	0.182	0.149	0.123
Aug	0.213	0.213	0.212	0.210	0.206	0.197	0.183	0.161	0.133	0.113
Sep	0.205	0.205	0.204	0.202	0.197	0.188	0.174	0.151	0.124	0.103

Total Reserve Flows

	% Points									
Month	**10%**	**20%**	**30%**	**40%**	**50%**	**60%**	**70%**	**80%**	**90%**	**99%**
Oct	0.207	0.207	0.206	0.203	0.198	0.189	0.174	0.151	0.123	0.103
Nov	0.600	0.598	0.592	0.581	0.559	0.519	0.454	0.360	0.248	0.164
Dec	0.645	0.642	0.636	0.624	0.600	0.559	0.491	0.393	0.279	0.194
Jan	1.500	1.351	1.224	1.111	1.002	0.822	0.718	0.571	0.400	0.274
Feb	4.753	4.188	3.707	3.245	2.125	2.013	1.823	1.476	0.930	0.524
Mar	0.425	0.424	0.421	0.416	0.405	0.386	0.355	0.311	0.258	0.218
Apr	0.519	0.518	0.514	0.507	0.493	0.466	0.421	0.355	0.276	0.216
May	0.339	0.339	0.337	0.333	0.326	0.312	0.288	0.252	0.208	0.174
Jun	0.303	0.303	0.301	0.298	0.292	0.279	0.258	0.225	0.185	0.154
Jul	0.243	0.243	0.242	0.240	0.235	0.225	0.208	0.182	0.149	0.123
Aug	0.213	0.213	0.212	0.210	0.206	0.197	0.183	0.161	0.133	0.113
Sep	0.330	0.329	0.327	0.322	0.312	0.294	0.263	0.216	0.158	0.114

8.8 CONFIDENCE

The confidence was evaluated according to a score of 0-5 with zero reflecting 'no confidence' and 5 reflecting 'very high' confidence (Table 8-17).

Table 8-17. Confidence Ratings for EWR site T1.

	EWR SITE	AVAILABLE DATA	ECOLOGICAL CLASSIF.	OUTPUT LOW FL	OUTPUT HIGH FL
HYDROLOGY		3	3		
	The Teespruit is not gauged so the flow time series was based on transposed model parameters. Confidence was rated as fair for available data and the ecological classification.				
HYDRAULICS	4	4/0=2		5	3
	Measured flows in the range 0.12 to 3.25m^3/s. Recommended low-flows for the PES (C) in the range 0.1 to 0.6m^3/s, and high flows in the range 2.5 to 20(within year) and 29-317 m^3/s (1:2-1:20).				
QUALITY		1	1		
	Low confidence in data due to limited number of samples (1). EC confidence in data was low (4 samples only). No temperature, dissolved oxygen, chlorophyll and turbidity data available				
GEOMORPH	4	2	3	N/A	3.5
	No daily hydrological data, site visit by specialist at high flows, visited catchment. No stream power based sediment transport model. Uncertainty as to extent of upstream impacts on storm runoff and sediment. Good coincidence between morphological clues and flood classes **GENERAL COMMENT ON CONFIDENCE IN FLOOD REQUIREMENTS** (same as EWR Site K3)				
RIP VEG	3	3	4		3
	EWR site: A good site, but new vehicle track crossing site is detractive **Available data:** Vegetation profile studied twice (once in winter and once in Autumn). **Ecological classification:** Confirmed by RVI analysis. **Output low flow:** Recommendations not tested **Output high flow:** Recommendations match current situation				
FISH	4	4	4	4	3
	Confidence in available data is moderately high because historic data goes back as far as the 1960's and 1970/80. Several surveys have been conducted in this Resource Unit over last three years. Moderately high confidence in EC based on the available data and several recent surveys conducted during last 3 years in this Resource Unit. Moderately high confidence in EWR site as it provided good indications of the abundance of critical habitat required by indicator species under different flows and could be used to set stress. Moderately high confidence in low flows based on the available hydraulic data and fish info it was possible to set realistic flows in terms of its stress and availability of critical habitat for indicator species. Moderate confidence in high flows based on our understanding of the species in this Resource Unit, fish has a need of Class 1 floods in terms of breeding and local migrations.				
INVERT	3	3	4	4	4

	Moderate diversity of biotopes present: Highly suitable MVOC; Suitable SIC, bedrock, MVIC, and sand; Moderate SOC and gravel; Absent biotopes are aquatic vegetation only, and mud habitats poor Benthic algae limits habitat availability. Data were available for 9 SASS samples recorded at 3 sampling sites within this Resource Unit, so confidence in the results was moderate. Information available was suitable for evaluation as required. The invertebrate requirements are being met. The invertebrate requirements are met by those of the fish.

9. EWR SITE L1 – KLEINDORINGKOP

9.1 ECOLOGICAL CATEGORIES

The PES for EWR Site L1 is summarised Table 9-1 and a description of the reference conditions, and PES for individual components is presented in Table 9-2. Although the ecosystem is fairly healthy, there has been a major change from reference conditions. The geomorphology is greatly modified from a fairly unstable mobile channel with large sand banks in 1937 to a vegetation-stabilized channel, with a negligible sand component. The vegetation is also greatly modified from natural, from a fairly sparsely vegetated channel in 1937 to a channel with a significant woody vegetation component. The fish comprise a greatly altered community structure in which temperate species have replaced tropical species. The PES EcoStatus measured against the original (natural) reference condition is in a Category D. The PES EcoStatus measured against modified reference conditions which include; (a) temperate fish species rather than tropical, (b) more woody material, (c) more defined channel and (d) increased natural base flows for all months (especially in the dry season) were in a Category C/D. Thus, on the basis of the assessments as summarized above, the present ecological status of the Lomati as represented by EWR Site L1, and using the natural condition as a reference, is in a Category D. The above assessment notwithstanding, the current biotic diversity is good, and the channel structure appears fairly stable. What this means is if a different reference condition was used, then the present ecological state would improve to a Category C/D. Flows were set to maintain the present ecological status, with the recommendation that the reference condition for this site be altered to reflect the historic changes that have taken place.

Table 9-1. The PES for EWR EWR Site L1.

Driver Components	Component PES	Driver PES	ECOSTATUS PES
HYDROLOGY	D	D	C/D
GEOMORPH	D		
WATER QUALITY	B/C		
Response Components	Component PES	Instream PES	
FISH	C	C	
AQUATIC INVERTS	C		
RIPARIAN VEG	B/C	C	

Table 9-2. Description of the PES categories for each habitat driver and biological response for EWR Site L1.

Category B/C = Largely Natural to Moderately Modified; C= Moderately Modified; C/D= Moderately to Largely Modified and D= Largely Modified.

Driver and responses	Reference conditions	PES	PES description
			Overall PES for Drivers Largely Modified (Category D).
Hydrology	nMAR= 322 million m^3/a	**D**	pMAR= 218 million m^3/a EWR site L1 lies approximately 20 km below Driekoppies Dam. This dam has a large capacity relative to the MAR of its catchment. The dam controls 90% of the catchment and 84% of the MAR at L1. The main changes from natural conditions include constant baseflows (high and low) since dam construction (abnormal peaks previously), a change in seasonality, heavily affected moderate events and no zero flows (although comes very close). The main changes from natural flows are as follows: • pMAR is 68% of nMAR; 38% reduction at 70% exceedance • Wet season is 2 months shorter • Moderate flows: 39% reduction at 50% exceedance • High flows: 22% reduction at 10% exceedance
Geomorphology	L1 is classified as a lower foothill site on account of its channel gradient of 0.002. Its gradient puts it close to a lowland river. The expected reach type would be an alluvial regime channel with a bed material dominated by gravel and sand. The bed would generally be highly mobile, forming mid-channel bars within a braided configuration. Stable substrate to support vegetation would be restricted to the channel margins and banks. Marginal vegetation would be an important habitat.	**D**	Driekoppies Dam is likely to have a serious future effect on geomorphological processes at L1. This dam was only completed in 1999, so many of its impacts will not yet have been felt in the channel. A large weir below Driekoppies, build in 1950, will also have had a moderating influence on event hydrology. The impact on flows in the past is estimated as moderate. These have caused following changes in sediment inputs, riparian vegetation and channel structure. **Sediment inputs**: The upstream weir (Schoemans) provides significant storage for trapping coarse sediment. Trapping of coarse sediment by Driekoppies during the floods of 2000 may have also contributed to the noticeable coarsening of the bed material. Significant coarsening of the bed material is evident. The impact on sediment input is probably large. **Riparian Vegetation**: Aerial photographs indicate a definite narrowing of the channel since 1939, loss of secondary channels and vegetation encroachment. Presently trees, shrubs and reeds provide a continuous cover on the flood zones, active channel banks and channel margins. These provide good protection against erosion. There is uncertainty as to the cause of vegetation change. This may be a response to changing sediment dynamics, with a reduction in unstable sandy substrate favouring woody vegetation. It may also be the case that the lack of woody vegetation in 1939 photographs was due to its removal by an extreme flood event at the beginning of the year. Floods and consequent loss of woody vegetation occurred in the Sabie River in the same year. The geomorphological impact of riparian vegetation is rated as large**,** but this may be an overestimate if changes are part of a natural cycle. **Channel structures**: There are a few small weirs in the lower reaches of the Lomati. The impact of channel

			obstruction at this site is rated as **small**.
Water Quality	The water quality of L1 would have been improved in a reference condition due to no flow reductions from Driekoppies Dam and weirs. The water quality problems such as nutrient enrichment (phosphates, nitrates, nitrites, ammonia), higher salinity values (electrical conductivity) and microbiological contamination.	**B/C**	The main water quality issues relate to altered water temperatures and reduced turbidity levels because of the upstream Driekoppies Dam, non-point sources of sewerage pollution and runoff from irrigated agriculture causing elevated nutrients and salinity.
			Overall Instream PES Moderately Modififed (Category C)
Riparian Vegetation		**B/C**	The main changes are triggered by flow related causes (high low flows, highly variable flows, including periods of zero flow, increased flows during weekends because of reduced agricultural demands, change in water quality post dam construction (cooler temperatures)) and non-flow related causes (organic enrichment from poor sanitation facilities, removal of riparian vegetation, cultivation within riparian zone, agricultural return flows, deforestation).
Marginal zone: Woodland on sandy floodplain and Reedbed on banks	• Annual flood bench comprising muddy substrate at water's edge would be dominated by clumps of *Phragmites mauritianus* reed and the grass *Ischaemum fasciculatum.* • Sedges such as *Cyperus distans* and ferns such as *Amelopteris prolifera* would occur at water's edge. • A sandy / boulder floodplain would support an open canopy of trees such as *Breonadia salicina, Olea woodiana, Sesbania sesban* and *Syzygium* species. • Mesophytic grasses such as *Bothriochloa insculpta* and *Imperata cylindrica* would dominate more seasonal pools hosting *Typha capensis* reeds. • Alien invader species would be absent.		• Moderate increase in biomass of *Phragmites mauritianus* reeds and of trees such as *Breonadia salicina* and *Syzygium* species as a result of high low flows and reduced flooding. This offset to some extent by the effects of deforestation. • Moderate increase in number of indigenous species (eg. *Antidesma venosum, Diospyros mespiliformis* and *Garcinia livingstonei*) as a result of terrestrialisation caused by reduced flooding • Small change in overall species composition due to invasion by *Chromalaena odorata, Sesbania punicea* and *Senna didymobotrya* • Moderate change in structure due to Phragmites reed encroachment caused by reduced flooding and deforestation.
Lower riparian zone: Woodland on loose sand terraces	• Mesophytic trees and shrubs such as *Combretum erythrophyllum, Ficus sycomorus, Syzygium guineense,* and *Kraussia floribunda* would occur in a mosaic of closed and open-canopy woodland. • Terrestrial species would not be dominant. • Alien invader species would be absent.		• Moderate increase in biomass of trees such as *Combretum erythrophyllum, Ficus sycomorus Syzygium guineense, Nuxia oppositifolia* and *Kraussia floribunda* as a result of reduced flooding. This offset to some extent by the effects of deforestation. • Moderate increase in number of indigenous species (eg. *Annona senegalensis*, *Dicrostachys cinerea*, *Diospyros mespiliformis, Euclea natalensis, Garcinia livingstonei* and *Gymnosporia senegalensis*) due to terrestrialisation caused by reduced flooding • Moderate change in overall species composition as a result of invasion by alien species such as *Lantana camara, Chromolaena odorata* and *Psidium guajava* • Moderate change in structure due to poor recruitment of dominant trees such as *Combretum erythrophyllum* and *Ficus sycomorus* and encroachment of shrubs and climbers such as *Canavalia virosa, Crotalaria* sp. and *Rhynchosia hirta* .
Upper riparian zone: Closed Woodland on firm colluvial slopes	• The colluvial hillslopes would support mostly 'non-riparian' tree species (eg. *Acacia robusta, Albizia versicolor, Diospyros mespiliformis,* and *Sclerocarya birrea*). • There would be a good ground cover of grasses such as *Themeda triandra,*		• Small reduction in biomass, cover and indigenous species due to deforestation • Large change in overall species composition due to invasion by alien species such as *Lantana camara, Chromolaena odorata* and *Psidium guajava* • Small change in structure due to deforestation.

	Panicum maximum and *Cymbopogon validus.* • There would be no alien invasive species present.		
Fish	Available information indicates that the site contained roughly 29 both temperate and more tropical species (similar to EWR Site K4). Reports from local farmers suggest that more tropical species (*Hydrocynus vittatus* and *Brycinus imberi)* historically occurred in this part of the river. The Mpumalanga Parks Board fish database and surveys by Schulz (1994) suggest that temperate species were mostly absent in this river before the construction of the dam and that species associated with large sandy pools such as *Labeo rosae* was very common. This data also suggest that limnophilic species dominated the fish assemblage in this river prior to dam construction and that rheophilic species only occurred intermittently. Most of the species recorded at this site pre dam construction have a flow requirement for at least a part of their life cycle (eurytopic).	**C**	The present indigenous species diversity probably does not reflect the natural fish assemblage for this site as the abundance of temperate, sensitive and rheophilic species has probably increased, while the abundance of some tropical, migratory and eurytopic species has decreased. *Serrranochromis robustus* (nembwe) has recently (within the last two years) established in this Resource Unit and may become a problem in future. **Flow depth;** Low abundance of fish preferring fast flowing habitats during certain life stages and slow flowing habitats with undercut banks and marginal vegetated areas. Absence of species preferring slow deep habitats, especially the more tropical species such as (*Labeo rosae*, Hydrocynus etc) . **Flow Modification:** Presence of all three eel species (low abundance) indicating that this river is still important for these fish and may increase if migration routes are improved. Migration of yellowfish and most tropical fish severely affected by weirs and dams. Common abundance of flow dependant and moderately flow dependants established after Driekoppies Dam. **Substrate:** Low abundance of fish preferring gravel / cobble substrate in fast deep habitats and species preferring undercut banks and marginal vegetated areas. Absence of fish preferring sandy substrate in slow deep habitats especially the more tropical species such as (*Labeo rosae*, Hydrocynus etc). **Water Quality:** Higher abundance of species intolerant of water quality (increase in rheophilic / temperate species). All other categories less abundant than expected.
Aquatic Invertebrates	The characteristic feature of the stones-in-current fauna under reference conditions was the dominance of the caddisfly *Cheumatopsyche zuluensis*, which comprised 25% of the fauna, followed by Tricorythidae (17%), Afronurus (13%), and *Eutharulus elegans* (11%). The marginal vegetation was dominated by helodid larvae (6%) and *Baetis bellus* (3%).	**C**	Confidence in the results was low to moderate. The main changes triggered by flow and non-flow related causes. The following aspects were noted: • reduced abundance of taxa that require moderate and good quality water • abundance of the pest blackfly *Simulium damnosum.* • characterised by the presence of Heptageniidae, Baetidae, Leptophlebiidae, Leptoceridae, Elmidae . • dominance of one species of the pest blackfly, *Simulium damnosum,* • absence or low numbers of Atyidae, Palaemonidae, Perlidae and Tricorythidae. • No taxa dominated the fauna, • flow-dependant flat-headed mayflies were common.

Additional tables providing scores for the individual driver components and biological responses (instream) and a summary of the EcoStatus are available in Appendix F.

9.2 TRENDS

Current management of releases from upstream impoundments is not likely to change and provided that deforestation and cultivation in the riparian zone does not escalate, the trend for riparian vegetation is considered to be stable for both the short and long term.

Fish are on a downward trend.

Aquatic invertebrate conditions are considered to be stable in the short-term, but deteriorating in the long-term. Driekoppies Dam is likely to lead to bed armouring and reduced diversity of substrate sizes and associated benthic habitat availability.

Channel morphology and bed structures will continue to adjust to changes in flow and sediment induced by Driekoppies Dam. The category is not likely to change. A key to the direction of geomorphological change will be the state of vegetation. Channel dynamics are contingent on the dynamics of the riparian vegetation. As the vegetation may be subject to flood-induced cyclical changes, the ability to recover from extreme floods is essential. It is therefore important to maintain the constructive intermediate floods, close to the one or two year floods.

9.3 IMPORTANCE

9.3.1 Ecological Importance and Sensitivity

The Ecological Importance and Sensitivity of Resource Unit M within the provincial reserve were considered *Very High* under natural conditions and *High* under present conditions. The confidence for this assessment was high. The main determinants were the diversity of habitats (pools and riffles), the presence of the endangered crocodile (*Crocodylus niloticus)*, *Chetia brevis*, *Opsaridium*, hippopotamus (*Hippopotamus amphibious*), African finfoot (*Podica senegalensis*), Half-collared kingfisher (*Alcedo semitorquata*), the presence of flow-dependent fish species (*Barbus utenia*, *Chiloglanis, Opsaridium*), the high number of fish species (15 fish species expected) and the importance of the area for conservation at a national scale. Detailed results are presented in Appendix G.

9.3.2 Socio-cultural Importance

The area was considered of *High* Socio-cultural Importance. The lower reaches of the Lomati River is used intensively for irrigated agriculture, sugarcane in particular. Direct dependence on the river by local communities is likely to be similar to Resource Unit D (ie, very important), but most villages are some distance from the river, and access to the river appears to have been restricted. Detailed results are presented in Appendix H.

9.4 RANGE OF ECOLOGICAL CATEGORIES

9.4.1 Recommended Ecological Category

The EIS (present) and the Socio-cultural Importance were rated as *High*, indicating that a higher category should be recommended. Flows were not set for a higher than PES condition, because it is probably neither feasible nor possible to improve present conditions significantly.

9.4.2 Alternative Ecological Categories

No alternative Ecological Categories were considered. Fish would be unable to go up a Category because it is a completely different suite of fish species from the reference condition. Geomorphology could not go up a category either. The discrepancy with the reference condition exacerbates this as the original condition cannot be achieved. The option therefore is to maintain its present state. One category down is not feasible as it is a matter of resolution as to whether one is actually in a Category D or C/D and is such that it does not warrant setting half a category down. The rule-based models for the individual components were run in a predictive manner and based on the above hypothetical scenario, the matrixes that would be affected were changed. These spreadsheets with the changes indicated as different colours are included in the specialist appendices.

9.5 STRESS INDICES

Refer to Appendix I for the flow stress indices for the REC for fish and aquatic invertebrates.

9.5.1 Stress Index: Fish

The rheophilic species, *Chiloglanis anoterus* and the semi rheophilic, *Labeo cylindricus* were selected with the former species (CANO) being used for final stress. The rheophilc species was more sensitive at all flows as the large pools downstream provide adequate cover during low flows for this species (Table 9-3).

With a flow of 4 m^3/s there is abundant fast habitat available and none of the life history requirements of *Chiloglanis anoterus* are likely to be stressed. At a flow of 2.82 m^3/s there is still moderate availability of fast habitats but most rifles tend to become quite shallow and will significantly affect breeding and, to a lesser extent, available habitat and suitable cover. At a flow of 1.16 m^3/s the availability of fast habitats is further reduced and breeding will be restricted to only a few areas. The availability of suitable cover will also reduce affecting the abundance of the species. At a flow of 0.5 m^3/s the species will only survive in limited numbers due to a lack of suitable habitat. At this flow available habitat is slow shallow which effects temperature in turn affecting water quality and upsetting the health of fish. At a flow of 0.1 m^3/s no suitable fast flowing habitats are present and species may be lost.

Table 9-3. Stress table for rheophilic and semi-rheophilic fish species showing Habitat Suitability at EWR Site L1.

FLOW (CUMEC)	4.36	2.820	1.160	0.400	0.240	0.050	0.000
RELATIVE ABUNDANCE FLOW-DEPTH & COVER RATING: 0=NONE;1=RARE;2=SPARSE;3=MODERATE;4=ABUNDANT;5=VERY ABUNDANT)							
FAST DEEP	5	4.0	3.0	2.0	1.0	0.0	0.0
FAST SHALLOW	2.0	3.0	3.0	2.0	1.0	0.0	0.0
SLOW DEEP	5.0	5.0	5.0	5.0	5.0	5.0	5.0
SLOW SHALLOW	3.0	3.0	3.0	4.0	4.0	3.0	2.0

SUITABILITY FOR DIFFERENT FISH REQUIREMENTS PER HABITAT GUILD							
RHEOPHILIC	**SPECIES:**						
	Cano						
Breeding and early life-stages=	5.0	5.0	4.0	1.0	0.0	0.0	
Survival /Abundance =	5.0	5.0	4.0	3.0	2.0	0.0	
Cover =	5.0	5.0	4.0	3.0	2.0	0.0	
Health and condition=	5.0	5.0	5.0	4.0	3.0	0.0	
Water quality=	5.0	5.0	5.0	4.0	2.0	0.0	
Rheophilic stress - (breeding requirements included)	**0**	**0**	**1**	**4**	**6**	**10**	
SEMI-RHEOPHILIC	**SPECIES:**						
	Lcyl						
Breeding and early life-stages=	5.0	3.0	1.0	0.0	0.0	0.0	0.0
Survival /Abundance =	5.0	5.0	5.0	3.0	3.0	2.0	2.0
Cover =	5.0	5.0	4.0	3.0	3.0	2.0	2.0
Health and condition=	5.0	5.0	5.0	4.0	4.0	3.0	3.0
Water quality=	5.0	5.0	5.0	4.0	3.0	3.0	3.0
Semi-rheophilic stress - (breeding requirements included)	**0**	**1**	**2**	**4**	**5**	**6**	**6**
FLOW (CUMEC)	4.36	2.82	1.16	0.40	0.24	0.05	0.00
FLOW-DEPTH CONVERTED TO HABITAT RESPONSE (10=ALL FLOW-DEPTH CLASSES ABSENT (RIVER DRY); 0=FLOW-DEPTH *CLASSES OPTIMUM FOR SITE*; 9=NO FLOW)							
Fast deep	0	2	4	6	8	10	10
Fast shallow	6	4	4	6	8	10	10
Slow deep	0	0	0	0	0	0	0
Slow shallow	4	4	4	2	2	4	6
OVERALL HABITAT RESPONSE	**3**	**3**	**3**	**4**	**5**	**6**	**7**

9.5.2 Stress Index: Aquatic Invertebrates

Optimum Flow rates: 0.3 and 0.6 m/s
Key Species: *Neoperla spio*
Critical Habitats: Riffle

The relationships between aquatic invertebrate habitats, flows, stresses and associated biological responses at EWR Site L1 are detailed in Table 9-4.

The critical factors that were used to determine the stress curve were the current speeds and overall species composition. During the field survey on 6th August 2003 the flow was 2.8 m^3/s, and a habitat stress score of 2 was allocated. Biomonitoring data showed that most flow-sensitive species, such as *Centroptiloides bifasciata* and *Neoperla spio* were still present at these flows, and so the biological response stress was also rated as 2.

Table 9-4. Stress Table – Flow Dependant Invertebrate at EWR Site L1.

Habitat Flow Response Index	HABITAT ABUNDANCE AND SUITABILITY					TOTAL	FLOW	HABITAT RESPONSE	HABITAT CHARACTERISTICS					BIOTIC RESPONSE	FLOW	SPECIES STRESS	INTEGRATED STRESS
	SIC	SOC	VIC	VOC	GSM				Max depth (m)	Avg depth (m)	Max vel (m/s)	Avg vel (m/s)	WP (m)				
0	5	2	5	4	3	19	4.360	All habitat in excess, very high quality: very fast, very deep, very wide wetted perimeter	0.7	0.38	1.6	0.63	20.56	All very abundant, all healthy, all species persist	3.650	0	0
1	5	2	5	4	2	18	3.650	All plentifull, high quality; fast, wide wetted perimeter	0.66	0.36		0.56	19.39	All abundant, all healthy, all species persist		1	1
2	4	3	4	4	2	17	2.800	Critical habitats sufficient; quality slightly reduced: fast, wetted perimeter slightly reduced	0.64	0.35	1.3	0.52	19.1	Slight reduction for sensitive rheophilic species, all healthy in some areas, all species persist	2.800	2	2
3	3	3	3	3	2	14	2.000	Reduced critical habitat, reduced critical quality; moderate velocity, fairly deep, wetted perimeter slightly/moderately reduced	0.6	0.34		0.36	17.49	Reduction for all rheophilic species; all healthy in limited areas; all species persist	2.000	3	3
4	3	3	2	2	2	12	1.160	Critical habitats limited; moderate quality: Moderate velocity, Some deep areas, Wide WP moderately reduced	0.56	0.32	0.9	0.25	16.65	Further reduction for all rheophilic species; all viable in limited areas, critical life stages of some sensitive rheophilic species at risk, all species persist	1.160	4	4
5	2	3	2	2	2	11	0.700	Critical habitat very reduced; moderate/ low quality; moderate/slow velocity, few deep areas wetted perimeter moderately/very reduced	0.52	0.28		0.17	16.19	Limited populations of all rheophilic species. Critical life-stages of sensitive rheophilic species at risk or non-viable; all species persist	-	5	5
6	1	3	1	2	2	9	0.440	Critical habitat residual. Low quality; Moderate/slow velocity.	0.48	0.25	0.5	0.11	15.71	Sensitive rheophilic species rare, critical stages of sensitive rheophilic species non-viable, and at risk for some less sensitive species. All species persisit in the short-term	-	6	6
7	1	3	0	1	2	7	0.240	No critical habitat, other habitats moderate quality; slow, narrow wetted perimeter	0.45	0.225	0.4	0.08	15.42	Most rheophilic species rare; All life-stages of sensitive rheophilic species at risk or non-viable. Most sensitive rheophilic species disappear	0.440	7	7
8	1	2	0	0	2	5	0.050	Flowing water habitats residual low quality: slow trickle, very narrow wetted perimeter	0.36	0.16	0.07	0.02	13.35	Remnant populations of some rheophilic species; all life stages of most rheophilic species at risk or non-viable, many rheophilic species disappear	0.240	8	8
9	0	2	0	0	2	4	-	Standing water habitats only, very low quality, no flow	0.18	0.06	0	0	6.43	Mostly pool dwellers; all life stages of most rheophilic species non-viable; most or all rheophilic species disappear	0.050	9	9
10	0	0	0	0	0	0	-	Only hyporheic refugia, no surface water	0	0	0	0	0	Only specialists persist, virtually no development.	-	10	10

* Estimate of the site
** Findings after calibration
1 SIC: Partially submerged hard substrate in current >0.1 m/s
2 SOC: Partially submerged hard substrate in current <0.1 m/s
3 MVIC: Submerged vegetation (at least 2-3cm submerged) in current >0.1 m/s
4 MVOC: Submerged vegetation (at least 2-3cm submerged) in current<0.1 m/s
5 GS pool: Gravel/sand/pool

9.5.3 Integrated Stress Curve

The individual component stresses are illustrated as well as the integrated stress line (black line) (Figure 9-1).

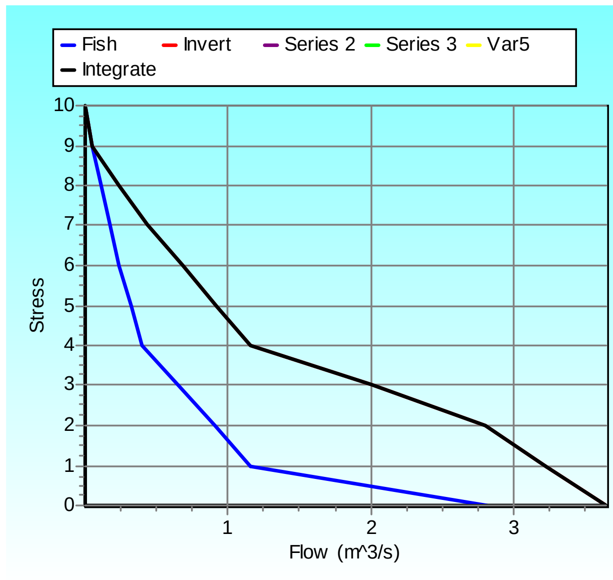


Figure 9-1. Index Stress Curves for EWR Site L1.

9.6 DETERMINATION OF EWR SCENARIOS

9.6.1 Low-Flow Requirements

The determined integrated stress index must now be used to identify required stress levels at specific durations for the wet and dry month / season. The requirements are illustrated in Figure 9-2.

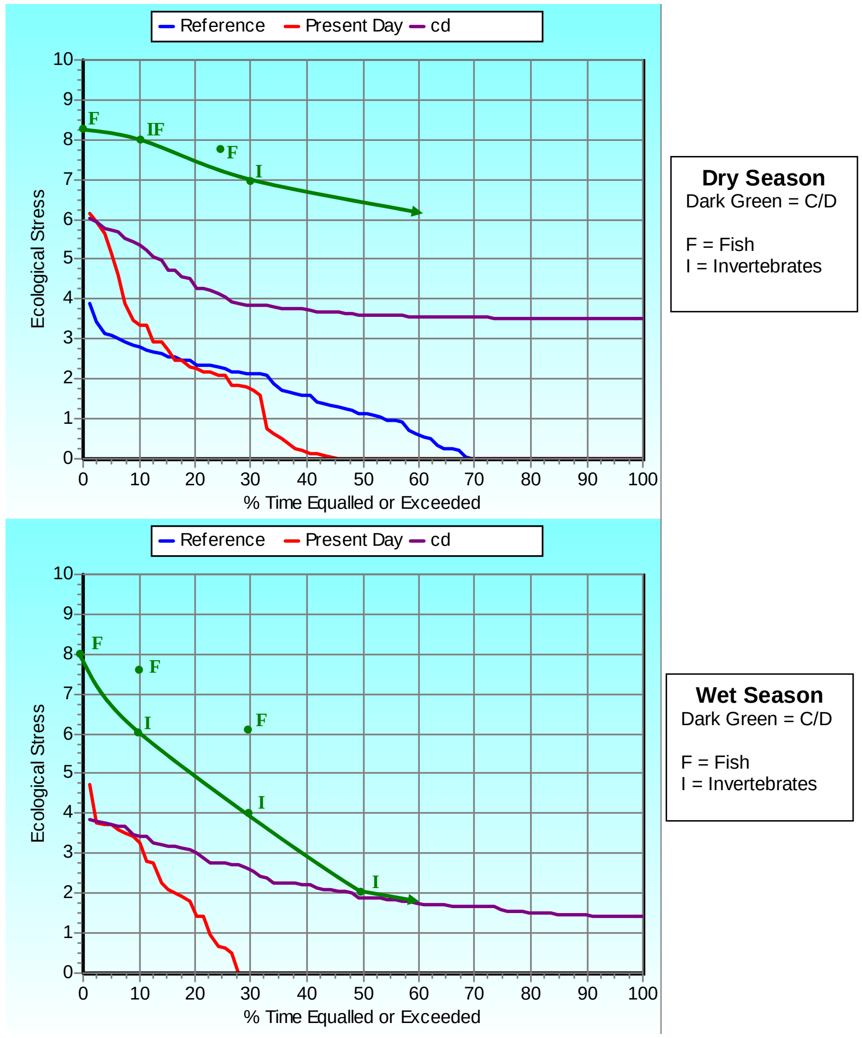


Figure 9-2. EWR Site L1 – Stress duration curves for all scenarios.

9.6.2 Motivations: Fish and Invertebrate

The stress referred to in the motiations below refers to fish stress, not component stress.

FISH: DURATIONS AND MOTIVATIONS TO BE USED FOR DETERMINING STRESS REQUIREMENTS
Indicator: *Chiloglanis anoterus.* The rheophilic species selected is dependant on perennial flow in fast deep and Fast Shallow habitats. The rheophilic species has become much more abundant and or established in this river after Driekoppies Dam.
DRY SEASON
DROUGHT: 10% at stress of 6 (IS=8) will allow for low survival of the species in sparse available fast deep and fast shallow habitat conditions. The habitat at this site is extremely sensitive to flow changes and at lower flows the critical habitat become very sparse or absent very rapidly. The stress level should never exceed 7 (IS=8.3) (0% of the time) otherwise the species and other rheophilic species could be lost.

MAINTENANCE: Maintaining it in its present state would comprise good habitat for the dry season and a stress of 4 (IS= 7.7) can be tolerated for 25% of the time.
WET SEASON
DROUGHT: 10%.at stress 4 (IS=7.1) will still allow spawning, but only with moderate available fast flowing sites with favourable habitat conditions. Relatively availability of FD and FS habitats moderately fragmented (patchy). A stress of 5 (IS= 7.6) must never (0% of time) occur as this will only allow for minimal survival and no recruitment or breeding. At this point summer temperatures may also become problematic and oxygen levels in water may become critical and species will be lost.
MAINTENANCE: Maintaining present state would comprise good survival habitat and good to moderately good breeding habitat and recruitment. Therefore a stress of 3 (IS=6.2) can be tolerated for 30% of the time.
General life history requirements *Chiloglanis anoterus* *Eggs:* Margins of FS (<0.3 m, >0.3 m/s) gravel cobble substrate. October – January. >16°C Duration 7 days 3 - 30% *Larva:* Feeding and Growth: Nursery areas (<0.3 m, >0.2 m/s), Margins of SS & overhanging vegetation. Duration larval period: 2 months. *Juvenile:* Feeding and Growth: Mostly FS and margins of SS (<0.30m deep >0.2 m/s). Cover: Cobbles & rocks overhanging vegetation. Duration 3-6 months. *Adult:* FD and FS (<0.3 m, >0.3 m/s) gravel, cobble Substrate. Spawning season: October – January. Cue: increased temperature, flow and changes in water quality (e.g. conductivity).

The stress referred to in the motiations below refers to aquatic invertebrate stress, not component stress.

AQUATIC INVERTEBRATES: DURATIONS AND MOTIVATIONS TO BE USED FOR DETERMINING STRESS REQUIREMENTS
Indicator: *Neoperla spio* The indicators are rheophilic species.
DRY SEASON
DROUGHT: +/-10%. Stress 8: Survival conditions. Ensure refuge habitats for taxa such as Turbellaria and freshwater shrimps (Atyidae). Flow more than a trickle must be maintained over the riffle, to protect against high temperatures and low oxygen concentrations. The river should never stop flowing as this eliminates many taxa and significantly reduces biodiversity. The habitat modelling data indicated that flows lower than this would lead to significant loss of habitats.
MAINTENANCE: 30%. Stress 7: Ensure sufficient current velocity (average 0.5m/s) for flow-dependent taxa such as *Cheumatopsyche afra*, Heptageniidae, Porifera and *Pseudocloeon glaucum.* Discourage bilharzia snails (*Bulinus africanus* and *Biomphalaria pfeifferi*), mosquitoes (Culicidae) and excessive numbers of Thiaridae. Photographs taken of the site in January 2004 showed that there would be sufficient habitats available at a flow of $0.24m^3/s$.
WET SEASON
DROUGHT: +/- 10%. Stress 6: Require riffle habitat to ensure sufficient current velocity (average 0.17m/s) for flow-dependent taxa such as Leptophlebiidae. Photographs taken of the site in April 2004 showed that there would be sufficient habitats available at a flow of $0.44m^3/s$.

MAINTENANCE: 30%. Stress 4: Ensure sufficient current velocity (average 0.9m/s) for flow-dependent taxa such as *Simulium hargreavesi, Simulium damnosum* and C*heumatopsyche afra*, *Amphipsyche scottae* and *Macrostenum capense.* Discourage bilharzia snails (*Bulinus africanus* and *Biomphalaria pfeifferi*) and mosquitoes (Culicidae). Ensure that stones in current habitats are kept free of benthic algae. Photographs taken of the site in November 2003 showed that there would be sufficient habitats available at a flow of 1.16m^3/s.
OTHER: 50%. Stress 2: Ensure sufficient current velocity (average 1.3m/s) for flow-dependent taxa such as *Centroptiloides bifasciata* and *Acanthiops varius.* Photographs taken of the site in August 2003 showed that there would be sufficient habitats available at a flow of 2.8m^3/s.

The low flow requirements set by fish and aquatic invertebrates were assessed for riparian vegetation.

RIPARIAN VEGETATION		
Flow	**Discharge (m^3/s)**	**Max flow depth (m)**
September drought	0.24	0.45
September maintenance	0.44	0.49
February drought	0.7	0.52
February maintenance	1.16	0.56
Acceptable for riparian vegetation provided that drought flows do not occur more than 5% of the time, and not in consecutive years.		

9.6.3 Final Low Flow Requirements

Adjustments to the Desktop Reserve Model requirements were made to fit the specialist requirements as shown in Table 9-5.

Table 9-5. EWR L1 - Maintenance and drought low flows (REC = CD).

Month	Desktop (m^3/s)		Modified (m^3/s)		Ratio (Mod/Desk)	
	Maintenance low flows	Drought low flows	Maintenance low flows	Drought low flows	Maintenance low flows	Drought low flows
Jan	1.444	0.997	0.750	0.320	52%	32%
Feb	1.850	1.271	1.160	0.403	63%	32%
Mar	1.726	1.185	1.060	0.375	61%	32%
Apr	1.656	1.140	0.950	0.362	57%	32%
May	1.434	0.991	0.800	0.314	56%	32%
Jun	1.331	0.923	0.680	0.292	51%	32%
Jul	1.139	0.794	0.500	0.251	44%	32%
Aug	1.004	0.704	0.363	0.224	36%	32%
Sep	0.948	0.668	0.342	0.211	36%	32%
Oct	0.915	0.644	0.330	0.200	36%	31%
Nov	1.054	0.739	0.450	0.240	43%	32%
Dec	1.211	0.842	0.600	0.300	50%	36%

The final curves for EWR L1 are shown in The low flow recommendations for each reserve scenario were finalised (Figure 9-3 and Figure 9-4).

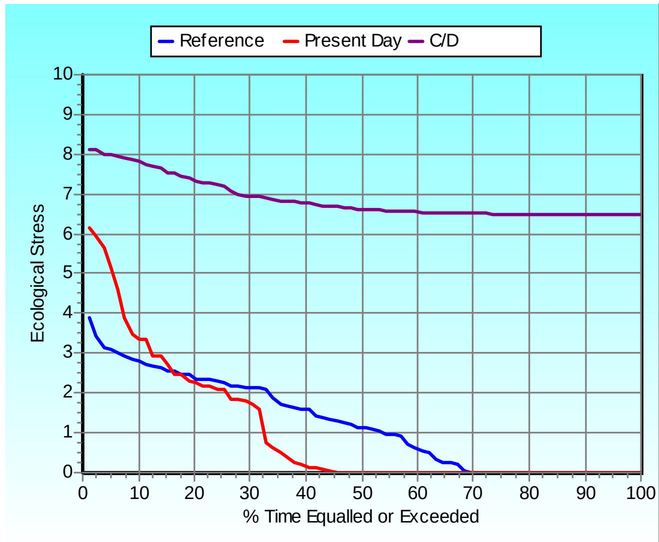


Figure 9-3. Final Stress Duration Curve for Reference conditions, present day and category C/D for the dry season (September) at EWR Site L1.

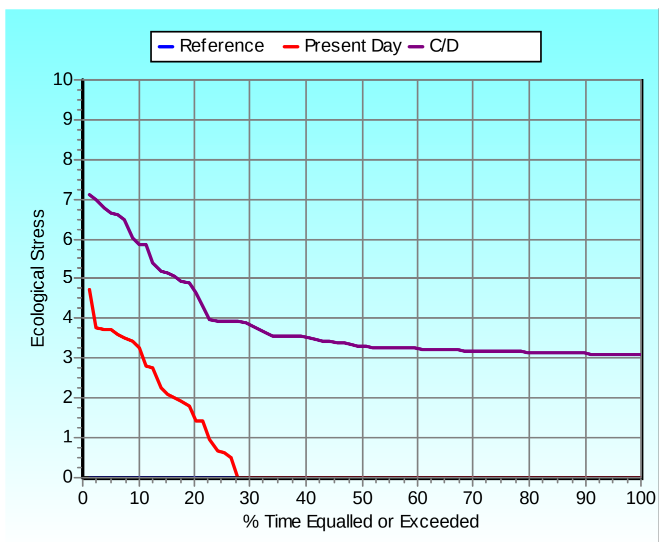


Figure 9-4. Final Stress Duration Curve for Reference conditions, present day and category C/D for wet season (February) at EWR Site L1.

9.6.4 High Flow Requirements

The functions for each Flood Class are described in spreadsheets. A summary of the flood class ranges and recommended number of high flow events required for the REC is provided in Table 9-5 below. Flood class motivations are detailed in Appendix J.

9.7 FINAL RESULTS

The final EWR results for the recommended and alternative categories are summarised below (Table 9-6 and Table 9-7) and the detailed results are presented in Appendix K.

Table 9-6. Flood class parameters and recommended number of high flow events required for the REC – EWR Site L1.

Note: *Timing: 1 = January; 12 = December

EC = C/D	Flood parameters			NUMBER OF EVENTS							Discussion of changes	
									FINAL			
FLOOD CLASSES	Range	Range Average	Duration (days)	**Geom No.**	**Veg No.**	**Invert No.**	**Fish No.**	**MIN**	**No.**	***Timing**	Primary	Secondary
Class 1	1.7-3.4	2.6	1.0		2.0	3.0		3.0	1.0	3-11	Veg. Maintain vegetation of marginal zone. Inundate grasses and sedges of fringing vegetation.	Inverts: · Flush out benthic algae and fines· Provide sufficient current speed to discourage bilharzia and Thiaridae snail populations. · Three events per annum should be sufficient to discourage unnaturally high populations of undesirable species, and flush out fines.
Class 2	3.4-6.75	5.1	2.0		2.0	2.0		2.0	2.0	11-4	Fish: Mainly for the Inundation of marginal vegetated areas for spawning. There is also a requirement for cleaning of the remaining sections of gravel/cobble beds for riffle spawning	Veg. Maintain vegetation of marginal zone. Inundate grasses and sedges of fringing vegetation. Saturate rooting zone of trees such as *Breonadia salicina* and *Syzygium species*.
Class 3	6.75-13.5	10.1	3.0	1.0	2.0			2.0	2.0	11-4	Geom. Maintain bed sorting. Retain some flow variability. 'Alternate' with the 1:2.	
Class 4	13.5-27	20.5	4.0	0.5	1.0			1.0	0.5	11-4	Veg. Maintain vegetation of marginal and lower riparian zones. Inundate grasses and sedges of fringing vegetation. Saturate rooting zone of trees such as *Breonadia salicina* and Syzygium species. Inundate side channels hosting Typha capensis. Facilitate seed dispersal of Syzygium species and *Breonadia salicina*. Transported sediments provide substrate for germination of key species. Prevent reed encroachment in marginal zone. Maintain habitat diversit. Control terrestrialisation.	Geom. Maintenance of channel geometry, deposition of sediment on flood bench. Key discharge for maintaining habitat of marginal riparian zone.
1:2	30	-	5.0	0.5	0.5			P	1:2	38295.0	Geom. Maintenance of channel geometry, deposition of sediment on flood bench. Key discharge for maintaining habitat of marginal riparian zone.	General habitat maintenance.
1:5	??	-						P	P	Any	Geom. Sediment deposition on terrace (fines). See notes below.	Inundate trees such as *Breonadia salicina* and Syzygium species. Scour side channels hosting *Typha capensis.* Facilitate seed dispersal of Syzygium species and *Breonadia salicina.* Transported sediments provide substrate for germination of key species. Prevent reed encroachment in marginal zone. Maintain habitat diversity. Control terrestrialisation. Remove debris. See notes below.
1:10	??	-									See notes below.	General habitat maintenance.
1:20	??	-										
Important Note:	It is important for the condition of the river that Driekoppies Dam is **not** operated as a flood control dam. The larger floods that occur naturally in the system are vital for resetting the system, and depositing fines (silt and clay) on the floodplain terraces.											

Table 9-7. EWR Summary Table for EWR Site L1 for REC: C/D.

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	VOL ($X10^6$ m^3)	nMAR%
EWR SITE L1: EMC = C/D.														
LOW FLOWS														
MAINTENANCE LOW FLOWS (m^3/s)[12]	0.3	0.5	0.6	0.8	1.2	1.1	1.0	0.8	0.7	0.5	0.4	0.3	**20.877**	**6.49**
DROUGHT LOW FLOWS (m^3/s)	*0.2*	*0.2*	*0.3*	*0.3*	*0.4*	*0.4*	*0.4*	*0.3*	*0.3*	*0.3*	*0.2*	*0.2*	***9.153***	***2.85***
HIGH FLOWS														
FLOOD (daily average: m^3/s)	-	5.1	5.1	10.0	10.0	1)20.5 2)30	-	-	-	-	-	2.6	**0.631**	**2.99**
Duration (in days)	-	2	2	3	3	1) 4 2) 5	-	-	-	-	-	1		
Return period (years)	-	1:1	1:1	1:1	1:1	1) 1:2 2) 1.2[13]	-	-	-	-	-	1:1		
LONG-TERM MEAN													***38.011***	***11.82***

[12] Figures rounded-off to the nearest one decimal place.
[13] Alternate years

Table 9-8. EWR rule table for REC: C/D

```
Desktop Version 2, Printed on 31/01/2005
Summary of EWR rule curves for : EWR L1 Monthly Nat EWR L1
Determination based on defined BBM Table with site specific assurance rules.
Regional Type : E.Escarp     REC = C/D

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

This EWR rule table can be used in combination with the natural duration curves below for implementation.

Reserve flows without High Flows

Month	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	0.542	0.541	0.537	0.529	0.513	0.484	0.435	0.362	0.274	0.209
Nov	0.739	0.737	0.731	0.718	0.693	0.649	0.576	0.471	0.346	0.252
Dec	0.986	0.982	0.973	0.954	0.919	0.858	0.757	0.613	0.443	0.317
Jan	1.232	1.225	1.212	1.185	1.137	1.052	0.917	0.727	0.506	0.342
Feb	1.905	1.896	1.876	1.836	1.760	1.624	1.404	1.089	0.717	0.440
Mar	1.740	1.734	1.717	1.681	1.614	1.493	1.294	1.006	0.664	0.409
Apr	1.560	1.556	1.542	1.514	1.458	1.355	1.183	0.929	0.623	0.392
May	1.314	1.312	1.302	1.280	1.236	1.153	1.012	0.799	0.538	0.340
Jun	1.117	1.116	1.108	1.091	1.056	0.989	0.873	0.697	0.479	0.313
Jul	0.821	0.821	0.817	0.806	0.783	0.739	0.660	0.538	0.384	0.266
Aug	0.597	0.596	0.593	0.585	0.569	0.539	0.486	0.407	0.309	0.234
Sep	0.562	0.561	0.558	0.550	0.535	0.506	0.456	0.381	0.290	0.220

Natural Duration curves

Oct	7.217	5.276	4.529	3.573	3.300	3.073	2.740	2.457	2.244	1.941
Nov	14.900	11.497	8.985	7.419	6.235	5.000	4.441	3.526	2.967	2.056
Dec	24.313	18.436	14.053	11.932	10.013	8.707	7.542	5.996	4.559	2.561
Jan	37.563	26.225	18.067	15.401	13.004	10.842	9.349	8.408	6.392	3.547
Feb	68.477	38.389	23.103	16.700	13.174	11.020	9.950	8.213	7.081	4.696
Mar	42.413	28.286	16.850	14.953	11.063	9.595	8.218	7.587	5.974	3.771
Apr	19.128	15.448	12.542	10.829	9.340	8.657	7.596	6.860	5.058	3.326
May	10.443	8.225	7.538	7.198	6.948	6.481	5.746	5.029	4.066	2.475
Jun	8.117	6.759	6.096	5.876	5.382	5.177	4.853	4.120	3.472	2.114
Jul	6.026	5.119	4.869	4.566	4.275	4.085	3.681	3.136	2.733	1.803
Aug	5.037	4.506	4.002	3.749	3.663	3.353	3.084	2.737	2.393	1.773
Sep	4.815	4.101	3.731	3.414	3.167	3.052	2.685	2.527	2.218	1.624

Total Reserve Flows

Month	% Points 10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	0.542	0.541	0.537	0.529	0.513	0.484	0.435	0.362	0.274	0.209
Nov	1.053	1.049	1.039	1.019	0.980	0.910	0.795	0.628	0.431	0.283
Dec	1.289	1.284	1.271	1.245	1.196	1.109	0.967	0.764	0.525	0.347
Jan	2.371	2.213	2.071	1.934	1.784	1.532	1.319	1.019	0.671	0.414
Feb	3.166	2.990	2.829	2.667	2.480	2.161	1.856	1.419	0.903	0.519
Mar	5.310	4.832	4.416	4.038	3.661	3.022	2.583	1.949	1.196	0.634
Apr	1.560	1.556	1.542	1.514	1.458	1.355	1.183	0.929	0.623	0.392
May	1.314	1.312	1.302	1.280	1.236	1.153	1.012	0.799	0.538	0.340
Jun	1.117	1.116	1.108	1.091	1.056	0.989	0.873	0.697	0.479	0.313
Jul	0.821	0.821	0.817	0.806	0.783	0.739	0.660	0.538	0.384	0.266
Aug	0.597	0.596	0.593	0.585	0.569	0.539	0.486	0.407	0.309	0.234
Sep	0.676	0.675	0.671	0.661	0.641	0.603	0.538	0.441	0.322	0.231

9.8 CONFIDENCE

The confidence was evaluated according to a score of 0-5 with zero reflecting 'no confidence' and 5 reflecting 'very high' confidence (Table 9-9).

Table 9-9. Confidence Ratings for EWR Site L1.

	EWR SITE	AVAILABLE DATA	ECOLOGICAL CLASSIF.	OUTPUT LOW FL	OUTPUT HIGH FL
HYDROLOGY		3	3		
	Confidence is fairly high on the accuracy of the simulation of observed (historic) flows. The simulation is based on calibrations done a number of years ago and is a reasonable representation of the time series in terms of the range of flows. The low flows are slightly higher based on nature of calibration.				
HYDRAULICS	2	4/1=2.5		4	2
	Measured flows in the range 0.44 to 4.4m^3/s. Recommended low-flows for the PES (C/D) in the range 0.20 to 2.0m^3/s (ie. min. value is half lowest measured flow), and high flows in the range 2.6-21 (within year) and 30 (1:2) (ie. above measured values).				
QUALITY		1	1		
	No temperature, dissolved oxygen and turbidity data available. Only 4 samples of water quality available. Confidence in the data is low (1). EC confidence in data was low (4 samples only). No temperature, dissolved oxygen, chlorophyll and turbidity data available				
GEOMORPH	4.5	3	3.5	N/A	4
	Long-term photos at small scale, post dam hydrology data only. Site visit by specialist. Clear evidence of change from aerial photos, confirmed by fish assemblages indicating switch from sand-bed to boulder bed river. Uncertainly about significance of vegetation changes, but upstream dam & weir impacts sufficient to justify a D. Good morphological clues that tie into hydrological record. Deposition **GENERAL COMMENT ON CONFIDENCE IN FLOOD REQUIREMENTS** (same as EWR Site K3)				
RIP VEG	4	3	3	n/a	3
	EWR site: A good site with high habitat diversity **Available data:** Vegetation profile studied twice (once in winter and once in Autumn). 1939 aerial photos. **Ecological classification:** Some uncertainty regarding reference conditions. **Output low flow:** Recommendations not tested **Output high flow:** Recommendations match current situation, but lower riparian zone requires 1:5 year flood which is not catered for.				
FISH	4	4	4	4	3
	Confidence in available data is moderately high because of Driekoppies Dam surveys and historic data going back as far as the 1960's. Several surveys have been conducted in this Resource Unit over last three years. Moderately high confidence in the EC based on the available data and several recent surveys conducted in this Resource Unit during last 3 years. Moderately high confidence in EWR site as it provided a good indication of the abundance of critical habitat required by indicator species and the sensitivity of the habitat under different flows. Moderately high confidence in low flows based on the available hydraulic data and fish information and it was possible to set realistic flows in terms of its stress and availability of critical habitat for indicator species. Moderate confidence in high flows based on our understanding of the species in this Resource Unit, fish has a need of Class II floods in terms of breeding and migrations. Class I floods too small to cater for spawning in marginal vegetated areas. Historically there was a requirement for a large flood to inundate floodplains in Komati River which will allow important massive upstream recolonisation and migrations of some tropical species.				
INVERT	3	3	3	3	3

	Moderate diversity of biotopes present: Highly suitable MVOC; Suitable SIC, bedrock, MVIC, and sand; Moderate SOC and gravel; Absent biotopes are aquatic vegetation only, and mud habitats poor. Benthic algae limits habitat availability. Data were available for 8 SASS samples recorded at 4 sampling sites within this Resource Unit, and reference data were limited, so confidence in the results was moderate. Moderate confidence in the classification. The invertebrate requirements are being met for low flows. The invertebrate requirements for high flows are met by those of the fish.

10. EWR SITE M1 – SILINGANI

10.1 ECOLOGICAL CATEGORIES

The PES for EWR Site M1 is summarised Table 10-1, and a description of the reference conditions, and PES for individual components is presented in Table 10-2.

Table 10-1. The PES for EWR Site M1.

Driver Components	Component PES	Driver PES	ECOSTATUS PES
HYDROLOGY	D	C	C
GEOMORPH	C		
WATER QUALITY	B/C		
Response Components	Component PES	Instream PES	
FISH	B/C	B/C	
AQUATIC INVERTS	B		
RIPARIAN VEG	D	D	

Table 10-2. Description of the PES categories for each habitat driver and biological response for EWR Site M1.

Category B= Largely Natural; Category B/C = Largely Natural to Moderately Modified; C= Moderately Modified and D= Largely Modified.

Driver and responses	Reference conditions	PES	PES description
			Overall PES for Drivers Moderately Modified (Category C).
Hydrology	857.1nMAR= million m^3/a.	**D**	599.9pMAR= million m^3/a EWR Site M1 is situated some 20 km downstream of Maguga Dam, which was completed in early 2002. This dam controls over 90% of both the catchment area and the MAR of the monitoring site. Dams upstream of Maguga (Nooitgedacht and Vygeboom) control 48% of the catchment area and 32% of the MAR. This dam has a relatively high capacity compared to the MAR of its catchment (78.4 against 64 Mm^3). It will therefore have a significant effect on moderating flows.
Geomorphology	M1 is classified as an upper foothill site on account of its channel gradient of 0.007. The expected reach type would be either plane bed, pool-riffle or pool rapid with a bed material dominated by cobble or bedrock and cobble. Secondary flood channels are a common feature of these rivers.	**C**	**Event hydrology & sediment load:** The construction of Maguga Dam in 2002 but is unlikely to have as yet had a significant impact on the geomorphology of the site. Vygeboom and Nooitgedacht Dams would have had a small impact to date on geomorphological processes at EWR Site M1. There may have been a small reduction in event hydrology and a depletion of sediment due to storage in the dams. Much of this sediment will, however, have been replaced through erosion of sediment from the channel bed downstream of Vygeboom Dam. **Riparian Vegetation:** There has been a moderate to

			large disturbance to the riparian zone vegetation. Locally the river banks have been stripped bare of vegetation, but the reach as a whole is in moderate condition. There is some encroachment of vegetation onto lateral bars, possible as a reduction of flood events following the closure of Maguga Dam. A reduction in the magnitude and frequency of floods also allows woody vegetation and reeds to encroach onto otherwise active morphological features such as bars and secondary channels. This either results in a loss of specific features or their stabilisation. More stable channel banks also leads to narrower, deeper channels. (Note that the rating for vegetation as a geomorphological factor is higher than the PES for vegetation in its own right because for geomorphology the structural characteristics are more important than the species composition). **Channel structures:** No channel structures such as weirs or causeways were observed in this reach.
Water Quality	The reference water quality would not have been impacted by changed natural flows and as a consequence the dissolved oxygen in the river would have been higher and the water temperatures lower.	**B/C**	The main change from natural conditions is seen in temperature and turbidity.
			Overall Instream PES Largely Natural to Moderately Modified (Category B/C)
Riparian Vegetation	No alien-invader species present.	**D**	The main changes triggered by flow related causes (attenuation of intra-annual floods caused by upstream Maguga Dam resulting in terrestrialisation and alien-plant invasion, reduced frequency and size of intra-annual floods and reduction in low-flows) and non-flow related causes (disturbance of riparian zone due to deforestation, cattle grazing and trampling, altered water quality)
Marginal zone: Woodland/Reedbed on stream banks and grassland on annual flood bench	• annual flood bench (cobble bar) dominated by mesophytic grasses and sedges • mesophytic forbs would feature • banks of main channel and lateral channels would be dominated by clumps of the reed *Phragmites mauritianus*, interspersed with trees such as *Breonadia salicina, Olea woodiana, Nuxia oppositifolia* and sedges such as *Cyperus marginatus*.		• Moderate decrease in biomass of tree species such as *Breonadia salicina* • Small decrease in cover of *Phragmites mauritianus* reeds, mesophytic grasses and sedges such as *Cyperus marginatus.* • Moderate reduction in number of indigenous species of trees, shrubs, grasses and sedges. • Large change in overall species composition, for example the presence of alien-invader species such as *Sesbania punicea, Senna didymobotrya* and *Chromolaena odorata*. • Large change in structure due to poor recruitment of large riparian tree species such as *Breonadia salicina.*
Lower riparian zone: Open/Closed Woodland on firm alluvial banks and islands	• Mesophytic trees and shrubs would occur in a mosaic of closed and open-canopy woodland. • Terrestrial pioneer species such as *Gymnosporia senegalensis* and *Trema orientalis* should not be dominant.		• Moderate increase in biomass as a result of encroachment by alien invader tree species such as *Melia azedarach.* • Moderate increase in cover of trees and shrubs due to contribution by alien-invader species. • Large reduction in number of indigenous species as terrestrialisation and encroachment by alien-invader species • Serious change in overall species composition. • Moderate change in structure due to poor recruitment of tree species such as *Celtis africana, Ficus sycomorus, Combretum erythrophyllum* and *Syzygium cordatum.*
Upper riparian zone: Open/Closed	• The colluvial hillslopes would support mostly non-riparian tree species		• Large decrease in biomass due to deforestation of indigenous tree species such as *Diospyros*

Woodland on firm colluvial slopes	• The woodland structure would be maintained by regular seedling recruitment of such species. • a good ground cover of grasses		*mespiliiformis, Terminalia sericea, Dombeya rotundifolia* and *Acacia* species. • Large decrease in cover due to deforestation and overgrazing of grass layer. • Moderate decrease in species richness due to deforestation of indigenous trees. • Moderate change in overall species composition as deforestation takes place and alien-invader species invade. • Large change in structure due to deforestation and poor recruitment of tree species such as *Albizia versicolor* and *Acacia* species.
Fish	Twenty five (25) both temperate and tropical species expected to occur.	**B/C**	Twenty five (25) both temperate and tropical species occur. **Flow depth**: Although all species are still present the abundance of all categories has been affected. **Flow Modification**: Lower abundance of flow dependant and moderately flow dependants. Lower abundance than pre-Maguga Dam surveys of rheophilic species such as Barbus *eutaenia, Opsaridium peringueyi, Chiloglanis pretoriae* and *C. swierstrai*. Most other categories also lower than expected. Migration of fish such as *Labeo molybdinus, L. cylindricus* and some of the small barb species (*Barbus* sp.) has been affected by downstream weirs and dams. **Cover:** Lower abundance of fish fauna dependant on substrate in fast habitats. All other categories also been affected. Lower Abundance of species preferring fast flowing habitats (*Labeo molybdinus* and *C. cylindricus*) and species preferring undercut banks and marginal vegetated areas (*Barbus* spp*, Tilapia rendalli* and *Pseudocrenilabrus philander*). **Water Quality:** Lower abundance of species in most categories **Introduced:** No records of any species yet.
Aquatic Invertebrates	The site is likely to have had a large variety of habitats, including extensive sand, pebble and cobble bars with a wide range of particle size distributions.	**B**	Confidence in the results was high. The main changes triggered by flow and non-flow related causes (see above). • increased abundance of limpets (*Burnupia* sp) and prongill mayflies (*Euthraulus elegans*) • reduction in taxa that require high quality water, such as *Simulium vorax* and *S. cervicornutum.*

Additional tables providing scores for the individual driver components and biological responses (instream) and a summary of the EcoStatus are available in Appendix F.

10.2 TRENDS

Aquatic invertebrate composition is considered to be stable in the short-term, but deteriorating in the long-term due to the impacts of Maguga Dam on bed armouring and bed substrate diversity. The trend for fish and riparian vegetation are considered to be on a negative trend due to the impeding impacts caused from the construction of Maguga Dam (i.e. flood attenuation and sediment depletion, bed armouring, channel incisement, erosion of cobble bars, bank stabilisation, reduced species diversity, and poor recruitment levels of indigenous trees). Riparian vegetation will deteriorate from a Category D in the short term to a Category E in the long term.

Geomorphology shows a negative trend as with completion of the dam significant morphological changes can be expected. Storage of sediment in the dam is likely to result in armouring of the channel bed due to removal of sands and gravels. Reduced flood flows are likely to result in less frequent activation of the secondary channel which is likely to suffer from vegetation encroachment. This is also a probable site for deposition of any available fine sediment. Encroachment of vegetation onto the cobble bars and deposition of fines here is also highly likely.

10.3 IMPORTANCE

10.3.1 Ecological Importance and Sensitivity

The Ecological Importance and Sensitivity in the vicinity of EWR Site M1 was rated *High* under natural and present conditions. The confidence for this assessment was high. The main determinants were the presence of the rare endangered *Opsaridium* and the presence of species intolerant to flow (*Chiloglanis, Opsaridium, Amphilius, B. eutenea) .* Detailed results are presented in Appendix G.

10.3.2 Socio-cultural Importance

The area was considered of *Very High* Socio-cultural Importance. Most of the area is within Swazi Nation Land and is considered culturally important. Rural communities are dependent on the river for irrigation, spiritual activities, drinking, washing and using various resources such as edible and medicinal plants, building materials, carving materials and firewood. Communities noted a reduction in flow which they attributed to low rainfall and weirs. In a Social Study undertaken of the area, the weirs were resented by the community because they were perceived to have altered the level of the river and affected access to the river (King 1998). Archaeological sites are present and the spiritual and aesthetic value of this area is highly significant.

10.4 RANGE OF ECOLOGICAL CATEGORIES

10.4.1 Recommended Ecological Category

The EIS (present) was rated as *High* and the socio-cultural importance was rated as*Very High.* Maintaining the river as a Category C would be adequate from an ecological point of view and the PES was accepted as the REC.

10.4.2 Alternative Ecological Categories

Two alternative Ecological Categories were considered (Category B and D). The conditions for achieving classes are given in Table 10-3 and summarised in Table 10-4.

Table 10-3. Summary of the conditions defining the alternative Ecological Categories.

Driver and responses	Alternative B	Alternative D
General	Category B conditions would comprise: (a) more moderate floods as diatoms and sediment a problem, (b) improved water quality (temperature difference by operating) and (c) addressing alien encroachment (moderate floods ill impede seeding etc.),	Category D conditions would comprise: (a) no release for moderate freshes, (b) increased baseflows in normal years, (c) very dry droughts (no sugar releases) and (d) a change in temperature. This alternative EC is applicable to the negative trend with Maguga Dam in place.
Geomorphology	Given the presence of Maguga Dam there is no realistic way in which the PES for geomorphology can be raised to a B. The ratings given for the upgraded PES can be considered to be the recommended scenario to maintain a C status. Flow releases will be required to keep an acceptable frequency of intermediate floods. There is no practical solution to loss of bedload due to sediment trapping behind dam wall. Bank stability could increase through rehabilitation of bank vegetation and the provision of flood flows preventing encroachment on to bars.	The PES-down ratings are given assuming that there is no attempt to mitigate the impact of Maguga Dam on channel geomorphology. Maguga Dam will trap all coarse sediment, reducing bedload to very low values, and will store or attenuate all but most extreme flood events. Armouring of the low flow channel will increase, with loss of fines and gravel, while the lateral bars and side channels will become stabilized, with consequent channel narrowing. The rating assumes no attempt to rehabilitate riparian vegetation. Encroachment on to lateral bars will result from a reduction in the magnitude and frequency of flood events.
Water Quality	Water quality will improve by reinstating top releases from Maguga Dam to mitigate temperature reductions	Water quality will deteriorate with a change in temperature.
Riparian Vegetation	Improvement within the Marginal zone: small decrease in biomass of tree species, small decrease in cover of reeds and of mesophytic grasses and sedges, moderate reduction in number of indigenous species of trees, shrubs, grasses and sedges, moderate change in overall species composition and a moderate change in structure due to poor recruitment of large riparian tree species such as *Breonadia salicina.* An improvement within the Lower Riparian Zone: small increase in biomass as a result of encroachment by alien invader tree species, small increase in cover of trees and shrubs, moderate reduction in number of indigenous species as terrestrialisation and encroachment by alien-invader species occurs, large change in overall species composition, moderate change in structure due to poor recruitment of tree species such as *Celtis africana* , *Ficus sycomorus, Combretum erythrophyllum* and *Syzygium cordatum.* Improvement within the Upper Riparian Zone: moderate decrease in biomass due to deforestation of indigenous tree species, moderate decrease in cover due to deforestation of indigenous tree species and overgrazing of grass layer, moderate decrease in species richness due to deforestation of indigenous trees, small change in overall species composition, moderate change in structure due to deforestation and poor recruitment of tree species such as *Albizia versicolor* and *Acacia* species	Marginal zone: moderate increase in biomass of Phragmites reeds and terrestrial species due to channel narrowing, moderate increase in cover of reeds and of terrestrial species, large reduction in number of indigenous species of trees, shrubs, grasses and sedges, large change in overall species composition and large change in structure due to poor recruitment of large riparian tree species . Lower Riparian Zone : large increase in biomass as a result of encroachment by alien invader tree species, large increase in cover of alien-invader species and terrestrial species, serious reduction in number of indigenous species , serious change in overall species composition, moderate change in structure due to poor recruitment of tree species. Upper Riparian Zone: large decrease in biomass due to deforestation of indigenous tree species and *Acacia* species, large decrease in cover due to deforestation of indigenous tree species and overgrazing, large decrease in species richness, large change in overall species composition and serious change in structure.
Fish	Reinstating medium flows and top releases from Maguga to mitigate temperature reductions and delayed onset of the spawning season will increase the abundance of most species, especially flow dependants, moderately flow dependants, fauna	Reduced habitat quality most likely affect species associated with fast shallow, fast deep and slow shallow habitat. Constant and/or unseasonable perennial base flow will reduce the presence and/or abundance of especially flow dependant and moderately flow dependant species. Diatom

Driver and responses	Alternative B	Alternative D
	dependent on substrate in fast habitats and rheophilic species. There will be a continued impact on migration of fish, however abundance and frequency of migratory species will benefit from top releases. Increase in abundance of species preferring fast flowing habitats as well as species preferring undercut banks and marginal vegetated areas. Increased abundance of intolerant and moderately intolerant species.	build-up on substrate due to absence of medium floods will reduce the quality of available habitat. Reduced water temperatures, especially during early season will prevent or delay spawning especially of the intolerant and moderately intolerant species.
Aquatic Invertebrates	An increase in the frequency and magnitude of freshets is likely to provide suitable habitat for taxa that prefer fast-flowing water, such as *Simulium bovis* and *S. vorax*, which are currently absent from the system. An improvement in the quality of water released from Maguga Dam should lead to the reappearance of taxa that have a preference for vegetation and good quality water, such as *Simulium impukane, S. rotundum*, *S. cervicornutum*, *S. alcocki*, Gerridae, Dytiscidae, *Dicercomyzon costale* and Sphaeriidae. An increase in the abundance of leptocerid caddisflies is also expected.	The absence of freshets will lead to a reduction in the abundance and diversity of taxa that prefer fast and moderately fast flowing water, such as *Simulium bovis* and Afronurus and trichorythid mayflies. Cobbles are likely to become increasingly covered in diatoms and this is likely to reduce the abundance of taxa such as the mayfly *Psuedopannata maculosa,* stoneflies (Perlidae) and tricorythid mayflies. The abundance of taxa with a preference for good to moderate quality water, such as *Simulium damnosum*, is expected to drop. As a result of these changes, SASS scores are expected to drop.

Table 10-4. Summary of the Alternative EcoStatus B and D for EWR Site M1.

Driver Components	Component PES	Driver PES	ECOSTATUS PES
HYDROLOGY	C	C	B
GEOMORPH	C		
WATER QUALITY	B		
Response Components	**Component PES**	**Instream PES**	
FISH	B	B	
AQUATIC INVERTS	B		
RIPARIAN VEG	C	c	

Driver Components	Component PES	Driver PES	ECOSTATUS PES
HYDROLOGY	D	D	D
GEOMORPH	D		
WATER QUALITY	C		
Response Components	**Component PES**	**Instream PES**	
FISH	C	C	
AQUATIC INVERTS	C		
RIPARIAN VEG	D	D	

The rule-based models for the individual components were run in a predictive manner and based on the above hypothetical scenarios, the matrixes that would be affected were changed. These spreadsheets with the changes indicated as different colours are included in the specialist appendices.

10.5 STRESS INDICES

Refer to Appendix I for the flow stress indices for the REC and alternative EC's for fish and aquatic invertebrates.

10.5.1 Stress Index: Fish

The rheophilic species selected was *Chiloglanis pretoriae* (CPRE) which is dependant on the presence of moderately fast flowing waters (FS and FD). The semi-rheophilic species selected was *Labeobarbus marequensis* (BMAR) and *Labeo cylindricus* (LCYL). The rheophilic species was the most stressed under all the flow conditions (Table 10-5) and was used for final stress.

With a flow of 10m^3/s there is abundant fast habitat available and none of the life history requirements of *Chiloglanis pretoriae* are likely to be stressed. At a flow of 6.6m^3/s there is still a moderate availability of fast habitats. Breeding and, to a lesser extent, habitats with suitable cover will be affected. At a flow of 3m^3/s the availability of fast habitats is further reduced and breeding will be restricted to only a few areas. The availability of suitable cover will also reduce the abundance of the species. The species will only survive in limited numbers at a flow of 0.5m^3/s due to a lack of suitable habitat. This flow will also start to affect water quality (temperature, O2, nutrients and salinity) and the health of the fish. At a flow of 0.2m^3/s there are no fast flowing habitats and suitable available habitats for the species. Species may be lost.

Table 10-5. Stress table for rheophilic, semi-rheophilic and limnophilic fish species showing Habitat Suitability at EWR Site M1.

FLOW (CUMEC)	10.00	6.600	3.000	1.000	0.500	0.200
RELATIVE ABUNDANCE FLOW-DEPTH & COVER RATING: 0=NONE;1=RARE;2=SPARSE;3=MODERATE;4=ABUNDANT;5=VERY ABUNDANT)						
FAST DEEP	4	3.0	2.0	1.0	1.0	0.0
FAST SHALLOW	4.0	3.0	2.0	2.0	1.0	0.0
SLOW DEEP	4.0	5.0	4.0	3.0	3.0	2.0
SLOW SHALLOW	2.0	3.0	4.0	5.0	5.0	4.0

SUITABILITY FOR DIFFERENT FISH REQUIREMENTS PER HABITAT GUILD						
RHEOPHILIC	***Chiloglanis pretoriae***					
	Cpre					
Breeding and early life-stages=	5.0	3.0	2.0	1.0	0.0	0.0
Survival /Abundance =	5.0	5.0	4.0	3.0	2.0	1.0
Cover =	5.0	5.0	4.0	3.0	2.0	1.0
Health and condition=	5.0	5.0	4.0	3.0	1.0	1.0
Water quality=	5.0	5.0	4.0	3.0	2.0	0.0
Rheophilic stress - (breeding requirements included)	**0**	**1**	**3**	**5**	**7**	**9**

SEMI-RHEOPHILIC	***Barbus marequensis***					
	Bmar					
Breeding and early life-stages=	5.0	4.0	3.0	1.0	0.0	0.0
Survival /Abundance =	5.0	5.0	4.0	4.0	4.0	3.0
Cover =	5.0	5.0	4.0	4.0	4.0	3.0
Health and condition=	5.0	5.0	5.0	4.0	4.0	3.0
Water quality=	5.0	5.0	5.0	4.0	4.0	3.0
Semi-rheophilic stress - (breeding requirements included)	**0**	**0**	**2**	**3**	**4**	**5**

SUITABILITY FOR DIFFERENT FISH REQUIREMENTS PER HABITAT GUILD						
LIMNOPHILIC	***Labeo cylindricus***					
	Lcyl					
Breeding and early life-stages=	5.0	4.0	3.0	1.0	0.0	0.0
Survival /Abundance =	5.0	5.0	4.0	4.0	3.0	2.0
Cover =	5.0	4.0	3.0	2.0	2.0	1.0
Health and condition=	5.0	5.0	4.0	4.0	3.0	2.0
Water quality=	5.0	5.0	4.0	4.0	3.0	2.0
Limnophilic stress (breeding requirements included)	**0**	**1**	**3**	**4**	**6**	**7**

FLOW-DEPTH CONVERTED TO HABITAT RESPONSE (10=ALL FLOW-DEPTH CLASSES ABSENT (RIVER DRY); 0=FLOW-DEPTH *CLASSES OPTIMUM FOR SITE* ; 9=NO FLOW)						
Fast deep	2	4	6	8	8	10
Fast shallow	2	4	6	6	8	10
Slow deep	2	0	2	4	4	6
Slow shallow	6	4	2	0	0	2
OVERALL HABITAT RESPONSE	**3**	**3**	**4**	**5**	**5**	**7**

10.5.2 Stress Index: Aquatic Invertebrates

Optimum Flow rates: 0.3 and 0.6m/s
Key Species: *Neoperla spio* and Tricorythidae
Critical Habitats: Cobble bar and riffle

The relationships between aquatic invertebrate habitats, flows, stresses and associated biological responses at EWR Site M1 are detailed in Table 10-6.

The critical factors that were used to determine the stress curve were the inflections in wetted perimeter, current speeds and overall species composition. Inflection points in wetted perimeter were observed at a flow of 3 m^3/s when the left channel was activated and again at 11 m^3/s when the large cobble bar at the centre of the site became inundated. The critical velocity for key species of between 0.3 and 0.6m/s was not present when flows were less than about 2m^3/s. Vegetation biotopes (in and out-of-current) remained in generally good condition as flows reduced, while stones in and out-of-current became unsuitable for benthic invertebrates at lower flows because of extensive growth of rheophilic diatoms. Highest biomonitoring scores were recorded during a field survey on 21 July 2004, when the daily average flow released from Maguga Dam was about 3.75m^3/s. These data showed that many flow-sensitive species were still present at these flows. The biological response stress was therefore modified accordingly.

Table 10-6. Stress Table – Flow Dependant Invertebrate at EWR Site M1.

Habitat Flow Response Index	HABITAT ABUNDANCE AND SUITABILITY					TOTAL	FLOW	HABITAT RESPONSE	HABITAT CHARACTERISTICS					BIOTIC RESPONSE	FLOW	SPECIES STRESS	INTEGRATED STRESS
	SIC	SOC	VIC	VOC	GSM				Max depth (m)	Avg depth (m)	Max vel (m/s)	Avg vel (m/s)	WP (m)				
0	**5**	**5**	**5**	**5**	**4**	**24**	**14.0**	All habitat in excess, very high quality: very fast, very deep, very wide wetted perimeter	0.91	0.41	.	0.76	46.5	All very abundant, all healthy, all species persist	**12.0**	**0**	**0**
1	**4**	**5**	**5**	**5**	**4**	**23**	**12.0**	All plentifull, high quality; fast, wide wetted perimeter	0.87	0.37		0.71	45.7	All abundant, all healthy, all species persist	**10.0**	**1**	**1**
2	**3**	**5**	**5**	**5**	**4**	**22**	**10.0**	Critical habitats sufficient; quality slightly reduced: fast, wetted perimeter slightly reduced	0.83	0.35	2.0	0.65	35.0	Slight reduction for sensitive rheophilic species, all healthy in some areas, all species persist	**7.0**	**2**	**2**
3	**3**	**3**	**5**	**5**	**3**	**19**	**7.0**	Reduced critical habitat, reduced critical quality; moderate velocity, fairly deep, wetted perimeter slightly/moderately reduced	0.77	0.35	1.7	0.57	36.3	Reduction for all rheophilic species; all healthy in limited areas; all species persist	**5.0**	**3**	**3**
4	**3**	**3**	**4**	**5**	**3**	**18**	**5.0**	Critical habitats limited; moderate quality: Moderate velocity, Some deep areas, Wide WP moderately reduced	0.71	0.34		0.49	31.5	Further reduction for all rheophilic species; all viable in limited areas, critical life stages of some sensitive rheophilic species at risk, all species persist	**3.0**	**4**	**4**
5	**3**	**3**	**4**	**4**	**3**	**17**	**3.0**	Critical habitat very reduced; moderate/ low quality; moderate/slow velocity, few deep areas wetted perimeter moderately/very reduced	0.62	0.39	1.1	0.37	20.6	Limited populations of all rheophilic species. Critical life-stages of sensitive rheophilic species at risk or non-viable; all species persist	**2.0**	**5**	**5**
6	**2**	**3**	**3**	**3**	**3**	**14**	**2.0**	Critical habitat residual. Low quality; Moderate/slow velocity.	0.56	0.35		0.29	19.15	Sensitive rheophilic species rare, critical stages of sensitive rheophilic species non-viable, and at risk for some less sensitive species. All species persisit in the short-term		**6**	**6**
7	**2**	**3**	**2**	**2**	**2**	**11**	**1.0**	No critical habitat, other habitats moderate quality; slow, narrow wetted perimeter	0.48	0.32	0.6	0.19	16.8	Most rheophilic species rare; All life-stages of sensitive rheophilic species at risk or non-viable. Most sensitive rheophilic species disappear	**1.0**	**7**	**7**
8	**1**	**2**	**1**	**2**	**2**	**8**	**0.5**	Flowing water habitats residual low quality: slow trickle, very narrow wetted perimeter	0.40	0.28		0.12	14.7	Remnant populations of some rheophilic species; all life stages of most rheophilic species at risk or non-viable, many rheophilic species disappear	**0.5**	**8**	**8**
9	**0**	**2**	**0**	**1**	**2**	**5**	**-**	Standing water habitats only, very low quality, no flow						Mostly pool dwellers; all life stages of most rheophilic species non-viable; most or all rheophilic species disappear		**9**	**9**
10	**0**	**0**	**0**	**0**	**0**	**0**	**-**	Only hyporheic refugia, no surface water						Only specialists persist, virtually no development.	**-**	**10**	**10**

1 SIC: Partially submerged hard substrate in current >0.1m/s
2 SOC: Partially submerged hard substrate in current <0.1m/s
3 VIC: Submerged vegetation (at least 2-3cm submerged) in current >0.1m/s
4 VOC: Submerged vegetation (at least 2-3cm submerged) in current<0.1m/s
5 GSM: Small particles submerged

10.5.3 Integrated Stress Curve

The individual component stresses are illustrated as well as the integrated stress line (black line) (Figure 9-1).

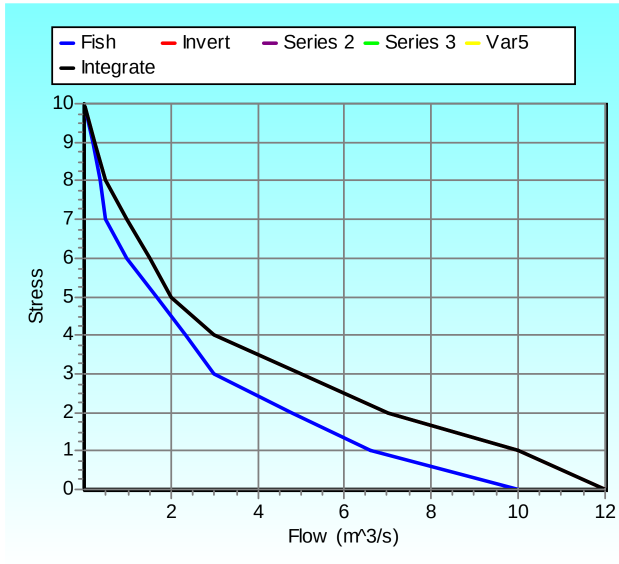


Figure 10-1. Index Stress Curves for EWR Site M1.

10.6 DETERMINATION OF EWR SCENARIOS

10.6.1 Low-Flow Requirements

The determined integrated stress index must now be used to identify required stress levels at specific durations for the wet and dry month / season. The requirements are illustrated in Figure 10-2.

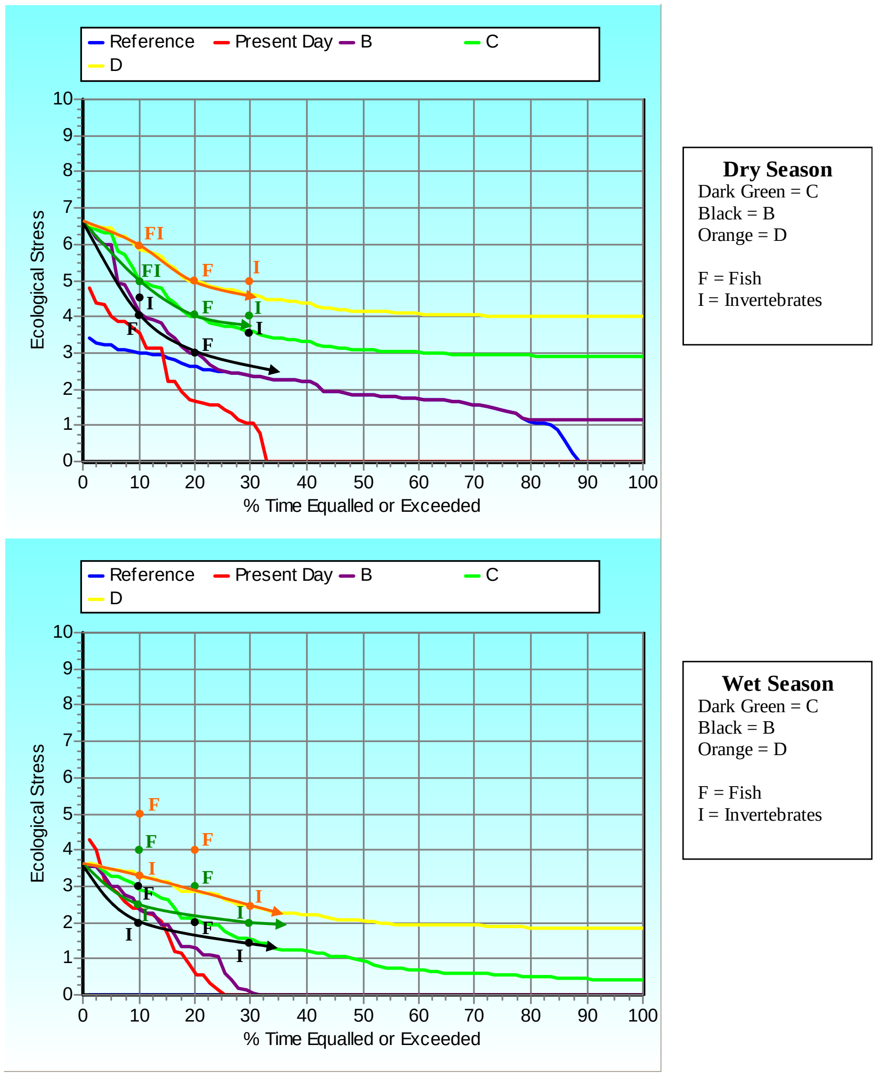


Figure 10-2. EWR Site M1 – Stress duration curves for all scenarios.

10.6.2 Motivations: Fish and Invertebrate

The stress referred to in the motiations below refers to fish stress, not component stress.

FISH: DURATIONS AND MOTIVATIONS TO BE USED FOR DETERMINING STRESS REQUIREMENTS
Indicator: *Chiloglanis pretoriae* This species is dependant on perennial flow in fast deep and fast shallow habitats and its requirements will cater for the other rheophilic species such as *Amphilius uranoscopus*, *Barbus eutenia* and *Opsaridium peringueyi.*
DRY SEASON
DROUGHT: A stress 5 for 10% of the time will allow for good survival of the species in moderate available fast deep and fast shallow conditions. At lower flows (6 for 10%) fast deep and fast shallow conditions will become rare and sparse in the river and fish survival and abundance will be largely affected. The stress level should never exceed 7 (0% of the time) as available habitat will be hugely reduced and the abundance and survival of species would be largely decreased.

MAINTENANCE B/C: comprise good available habitat for the dry season and stress of 4 can be tolerated for 20% of the time to ensure good survival and maintaining abundance.

MAINTENANCE B: Comprise more constant availability of good habitat and a stress of 3 can be tolerated for 20% of the time.

MAINTAINANCE C: At a stress of 5 for 20% of the time will decrease the survival and abundance of the species will be reduced.

WET SEASON

DROUGHT: 10% at stress 4 will still allow spawning, but only with sparse fast shallow sites with favourable habitat conditions. Relatively limited FD available but fragmented (patchy). A stress of 6 must never (0% of time) occur as this will only allow for minimal survival and no recruitment or breeding. At this point temperatures may also become problematic and oxygen levels in water may become critical.

MAINTENANCE B/C: Comprise good survival habitat and good breeding habitat and recruitment. Therefore a stress of 3 can be tolerated for 20% of the time.

MAINTENANCE B: Comprise good survival habitat and good breeding habitat and recruitment. Therefore a stress of 2 can be tolerated for 20% of the time.

MAINTENANCE C: At a stress of 4 for 20% will reduce the available breeding habitat and recruitment significantly .

General life history requirements
Chiloglanis pretoriae
Eggs: Margins of FS (<0.3 m, >0.3 m/s) gravel cobble substrate. October – January. >16°C Duration 7 days 3 - 30%
Larva: Feeding and Growth: Nursery areas (<0.3 m, >0.2 m/s), Margins of SS & overhanging vegetation. Duration larval period: 2 months.
Juvenile: Feeding and Growth: Mostly FS and margins of SS (<0.30m deep >0.2 m/s). Cover: Cobbles & rocks overhanging vegetation. Duration 3-6 months.
Adult: FD and FS (<0.3 m, >0.3 m/s) gravel, cobble Substrate. Spawning season: October – January. Cue: increased temperature, flow and changes in water quality (e.g. conductivity).

The stress referred to in the motiations below refers to aquatic invertebrate stress, not component stress.

AQUATIC INVERTEBRATES: DURATIONS AND MOTIVATIONS TO BE USED FOR DETERMINING STRESS REQUIREMENTS

Indicator:
The indicators are rheophilic taxa such as Philopotamidae, *Neoperla spio* and Tricorythidae

DRY SEASON

DROUGHT: +/-**10%.** Stress 5, equivalent to a discharge of $2m^3/s$, which is needed to provide refuge habitats for rheophilic taxa. This flow would provide an average velocity of about 0.29m/s which should be sufficient to protect against high temperatures developing. At lower flows (higher stress), habitat availability would reduce significantly. The natural stress value at this site during these conditions is 3.

MAINTENANCE C: 30%. Stress 4, equivalent to a discharge of $3\ m^3/s$, which is the flow needed to maintain the secondary channel on the right bank. This flow would provide adequate riffle habitat for the dry season to ensure sufficient current velocity (average 0.6 m/s) for flow-dependent taxa such as *Simulium damnosum, Cheumatopsyche afra* and Philopotamidae. These flows would also discourage bilharzia snails (*Bulinus africanus* and *Biomphalaria pfeifferi*) and mosquitoes (Culicidae). Biotope availability at stresses higher than this reduces significantly because of the secondary channel on the left bank is predicted to cease flowing. The

natural stress value at this site during these conditions is 2.5. **MAINTENANCE D:** a stress of 5 was assigned for maintenance conditions in the dry season. **MAINTENANCE B:** a stress of 3.5 was assigned for maintenance conditions.
WET SEASON
DROUGHT: +/- **10%.** Stress 2.5, equivalent to a discharge of about 6m^3/s. This flow is needed to maintain riffle habitat to ensure sufficient current velocity for flow-dependent taxa, including freshwater sponges which would be expected for a Category C. The natural stress value at this site during these conditions is 0.
MAINTENANCE C: 30%. Stress 2, equivalent to a discharge of about 7m^3/s. This flow is needed to provide sufficient current velocity (average 0.37m/s) for flow-dependent taxa such as Porifera, which would be expected for a Category C. Discourage bilharzia snails (*Bulinus africanus* and *Biomphalaria pfeifferi*) and mosquitoes (Culicidae). The natural stress value at this site during these conditions is 0. **MAINTENANCE D**: For the wet season a stress of 3.5 was assigned for the drought, while a stress of 2.5 was assigned for maintenance conditions. Sensitive taxa expected to disappear at these higher stresses include *Neoperla spio* and Tricorythidae. **MAINTENANCE B:** For the wet season a stress of 1.5 was assigned for maintenance conditions. It is predicted that these lower stresses would result in the return of taxa found in the marginal vegetation that appear to have disappeared, including Pleidae, Gerridae and Dytiscidae, as well as taxa found in the cobbles in-current, such as Chlorocyphidae.

The low flow requirements set by fish and aquatic invertebrates were assessed for riparian vegetation.

RIPARIAN VEGETATION		
Flow	**Discharge (m^3/s)**	**Max flow depth (m)**
September drought	2	Active channel: 0.57 Seasonal channel: 0.00
September maintenance	3	Active channel: 0.63 Seasonal channel: 0.00
February drought	6	Active channel: 0.74 Seasonal channel: 0.14
February maintenance	9	Active channel: 0.82 Seasonal channel: 0.23
A prolonged drought flow (> 4 weeks) in September may prove detrimental to grassland and sedgeland vegetation of seasonal bars in the marginal zone. Therefore the Class I freshes will be important at this time for activating seasonal channels and for preventing dessication and a potential increase in terrestrialisation and alien plant invasion.		

10.6.3 Final Low Flow Requirements

Adjustments to the Desktop Reserve Model requirements were made to fit the specialist requirements as shown in Tables 10-7 to 10-9.

Table 10-7. EWR M1 - Maintenance and drought low flows (EC = B).

Month	Desktop	Modified	Ratio (Mod/Desk)
	(m^3/s)		

	Maintenance low flows	Drought low flows	Maintenance low flows	Drought low flows	Maintenance low flows	Drought low flows
Jan	9.360	2.844	11.400	3.000	122%	105%
Feb	11.955	3.578	14.000	3.750	117%	105%
Mar	10.580	3.173	13.000	3.300	123%	104%
Apr	9.851	2.987	12.000	3.000	122%	100%
May	8.470	2.604	10.800	2.500	128%	96%
Jun	7.534	2.361	10.000	2.200	133%	93%
Jul	6.105	1.965	9.000	1.800	147%	92%
Aug	5.273	1.740	8.500	1.500	161%	86%
Sep	4.993	1.675	8.000	1.200	160%	72%
Oct	4.993	1.665	8.000	1.300	160%	78%
Nov	6.215	2.005	8.400	2.000	135%	100%
Dec	7.501	2.342	9.500	2.600	127%	111%

Table 10-8. EWR M1 – Maintenance and drought flows (REC = C).

Month	Desktop		Modified		Ratio (Mod/Desk)	
	Maintenance low flows	Drought low flows	Maintenance low flows	Drought low flows	Maintenance low flows	Drought low flows
Jan	5.360	2.844	6.500	3.000	121%	105%
Feb	6.795	3.578	8.000	3.750	118%	105%
Mar	6.019	3.173	7.000	3.300	116%	104%
Apr	5.635	2.987	6.500	3.000	115%	100%
May	4.879	2.604	5.800	2.500	119%	96%
Jun	4.383	2.361	5.200	2.200	119%	93%
Jul	3.601	1.965	4.500	1.800	125%	92%
Aug	3.151	1.740	4.000	1.500	127%	86%
Sep	3.010	1.675	3.700	1.200	123%	72%
Oct	3.000	1.665	3.700	1.300	123%	78%
Nov	3.671	2.005	4.500	2.000	123%	100%
Dec	4.355	2.342	5.300	2.600	122%	111%

Table 10-9. EWR M1 – Maintenance and drought flows (EC = D).

Month	Desktop		Modified		Ratio (Mod/Desk)	
	Maintenance low flows	Drought low flows	Maintenance low flows	Drought low flows	Maintenance low flows	Drought low flows
Jan	2.844	2.844	1.300	0.280	46%	10%
Feb	3.578	3.578	1.450	0.350	41%	10%
Mar	3.173	3.173	1.400	0.320	44%	10%
Apr	2.987	2.987	1.200	0.275	40%	9%
May	2.604	2.604	0.920	0.250	35%	10%
Jun	2.361	2.361	0.675	0.210	29%	9%
Jul	1.965	1.965	0.490	0.180	25%	9%
Aug	1.740	1.740	0.380	0.170	22%	10%
Sep	1.675	1.675	0.400	0.165	24%	10%
Oct	1.665	1.665	0.440	0.175	26%	11%
Nov	2.005	2.005	0.718	0.210	36%	10%
Dec	2.342	2.342	1.000	0.260	43%	11%

The final curves for EWR 1 are shown in The low flow recommendations for each reserve scenario were finalised (Figure 10-3 and Figure 10-4).

Dry Season

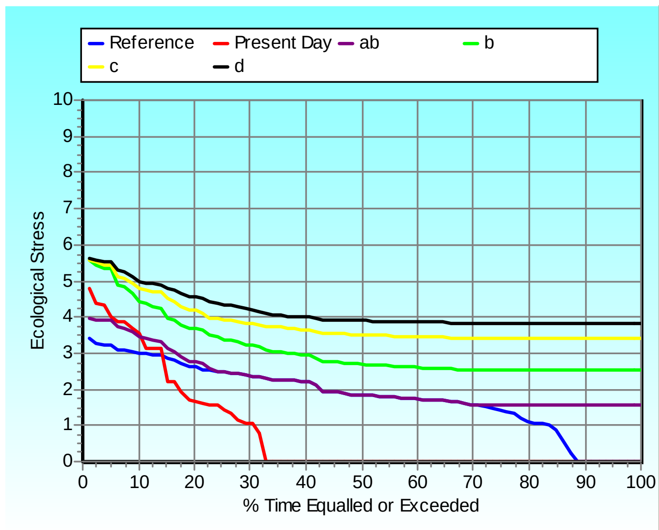


Figure 10-3. Final Stress Duration Curve for Reference conditions, present day and categories B, C and D for the dry season (September) at EWR Site M1.

Wet Season

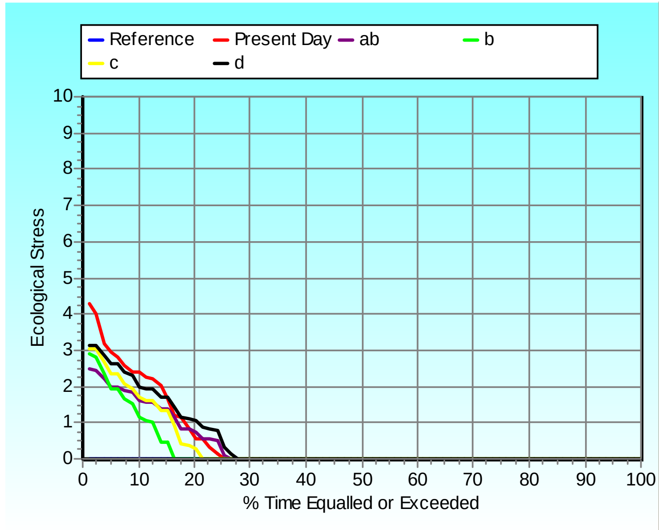


Figure 10-4. Final Stress Duration Curve for Reference conditions, present day and categories B, C and D for wet season (February) at EWR Site M1.

10.6.4 High Flow Requirements

The functions for each Flood Class are described in spreadsheets. A summary of the flood class ranges and recommended number of high flow events required for each EC is provided in Table 10-7 below. Flood class motivations are detailed in Appendix J.

10.7 FINAL RESULTS

The final EWR results for the recommended and alternative categories are summarised below (Table10-10 to Table 10-16) and the detailed results are presented in Appendix K.

Table 10-10. Flood class parameters and recommended number of high flow events required for each EC – EWR Site M1.
Note: *Timing: 1 = January; 12 = December

EC = C	Flood parameters			NUMBER OF EVENTS					FINAL		Discussion of changes	
FLOOD CLASSES	Range	Range Average	Duration (days)	Geom No.	Veg No.	Invert No.	Fish No.	MIN	No.	*Timing	Primary	Secondary
Class 1	14-27	20.5	1.0	5.0	3.0	3.0	3.0	5.0	5.0	6-12	Geom: Maintain sorting of bed in low flow channel; reconstruct lateral bars after major flood events	Fish: Important for local migrations, breeding and recruitment. It is important for at least two events to activate backwaters (nursery areas) and create opportunities for fish fry re-enter the mainstream and reduce losses due to drying of backwaters before fry can re-enter. Most of the fish are serial spawners and this will create at least two opportunities per annum to ensure that some recruitment do take place.
Class 2	27-54	40.5	2.0	1.0	3.0	2.0	1.0	3.0	3.0	9-5	Veg: Prevent terrestrialisation of main channel. Reduce moisture stress for large trees. Inundate key waterside species (eg. *Sagitarius graminea* and sedges). Partially saturate seasonal bars to maintain grass cover.	Inverts: Epilithic diatoms greatly reduce habitat availability for aquatic invertebrates.
Class 3	54-109	81.5	4.0		3.0			3.0	3.0	11-3	Veg: Prevent terrestrialisation of banks and islands. Inundate key species (eg. *Breonadia salicina, Syzygium cordatu* m).	None
Class 4	109-217	163.0	6.0		1.0			1.0	1.0	12-2	Veg: Prevent terrestrialisation of banks and islands. Recharge banks to supply moisture to riparian trees. Prevent reed encroachment in channels. Inundate key species (eg. *Ficus sur*). Facilitate seed dispersal of key species. Remove debris.	None
1:2	241	-			0.5			0.5	1:3	12-2	Veg: Prevent terrestrialisation of banks and islands. Recharge banks to supply moisture to riparian trees. Prevent reed encroachment in channels. Inundate key species (eg. *Celtis african, Bridelia micrantha*). Facilitate seed dispersal of key species. Remove debris.	None
1:5	692	-		P	1.0			1.0	-	-	Veg: Prevent terrestrialisation of banks and islands. Recharge banks to supply moisture to riparian trees. Prevent reed encroachment in channels.Inundate key species (eg. *Celtis africana, Syzygium cordatum*). Facilitate seed dispersal of key species. Remove debris.	None
1:10		-		P					-	-		
1:20	1637	-			1.0				-	-		

EC = B	Flood parameters			NUMBER OF EVENTS							Discussion of changes	
				Geom	Veg	Inverts	Fish		FINAL			
FLOOD CLASSES	Peak (m3/s)		Duration (days)	No.	No.	No.	No.	MIN	No.	Timing		
	Range	Average									Primary	Secondary
Class 1	14-27	20.5	1.0		4.0	4.0	4.0	4.0	4.0	6-12	Veg. Prevent terrestrialisation of main channel. Reduce moisture stress for large trees. Inundate key species (eg. Sagitarius graminea and sedges). Keep secondary channel active .Saturate seasonal bars to maintain grass cover	Inverts. Maintain productivity by providing relevant cue for emergence or breeding. Marginal vegetation should be inundated periodically. Fish. Important for local migrations, breeding and recruitment. It is important for more than one event to activate backwaters (nursery areas) and create opportunities for fish fry re-enter the mainstream and reduce losses due to drying of backwaters before fry can re-enter. Most of the fish are serial spawners and need more than two opportunity per annum to ensure that sufficient recruitment do take place
Class 2	27-54	40.5	2.0	2.0	4.0	3.0	1.0	4.0	4.0	9-5	Veg: • Prevent terrestrialisation of banks and islands. Inundate key species (eg. Breonadia salicina, Syzygium cordatum)	Inverts: Epilithic diatoms greatly reduce habitat availability for aquatic invertebrates, but increased number of events.
Class 3	54-109	81.5	4.0		4.0			4.0	4.0	11-3	Veg: • Prevent terrestrialisation of banks and islands. Inundate key species (eg. Breonadia salicina, Syzygium cordatum, Ficus sur). Facilitate seed dispersal and germinant establishment of key species. Remove debris	None
Class 4	109-217	163.0	6.0		1.0			1.0	1.0	12-2	Veg: • Prevent terrestrialisation of banks and islands. Recharge banks to supply moisture to riparian trees. Prevent reed encroachment in channels. Inundate key species (eg. Ficus sur) . Facilitate seed dispersal of key species. Remove debris	None
1:2	241	-	-		0.5			0.5	1:3	12-2	Veg: as for EC=C	None
1:5	692	-	-	P	1.0			1.0	-	-	Veg: as for EC=C	
1:10		-	-	P					-	-		
1:20	1637	-	-		1.0				-	-		

EC = B	**Flood parameters**			**NUMBER OF EVENTS**							**Discussion of changes**	
				Geom	**Veg**	**Inverts**	**Fish**		**FINAL**			
FLOOD CLASSES	**Peak (m3/s)**		**Duration (days)**	**No.**	**No.**	**No.**	**No.**	**MIN**	**No.**	**Timing**		
	Range	*Average*									Primary	Secondary
Class 1	14-27	20.5	1.0		4.0	4.0	4.0	4.0	4.0	6-12	Veg. Prevent terrestrialisation of main channel. Reduce moisture stress for large trees. Inundate key species (eg. *Sagitarius graminea* and sedges). Keep secondary channel active .Saturate seasonal bars to maintain grass cover	Inverts. Maintain productivity by providing relevant cue for emergence or breeding. Marginal vegetation should be inundated periodically. Fish. Important for local migrations, breeding and recruitment. It is important for more than one event to activate backwaters (nursery areas) and create opportunities for fish fry re-enter the mainstream and reduce losses due to drying of backwaters before fry can re-enter. Most of the fish are serial spawners and need more than two opportunity per annum to ensure that sufficient recruitment do take place
Class 2	27-54	40.5	2.0	2.0	4.0	3.0	1.0	4.0	4.0	9-5	Veg: • Prevent terrestrialisation of banks and islands. Inundate key species (eg. *Breonadia salicina, Syzygium cordatum*)	Inverts: Epilithic diatoms greatly reduce habitat availability for aquatic invertebrates, but increased number of events.
Class 3	54-109	81.5	4.0		4.0			4.0	4.0	11-3	Veg: • Prevent terrestrialisation of banks and islands. Inundate key species (eg. *Breonadia salicina, Syzygium cordatum* , Ficus sur). Facilitate seed dispersal and germinant establishment of key species. Remove debris	None
Class 4	109-217	163.0	6.0		1.0			1.0	1.0	12-2	Veg: • Prevent terrestrialisation of banks and islands. Recharge banks to supply moisture to riparian trees. Prevent reed encroachment in channels. Inundate key species (eg. Ficus sur) . Facilitate seed dispersal of key species. Remove debris	None
1:2	241	-	-		0.5			0.5	1:3	12-2	Veg: as for EC=C	None
1:5	692	-	-	P	1.0			1.0	-	-	Veg: as for EC=C	
1:10		-	-	P					-	-		
1:20	1637	-	-		1.0				-	-		

Table 10-11. EWR Summary Table for EWR Site M1 for REC: C.

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	VOL ($X10^6$ m^3)	nMAR%
EWR SITE M1: EMC =C.														
LOW FLOWS														
MAINTENANCE LOW FLOWS (m^3/s)	3.7	4.5	5.3	6.5	8.0	7.0	6.5	5.8	5.2	4.5	4	3.7	**169.500**	**19.78**
DROUGHT LOW FLOWS (m^3/s)	*1.3*	*2*	*2.6*	*3*	*3.8*	*3.3*	*3*	*2.5*	*2.2*	*1.8*	*1.5*	*1.2*	***73.699***	***8.6***
HIGH FLOWS														
FLOOD (daily average: m^3/s)	10	1)20 2)35	35	35	1)35 2)70	35	10					10	**52.933**	**6.18**
Duration (in days)	1	1)2 2)4	4	4	1)4 2)6	4	1					1		
Return period (years)	1:1	1) 1:1 2) 1:1	1:1	1:1	1) 1:1 2) 1:2	1:1						1:1		
LONG-TERM MEAN													***246.761***	***28.79***

Table 10-12. EWR Summary Table for EWR Site M1 for Alternative EC: B.

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	VOL ($X10^6$ m^3)	nMAR%
EWR SITE M1: EMC =B.														
LOW FLOWS														
MAINTENANCE LOW FLOWS (m^3/s)	8.0	8.4	9.5	11.4	14.0	13.0	12.0	10.8	10.0	9.0	8.5	8.0	**321.425**	**37.5**
DROUGHT LOW FLOWS (m^3/s)	*1.3*	*2.0*	*2.6*	*3.0*	*3.8*	*3.3*	*3.0*	*2.5*	*2.2*	*1.8*	*1.5*	*1.2*	***73.699***	***8.6***
HIGH FLOWS														
FLOOD (daily average: m^3/s)	1)10 2)20	1)20 2)35	35	35	1)35 2)70	1)10 2)20 3)35	10					10	**60.709**	**7.08**
Duration (in days)	1)1 2)2	1)2 2)4	4	4	1)4 2)6	1)1 2)2 3)4	1					1		
Return period (years)	1) 1:1 2) 1:1	1) 1:1 2) 1:1	1:1	1:1	1) 1:1 2) 1:2	1) 1:1 2) 1:1 3)1:1	1:1					1:1		
LONG-TERM MEAN													**359.886**	**41.99**

Table 10-13. EWR Summary Table for EWR Site M1 for Alternative EC: D

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	VOL ($X10^6$ m^3)	nMAR%
EWR SITE M1: EMC =D.														
LOW FLOWS														
MAINTENANCE LOW FLOWS (m^3/s)	1.5	2.0	2.7	3.0	3.8	3.3	3	2.6	2.3	2	1.6	1.5	**76.611**	**8.94**
DROUGHT LOW FLOWS (m^3/s)	*1.3*	*2.0*	*2.6*	*3.0*	*3.8*	*3.3*	*3*	*2.5*	*2.2*	*1.8*	*1.5*	*1.2*	***73.699***	***8.6***
HIGH FLOWS														
FLOOD (daily average: m^3/s)	10	20	35	35	35	35	10					10	**32.076**	**3.74**
Duration (in days)	1	2	4	4	6	4	1					1		
Return period (years)	1:1	1:1	1:1	1:1	1:2	1:1	1:1					1:1		
LONG-TERM MEAN													**167.865**	**19.59**

Table 10-14. EWR rule table for REC: C

Desktop Version 2, Printed on 01/02/2005
Summary of EWR rule curves for : EWR M1 Generic Name
Determination based on defined BBM Table with site specific assurance rules.
Regional Type : E.Escarp REC = C

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

This EWR rule table can be used in combination with the natural duration curves below for implementation.

Reserve flows without High Flows

Month	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	5.156	5.144	5.099	5.007	4.827	4.496	3.942	3.125	2.139	1.398
Nov	6.273	6.253	6.199	6.088	5.877	5.497	4.875	3.974	2.905	2.107
Dec	7.390	7.364	7.299	7.171	6.927	6.495	5.793	4.787	3.601	2.719
Jan	9.062	9.018	8.929	8.754	8.429	7.866	6.968	5.703	4.234	3.148
Feb	11.153	11.113	11.013	10.815	10.438	9.771	8.686	7.130	5.297	3.933
Mar	9.759	9.729	9.647	9.480	9.160	8.587	7.646	6.284	4.668	3.461
Apr	9.062	9.043	8.973	8.829	8.545	8.025	7.154	5.869	4.319	3.153
May	8.085	8.075	8.018	7.895	7.650	7.188	6.398	5.208	3.749	2.643
Jun	7.248	7.243	7.194	7.088	6.873	6.464	5.756	4.678	3.345	2.331
Jul	6.272	6.272	6.234	6.149	5.971	5.624	5.008	4.050	2.844	1.918
Aug	5.574	5.570	5.530	5.445	5.272	4.942	4.370	3.500	2.424	1.605
Sep	5.155	5.148	5.107	5.021	4.847	4.520	3.960	3.118	2.085	1.302

Natural Duration curves

Oct	18.884	15.379	11.193	10.002	8.822	7.616	6.806	6.261	5.395	4.219
Nov	54.414	32.377	24.190	19.541	16.755	15.193	13.611	12.388	8.144	5.421
Dec	74.485	60.372	51.643	35.667	29.040	24.194	20.755	18.851	14.434	6.549
Jan	112.003	80.070	63.885	51.867	37.549	31.235	27.012	23.488	18.298	15.177
Feb	192.717	108.565	65.348	48.950	38.496	29.353	25.686	23.458	20.230	16.328
Mar	107.344	57.687	41.211	32.415	26.400	24.619	22.092	19.243	16.136	13.232
Apr	47.955	31.011	27.928	24.850	23.391	21.863	20.096	17.203	13.696	10.853
May	24.630	21.005	19.579	18.209	17.342	15.744	13.949	12.179	11.115	7.616
Jun	20.096	17.014	14.433	13.723	13.175	11.964	10.922	9.167	8.468	5.706
Jul	14.848	12.743	11.320	10.181	9.427	8.927	8.236	7.288	6.440	4.477
Aug	12.089	10.529	9.554	8.259	7.803	7.213	6.709	6.201	5.556	4.219
Sep	12.836	9.838	8.245	7.832	7.523	6.782	6.335	5.895	5.042	4.464

Total Reserve Flows

	% Points									
Month	**10%**	**20%**	**30%**	**40%**	**50%**	**60%**	**70%**	**80%**	**90%**	**99%**
Oct	5.541	5.527	5.479	5.379	5.182	4.821	4.216	3.324	2.248	1.439
Nov	10.389	10.352	10.249	10.041	9.643	8.929	7.757	6.061	4.049	2.546
Dec	10.219	10.178	10.079	9.881	9.506	8.840	7.758	6.207	4.380	3.020
Jan	13.667	13.010	12.401	11.778	11.046	9.805	8.593	6.886	4.903	3.437
Feb	29.094	26.679	24.568	22.641	20.696	17.413	15.118	11.826	7.948	5.061
Mar	14.364	13.726	13.129	12.521	11.801	10.559	9.310	7.501	5.354	3.751
Apr	9.460	9.439	9.365	9.212	8.912	8.361	7.437	6.074	4.432	3.196
May	8.085	8.075	8.018	7.895	7.650	7.188	6.398	5.208	3.749	2.643
Jun	7.248	7.243	7.194	7.088	6.873	6.464	5.756	4.678	3.345	2.331
Jul	6.272	6.272	6.234	6.149	5.971	5.624	5.008	4.050	2.844	1.918
Aug	5.574	5.570	5.530	5.445	5.272	4.942	4.370	3.500	2.424	1.605
Sep	5.553	5.545	5.501	5.406	5.216	4.859	4.248	3.328	2.200	1.344

Table 10-15. EWR rule table for EC: B.

Desktop Version 2, Printed on 01/02/2005
Summary of EWR rule curves for : EWR M1 Generic Name
Determination based on defined BBM Table with site specific assurance rules.
Regional Type : E.Escarp   EC = B

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

This EWR rule table can be used in combination with the natural duration curves below for implementation.

Reserve flows without High Flows

Month	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	9.548	9.522	9.427	9.231	8.822	7.616	6.806	5.203	3.095	1.509
Nov	10.029	9.992	9.890	9.682	9.285	8.572	7.402	5.710	3.700	2.200
Dec	11.345	11.297	11.180	10.945	10.500	9.711	8.430	6.592	4.428	2.816
Jan	13.613	13.537	13.380	13.074	12.506	11.519	9.948	7.733	5.161	3.259
Feb	16.718	16.647	16.473	16.125	15.466	14.296	12.396	9.671	6.460	4.071
Mar	15.523	15.466	15.310	14.994	14.389	13.304	11.524	8.947	5.889	3.605
Apr	14.329	14.293	14.163	13.893	13.363	12.391	10.763	8.361	5.465	3.287
May	12.895	12.876	12.769	12.542	12.085	11.226	9.755	7.540	4.825	2.767
Jun	11.939	11.928	11.833	11.630	11.215	10.427	9.060	6.980	4.409	2.452
Jul	10.744	10.744	10.667	10.181	9.427	8.927	8.216	6.300	3.888	2.035
Aug	10.146	10.136	9.554	8.259	7.803	7.213	6.709	5.744	3.461	1.724
Sep	9.547	9.533	8.245	7.832	7.523	6.782	6.335	5.247	3.067	1.414

Total Reserve Flows

	% Points									
Month	**10%**	**20%**	**30%**	**40%**	**50%**	**60%**	**70%**	**80%**	**90%**	**99%**
Oct	11.242	11.211	11.098	10.002	8.822	7.616	6.806	6.086	3.584	1.702
Nov	13.803	13.750	13.603	13.307	12.740	11.723	10.054	7.639	4.772	2.631
Dec	13.938	13.877	13.728	13.431	12.866	11.865	10.238	7.905	5.157	3.112
Jan	18.218	17.528	16.852	16.098	15.122	13.458	11.573	8.916	5.830	3.548
Feb	34.659	32.214	30.028	27.951	25.723	21.938	18.828	14.366	9.111	5.199
Mar	22.759	21.747	20.782	19.772	18.539	16.404	14.139	10.859	6.967	4.060
Apr	14.693	14.657	14.523	14.245	13.699	12.699	11.024	8.551	5.570	3.328
May	12.895	12.876	12.769	12.542	12.085	11.226	9.755	7.540	4.825	2.767
Jun	11.939	11.928	11.833	11.630	11.215	10.427	9.060	6.980	4.409	2.452
Jul	10.744	10.744	10.667	10.181	9.427	8.927	8.216	6.300	3.888	2.035
Aug	10.146	10.136	9.554	8.259	7.803	7.213	6.709	5.744	3.461	1.724
Sep	10.277	9.838	8.245	7.832	7.523	6.782	6.335	5.635	3.282	1.498

Table 10-16. EWR rule table for EC: D.

```
Desktop Version 2, Printed on 01/02/2005
Summary of EWR rule curves for : EWR M1 Generic Name
Determination based on defined BBM Table with site specific assurance rules.
Regional Type : E.Escarp     EC = D

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

This EWR rule table can be used in combination with the natural duration curves below for implementation.

Reserve flows without High Flows

Month	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	2.989	2.984	2.965	2.924	2.845	2.700	2.458	2.099	1.668	1.343
Nov	3.987	3.978	3.953	3.902	3.803	3.627	3.337	2.918	2.421	2.050
Dec	5.382	5.367	5.330	5.255	5.114	4.863	4.455	3.870	3.182	2.669
Jan	5.981	5.960	5.916	5.830	5.670	5.393	4.952	4.329	3.607	3.073
Feb	7.477	7.456	7.406	7.306	7.117	6.780	6.234	5.451	4.529	3.842
Mar	6.579	6.564	6.522	6.438	6.275	5.984	5.506	4.815	3.995	3.382
Apr	5.981	5.972	5.938	5.867	5.727	5.471	5.043	4.411	3.649	3.075
May	5.183	5.178	5.151	5.092	4.974	4.752	4.373	3.801	3.100	2.569
Jun	4.585	4.582	4.559	4.509	4.408	4.215	3.880	3.371	2.741	2.262
Jul	3.986	3.986	3.968	3.926	3.839	3.670	3.368	2.900	2.310	1.857
Aug	3.189	3.187	3.171	3.136	3.064	2.927	2.690	2.329	1.883	1.544
Sep	2.989	2.986	2.967	2.928	2.849	2.702	2.448	2.067	1.600	1.246

Total Reserve Flows

	% Points									
Month	**10%**	**20%**	**30%**	**40%**	**50%**	**60%**	**70%**	**80%**	**90%**	**99%**
Oct	3.470	3.464	3.439	3.388	3.288	3.105	2.797	2.344	1.797	1.386
Nov	5.379	5.364	5.322	5.237	5.074	4.783	4.304	3.611	2.789	2.175
Dec	8.918	8.885	8.803	8.640	8.331	7.782	6.891	5.613	4.108	2.988
Jan	10.586	9.951	9.388	8.854	8.286	7.332	6.577	5.512	4.276	3.362
Feb	13.910	13.038	12.267	11.547	10.795	9.521	8.541	7.135	5.479	4.247
Mar	11.184	10.561	10.004	9.478	8.916	7.957	7.170	6.032	4.681	3.672
Apr	6.478	6.467	6.428	6.346	6.185	5.889	5.394	4.664	3.783	3.120
May	5.183	5.178	5.151	5.092	4.974	4.752	4.373	3.801	3.100	2.569
Jun	4.585	4.582	4.559	4.509	4.408	4.215	3.880	3.371	2.741	2.262
Jul	3.986	3.986	3.968	3.926	3.839	3.670	3.368	2.900	2.310	1.857
Aug	3.189	3.187	3.171	3.136	3.064	2.927	2.690	2.329	1.883	1.544
Sep	3.486	3.482	3.459	3.409	3.310	3.124	2.805	2.325	1.737	1.291

10.8 CONFIDENCE

The confidence was evaluated according to a score of 0-5 with zero reflecting 'no confidence' and 5 reflecting 'very high' confidence (Table 10-17).

Table 10-17. Confidence Ratings for EWR Site M1.

	EWR SITE	AVAILABLE DATA	ECOLOGICAL CLASSIF.	OUTPUT LOW FL	OUTPUT HIGH FL
HYDROLOGY		4	4		
	Confidence is fairly high on the accuracy of the simulation of observed (historic) flows. The simulation is based on calibrations done a number of years ago and is a reasonable representation of the time series in terms of the range of flows. The low flows are a slightly higher based on nature of calibration.				
HYDRAULICS	3	2/3=3		2	3
	Measured flows in the range 6.7 to 40m^3/s. Recommended low-flows for the PES (C) in the range 1.0 to 9m^3/s (ie. mostly below lowest measured value of 6.7m^3/s), and high flows in the range (14-217) (within year) to 241-1637 (1:2-1:20).				
QUALITY		1	2		
	Low confidence in data due to limited number of samples. EC confidence in data was low. Impoundment profile temperature, dissolved oxygen, and chlorophyll data available but data is limited due to dam age.				
GEOMORPH	n/a	2	3.5	n/a	3
	No access to site hydrology or hydraulics against which to assess flow recommendations; acceptable sediment and cross-section data. Reasonable data available based on site visits and report for earlier Maguga EWR. Impact of Maguga Dam not yet evident. Assessments for high flows have not been checked against hydraulic calibration or hydrology				
RIP VEG	3	2	3	n/a	3
	EWR site: A good site except for presence of alien-invader plants, deforestation and cattle grazing **Available data:** Limited by use of 1998 (EWR 1b) profile and different methodology (RVI and BBM) in which vegetation zonation and species composition is not as well defined as in other sites **Ecological classification:** RVI index indicated a lower PES **Output low flow:** **Output high flow:**				
FISH	4	4	4	4	4
	Confidence in available data is moderately high because historic data goes back as far as the pre Maguga Dam surveys. Some earlier data is also available for Swaziland. Several surveys have been conducted in this Resource Unit over last two years. Moderately high confidence in EC based on the available data and several recent surveys conducted during last 2 years in this Resource Unit. Moderately high confidence in the site as it provided good indications of the abundance of critical habitat required by indicator species under different flows and could be used to set stress. Moderately high confidence in low flows based on the available hydraulic data and fish information it was possible to set realistic flows in terms of its stress and availability of critical habitat for indicator species. Moderately high confidence in high flows based on our understanding of the species in this Resource Unit, fish has a need of Class 1 floods in terms of breeding and migrations. There is a requirement for a Class 2 flood to clean diatoms from cobbles and backwaters.				
INVERT	4	5	4	4	4

	High diversity of biotopes present: Highly suitable vegetation (in and out-of-current), cobbles (in and out-of-current), sand and gravel; Absent biotopes include bedrock and mud. Abundance of epilithic diatoms limits habitat availability considerably. Data were available for 9 SASS samples recorded at this site alone, so confidence in the available data was high. Information available was suitable for the EcoClassification. The invertebrate low flow requirements are met or exceeded during the dry season, and well-exceeded during the wet season, so confidence in the results was rated as high. The invertebrate high flow requirements are being met or exceeded by the recommended high flows for other ecosystem components, so confidence was rated as high

11. CONCLUSIONS

11.1 PRESENT ECOLOGICAL STATE

Upper Reaches

The upper Komati River and its tributaries were generally in a good ecological condition (Category B/C), when this study was conducted (2003). The Gladdespruit was a notable exception, and was degraded through erosion and sedimentation associated with forestry, severe encroachment of alien invasive plants and historical gold mining (Category D). In areas where flows had not ceased (K1, K2, G1), the duration of the low-flow period had been extended. The Lomati River upstream of Driekoppies Dam, by contrast, was in an excellent condition (Category B).

Middle Reaches

The middle Komati River were in a moderate ecological condition (Category C), but conditions were expected to deteriorate downstream of Maguga Dam because of the long-term impacts of reduced sediment transport.

Lower Reaches

The lower reaches of the Komati River, particularly downstream of Tonga (K3), have been severely impacted by the effects of dams, numerous weirs and associated irrigation developments, and was in a Category E. This reach of river has deteriorated significantly since surveys conducted in 1997 and 1998 (ie, over a period of five years). Part of the degradation can be attributed to the drought conditions experienced in 2003. However, most of the weirs have inadequate outlet capacities, and have had major impacts on habitat availability, fish migrations and low-flow conditions in particular. In 2003 and 2004 the river frequently ceased to flow for extended periods, leading to the loss of all flow-dependent species.

Low flows in the lower Lomati River, by contrast, were usually higher on account of Driekoppies Dam supplying irrigation demands in the lower Lomati and Komati Rivers. Although ecological conditions in the lower Lomati River have changed significantly from natural reference conditions, the system remained ecologically healthy and provided an important ecological refuge for flow-dependent species.

11.2 RECOMMENDED ECOLOGICAL CATEGORY

The REC remained the same as the PES for all sites except EWR Site K3 (Tonga), where an improvement in ecological conditions, from Category E to D, was recommended. The scope for improving ecological conditions in most of the catchment was limited by the following:

- ***Non-flow related Impacts:*** Many of the causes of ecological degradation in the Komati Catchment, such as sand mining, encroachment of alien invasive vegetation, harvesting of riparian vegetation etc, are not caused by flow modification, so improving flows will not necessarily solve the ecological problems or improve the ecological category. For example, EWR Site K2 is of high historical value and is undergoing improved landuse practices due to the conversion of land from dryland cropping to conservation, but ecological improvements from a Category C to a B would be unlikely because the underlying causes of the present EC were catchment-related rather than flow-related.

- ***Electricity Demands:*** The strategic demands by ESKOM for water from the upper reaches of the Komati catchment suggests that it is unlikely that the hydrology could be improved in the foreseeable future. Water requirements for ESKOM are of national strategic importance and this overrides Ecological Reserve requirements.

- ***Irriversable Changes:*** The construction of dams and weirs have had irriversable impacts on the downstream ecology and these changes cannot be mitigated through flow manipulation.

11.3 ECOLOGICAL WATER REQUIREMENTS

The recommended EWR constituted between12 and 37% of the nMAR. At all regulated EWR sites the recommended flows were lower than the outputs of the Desktop Model. The reason for this is probably related to the river channel having adusted over the years to lower flows following impoundment in the 1970's. At unregulated sites, the recommended flows were similar to the outputs of the Desktop Model.

11.4 CONFIDENCE

A large amount of historical data have been collected from the main Komati River, so confidence in the available biological data was generally high for the main river, and less so for the tributaries. The confidence in the low-flow hydraulics was generally high, but confidence in high flow hydraulics was low because the study was conducted during an extended dry period, which made it impossible to calibrate the hydraulics under high flow conditions. Confidence in the sites selected was high, with the notable exeption of EWR Site K3 (Tonga), which had been histoirically inundated by backup from a weir, and was reinundated during the course of the study. Confidence in the hydrology was moderate for most sites, with the notable exception EWR Site G1 (Gladdespruit), where confidence was low.

12. RECOMMENDATIONS

Implementation and Monitoring

The EWR recommendations should integrated into the system operation, and modified if necessary, and the modified recommendations should be implemented with immediate effect. A monitoring programme to assess compliance should be developed within the framework of a practical decision support system that specifies what actions need to be taken by whom when recommended thresholds are exceeded.

Komati River

The most important recommendation for the Komati River is to restore perennial flows in the lower reaches. The EWR recommendations are unlikely to be met unless releases from all dams and weirs in the catchment, including those in Swaziland, are co-ordinated. Related to this is the need for all regulatory structures, large and small, to have outlet facilities capable of providing the downstream ecological requirements, particularly during low-flow periods. The recommended EWR alone will not address the ecological problems in the Komati River, and the Catchment Management Agency could play an important role in co-ordinating efforts to address some of the main non-flow related impacts, which include:

- The need to develop and implement a plan to install fish ladders on weirs, and remove weirs that are no longer needed or used (eg at Diepgezet);
- The need to improve riparian zones as a buffers and control deforestation, cultivation and grazing in riparian zones;
- The need to develop and implement a soil conservation plan that addresses the problem of erosion;
- The need to continue controlling the spread of alien invasive vegetation, particularly along river courses.

Gladdespruit River

The recommended ecological flows for the Gladdespruit River are intended to address some of the ecological problems in the sub-catchment. However, it is recommended that further steps are taken to rehabilitate this river, which is currently impacted due to a wide range of factors including acid drainage from historical mines, sewerage inputs and erosion.

Lomati River

The Lomati River downstream of Driekoppies Dam remains fairly healthy, although there has been a significant change from reference conditions in that the system has changed from warm tropical system to a cooler temperate system. This is as a result of hydrological and water temperature changes. It was the opinion of the specialist team that such changes are irreversible. For this reason, and the fact that the system is currently receiving more water than under natural conditions, the EWR was based on maintaining current conditions.

Teepsruit

Conditions in the Teespruit could be improved by addressing non-flow related factors, including sewerage, peri-urban development, alien invasive vegetation and clearing in riparian zone.

Integrating EWR studies

The comprehensive determination of the ecological component of the Reserve requires, in addition to the riverine water quantity component (this study), an assessment of riverine water quality EWRs, and groundwater and wetland EWRs for water quality and water quantity. The results of these assessments need to be integrated into a single set of EWR recommendations, as required in terms of the Resource Directed Measures for the protection of aquatic ecosystems.

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14. APPENDICES

APPENDIX A: HYDRAULICS AND HABITAT MODELLING

APPENDIX B: GEOMORPHOLOGY

APPENDIX C: RIPARIAN VEGETATION

APPENDIX D: AQUATIC INVERTEBRATES

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APPENDIX K: DETAILED EWR RESULTS PRESENTED AS EWR TABLES