Comprehensive Reserve Determination Study for Selected Water Resources (Rivers, Groundwater and Wetlands) in the INKOMATI WATER MANAGEMENT AREA, MPUMALANGA

PROJECT NO: WP 9133

EWR Scenario Assessment for the Crocodile and Sabie-Sand Systems: VOLUME 1: SABIE-SAND SYSTEM

INKOMATI

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DEPARTMENT OF WATER AFFAIRS
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COMPREHENSIVE RESERVE DETERMINATION STUDY FOR SELECTED WATER RESOURCES IN THE INKOMATI WATER MANAGEMENT AREA, MPUMALANGA.

SABIE AND CROCODILE SYSTEMS: SABIE EWR SCENARIO REPORT: VOLUME 1 & 2 FINAL

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Reports as part of this project:

Report no	Report title
26/8/3/10/12/001	Comprehensive Reserve Determination Study for selected water resources in the Inkomati WMA, Mpumalanga: Inception report
26/8/3/10/12/002	Comprehensive Reserve Determination Study for selected water resources in the Inkomati WMA, Mpumalanga: Desktop EcoClassification report
26/8/3/10/12/003	Newsletters
26/8/3/10/12/004	Comprehensive Reserve Determination Study for selected water resources in the Inkomati WMA, Mpumalanga: Basic Human Needs Reserve report
26/8/3/10/12/005	Comprehensive Reserve Determination Study for selected water resources in the Inkomati WMA, Mpumalanga: Groundwater report
26/8/3/10/12/006	Comprehensive Reserve Determination Study for selected water resources in the Inkomati WMA, Mpumalanga: Resource Unit report
26/8/3/10/12/007	Comprehensive Reserve Determination Study for selected water resources in the Inkomati WMA, Mpumalanga: Desktop Estimation report
26/8/3/10/12/008	Comprehensive Reserve Determination Study for selected water resources in the Inkomati WMA, Mpumalanga: Wetland report
26/8/3/10/12/009	Comprehensive Reserve Determination Study for selected water resources in the Inkomati WMA, Mpumalanga: EcoClassification report
26/8/3/10/12/010	**Comprehensive Reserve Determination Study for selected water resources in the Inkomati WMA, Mpumalanga: EWR scenario report**
26/8/3/10/12/011	Comprehensive Reserve Determination Study for selected water resources in the Inkomati WMA, Mpumalanga: Operation scenarios and consequences report
26/8/3/10/12/012	Comprehensive Reserve Determination Study for selected water resources in the Inkomati WMA, Mpumalanga: EcoSpecs report
26/8/3/10/12/013	Comprehensive Reserve Determination Study for selected water resources in the Inkomati WMA, Mpumalanga: Socio Economic Present State Evaluation Report
26/8/3/10/12/014	Comprehensive Reserve Determination Study for selected water resources in the Inkomati WMA, Mpumalanga: Training audit and report
26/8/3/10/12/015	Comprehensive Reserve Determination Study for selected water resources in the Inkomati WMA, Mpumalanga: Main report
26/8/3/10/12/016	Comprehensive Reserve Determination Study for selected water resources in the Inkomati WMA, Mpumalanga: Electronic information and data
26/8/3/10/12/016	Comprehensive Reserve Determination Study for selected water resources in the Inkomati WMA, Mpumalanga: Electronic information and data

Bold indicates this report

REFERENCES

This report is to be referred in bibliographies as:

Department of Water Affairs, South Africa. 2010. Comprehensive Reserve Determination Study for Selected Water Resources (Rivers, Groundwater and Wetlands) in the Inkomati Water Management Area, Mpumalanga. EWR Scenario Assessment for the Crocodile and Sabie-Sand Systems: Volume 1: Sabie-Sand System Prepared by Rivers for Africa, edited by Louw, MD and Koekemoer, S. RDM Report no 26/8/3/10/12/010.

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EXECUTIVE SUMMARY

BACKGROUND

The Reserve for the Komati River was determined at a Comprehensive level and approved in 2006. Subsequently the Chief Directorate Resource Directed Measures (CD: RDM) identified that the remaining catchments within WMA 5 also requires a high confidence Reserve. High confidence results are needed in light of the initiation of the Compulsory Licensing Process in the WMA and the proposed new developments.

STUDY AREA

The Inkomati WMA is largely located within the Mpumulanga Province. It can be considered to consist of three largely independent catchments, the Komati, Crocodile (East) and Sabie–Sand River catchments. All these rivers drain the WMA and confluence to form the Incomati River in Mozambique which flows into the Indian Ocean.

The focus of this study is on the determination of the Ecological Reserve for the Sabie (X31, X33) and Sand (X32) catchments. Eight EWR sites were chosen to represent these catchments, the locality and characteristics of which are provided in the table below. These EWR sites were chosen according to the criteria described in report 26/8/3/10/12/006 (DWAF, 2008).

EWR site no	EWR site name	River	Coordinates		EcoRegion (Level 2)	Geomorphic Zone	Quat
			Latitude	Longitude			
EWR 1	Upper Sabie	Sabie River	S25 04.424	E30 50.924	4.04	Upper Foothills	X31B
EWR 2	Aan de Vliet	Sabie River	S25 01.675	E31 03.099	4.04	Lower Foothills	X31D
EWR 3	Kidney	Sabie River	S24 59.256	E31 17.572	3.07	Lower Foothills	X31K
EWR 4	MacMac	Mac Mac River	S25 00.800	E31 00.243	4.04	Upper Foothills	X31C
EWR 5	Marite	Marite River	S25 01.077	E31 07.997	4.04	Upper Foothills	X31G
EWR 6	Mutlumuvi	Mutlumuvi River	S24 45.352	E31 07.923	3.07	Upper Foothills	X32F
EWR 7	Tlulandziteka	Tlulandziteka River	S24 40.829	E31 05.188	3.07	Lower Foothills	X32C
EWR 8	Sand	Sand River	S24 58.045	E31 37.641	3.07	Lower Foothills	X32J

THIS REPORT

This report summarizes the results of the EWR scenario determination task. This task consists of determining the EWR for different ecological river states, i.e. different Ecological Categories. The report consists of a main summary report (Volume 1) supported by the specialist appendices (Volume 3) (RDM Report 26/8/3/10/12/010). Volume 3 will only be made available electronically as part of RDM Report 26/8/3/10/12/016 - Electronic information and data.

APPROACH

The Habitat Flow Stressor Response method (HFSR) (IWR S2S, 2004; O'Keeffe *et al*., 2002), a modification of the Building Block Methodology (BBM) (King and Louw, 1998) was used to determine the low (base) flow EWRs. The approach to set high flows is a combination of the Downstream Response to Imposed Flow Transformation (DRIFT; Brown and King, 2001) approach and BBM. These results generated will then form the basis against which the ecological consequences of operational flow scenarios will be tested during a further task in this study.

RESULTS

The results are summarised in the table below for the different EWR sites as a percentage of the natural Mean Annual Runoff (nMAR).

EWR site	EC[1]	Maintenance low flows (%nMAR)	Drought low flows (%nMAR)	High flows (%nMAR)	Long term mean (% nMAR)
EWR 1	B/C PES	33.2	12.1	5.3	37.8
	B REC	44.1	12.1	6.1	46.3
	C/D AEC	20.7	12.1	4.5	31
EWR 2	B/C PES	19.8	11.1	4.4	28
	B REC	31.1	11.1	5	35.7
	C/D AEC	12.5	11.1	3.6	22.1
EWR 3	A/B REC	31.3	9.7	6.4	37
	B/C AEC	20.4	9.7	5.4	27.1
EWR 4	A/B PES	31.3	9.7	6.4	37
	B/C AEC	20.4	9.7	5.4	27.1
EWR 5	B/C PES	20.8	8	6.5	28.2
	B REC	30.2	8	7.1	36.3
	C/D AEC	9.8	8	5.4	19.8
EWR 6	C PES	22.2	10.3	6.3	32.4
	B AEC	32.2	13.4	6.3	38.6
	C/D AEC	13.8	10.3	5.7	25.7
EWR 7	C PES	17.7	7.1	11	31.7
	B AEC	26.5	11.2	13.2	39.4
	D AEC	9.4	7.1	10.2	26.9
EWR 8	B PES[2]/REC	17.4	3.4	7.3	25.3
	C AEC	9.5	3.4	6.6	18.4

1 Refer to Report 26/8/3/10/12/009 (DWA, 2009).
2 The attainable and realistic objective was to maintain the PES, but improve the macroinvertebrate EC by improving low flows.

CONCLUSIONS AND RECOMMENDATIONS

The confidence in the low and high flow Ecological Reserve requirements for each EWR site is provided in the table below. A score of 1 - 2 indicates a low confidence, 3 - 4 a moderate confidence and 5, high confidence in the results.

EWR SITE	HYDROLOGY	LOW FLOWS				HIGH FLOWS			
		BIOLOGICAL RESPONSES	HYDRAULICS	CONFIDENCE	Comment	BIOLOGICAL RESPONSES	HYDRAULICS	CONFIDENCE	Comment
EWR 1	2.5	3.5	3.5	3.5	Moderate - High confidence for both biophysical and hydraulic aspects. Hydraulics is not of higher confidence due to EWR being below the measured minimum discharge and the presence of non-uniform flow conditions.	3.3	3	3	Moderate confidence due to hydraulics where flood requirements is above the measured maximum discharge and the presence of non-uniform conditions.
EWR 2	3	3.5	3.5	3.5	Moderate - High confidence for both biophysical and hydraulic aspects. Hydraulics is not of higher confidence due to some of the EWR recommendations being below the measured minimum.	3	3	3	Moderate confidence. The hydraulics is complex as during flood conditions various channels form in a floodplain on a bend.
EWR 3	3	4	3.5	3.5	Moderate - High confidence for hydraulics due to uncertainty with low flow 2-D modelling.	4	4	4	The site is complex with multi-distributary channels, however the flood recommendations are below the highest measured flow.
EWR 4	0.5	4	4	4	High confidence for both hydraulics and biophysical aspects.	2.3	3	2.3	Moderate confidence for hydraulics due to downstream bridge that can cause back-up during flooding conditions. Biophysical confidence lower due to the lack of geomorphological cues and a nearby gauge with reliable data.
EWR 5	2.5	4	3.5	3.5	Two channels at different stages and some flows recommended lower than measured discharge.	2.8	3	3	Confidence related to lack of hydrological data and geomorphological cues at the site and moderate hydraulic confidence as flood recommendations are mostly above measured maximum.
EWR 6	1	3.5	4	3.5	Lower confidence in the fish than the other components, mostly due to the position of the cross-section which does not represent the most critical habitats for fish.	2.8	3	3	Complex hydraulic site. Bedrock nature of site - lack of geomorphological cues and hydrological information.
EWR 7	0.5	2.5	3.5	2.5	The site was approached at a rapid level and only one biological survey was undertaken. Confidence therefore relates to lack of surveyed and any historical information. Only one low flow hydraulic point was available.	2.3	3	2.3	Geomorphological confidence low due to lack of a gauge, no hydrology, paired terraces, bedrock and lack of cues. Only one hydraulic measurement at the bottom of the high flow range was available.
EWR 8	1.5	3	2	2	Although this is an old EWR site, the cross-section had to be moved as the previous one was overgrown with reeds. Previous hydraulic data could not be used. Minimal measurements at low flows were available and the bed and channel is mobile. There is backup from bedrock and uncertainty with the flow class modelling.	4	3	3	Confidence due to the hydraulics is moderate as recommended floods are above the measured maximum and vegetation resistance in the channel is problematic.

Recommendations were determined based on the possibility and necessity of improving the confidence of the individual assessments (biological response and hydraulics) by implementing an Ecological Water Resource Monitoring Programme (EWRM), hydrological monitoring and hydraulic assessments. This will provide the additional information to improve confidence in the EWRs. These recommendations are summarised in the table below.

EWR sites	Low flow confidence	High flow confidence	Recommendations
EWR 1	3.5	3	EWRM.
EWR 2	3.5	3	EWRM.
EWR 3	3.5	4	EWRM.
EWR 4	4	2.3	EWRM.
EWR 5	3.5	3	EWRM.
EWR 6	3.5	3	Hydrological monitoring. EWRM.
EWR 7	2.5	2.3	Hydrological monitoring. EWRM.
EWR 8	2	3	Additional low flow hydraulic information for calibration purposes. Hydrological monitoring. EWRM.

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APPENDIX C	Supporting information for the determination of stress indices and EWR scenarios of EWR 2: Goedehoop
APPENDIX D	Supporting information for the determination of stress indices and EWR scenarios of EWR 3: Poplar Creek
APPENDIX E	Supporting information for the determination of stress indices and EWR scenarios of EWR 4: Kanyamazane
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ABBREVIATIONS AND ACRONYMS

AEC	Alternative Ecological Category
Ave	Average
BBM	Building Block Methodology
CD: RDM	Chief Directorate: Resource Directed Measures
DLIFR	Drought low flow
D:RQS	Directorate: Resource Quality Services
DRIFT	Downstream Response to Imposed Flow Transformation
DRM	Desktop Reserve Model
DWA	Department of Water Affairs (Name change 2009)
DWAF	Department of Water Affairs and Forestry
EC	Ecological Category
EIS	Ecological Importance and Sensitivity
EWR	Ecological Water Requirements
EWRM	Ecological Water Resource Monitoring
EWRMP	Ecological Water Resource Monitoring Programme
FD	Fast deep fish habitat
FDI	Flow dependent macroinvertebrate
FI	Fast intermediate fish habitat
FROC	Frequency of Occurrence
FS	Fast shallow fish habitat
HFSR	Habitat Flow Stressor Response
Integ	Integrated
LR	Large rheophilic fish
MAR	Mean Annual Runoff
MCM	Million Cubic Meters
MHIFR	Maintenance high flow
MLIFR	Maintenance low flow
MVI	Marginal vegetation macroinvertebrate
MV	Marginal vegetation
nMAR	Natural Mean Annual Runoff
PES	Present Ecological State
REC	Recommended Ecological Category
RU	Resource Unit
SD	Slow deep fish habitat
SPATSIM	Spatial and Time Series Information Modelling
SR	Small rheophilic fish
SS	Slow shallow fish habitat
Veg	Vegetation
WMA	Water Management Area

1 INTRODUCTION

1.1 BACKGROUND

The Reserve for the Komati River was determined at a Comprehensive level and approved in 2006. Subsequently the Chief Directorate Resource Directed Measures (CD: RDM) identified that the remaining catchments within WMA 5 also requires a high confidence Reserve. High confidence results are needed in light of the initiation of the Compulsory Licensing Process in the WMA and the proposed new developments.

Figure 1-1 is a schematic representation of the 8 - step Ecological Reserve process followed in this study. This report summarizes step 4 of the Ecological Reserve process.

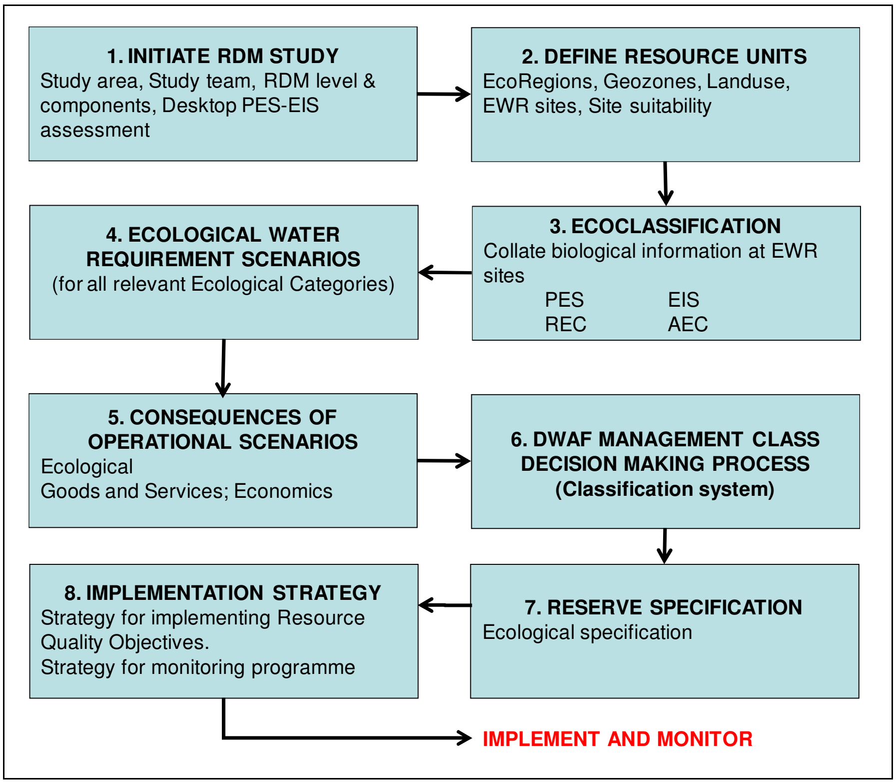

Figure 1-1 The 8-step Ecological Reserve procedure (adapted from DWAF, 1999)

1.2 STUDY AREA

The Inkomati WMA is largely located within the Mpumalanga Province. It can be considered to consist of three largely independent catchments, the Komati, Crocodile (East) and Sabie–Sand River catchments. All these rivers drain the WMA and confluence to form the Incomati River in Mozambique which flows into the Indian Ocean.

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Table 1.1 Locality of EWR sites for the Sabie-Sand River System

EWR site no	EWR site name	River	Coordinates		EcoRegion (Level 2)[1]	Geomorphic Zone	Quat[2]
			Latitude	Longitude			
EWR 1	Upper Sabie	Sabie River	S25 04.424	E30 50.924	4.04	Upper Foothills	X31B
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EWR 8	Sand	Sand River	S24 58.045	E31 37.641	3.07	Lower Foothills	X32J

1 Refer to Kleynhans *et al*. (2007) for EcoRegion description
2 Quaternary catchment

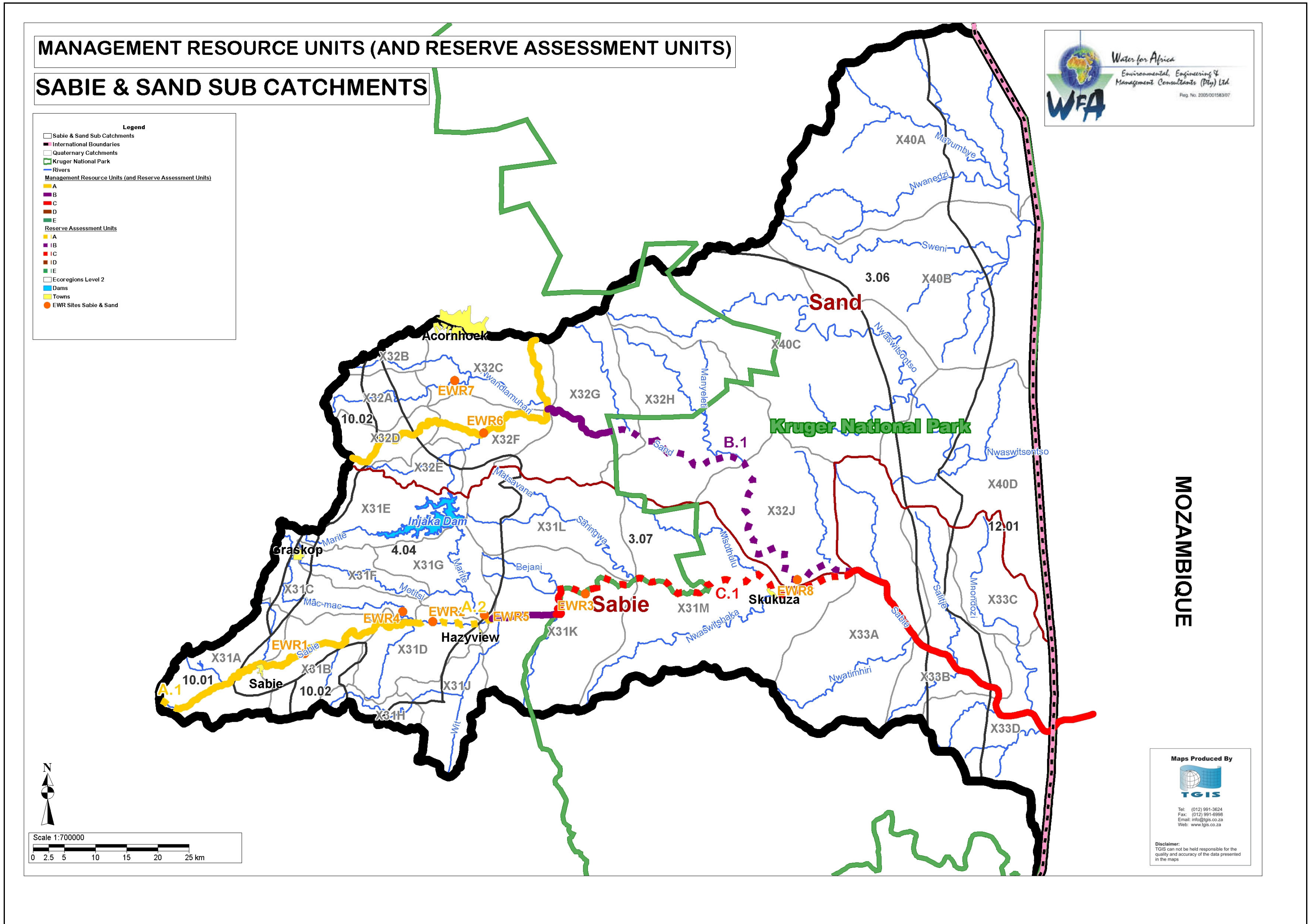

Figure 1-2 Sabie-Sand River catchment and locality of EWR sites

1.3 PURPOSE OF THE REPORT

This report serves to document the results of the specialist meeting held from 28 – 31 July 2008. The purpose of this report is to determine the low as well as high flows that are required to maintain the current state of ecological health (PES) at each EWR Site. This requires the specialists to determine the flows that would be required to either improve the ecological health of the specific River (the REC) or to maintain the river in a lower health status than its current situation (the AEC). The current state as well as feasible alternatives (REC, AEC) to the current state for the Sabie catchment was described as part of the EcoClassification Task (Report 26/8/3/10/12/009; DWA, 2009). This report subsequently provides the low and high flows that are required to achieve each of these ecological categories, where the results are referred to as EWR scenarios.

1.4 OUTLINE OF THE REPORT

Volume one (this report) is outlined below. It must be noted however that this report should be read in conjunction with EWR scenario Report - Volume 3 (provided as part of RDM report 26/8/3/10/12/016 - Electronic information and data), which contains the relevant supporting specialist information.

Chapter 1: Introduction
This chapter.

Chapter 2: Methodology for setting riverine EWR scenarios
This chapter outlines the methods followed for Step 4 of the Ecological Reserve process.

Chapter 3, 5, 7, 9, 11, 13, 15, 17: Determination of stress indices
The stress indices for all physical and biological components at each EWR site are provided.

Chapter 4, 6, 8, 10, 12, 14, 16, 18: Determination of EWR scenarios
These chapters provide results of different EWR scenarios with respect to low and high flows for the respective EWR sites. Aspects covered in these chapters are component and integrated/stress curves, generating stress requirements, general approach to high flows, final results and confidence in the final results.

Chapter 19: Conclusions and Recommendations
The EWR Scenario results are summarised and recommendations are made with regards to actions that should be taken to improve the confidence in these results.

Chapter 20: References

2 METHODOLOGY FOR SETTING RIVERINE EWR SCENARIOS

The section below describes the methods and data that were used to determine the EWR scenarios for each of the 8 EWR sites in the Sabie-Sand River Catchment.

2.1 LOW FLOWS

The Habitat Flow Stressor Response method (HFSR) (IWR S2S, 2004; O'Keeffe *et al*., 2002), a modification of the Building Block Methodology (BBM) (King and Louw, 1998) was used to determine the low (base) flow EWRs. This method is an accepted DWA method for determining EWRs. A short summary of the approach is provided below. For more detail as well the specific specialist approaches, the reader is referred to the manual and the paper on the principles of the method (albeit out of date). Further development of the approach has since been undertaken in consultation with DWA specialists since 2004 with a manual to follow at some stage. Note that it is not part of the TOR of this study to provide detailed methods.

The basic approach is to set stress indices for fish and macroinvertebrates and, where appropriate, riparian vegetation. The stress index describes the consequences of flow reduction on flow dependant biota and is determined by first assessing the response of habitat to a flow reduction. The habitat flow index is described separately for fish, macroinvertebrates and riparian vegetation as an instantaneous response of habitat to flow in terms of a 0 – 10 index relevant for the specific site. The zero stress (best habitat) and 10 stress (worst habitat) is fixed as follows to ensure that the range for fish macroinvertebrates and riparian vegetation are the same:

- 0: Optimum habitat represented by the maximum natural base flow. Note that without adequate hydrological data, this is difficult to identify.
- 10: No flow.

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

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

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

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

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

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

Figure 2-1 illustrates an example of a flow stress matrix. The black line represents the integrated stress and the other lines the stress flow relationships for the various biotic components where:

- The large rheophilic (LR) guild is represented by the blue line.
- The small rheophilic (SR) guild is represented by the red line.
- The flow dependant macroinvertebrate (FDI) stress is represented by the purple line; and
- Reed and *Ficus* stress is represented by the green and yellow line respectively.

The integrated curve in this case consists of the LR guild (blue line) for the stress range 0 - 10.

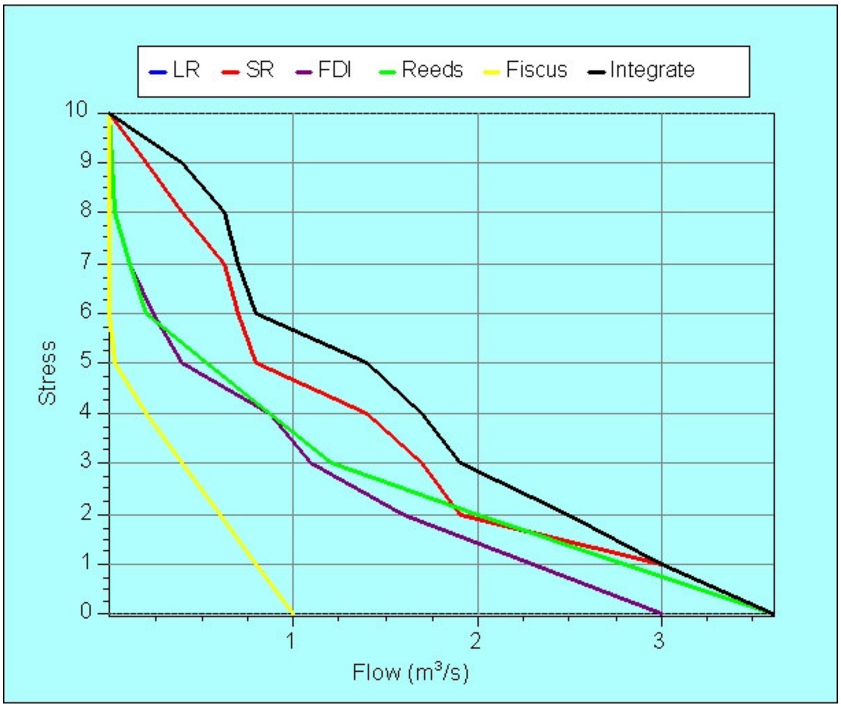

Figure 2-1 Component and integrated stress curves

Specialists determine the required stress (based on the habitat and biota response) for different durations and for different Ecological Categories (ECs). The complexity here, as with all flow requirement methods, is the interpretation of an instantaneous response in terms of duration and seasonal requirements. The biota stress requirement is converted to integrated stress and plotted (as circles) on a flow duration graph (Figure 2.2) which also shows the natural (red line) and present day flow (blue line) converted to integrated stress. This therefore supplies the 'hydrological check' to ensure that the requirements are realistic in terms of the natural hydrology and present day hydrology (only used when realistic and of reasonable confidence is available). The low flow stress requirement for an EC consists of the component requirement with the lowest stress requirement (highest flow requirements). For example, if fish has a requirement at 5% duration of a stress of 6 to achieve a C EC, and macroinvertebrates has a requirement for a C EC of 8, the final requirement will be a stress of 6 as the 6 stress would cater for the macroinvertebrates, whereas the 8 stress could not cater for the fish and will result in the fish being in a lower EC. These final requirements are therefore connected manually (a 'hand drawn line' as the required stress duration).

Figure 2.2 is an example of a stress duration graph and illustrates the stress requirements and stress points required for a B/C PES (green arrowed line), B REC (purple arrowed line) and a C/D AEC (yellow arrowed line). The different coloured circles indicate the requirements of the instream biota for the specific EC. Each circle is labeled as follows and indicates a different biotic component:

- SR – Small rheophilic fish guild.
- LR – Large rheophilic fish guild.
- FDI – Flow dependent macroinvertebrates
- Vegetation – By Family/genus/species

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

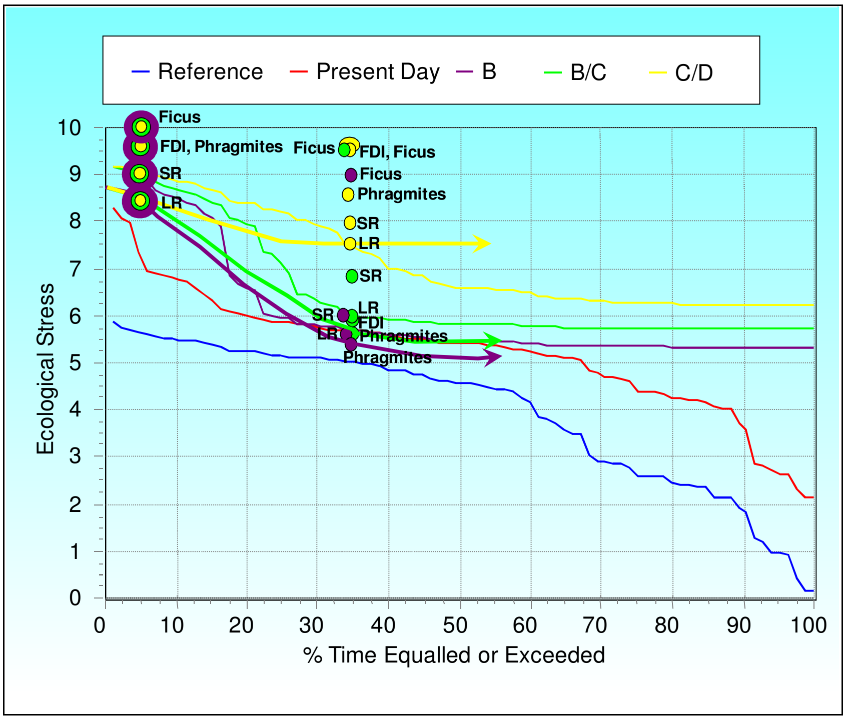

Figure 2-2 Stress duration curve for a B/C PES, B REC and C/D AEC - DRY season

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

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

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

2.2 HIGH FLOWS

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

- Geomorphology and riparian vegetation specialists describe a range of floods from very small to large based on the function they perform. Each of these different floods are described by a range of flood peaks that perform a specific function. The smallest group of floods with similar ranges are grouped into Class 1 floods. The second group of floods which is larger than group 1 will are therefore the Class 2 floods etc.
- These are provided to the instream specialists who indicate:
  - which instream function these floods cater for,
  - whether additional instream functions are required,
  - whether they require any additional flood classes to the ones identified.
- The number of floods for each flood class is identified as well as where (early, mid, late) in the season they should occur.
- These numbers of floods are then adjusted for the different Ecological Categories.
- The floods are evaluated by the hydrologist to determine whether they are realistic. A nearby gauge[3] with daily data is used for this assessment. Without this information it is difficult to judge whether floods are realistic.
- The hydrologist then determines the daily average and documents the months in which the floods are spaced.

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[1] SPATSIM is an integrated data management and modelling software package developed in Delphi using the spatial data handling functions of Map Objects. It has been designed to allow the efficient management, processing and modelling of the type of data associated with a range of water resource assessment approaches used in South Africa including streamflow and other time series data display and analysis, rainfall-runoff models (including the Pitman monthly model) and a variety of Ecological Reserve determination models.

[2] The desktop estimates for specific ECs include rules for these ECs based on long-term data records and expert information.

[3] Refer to report 26/8/3/10/12/009 (Volume 2, Appendix A) on hydrological information.

- The floods are then entered into the DRM to provide the final .rul and .tab files.

2.3 FINAL FLOW REQUIREMENTS

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

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

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

3 EWR 1: UPPER SABIE (SABIE RIVER) – DETERMINATION OF STRESS INDICES

NOTE: All supporting specialist information for EWR 1 is summarized in Volume 3, Appendix J.

Stress indices are set for fish, macroinvertebrates and riparian vegetation to aid in the determination of low flow requirements. The stress index describes the consequences of flow reduction on flow dependant biota. It therefore describes the habitat conditions for fish, macroinvertebrates and riparian vegetation indicator species for various low flows. These habitat conditions for different flows are rated from 10 (zero flows) to 0, which is the optimum habitat for the indicator species. It must be noted that the use of vegetation in this process is still in the developmental phase. The response to stress for riparian vegetation is much slower than that for the instream biota. The riparian vegetation information must therefore be used with care. This is relevant for all the sites.

3.1 INDICATOR SPECIES OR GROUP

3.1.1 Fish indicator group 1: Large rheophilic species (VNEL)

The large rheophilic[4] (LR) species, *Varicorhinus nelspruitensis* (VNEL) is the most important indicator species regarding the setting of flows as it is the biggest species at the site having a preference for continuous flowing water for all of its life stages. Information on the habitat requirements for different life stages of VNEL are provided in Appendix J, Table J1. Information regarding the habitat requirements for different life stages (especially early life stages) of this species, and deficiencies were addressed by reference to fish species with similar behaviour and requirements of which information is available. VNEL is intolerant to no flow and requires flowing habitat, namely fast intermediate (FI) and fast deep (FD) with substrate and water column as preferred cover for most of its life stage. They also require margins of fast shallow (FS), slow shallow (SS) and slow deep (SD) with overhanging vegetation as nursery habitats. Flows should furthermore remain adequate to allow migration between reaches, thus depth in riffle and rapids should remain adequate, especially during the wet season.

3.1.2 Fish indicator group 2: Small rheophilic species (AURA, CANO)

The small rheophilic (SR) species *Amphilius uranoscopus* (AURA) and *Chiloglanis anoterus* (CANO) are good indicators for setting flows as a result of their strong preference for flowing water. Information on the habitat requirements for different life stages of AURA and CANO are provided in Appendix J, Table J2. These species all require flowing water over substrates during all life stages, with some stages also preferring overhanging vegetation as cover. Optimal conditions for spawning of this guild consist of fast deep (FD), fast intermediate (FI), fast shallow (FS) and slow shallow (SS) with good quality substrate (clean cobbles and gravel), while the margins of the FS and SS are important for egg development and nursery areas for larvae, often with overhanging vegetation as cover. Juvenile and adult stages of this guild have a high preference for FS, FI and

[4] Rheophilic: Aquatic biota requiring flowing water during all phases of the life-cycle. These include fast-rheophilics (requiring fast flow (>0.3 m/s) during most phases of the life cycle and slow-rheophilics (requiring slow (<0.3 m/s) during most phases of the life-cycle.

FD over substrates. Flows should furthermore remain adequate to allow migration between reaches, thus depth in riffles and rapids should remain adequate, especially during the wet season.

3.1.3 Macroinvertebrate indicator taxa

A number of flow dependent (FDI) cobble dwelling macroinvertebrate taxa were selected on the basis of their sensitivity to changes in velocity and water quality. Only taxa that occurred commonly at the site were selected. The taxa used were:

- Stonefly family: Perlidae preferring velocities > 0.6 m/s; and
- Beetle family: Elmidae also preferring velocities between 0.3 and 0.6 m/s.

3.1.4 Riparian vegetation indicator species

Two indicator species were selected:

- *Phragmites mauritianus:* Hardy reed that is an obligate[5] hydrophyte[6]. It has a wide habitat tolerance, but optimal habitat and large stands usually occur in the marginal and lower zones, associated with permanent or near-permanent water. It prefers alluvial sediments and also facilitates sedimentation. Although it is drought and flood resistant, it is also a heavy water user. This riparian reed species is thus a fair indicator of flow requirements if high density, high vigour stands is used.
- *Ficus sur*: This is not a riparian obligate species, and is therefore not the best indicator of flow, but it can be used to check flow requirements for common woody species occurring in the riparian zone. This tree species is common along rivers and moist ravines in this area, but would be considered a facultative[7] riparian species and is therefore hardier than an obligate.

3.2 STRESS FLOW INDEX

A stress flow index is generated for every component, and describes the progressive consequences to the flow dependent biota of flow reduction (O'Keeffe and Hughes, 2004). The stress flow index is generated in terms of habitat response and biotic response and is discussed below.

3.2.1 Habitat response

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

- 0 - Optimum habitat (fixed at the natural maximum base flow – calculated using the wettest flow month discharge at the maintenance percentage of 30% - 40% for the Sabie River at the EWR site).
- 10 - No flow (although there may still be surface water in pools).

The instantaneous response of fish habitat in terms of spawning and nursery areas, abundance, cover, connectivity, and water quality are derived by considering (amongst others) the abundance of rated velocity depth classes and their response to flow changes based on a 0 - 10 scale where:

- 0 = Velocity - depth class is absent under the specific flow condition.

[5] The probability of occurrence in the riparian zone is more than 90%.
[6] Plants that have adapted to live in or on aquatic environments.
[7] Occurs in the riparian zone 25 - 75% of the time

- 10 = Velocity - depth class is very abundant under the specific flow condition.

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

Specific results for the fish indicator species are summarised in Appendix J, Table J3.

The instantaneous response of flow dependent macroinvertebrate (FDI) taxa provides the % occurrence of various velocity-substrate classes under different flow conditions. (Appendix J, Table J5).

3.2.2 Biota response

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

- 0 = Optimum habitat with least amount of stress possible for the indicator groups ***at the site*** (fixed at the natural maximum base flow in the same way as for the habitat response).
- 10 = No flow (there can still be surface water in pools). The biota response will depend on the indicator groups present, i.e. rheophilics will have left whereas semi-rheophilics[8] will still be present and survive.

The fish species response index is calculated using the fish habitat rating (cf Section 3.2.1) (Appendix J, Table J4) for each of the discharges evaluated for assessing habitat response. The macroinvertebrate (FDI) index is derived by considering the habitat response and % occurrence of habitat conditions at different flows. The FDI responses are described and coupled to a stress level (Appendix J, Table J6).

A riparian vegetation stress index is also provided (Appendix J, Table J7). This index considers the following:

- All responses to be assessed in combination with high flows / floods since the response will be dependent on the combined impact of both high and low flows.
- Increases in stress can be caused by progressive drying or inundation.
- Rooting depth is measured as the difference in elevation between the water level and the point at which individuals are rooted.

3.2.3 Integrated stress curve

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

[8] Semi-rheophilics: Requiring flowing water during certain phases of the life-cycle. These include fast semi-rheophilics (requiring fast flowing water (>0.3 m/s) during certain phases of the life-cycle) and slow semi-rheophilics (requiring slow flowing water (<0.3 m/s) during certain phases of the life-cycle).

The shaded species stress discharges in Table 3.1 indicate the discharge evaluated by specialists to determine the biota stress. The values that are not shaded are interpolated[9]. The highest discharge representing a specific stress is used to define the integrated stress curve. Figure 3-1 illustrates this graphically.

In this specific case, the LR fish stress index represents the integrated stress index (these values are the highest flow for a stress), therefore the blue line (representing the LR stress index) is lying 'beneath' the integrated stress line (black) (Figure 3-1).

Table 3.1 Species stress discharges used to determine biotic stress

Stress	Flow (m^3/s)					Integrated Flow (m^3/s)
	SR	LR	FDI	Reeds *Phragmites*	Tree *Ficus*	
0	3.6	3.6	3	3.6	1	3.6
1	3	3	2.3	2.8	0.8	3
2	1.9	2.5	1.6	2	0.6	2.5
3	1.7	1.9	1.1	1.2	0.4	1.9
4	1.4	1.7	0.87	0.867	0.2	1.7
5	0.8	1.4	0.4	0.533	0.03	1.4
6	0.7	0.8	0.23	0.2	0	0.8
7	0.63	0.7	0.11	0.115	0	0.7
8	0.4	0.63	0.035	0.03	0	0.63
9	0.2	0.4	0.006	0.015	0	0.4
10	0	0	0	0	0	0.001

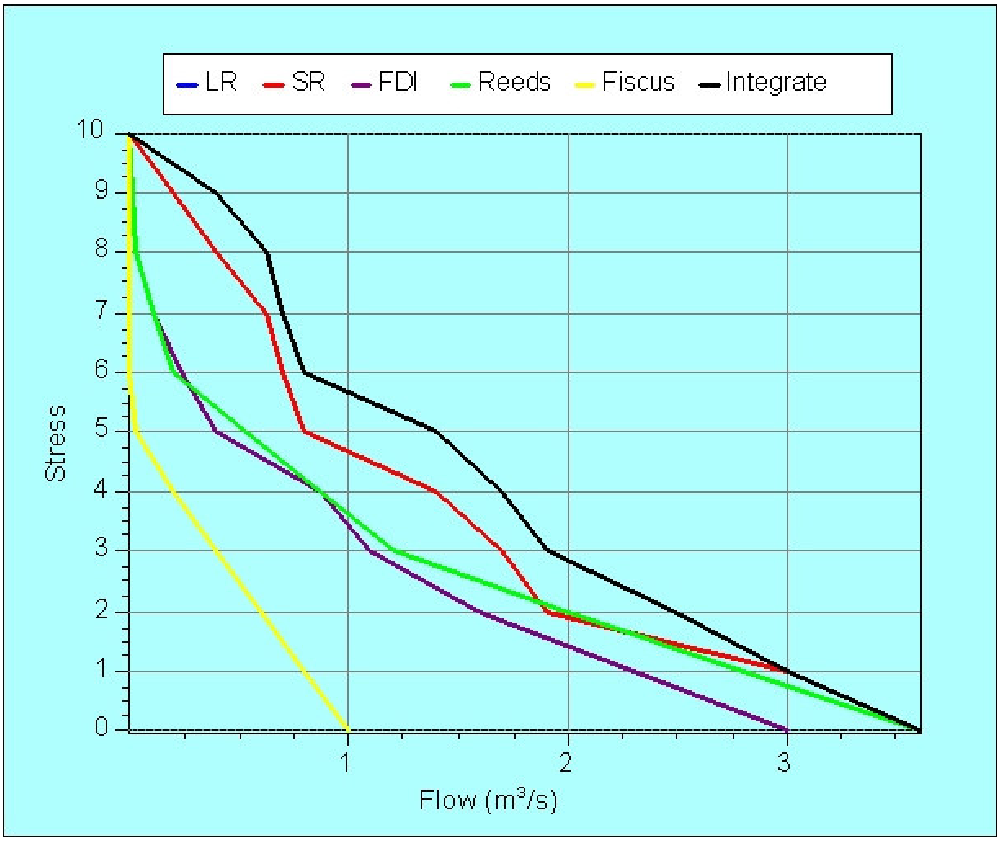

Figure 3–1 Component and integrated stress curves for EWR 1

[9] A method of constructing new data points within the range of a discrete set of known data points (www.wikipedia.org)

Table 3.2 provides the summarised biotic response for the integrated stresses.

Table 3.2 Integrated stress and summarised habitat/biotic responses

Integrated stress	Flow m^3/s	Habitat and/or Biotic responses
0 (SR)	3.6	All fish SR (5) and LR (4.5 – 5*) habitats are good - optimum. Riparian vegetation indicators with full vigour and at maximum reproductive capacity.
1 (SR)	3	All fish SR (4.5 - 5) and LR (4 - 5) habitats although slightly reduced are good to optimum. All indicator taxa very abundant and healthy and habitat plentiful.
2 (LR)	2.5	Fish SR (4.5 - 4) habitats are good to optimum. Fish LR (3.5 - 5). Although nursery habitat is optimum, habitat abundance and cover as well as spawning areas are moderate. Critical habitats sufficient, indicator taxa healthy.
3 (LR)	1.9	Fish SR (3.5 - 4). Spawning and nursery habitat is good, while rest of habitat metrics are moderate. Fish LR (3 - 4.5) - nursery and water quality is good while other habitat is moderate.
4 (LR)	1.7	SR guild (3 - 4) - Good nursery habitat available while other habitats are in moderate occurrence. LR guild (2 - 4) - Habitat abundance, cover and connectivity is low - moderate while the rest of the habitats are in moderate - high abundance. Slightly reduced critical FDI habitat. Most indicator taxa persist, but slight reduction in abundances.
5 (LR)	1.4	SR guild (2 - 3). Nursery habitat moderate while all other habitat is rare. LR guild (2 -4). Nursery habitat is good, water quality moderate and rest of habitat rare. Riparian indicators: Leaf wilting/stress commences, but is slight.
6 (LR)	0.8	SR guild (1 - 2) and LR guild (1.5 - 2.5). SR fish habitats are low and spawning habitat is rare. LR fish has low occurrence of nursery habitat while rest of habitats are rare. Critical FDI habitat limited. All life stages of Elmids viable in limited areas. Critical life stages of the more sensitive indicators, Perlids, at risk.
7 (LR)	0.7	SR and LR fish guild (1 - 2). SR fish have low occurrence of nursery habitat and there is little connectivity in the river while all other habitat is rare. All LR fish habitats are rare.
8 (LR)	0.6	Fish SR (0 - 1) and LR (0 - 1.5) No spawning habitat available; other habitats very rare.
9 (LR)	0.4	Fish SR and LR guild (0 - 1). SR fish only have rare cover and abundance in habitat (1) and no spawning habitat (0). LR fish habitat reduced to nearly zero (0.5) Critical habitat reduced, almost equivalent flow and non-flow habitats present. Critical life-stages of sensitive indicator taxa at risk or non-viable..
10	0.001	SR and LR guilds (0 - 1). All habitats are nearly absent. Only available habitat is standing water over coarse, fine or very fine sediments. Perlids and Elmids absent. Riparian vegetation indicators: Widespread and complete mortality of population.

* Suitability rating 0 (not suitable) – 5 (highly suitable)

4 EWR 1: UPPER SABIE (SABIE RIVER): DETERMINATION OF EWR SCENARIOS

4.1 ECOCLASSIFICATION SUMMARY OF EWR 1

EWR 1: Upper Sabie (Sabie River)

EIS: High
Rare and endangered fish and vegetation species. Fish species present that are intolerant to flow and flow related water quality changes. .
PES: B/C
Impacts due to forestry, exotic vegetation species, and abstraction. Impacts largely non-flow related.
REC: B
The EIS is high, therefore the REC is an improvement of the PES. Inactivity of picnic site and removal of aliens is required. Improved fish EC dependent on improved vegetation cover.
AEC down: C/D
Decreased low flows resulting in increased sediment with increased nutrients, turbidity, temperature, additional toxics. Increased vegetation exotics and reeds on bars.

Driver Components	PES Category	Trend	REC	AEC↓
HYDROLOGY	A/B		A/B	B/C
WATER QUALITY	A/B		A/B	B/C
GEOMORPHOLOGY	B	Stable	B	C
Response Components	**PES Category**	**Trend**	**REC**	**AEC↓**
FISH	B/C	Stable	B	C/D
MACRO INVERTEBRATES	B	Stable	A/B	C
INSTREAM	B/C		B	C
RIPARIAN VEGETATION	B/C	Negative	B	C/D
ECOSTATUS	B/C		B	C/D

4.2 HYDROLOGY

The highest and lowest low flow months selected as the key months are February (wet) and October (dry). The key assurance percentages for which stress requirements had to be set were:

- 95%: Representing droughts for both wet and dry months. This would represent 5% on the stress duration graphs.
- 65%: Representing maintenance flows for both wet and dry months. This would represent 35% on the stress duration graphs.

4.3 LOW FLOW REQUIREMENTS (IN TERMS OF STRESS)

The integrated stress index is used to identify required stress levels at specific durations for the wet and dry month/season. Specialist motivations for the stresses are provided in Appendix J, Section J2.1 – 2.3.

4.3.1 Low flow (in terms of stress) requirements

The fish, macroinvertebrate and riparian vegetation flow requirements for different Ecological Categories (ECs) are provided in Table 4.1 and Figure 4-1 and 4-2. The results are plotted for the wet and dry season on stress duration graphs and compared to the Desktop Reserve Model (DRM) low flow estimates for the same range of ECs. The stress requirements (as a 'hand drawn line') are illustrated in Figures 4-1 and 4-2.

For easier reference the range of ECs are colour coded in the Tables and Figures:

PES: Green REC: Purple AEC: Yellow

Summarised motivations for the final requirements are provided in Table 4.2.

Table 4.1 Species and integrates stress requirements as well as the final integrated stress and flow requirement

Duration	LR stress	Integrated stress	SR stress	Integrated stress	FDI stress	Integrated stress	*Phragmites* (Reeds) stress	Integrated stress	*Ficus* stress	Integrated stress	FINAL* (Integrated stress)*	FLOW (m^3/s)
PES: B/C EcoStatus			**FISH: B/C**			**MACROINVERTEBRATES: B**					**RIP VEG: B/C**	
DRY SEASON												
5%	8.5	8.5	8	9	7	9.8	6	9.75	6	10	**8.5**	**0.5**
35%	6	6	6	6.9	4	5.9	4	5.75	4	9.5	**5.75**	**1**
WET SEASON												
5%	6	6	5.5	6.5	6	9.5	5	8.5	5	10	**6**	**0.8**
35%	3	3	3	4	3	5.5	2	2.75	2	8.25	**3**	**1.9**
REC: B EcoStatus			**FISH: B**		**MACROINVERTEBRATES: A/B**						**RIP VEG: B**	
DRY SEASON												
35%	5.75	5.75	5	6			3.5	5.5	3	9	**5.5**	**1.1**
WET SEASON												
35%	2	2	2.5	3.5			1	1.5	1.5	7	**2**	**2.5**
AEC: C/D EcoStatus			**FISH: C/D**		**MACROINVERTEBRATES: C**						**RIP VEG: C/D**	
DRY SEASON												
35%	7.5	7.5	7	8	6	9.5	5	8.5	4	9.5	**7.5**	**0.67**
WET SEASON												
35%	4.5	4.5	4.5	5.5	5	9	3	5.25	3	9	**4.5**	**1.55**

* Final refers to the final stress selected as the EWR requirement, usually the lowest integrated stress. In some cases, vegetation was ignored due to the much lower confidence in the requirements.

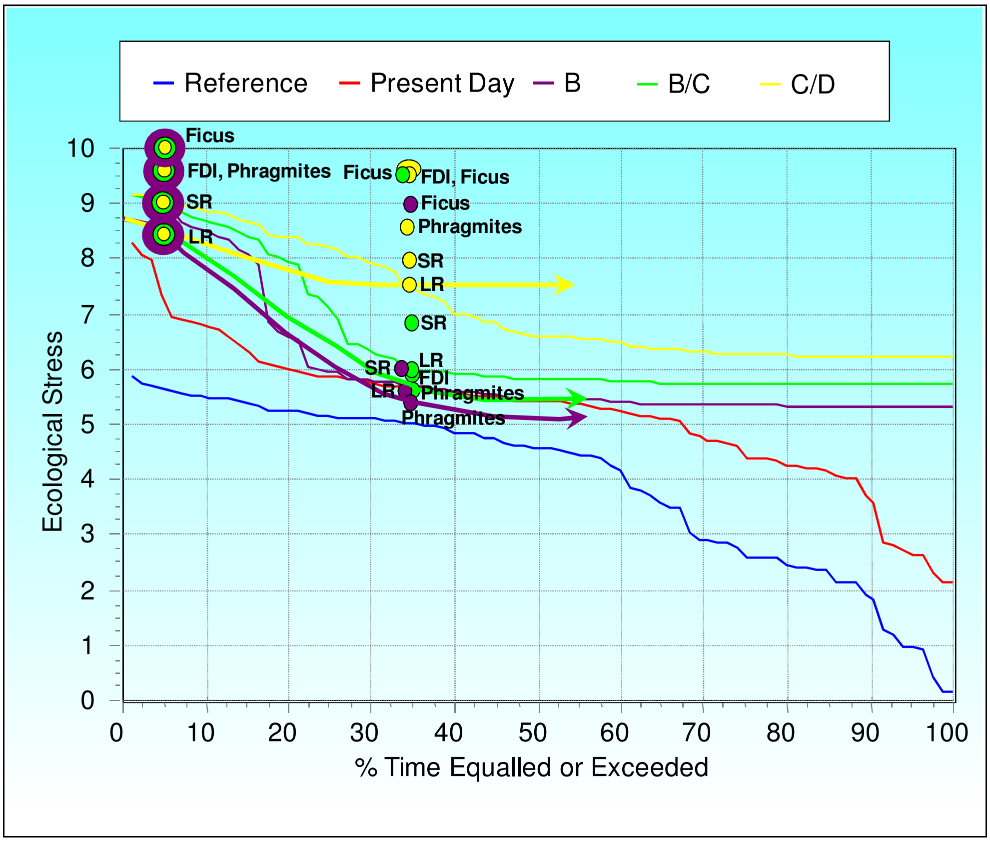

Figure 4–1 **EWR 1: Stress duration curve for a B/C PES, B REC and C/D AEC - DRY season**

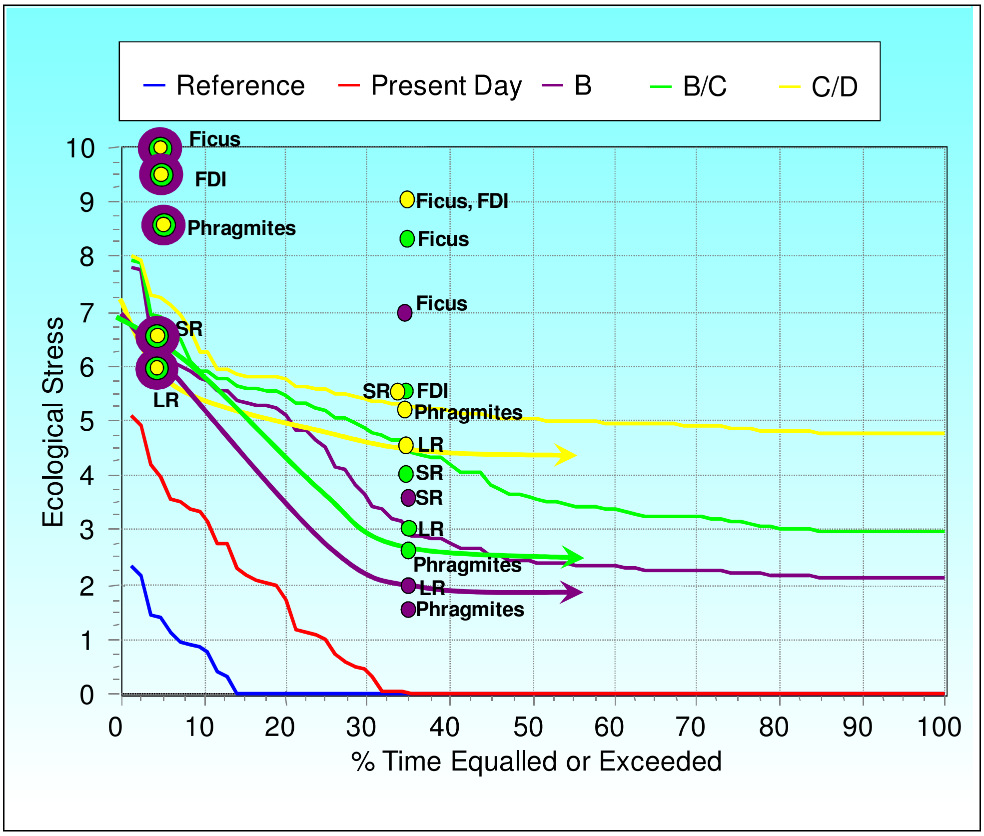

Figure 4–2 **EWR 1: Stress duration curve for a B/C PES, B REC and C/D AEC - WET season**

Table 4.2 Summary of EWR 1 motivations

Month	% Stress duration	Component stress	Integrated stress	Flow m^3/s	Comment
PES: B/C EcoStatus	**FISH: B/C**		**MACROINVERTEBRATES: B**		**RIP VEG: B/C**
Oct	5% drought	8.5 LR	8.5	0.5	Critical habitats will be maintained to ensure survival of LR guild.
	35% maintenance	4 *Phragmites*	5.75	1	Leaf wilting/stress commences but is slight, and flower/fruit abortion commences.
Feb	5% drought	6 LR	6	0.8	Critical habitats greatly reduced but will cater for spawning and maintenance of life stages.
	35% maintenance	3 LR	3	1.9	Adequate critical habitat to maintain life stages and biological processes.
REC: B EcoStatus	**FISH: B**	**MACROINVERTEBRATES: A/B**			**RIP VEG: B**
Oct	5% drought	8.5 LR	8.5	0.5	See PES.
	35% maintenance	3.5 *Phragmites*	5.5	1.1	Similar to PES conditions. Less stress associated with more flows.
Feb	5% drought	6 LR	6	0.8	See PES.
	50% maintenance	2 LR	2	2.5	Improved FI and FD habitat will improve the Fish EC.
AEC: C/D EcoStatus	**FISH: C/D**		**MACROINVERTEBRATES: C**		**RIP VEG: C/D**
Oct	5% drought	8.5 LR	8.5	0.5	See PES.
	35% maintenance	7.5 LR	7.5	0.67	Adequate fast habitat for survival however species occur at reduced abundance.
Feb	5% drought	6 LR	6	0.8	See PES.
	35% maintenance	4.5 LR	4.5	1.55	Less critical habitat available than under PES conditions. Life stages will be maintained, but species abundances and FROC will decrease resulting in lower EC.

4.3.2 Final low flow requirements

To produce the final results (Figure 4-3), the DRM results for the specific category are modified according to specialists' requirements (Figure 4-1 and 4-2). There are a range of options one can use to make these modifications, such as changing the total volume required for the year, changing specific monthly volumes, changing durations of either drought or maintenance flows, changing the seasonal distribution and changing the category rules and shape factors. The following changes were required:

- Assurance rule shape factors were changed to 6 for all months.
- Seasonal distribution factor changes:
  - B EC: 1.03 for maintenance; 0.66 for drought.
  - B/C EC: 1.1 for maintenance; 0.66 for drought.
  - C/D EC: 1:2 for maintenance; 0.66 for drought.
- Tables for maintenance were manually edited (based on the desktop).

Dry season (October) **Wet season (February)**

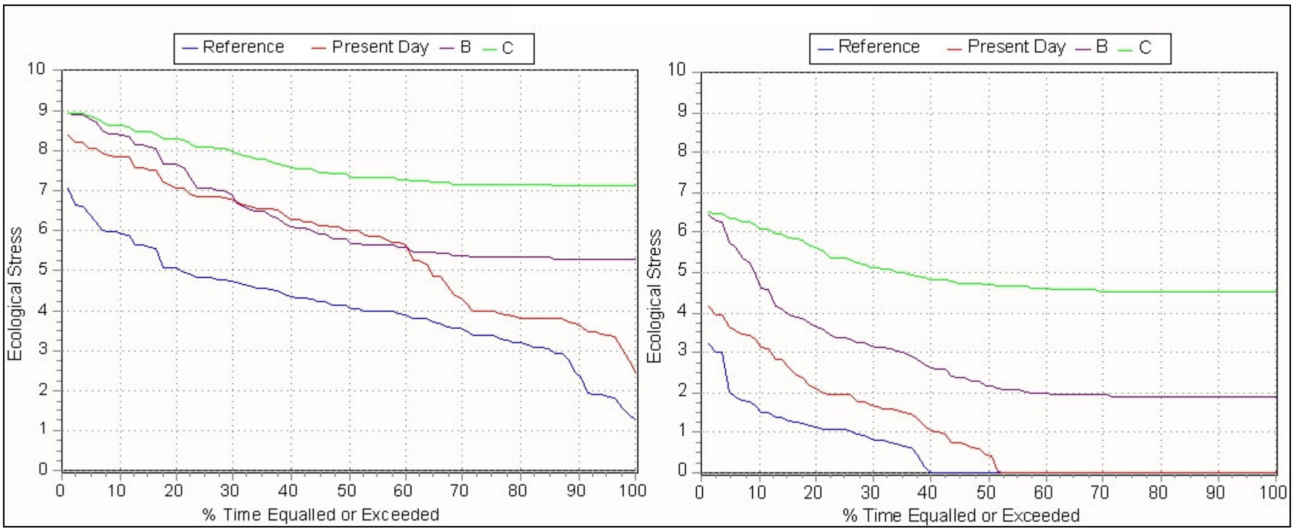

Figure 4–3 EWR 1: Final stress requirements for low flows

4.4 HIGH FLOW REQUIREMENTS

The high flow classes were identified as follows:

- The geomorphologist and riparian vegetation specialist identified the range of flood classes required and listed the functions of each flood.
- The instream specialists then indicated which of the instream flooding functions were addressed by the floods identified for geomorphology and riparian vegetation (indicated by a √ in Table 4.3).
- Any of the floods required by the instream biota and not addressed by the floods already identified, were then described (in terms of ranges and functions) for the instream biota.

Results are provided in Table 4.3 and detailed motivations provided in Table 4.4.

Table 4.3 Identification of instream functions addressed by the identified floods for geomorphology and riparian vegetation

FLOOD CLASS	FLOOD RANGE (m^3/s)	GEOMORPHOLOGY AND RIPARIAN VEGETATION MOTIVATION	Fish flood functions							Macroinvertebrate flood functions				
			Migration cues	Migration habitat (depth etc.)	Clean spawning substrate	Create spawning habitat	Create nursery areas	Resetting water quality	Inundate vegetation for spawning	Breeding and hatching cues	Clear fines	Scour substrate	Reach or inundate specific areas	Reset water quality
I	5 - 7 (6 ave)	**Geomorphology:** This flow class is the effective discharge for the fines (sands) at the site preventing infilling of interstitial spaces. **Vegetation:** 30 – 45 cm inundation of *P. mauritianus* maintains reedbeds. Also inundates large-leaved aquatic macrophytes. REC has the same flood requirements as the PES since this scenario is due to non-flow related issues (exotic vegetation and recreation activities). Only small floods and base flow reduction occur to result in the AEC (down) with an associated increase in reeds.	√	√	√	√	√	√	√	√	√	√	√	√
II	10 – 20 (15 ave)	**Geomorphology:** This flow class is the effective discharge for the gravels (10 mm) at the site maintaining clean bed conditions. **Vegetation:** Wets but does not inundate the fern line; inundates the marginal zone and a high proportion of the reed-beds. Inundates lower portion of the tree-line (*Ficus sur*).	√	√	√	√	√	√	√	√	√	√	√	√
III	35 – 55 (30 ave)	**Geomorphology:** This flow class is the effective discharge for the small cobbles at the site; maintaining bed mobility and interstitial spaces. **Vegetation:** Inundates 50 - 100% of the lower zone; maintains *Syzigium cordatum* population.	√	√	√	√	√	√	√					
IV	70 +	**Vegetation:** Inundates lower portion of the upper zone, wets ephemeral terrace, maintains *Combretum erythrophyllum* population and provides recruitment opportunities.	√	√	√	√	√	√	√					

Further information is provided in Appendix J, Table J12.

The number of high flow events required for each EC is provided in Table 4.4. No observed daily data was available to check flood requirements against.

Table 4.4 EWR 1: Recommended size and frequency of high flow events.

FLOOD CLASS	FLOOD RANGE (m^3/s)	INVERTEBRATES	FISH	VEGETATION	GEOMORPHOLOGY	FINAL* (No of events)	MONTHS	DAILY AVERAGE (m^3/s)	DURATION (Days)
PES SCENARIO: B/C									
I	5 - 7	4		4	4	4	Oct, Dec, Feb, Mar	6	4
II	10 - 20	1		1	1	1	Jan	15	5
III	35 - 55			1:2	1:3	1:2**			
IV	< 70			1:3 to 1:5		1:3			

FLOOD CLASS	FLOOD RANGE (m^3/s)	INVERTEBRATES	FISH	VEGETATION	GEOMORPHOLOGY	FINAL* (No of events)	MONTHS	DAILY AVERAGE (m^3/s)	DURATION (Days)
REC SCENARIO: B									
I	5 - 7	4		4	5	5	Oct, Nov, Dec, Feb, Apr	6	4
II	10 - 20	1		1	1	1	Jan	15	5
III	35 - 55			1:2	1:2	1:2			
IV	< 70			1:3 to 1:5		1:3			
AEC SCENARIO: C/D									
I	5 - 7	3		2	3	3	Oct, Dec, Mar	6	<3
II	10 - 20	1		1	1:2	1	Jan	15	3
III	35 - 55			1:2	1:4	1:2			
IV	< 70			1:3 to 1:5					

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

4.5 FINAL FLOW REQUIREMENTS

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

- An EWR table, which shows the results of high flows and low flows for each month separately (Table 4.5 – 4.7). Floods with a frequency higher than 1:1 are not included.
- An EWR rule table which provides the recommended EWR flows as a duration table, showing flows which should be provided when linked to a natural trigger (natural modelled hydrology in this case). EWR rules are supplied for total flows as well as for low flows only (Appendix J, Section J2.5).

Table 4.5 EWR table for PES: B/C

Desktop version:		**2**	**Virgin MAR (MCM)**	**140.18**
BFI index	**0.517**	**Distribution type**		**Eastern escarpment**
MONTH	**LOW FLOWS**		**HIGH FLOWS**	
	Maintenance (m^3/s)	**Drought (m^3/s)**	**Daily average (m^3/s) on top of base flow**	**Duration (days)**
OCTOBER	0.97	0.4	6	4
NOVEMBER	1.14	0.451		
DECEMBER	1.32	0.494	6	4
JANUARY	1.6	0.569	15	5
FEBRUARY	2.1	0.722	6	4
MARCH	2	0.677	6	4
APRIL	1.93	0.661		
MAY	1.7	0.598		
JUNE	1.58	0.567		
JULY	1.31	0.492		
AUGUST	1.12	0.439		
SEPTEMBER	1.02	0.417		
TOTAL MCM	46.615	17.007	7.426	
% OF VIRGIN	33.25	12.13	5.30	

Table 4.6 EWR table for REC: B

Desktop version:		**2**	**Virgin MAR (MCM)**	**140.18**
BFI index	**0.517**		**Distribution type**	**Eastern escarpment**
MONTH	**LOW FLOWS**		**HIGH FLOWS**	
	Maintenance (m^3/s)	**Drought (m^3/s)**	**Daily average (m^3/s) on top of base flow**	**Duration (days)**
OCTOBER	1.25	0.4	6	4
NOVEMBER	1.5	0.451	6	4
DECEMBER	1.8	0.494	6	4
JANUARY	2.1	0.569	15	5
FEBRUARY	2.8	0.722	6	4
MARCH	2.75	0.677		
APRIL	2.6	0.661	6	4
MAY	2.25	0.598		
JUNE	2.1	0.567		
JULY	1.7	0.492		
AUGUST	1.44	0.439		
SEPTEMBER	1.3	0.417		
TOTAL MCM	61.81	17.007	8.515	
% OF VIRGIN	44.09	12.13	6.07	

Table 4.7 EWR table for AEC: C/D

Desktop version:		**2**	**Virgin MAR (MCM)**	**140.18**
BFI index	**0.517**	**Distribution type**		**Eastern escarpment**
MONTH	**LOW FLOWS**		**HIGH FLOWS**	
	Maintenance (m^3/s)	**Drought (m^3/s)**	**Daily average (m^3/s) on top of base flow**	**Duration (days)**
OCTOBER	0.535	0.4	6	<3
NOVEMBER	0.671	0.451		
DECEMBER	0.8	0.494	6	<3
JANUARY	1	0.569	15	3
FEBRUARY	1.4	0.722		
MARCH	1.3	0.677	6	<3
APRIL	1.25	0.661		
MAY	1.1	0.598		
JUNE	1	0.567		
JULY	0.8	0.492		
AUGUST	0.65	0.439		
SEPTEMBER	0.6	0.417		
TOTAL MCM	29.079	17.007	6.337	
% OF VIRGIN	20.74	12.13	4.52	

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A comparison between the Desktop Reserve Model estimates and the EWR results in terms of percentages of natural flow are provided in Table 4.8.

Table 4.8 Modifications made to the DRM for EWR 1

Changes	PES B/C		REC B		AEC C/D	
	DRM	EWR	DRM	EWR	DRM	EWR
MLIFR - Maintenance low flow	26.1%	33.2%	32.9%	44.1%	14.8%	20.7%
DLIFR - Drought low flow	10.4%	12.1%	10.4%	12.1%	10.4%	12.1%
MHIFR - Maintenance high flow	7.4%	5.3%	8.2%	6.1%	6.1%	4.5%
Long-term % of virgin MAR	34.5%	37.8%	40.5%	46.3%	27.4%	31.0%

5 EWR 2: AAN DE VLIET (SABIE RIVER) – DETERMINATION OF STRESS INDICES

NOTE: All supporting specialist information for EWR 2 is summarized in Volume 3, Appendix K.

5.1 INDICATOR SPECIES OR GROUP

5.1.1 Fish indicator group 1: Large rheophilic species (VNEL)

Varicorhinus nelspruitensis (VNEL): See Section 3.1.2 and Appendix J, Table J1.

5.1.2 Fish indicator group 2: Small rheophilic species (AURA, CANO)

The small rheophilic species *Chiloglanis anoterus* (CANO) and *Opsaridium peringueyi* (OPER) at the site are good indicators for setting flows as a result of their high requirement for flowing water. Information on the habitat requirements for different life stages are provided in Appendix K, Table K1. These species all requires flowing water over substrates during all life stages, with some stages also preferring overhanging vegetation as cover. Optimal conditions for spawning of this guild consist of FD, FI, FS and SS with good quality substrate (clean cobbles and gravel), while the margins of the FS and SS are important for egg development and nursery areas for larvae, often with overhanging vegetation as cover. Juvenile and adult stages of this guild have a high preference for FS, FI and FD over substrates. Flows should furthermore remain adequate to allow migration between reaches, thus depth in riffle and rapids should remain adequate, especially during the wet season.

5.1.3 Macroinvertebrate indicator taxa

A number of FDI taxa were selected on the basis of their sensitivity to changes in velocity and water quality. Only taxa that occur commonly at the site were selected. The taxa used were:

- Stonefly family: Perlidae preferring velocities > 0.6 m/s.
- Mayfly family: Heptageniidae preferring velocities between 0.3 and 0.6 m/s.
- Beetle family: Elmidae also preferring velocities between 0.3 and 0.6 m/s.

5.1.4 Riparian vegetation indicator species

One indicator species was selected:

- *Breonadia salicina* (Minger/Ouhout)*:* Woody riparian obligate associated with exposed rocky substrates. Usually occurs on the marginal and lower zones, but can occur on the upper zone. Drought and flood resistant, but wide scale mortality has been observed where perched water tables run dry.

5.2 STRESS FLOW INDEX

The stress flow index is generated in terms of habitat and biotic response and is discussed below.

5.2.1 Habitat response

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

- 0 - Optimum habitat (fixed at the natural maximum base flow – calculated using the wettest flow month discharge at the maintenance percentage of 30% - 40% for the Sabie River at the EWR site).
- 10 - No flow (although there may still be surface water in pools).

The abundance of fish velocity-depth classes are provided in Appendix K, Table K2.

The instantaneous response of FDI taxa provides the % occurrence of various velocity-substrate classes under different flow conditions are provided in Appendix K, Table K4).

5.2.2 Biota response

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

The fish species response index is calculated using the fish habitat rating (cf Section 3.2.1) (Appendix K, Table K3) for each of the discharges evaluated for assessing habitat response. The FDI index is derived by considering the habitat response and % occurrence of habitat conditions at different flows. The FDI responses are described and coupled to a stress level (Appendix K, Table K5).

A riparian vegetation stress index is also provided (Appendix K, Table K6).

5.2.3 Integrated stress curve

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

The shaded species stress discharges in Table 5.1 indicate the discharge evaluated by specialists to determine the biota stress. The values that are not shaded are interpolated. The highest discharge representing a specific stress is used to define the integrated stress curve. Figure 5-1 illustrates this graphically.

In this specific case, the LR fish stress index represents the integrated stress index (these values are the highest flow for a stress). Therefore the blue line (representing the LR stress index) is lying 'beneath' the integrated stress line (black) (Figure 5-1).

Table 5.1 Species stress discharges used to determine biotic stress

Stress	Flow (m^3/s)				Integrated Flow (m^3/s)
	SR	LR	FDI	Minger *Breaonadia*	
0	5.78	5.78	4.97	4.5	5.78
1	5.43	5.43	2.93	3.233	5.43
2	2.93	2.93	1.5	1.967	2.93
3	2.59	2.59	1.04	0.7	2.59
4	2	2	0.67	0.55	2
5	1.73	1.73	0.4	0.4	1.73
6	1.49	1.49	0.22	0.25	1.49
7	1.03	1.03	0.165	0.2	1.03
8	0.66	0.845	0.11	0.15	0.845
9	0.3	0.66	0.013	0.076	0.66
10	0	0	0	0	0

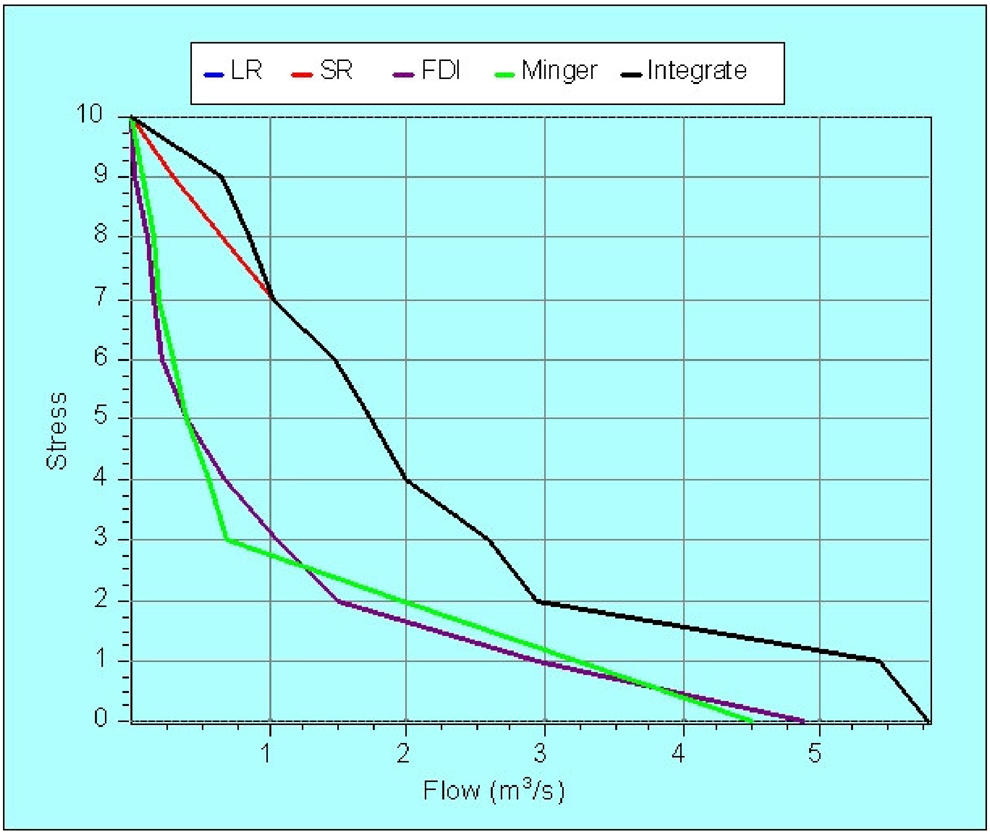

Figure 5–1 Component and integrated stress curves for EWR 2

Table 5.2 provides the summarised biotic response for the integrated stresses.

Table 5.2 Integrated stress and summarised habitat/biotic responses

Integrated stress	Flow m^3/s	Habitat and/or Biotic responses
0 (SR)	5.78	Fish guild habitats are at an optimum (5*). Lower limit of *B. salicina* inundated. No water stress.
1 (SR)	5.43	Fish guild habitat as above. All FDI indicator taxa very abundant and taxa very abundant and healthy.
2 (SR)	2.93	All fish guild habitats are good. Critical FDI habitats sufficient, indicator taxa healthy. 90% of taxa persist.
3 (SR)	2.59	All habitats are slightly better than moderate (3.5) with the LR spawning habitat moderate (3).
4 (SR)	2	All habitats are moderate (3) with the LR spawning habitat slightly degraded (2.5).
5 (SR)	1.73	SR guild: Connectivity and water quality is moderate while rest of habitats are slightly worse (2.5). LR guild: Nursery and connectivity is higher than low (2.5), spawning habitat is low and abundance and cover is moderate.
6 (SR)	1.49	Reduced critical FDI habitat. Most indicator taxa persist, but slight (80%) reduction.
7 (SR)	1.03	SR and LR fish guild: Spawning habitat is very low. Rest of habitats are slightly better (1.5) while connectivity for the LR guild is very rare (0.5). Critical FDI habitats limited. Most indicator taxa persist, but abundances reduced.
8 (LR)	0.845	B. salicina lower limit requires 25 cm substrate depth to inundation.
9 (LR)	0.66	SR guild: Spawning and connectivity is nearly absent (0.5) while rest of habitats are very low. LR guild: Spawning, abundance and cover is nearly absent, while nursery habitats is very low. Connectivity is absent. Critical FDI habitat very reduced and of moderate – low quality. All life stages viable in limited areas, critical life stages of some sensitive indicator taxa at risk.
10	0	Only pool dwelling species present. Only hyporheic refugia, no surface water for FDI. Indicator taxa no longer present.

* Suitability rating 0 (not suitable) – 5 (highly suitable)

6 EWR 2: AAN DE VLIET (SABIE RIVER): DETERMINATION OF EWR SCENARIOS

6.1 ECOCLASSIFICATION SUMMARY OF EWR 2

EWR 2: Aan de Vliet (Sabie River)

EIS: High
Rare and endangered fish and vegetation species. Species present intolerant to flow and flow related water quality changes.
PES: C
Forestry and landuse activities, mostly non-flow related.
REC: B
Changes in flow are not required to improve the state.
Remove exotic vegetation and cease mowing in the riparian zone. Reduce recreational disturbances. The nutrient status must also be improved.
AEC down: C/D
Increased abstraction could lead to increased return flows that will cause problems due to pesticides, nutrient loading etc. Mismanagement of land use in terms of forestry and agriculture

Driver Components	PES Category	Trend	REC	AEC↓
HYDROLOGY	C		B/C	D
WATER QUALITY	B		A/B	C
GEOMORPHOLOGY	B	Negative	B	C
Response Components	**PES Category**	**Trend**	**REC**	**AEC↓**
FISH	B/C	Stable	B	C/D
MACRO INVERTEBRATES	B/C	Stable	B	C
INSTREAM	B/C		B	C
RIPARIAN VEGETATION	C	Negative	B	D
ECOSTATUS	C		B	C/D

6.2 HYDROLOGY

The highest and lowest low flow months selected as the key months are February (wet) and October (dry). The key assurance percentages for which stress requirements had to be set were:

- 95%: Representing droughts for both wet and dry months. This would represent 5% on the stress duration graphs.
- 65%: Representing maintenance flows for both wet and dry months. This would represent 35% on the stress duration graphs.

6.3 LOW FLOW REQUIREMENTS (IN TERMS OF STRESS)

The integrated stress index is used to identify required stress levels at specific durations for the wet and dry month/season. Specialist motivations for the stresses are provided in Appendix K, Section K2.1 – 2.3.

6.3.1 Low flow (in terms of stress) requirements

The fish, macroinvertebrate and riparian vegetation flow requirements for different Ecological Categories (ECs) are provided in Table 6.1, Figure 6-1 and 6-2. The results are plotted for the wet and dry season on stress duration graphs and compared to the DRM low flow estimates for the same range of ECs. The stress requirements (as a 'hand drawn line') are illustrated in Figures 6-1 and 6-2.

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

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

Table 6.1 Species and integrates stress requirements as well as the final integrated stress and flow requirement

Duration	LR stress	Integrated stress	SR stress	Integrated stress	FDI stress	Integrated stress	*B. salicina* (Minger) stress	Integrated stress	FINAL* (Integrated stress)	FLOW (m^3/s)
PES: C EcoStatus		**FISH: B/C**			**MACROINVERTEBRATES: B/C**				**RIP VEG: C**	
					DRY SEASON					
5%	8	8	8	9	5	9.4	6	9.5	**8**	**0.845**
35%	6	6	6.5	6.5	3	7.1	4	9	**6**	**1.49**
					WET SEASON					
5%	6	6	7	7	3	7.1	5	9.5	**6**	**1.49**
35%	3.5	3.5	4	4	2	7.3	2	4	**3.5**	**2.3**
REC: B EcoStatus		**FISH: B**		**MACROINVERTEBRATES: B**					**RIP VEG: B**	
					DRY SEASON					
35%	5.5	5.5	5.5	5.5	2	7.3	3	8.5	**5.5**	**1.6**
					WET SEASON					
35%	2	2	2.5	2.5	1	6.2	1.5	2.5	**2**	**2.93**
AEC: C/D EcoStatus		**FISH: C/D**		**MACROINVERTEBRATES: C**					**RIP VEG: D**	
					DRY SEASON					
35%	6.5	6.5	7.5	8	4	8.9	4.5	9.25	**6.5**	**1.26**
					WET SEASON					
35%	5	5	5.5	5.5	2	7.3	3.5	9	**5**	**1.73**

* Final refers to the final stress selected as the EWR requirement, usually the lowest integrated stress. In some cases, vegetation was ignored due to the much lower confidence in the requirements.

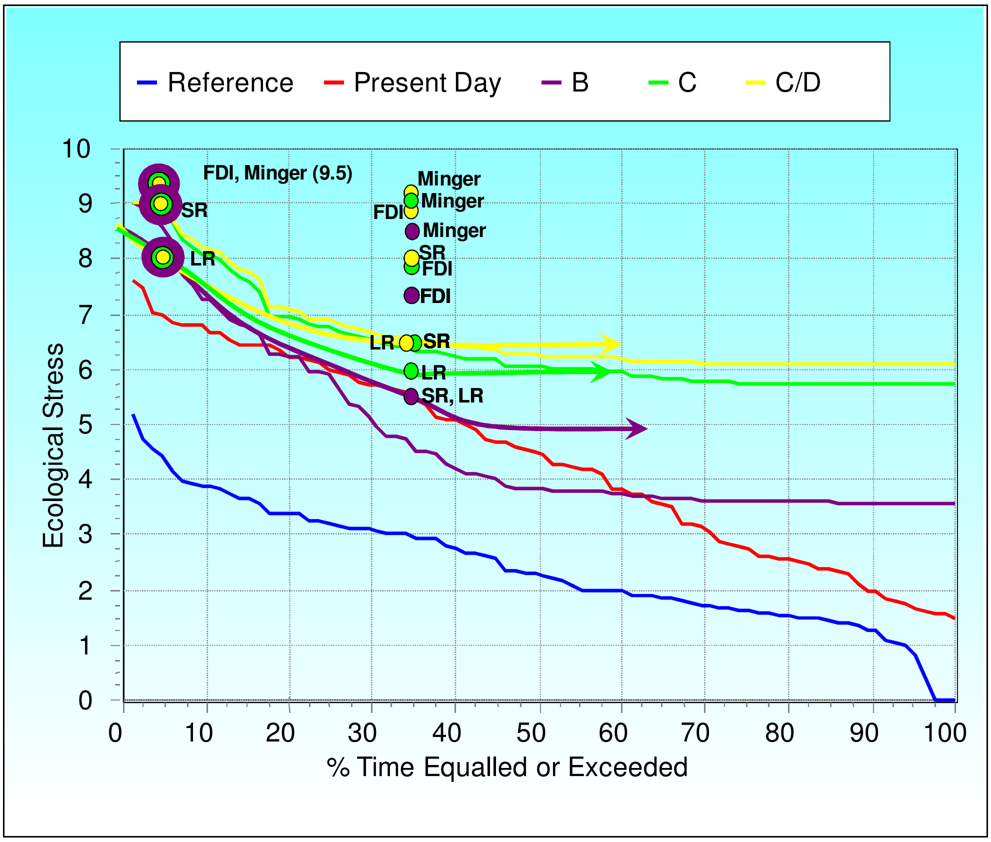

Figure 6–1 EWR 2: Stress duration curve for a C PES, B REC and C/D AEC - DRY season

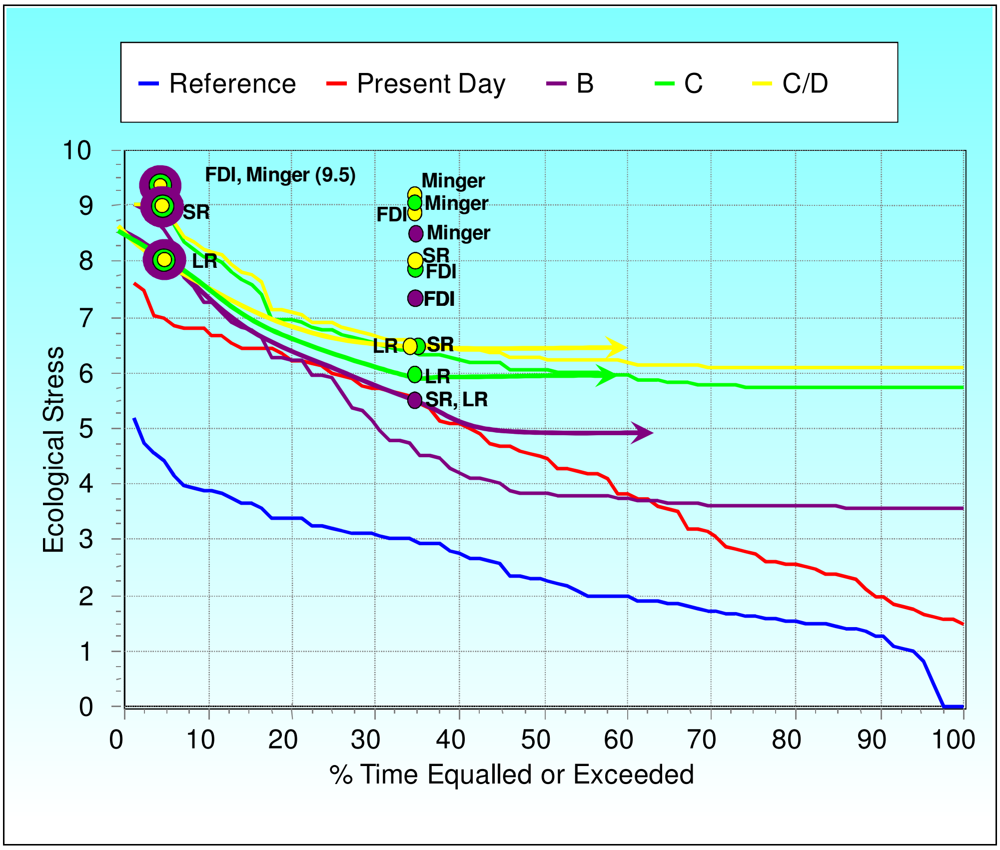

Figure 6–2 EWR 2: Stress duration curve for a C PES, B REC and C/D AEC - WET season

Table 6.2 Summary of EWR 2 motivations

Month	% Stress duration	Component stress	Integrated stress	Flow m³/s	Comment
PES: B/C EcoStatus	**FISH: B/C**			**MACROINVERTEBRATES: B**	**RIP VEG: B/C**
Oct	5% drought	8 LR	8	0.845	No FD habitats available, but should be adequate for species survival.
	35% maintenance	6 LR	6	1.49	Critical habitats will be maintained to ensure survival of LR guild.
Feb	5% drought	6 LR	6	1.49	Critical habitats are limited, but adequate to allow spawning and maintenance of other life changes.
	35% maintenance	3.5 LR	3.5	2.3	Adequate critical habitat to maintain life stages and biological processes.
REC: B EcoStatus	**FISH: B**			**MACROINVERTEBRATES: A/B**	**RIP VEG: B**
Oct	5% drought	8 LR	8	0.845	See PES.
	35% maintenance	5.5 LR	5.5	1.6	Good availability of preferred habitat.
Feb	5% drought	6 LR	6	1.49	See PES.
	50% maintenance	2 LR	2	2.93	Improved FI and FD habitat will improve the Fish EC.
AEC: C/D EcoStatus	**FISH: C/D**			**MACROINVERTEBRATES: C**	**RIP VEG: C/D**
Oct	5% drought	8 LR	8	0.845	See PES.
	35% maintenance	6.5 LR	6.5	1.26	Limited FD habitats and adequate FI habitat will cause reduced abundance and FROC of guild.
Feb	5% drought	6 LR	6	1.49	See PES.
	35% maintenance	5 LR	5	1.73	Less critical habitat available than under PES conditions. Life stages will be maintained, but species abundances and FROC will decrease resulting in lower EC.

6.3.2 Final low flow requirements

To produce the final results (Figure 6-3), the DRM results for the specific category are modified according to specialists' requirements (Figure 6-1 and 6-2). The following changes were required:

- Seasonal distribution factor changes:
  - B EC: 1.2 for maintenance; 0.44 for drought.
  - C EC: 0.6 for maintenance; 0.44 for drought.
  - C/D EC: 0.4 for maintenance; 0.44 for drought.

Dry season (October) **Wet season (February)**

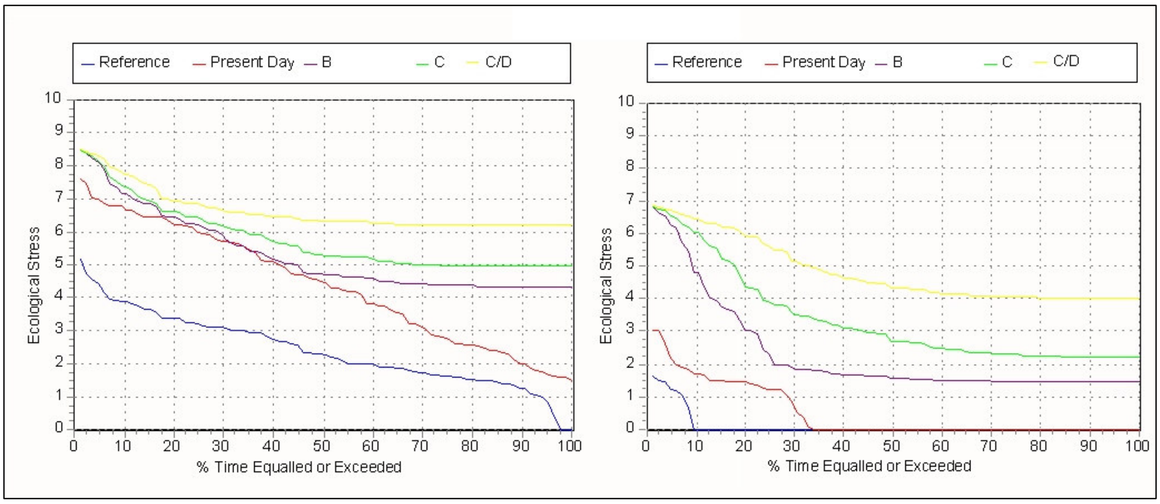

Figure 6–3 EWR 2: Final stress requirements for low flows

6.4 HIGH FLOW REQUIREMENTS

High low classes were identified as outlined in Section 4.4. Results are provided in Table 6.3 and detailed motivations provided in Table 6.4.

Table 6.3 Identification of instream functions addressed by the identified floods for geomorphology and riparian vegetation

FLOOD CLASS	FLOOD RANGE (m^3/s)	GEOMORPHOLOGY AND RIPARIAN VEGETATION MOTIVATION	Fish flood functions							Macroinvertebrate flood functions				
			Migration cues	Migration habitat (depth etc.)	Clean spawning substrate	Create spawning habitat	Create nursery areas	Resetting water quality	Inundate vegetation for spawning	Breeding and hatching cues	Clear fines	Scour substrate	Reach or inundate specific areas	Reset water quality
I	9 – 12	**Geomorphology:** The lower flow classes (high base flows and intra-annual floods) play a crucial role in maintaining the movement of fine sands through the site. **Vegetation:** Maintains reeds and other grasses at the site (50% inundation); likely to activate back channel which supports marginal zone obligates. Inundates the lower portion of the marginal zone and the lower portion of the *B. salicina* population. Maintains soil moisture in alluvial bars which supports riparian closed-canopy forests (*Syzigium* and *Breonadia* mainly).	√	√	√	√	√	√	√	√	√	√	√	√
II	15 - 25	**Geomorphology:** This annual flood is responsible for a large proportion of both sands and small gravel (10 mm) transport; preventing sedimentation and embeddedness of the riffle. This flow class is also responsible for the activation and scouring of the seasonal back channel. **Vegetation:** Inundates marginal zone, the majority of reeds and grasses and all leafy aquatic marginal zone macrophytes. Activates and inundates *B. salicina and S. cordatum* populations and provides recruitment opportunities. Also facilitates existing juvenile survival. Activates back channel which supports marginal zone obligates.									√	√	√	√
III	35 - 55	**Geomorphology:** This flow class is the effective discharge for the gravels (10 mm sediments); maintaining the condition of the riffles and other gravel areas. This flow class also inundates the lower floodplain area. **Vegetation:** Floods most of the *S. cordatum* population and facilitates recruitment of vegetation growing on alluvial lateral/point bar.												
IV	70 +	**Geomorphology:** This infrequent flood inundates most of the floodplain, and is the effective discharge class for the larger sediments (cobbles) for the site - this would activate the larger cobbles in the riffle areas. **Vegetation:** Activate lateral alluvial deposits. Maintains MCB species (*C. erythrophyllum*, *F. sycomorus* and *Anthocleista* mainly). Inundates the lower zone and activates lowest portion of upper zone.												

Further information is provided in Appendix K, Table K11.

The number of high flow events required for each EC is provided in Table 6.4. The high flows were checked, using available daily hydrology.

Table 6.4 EWR 2: The recommended number of high flow events required

FLOOD CLASS	FLOOD RANGE (m^3/s)	INVERTEBRATES	FISH	VEGETATION	GEOMORPHOLOGY	FINAL (No of events)	MONTHS	DAILY AVERAGE (m^3/s)	DURATION (Days)
PES SCENARIO: C									
I	9 - 12	4		4	4	4	Nov, Dec, Jan, Mar	10	4
II	15 - 25	1		1	1	1	Feb	20	5
III	35 -55	1:2		1:2	1:2	1:2			
IV	70 +	1:3		1:3+	1:5	1:3			
REC SCENARIO: B									
I	9 - 12	5		4*	5#	5	Nov, Dec, Jan, Feb, Mar	10	4
II	15 - 25	1		1	1	1	Feb	20	5
III	35 -55	1:2		1:2	1:2	1:2			
IV	70 +	1:3		1:3+	1:5	1:3			
AEC SCENARIO: C/D									
I	9 - 12	3		3*	3#	3	Nov, Jan, Mar	10	4
II	15 - 25	1		1	1:2	1	Feb	20	3
III	35 -55	1:2		1:2	1:3	1:2			
IV	70 +	1:3+		1:3+	1:5	1:3+			

* REC has the same flood requirements as the PES since this scenario is due to non-flow related issues (exotic vegetation and recreation activities). Only small floods and base flow reduction occur to result in the AEC (down) with an associated increase in reeds. AEC (down) was also non-flow related for riparian vegetation (alien species were left unchecked), but some reduction in small floods and base flow was also part of the scenario. Reduced frequency of Class I floods will be associated with AEC of D for riparian vegetation.

\# Annual and larger floods do not change for REC and AEC scenarios.

6.5 FINAL FLOW REQUIREMENTS

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

- An EWR table, which shows the results of high flows and low flows for each month separately (Table 6.5 – 6.7). Floods with a frequency higher than 1:1 were not included.
- An EWR rule table which provides the recommended EWR flows as a duration table, showing flows which should be provided when linked to a natural trigger (natural modelled hydrology in this case). EWR rules are supplied for total flows as well as for low flows only (Appendix K, Section K2.5).

Table 6.5 EWR table for PES: C

Desktop version:	2		Virgin MAR (MCM)	262.106
BFI index	0.517	Distribution type		Eastern Escarpment
MONTH	LOW FLOWS		HIGH FLOWS	
	Maintenance (m^3/s)	Drought (m^3/s)	Daily average (m^3/s) on top of base flow	Duration (days)
OCTOBER	1.252	0.747		
NOVEMBER	1.392	0.815	10	4
DECEMBER	1.513	0.861	10	4
JANUARY	1.721	0.952	10	4
FEBRUARY	2.170	1.170	20	5
MARCH	2.043	1.093	10	4

Desktop version:		2	Virgin MAR (MCM)	262.106
BFI index	0.517	Distribution type		Eastern Escarpment
MONTH	LOW FLOWS		HIGH FLOWS	
	Maintenance (m^3/s)	Drought (m^3/s)	Daily average (m^3/s) on top of base flow	Duration (days)
APRIL	2.002	1.082		
MAY	1.812	0.992		
JUNE	1.733	0.964		
JULY	1.516	0.863		
AUGUST	1.369	0.798		
SEPTEMBER	1.309	0.779		
TOTAL MCM	51.999	29.155	11.353	
% OF VIRGIN	19.84	11.12	4.33	

Table 6.6 EWR table for REC: B

Desktop version:		2	Virgin MAR (MCM)	262.106
BFI index	0.517	Distribution type		Eastern Escarpment
MONTH	LOW FLOWS		HIGH FLOWS	
	Maintenance (m^3/s)	Drought (m^3/s)	Daily average (m^3/s) on top of base flow	Duration (days)
OCTOBER	1.598	0.747		
NOVEMBER	1.904	0.815	10	4
DECEMBER	2.265	0.861	10	4
JANUARY	2.797	0.952	10	4
FEBRUARY	3.772	1.170	10 20	4 5
MARCH	3.619	1.093	10	4
APRIL	3.461	1.082		
MAY	3.028	0.992		
JUNE	2.774	0.964		
JULY	2.274	0.863		
AUGUST	1.897	0.798		
SEPTEMBER	1.692	0.779		
TOTAL MCM	81.420	29.155	13.159	
% OF VIRGIN	31.06	11.12	5.02	

Table 6.7 EWR table for AEC: C/D

Desktop version:		2	Virgin MAR (MCM)	262.106
BFI index	0.5	Distribution type		Eastern Escarpment
MONTH	LOW FLOWS		HIGH FLOWS	
	Maintenance (m^3/s)	Drought (m^3/s)	Daily average (m^3/s) on top of base flow	Duration (days)
OCTOBER	0.851	0.747		
NOVEMBER	0.924	0.815	10	4
DECEMBER	0.969	0.861		
JANUARY	1.064	0.952	10	4
FEBRUARY	1.298	1.170	20	3
MARCH	1.210	1.093	10	4

Desktop version:		2	Virgin MAR (MCM)	262.106
BFI index	0.5	Distribution type		Eastern Escarpment
MONTH	LOW FLOWS		HIGH FLOWS	
	Maintenance (m^3/s)	Drought (m^3/s)	Daily average (m^3/s) on top of base flow	Duration (days)
APRIL	1.201	1.082		
MAY	1.105	0.992		
JUNE	1.079	0.964		
JULY	0.971	0.863		
AUGUST	0.904	0.798		
SEPTEMBER	0.887	0.779		
TOTAL MCM	32.691	29.155	9.539	
% OF VIRGIN	12.47	11.12	3.64	

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A comparison between the Desktop Reserve Model estimates and the EWR results in terms of percentages of natural flow are provided in Table 6.8.

Table 6.8 Modifications made to the DRM for EWR 2

Changes	PES B/C		REC B		AEC C/D	
	DRM	EWR	DRM	EWR	DRM	EWR
MLIFR - Maintenance low flow	18.9%	19.8%	32.9%	31.1%	14.8%	12.5%
DLIFR - Drought low flow	10.4%	11.1%	10.4%	11.1%	10.4%	11.1%
MHIFR - Maintenance high flow	6.8%	4.4%	8.2%	5.0%	6.1%	3.6%
Long-term % of virgin MAR	29.4%	28.0%	40.5%	35.7%	27.3%	22.1%

7 EWR 3: KIDNEY (SABIE RIVER) – DETERMINATION OF STRESS INDICES

NOTE: All supporting specialist information for EWR 3 is summarized in Volume 3, Appendix L.

7.1 INDICATOR SPECIES OR GROUP

7.1.1 Fish indicator group 1: Small rheophilic species (CANO, OPER)

Chiloglanis anoterus (CANO) and *Opsaridium peringueyi* (OPER): See Section 3.1.2 and Appendix K, Table K1.

7.1.2 Fish indicator group 2: Large semi-rheophilic species (BMAR, HVIT, LCON)

The large semi-rheophilic (LSR) species *Labeobarbus marequensis* (BMAR), *Hydrocynus vittatus* (HVIT) and *Labeo congoro* (LCON) were another important indicator guild present at this EWR site. Information on the habitat requirements for different life stages are provided in Appendix L, Table L1. BMAR, HVIT and LCON were therefore used as indicators for the LSR guild. These species utilises most habitats (SD, SS, FD, FI and FS) with substrate and water column as preferred cover. They also require overhanging vegetation as nursery habitats. Flows should furthermore remain adequate to allow migration between reaches, thus depth in riffle and rapids should remain adequate, especially during the wet season

7.1.3 Macroinvertebrate indicator taxa

Perlidae, Heptageniidae and Elmidae were selected as FDI indicator taxa. Refer to Section 5.1.3.

7.1.4 Riparian vegetation indicator species

Two indicator species was selected:

- *Breonadia salicina:* See Section 5.1.4.
- *Phragmites mauritianus:* See Section 3.1.4.

7.2 STRESS FLOW INDEX

The stress flow index is generated in terms of habitat and biotic response and is discussed below.

7.2.1 Habitat response

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

- 0 – Optimum habitat (fixed at the natural maximum base flow – calculated using the wettest flow month discharge at the maintenance percentage - 30 – 40% for the Sabie River at the EWR site).
- 10 - No flow (i.e., there can still be surface water in pools).

The abundance of fish velocity-depth classes are provided in Appendix L, Table L2.

The instantaneous response of FDI taxa provides the % occurrence of various velocity-substrate classes under different flow conditions are provided in Appendix L, Table L4).

7.2.2 Biota response

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

The fish species response index is calculated using the fish habitat rating (cf Section 3.2.1) (Appendix L, Table L3) for each of the discharges evaluated for assessing habitat response. The FDI index is derived by considering the habitat response and % occurrence of habitat conditions at different flows. The FDI responses are described and coupled to a stress level (Appendix L, Table L5)

A riparian vegetation stress index is also provided (Appendix L, Table L6).

7.2.3 Integrated stress curve

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

The shaded species stress discharges in Table 7.1 indicate the discharge evaluated by specialists to determine the biota stress. The values that are not shaded are interpolated. The highest discharge representing a specific stress is used to define the integrated stress curve. Figure 7-1 illustrates this graphically.

Table 7.1 Species stress discharges used to determine biotic stress

Stress	Flow (m^3/s)					Integrated Stress Flow (m^3/s)
	SR	LSR	FDI	Minger *Breonadia*	Reed *Phragmites*	
0	16.55	13.74	12.85	6	8.8	16.55
1	13.74	10.33	10.33	4.733	7.633	13.74
2	10.33	8.78	9.555	3.467	6.467	10.33
3	7.33	6	8.78	2.2	5.3	8.78
4	6	3.67	6.65	1.6	4.067	6.65
5	3.67	3.17	4.78	1	2.833	4.78
6	2.25	2.25	2.25	0.4	1.6	2.25
7	1.84	1.84	1.535	0.3	0.801	1.84
8	1.46	1.46	0.82	0.2	0	1.46
9	1.13	0.82	0.35	0.101	0	1.13
10	0	0	0	0	0	0

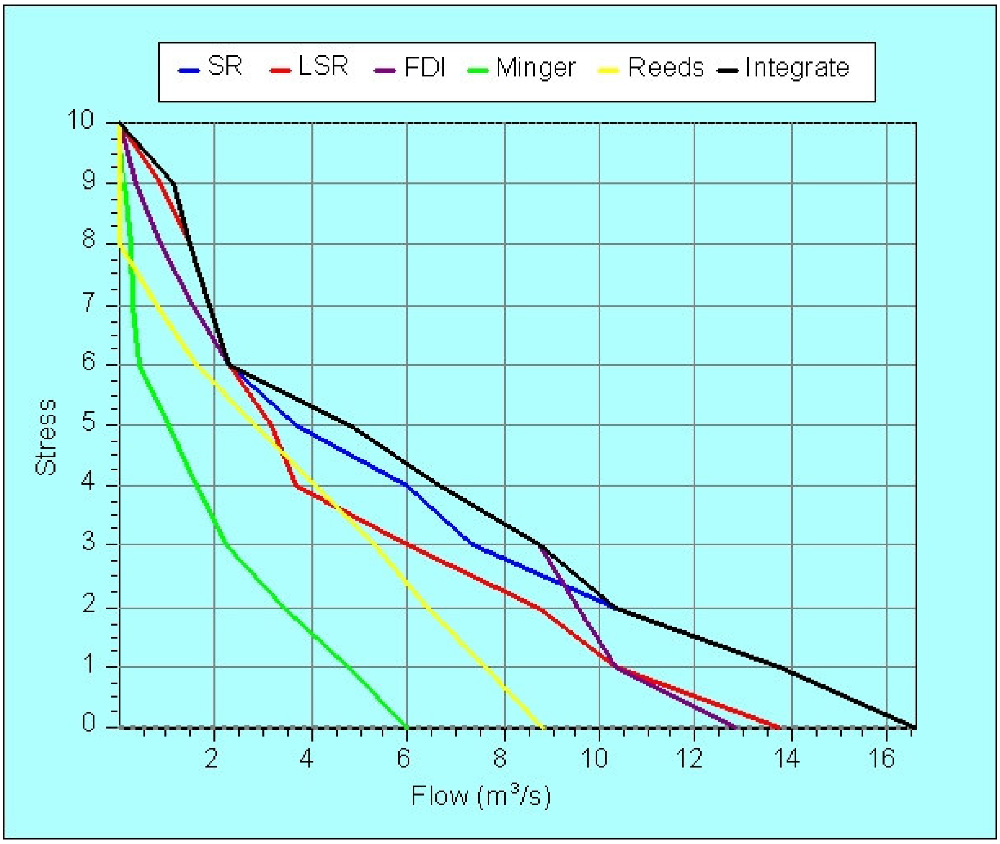

Figure 7–1 Component and integrated stress curves for EWR 3

Table 7.2 provides the summarised biotic response for the integrated stresses.

Table 7.2 Integrated stress and summarised habitat/biotic responses

Integrated stress	Flow m^3/s	Habitat and/or Biotic responses
0 (SR)	16.55	Fish guild habitats are at an optimum (5*). FDI Habitat is heterogeneous and plentiful. Lower limit of *B. salicina* inundated. No water stress. Riparian vegetation: Adults with full vigour and at maximum reproductive capacity.
1 (SR)	13.74	LSR habitat is at optimum with spawning habitat slightly reduced. SR habitat is slightly reduced (4.5)* but water quality and connectivity is optimal. FDI as above. Taxa abundant and healthy.
2 (SR)	10.33	SR habitat is good while connectivity and water quality along with LSR habitat is slightly better. Critical habitats sufficient. Indicator taxa persist.
3 (FDI)	8.78	SR habitat is slightly higher than moderate while connectivity and water quality is good. LSR habitat is good. Critical FDI habitat reduced with moderate quality. Most indicator taxa persist at reduced abundances. Riparian vegetation: Adults with full vigour and at maximum reproductive capacity.
4 (FDI)	6.65	Critical FDI habitat limited. Life stages of indicator taxa viable.
5 (FDI)	4.78	SR guild: Connectivity and water quality is moderate while rest of habitats are slightly worse (2.5). LSR guild: Nursery and connectivity is higher than low (2.5), spawning habitat is low and abundance and cover is moderate. Critical FDI habitat very reduced. Perlidae decline in abundance and occupy remaining fast flowing areas. Heptageniidae and Elmidae persist at low abundances. *P. mauritianus*: Leaf wilting/stress commences, but is slight.
6 (FDI)	2.25	SR guild: Spawning and nursery habitat is low (1.5 – 2), connectivity is moderate. LSR habitat is low while spawning areas are very low in occurrence. Critical habitat residual and of low quality. Perlidae rare, critical stages of sensitive indicator taxa non-viable, and at risk for less sensitive Heptageniidae and Elmidae. *B salicina*: Leaf wilting/stress commences, but is slight.

Integrated stress	Flow m^3/s	Habitat and/or Biotic responses
7 (SR)	1.84	SR and LSR habitat is very low with some connectivity.
8 (SR)	1.46	SR and LSR habitat is as above although slightly deteriorated. LSR spawning habitat has nearly disappeared. Heptageniidae and Elmidae persist, but Perlids all but disappear, with all life-stages of sensitive indicator taxa at risk or non-viable. *P. mauritianus*: Unseasonal thinning or partial mortality of above-ground parts (majority of the plant/s remains viable, but water stressed).
9 (SR)	1.13	SR guild: All habitats are very low and rare. LSR guild: Habitat is very low and spawning habitat is very rare.
10	0	Only pool dwelling species present. Standing water habitats only, very poor quality. Indicator taxa disappear. Widespread and complete mortality of riparian population.

* Suitability rating 0 (not suitable) – 5 (highly suitable)

8 EWR 3: KIDNEY (SABIE RIVER): DETERMINATION OF EWR SCENARIOS

8.1 ECOCLASSIFICATION SUMMARY OF EWR 3

EWR 3 Kidney (Sabie River)

EIS: Very High
Rare and endangered species, taxon richness and species intolerant to flow and flow related water quality changes. Refuge area for biota and an important migration corridor for birds and fish. Within KNP.
PES: A/B
Forestry, abstraction, Inyaka Dam and landuse activities. (Flow and non-flow related)
REC: A/B
As the PES is already an A/B, the REC = the PES.
AEC Down: B/C
Increased abstractions, no Reserve implementation, less floods. Increased nutrients, changes in temperature, oxygen etc. Riffles lost due to sedimentation, channel shallower and sandier. Vegetation exotics will increase.
More reeds will be present in sandier areas.

Driver Components	PES & REC Category	Trend	AEC↓
HYDROLOGY	C		C/D
WATER QUALITY	B		C
GEOMORPHOLOGY	B	Negative	C
Response Components	**PES & REC Category**	**Trend**	**AEC↓**
FISH	B	Stable	C
MACRO INVERTEBRATES	B	Stable	C
INSTREAM	B		C
RIPARIAN VEGETATION	A/B	Stable	B/C
ECOSTATUS	A/B		B/C

8.2 HYDROLOGY

The highest and lowest low flow months selected as the key months are February (wet) and October (dry). The key assurance percentages for which stress requirements had to be set were:

- 95%: Representing droughts for both wet and dry months. This would represent 5% on the stress duration graphs.
- 65%: Representing maintenance flows for both wet and dry months. This would represent 35% on the stress duration graphs.

8.3 LOW FLOW REQUIREMENTS (IN TERMS OF STRESS)

The integrated stress index is used to identify required stress levels at specific durations for the wet and dry month/season. Specialist motivations for the stresses are provided in Appendix L, Section L2.1 – 2.3.

8.3.1 Low flow (in terms of stress) requirements

The fish, macroinvertebrate and riparian vegetation flow requirements for different Ecological Categories (ECs) are provided in Table 8.1, Figure 8-1 and 8-2. The results are plotted for the wet and dry season on stress duration graphs and compared to the DRM low flow estimates for the same range of ECs. The stress requirements (as a 'hand drawn line') are illustrated in Figures 8-1 and 8-2.

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

Summarised motivations for the final requirements are provided in Table 8.2.

Table 8.1 Species and integrates stress requirements as well as the final integrated stress and flow requirement

Duration	SR stress	Integ stress	LSR stress	Integ stress	FDI stress	Integr stress	*B. salicina (Minger)* stress	Integ stress	*Phragmites* (Reeds) stress	Integ stress	FINAL* (Integ stress)	FLOW (m^3/s)
PES and REC: A/B EcoStatus			**FISH: B**			**MACROINVERTEBRATES: B**					**RIP VEG: A/B**	
DRY SEASON												
5%	8	8	9	9.2	8	9.2	6	9.76	7	9.25	**8**	**1.46**
35%	6	6	7	7	7	7.9	4.5	8.5	5	5.75	**6**	**2.25**
WET SEASON												
5%	7	7	6	6	6	6	5	9.25	5	5.75	**5.75**	**2.8**
35%	3	3.8	2.5	3.8	4	4	2	5.5	2	4	**3.8**	**7.1**
AEC: B/C EcoStatus			**FISH: C**			**MACROINVERTEBRATES: C**					**RIP VEG: B/C**	
DRY SEASON												
5	8.9	8.9	9	9.2	8	9.2	6	9.76	7	9.25	**8.9**	**0.95**
35%	7.8	7.8	8.5	9	7.5	9	5	9.25	6	7.5	**7.8**	**1.4**
WET SEASON												
35%	4.5	4.9	4	5.5	5	5	3	6	3	4.75	**4.75**	**5.2**

* Final refers to the final stress selected as the EWR requirement, usually the lowest integrated stress. In some cases, vegetation was ignored due to the much lower confidence in the requirements.

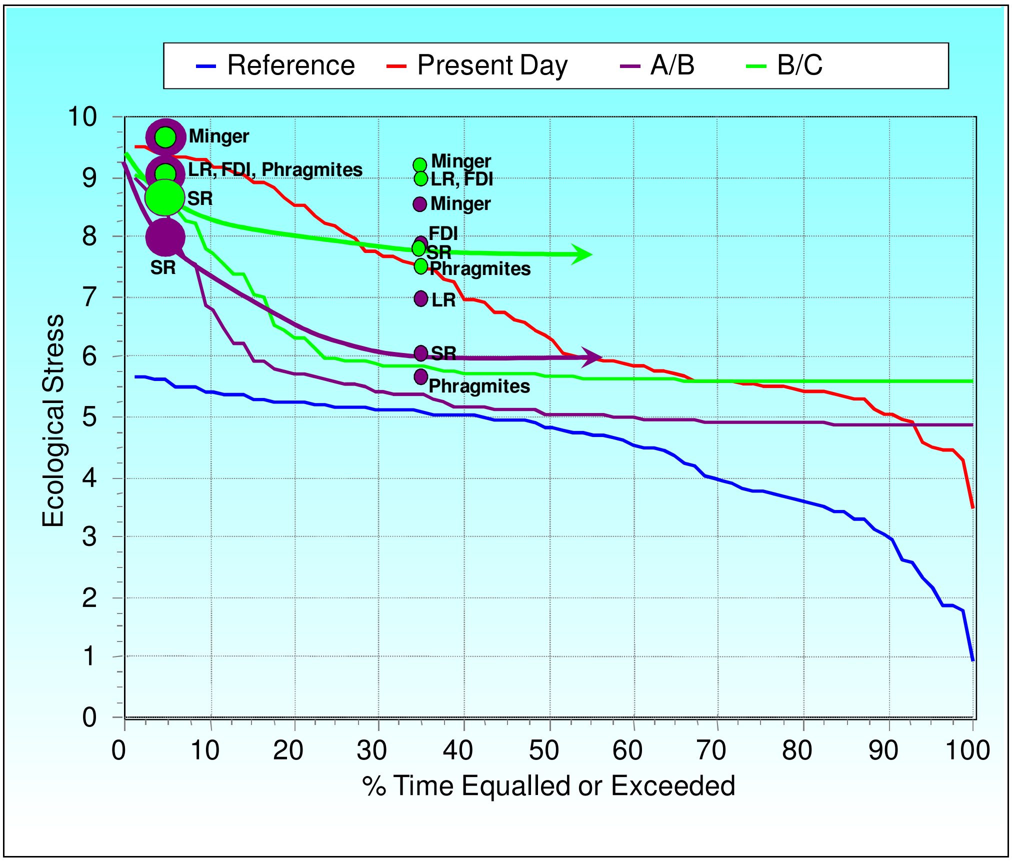

Figure 8–1 EWR 3: Stress duration curve for a A/B PES and REC and B/C AEC - DRY season

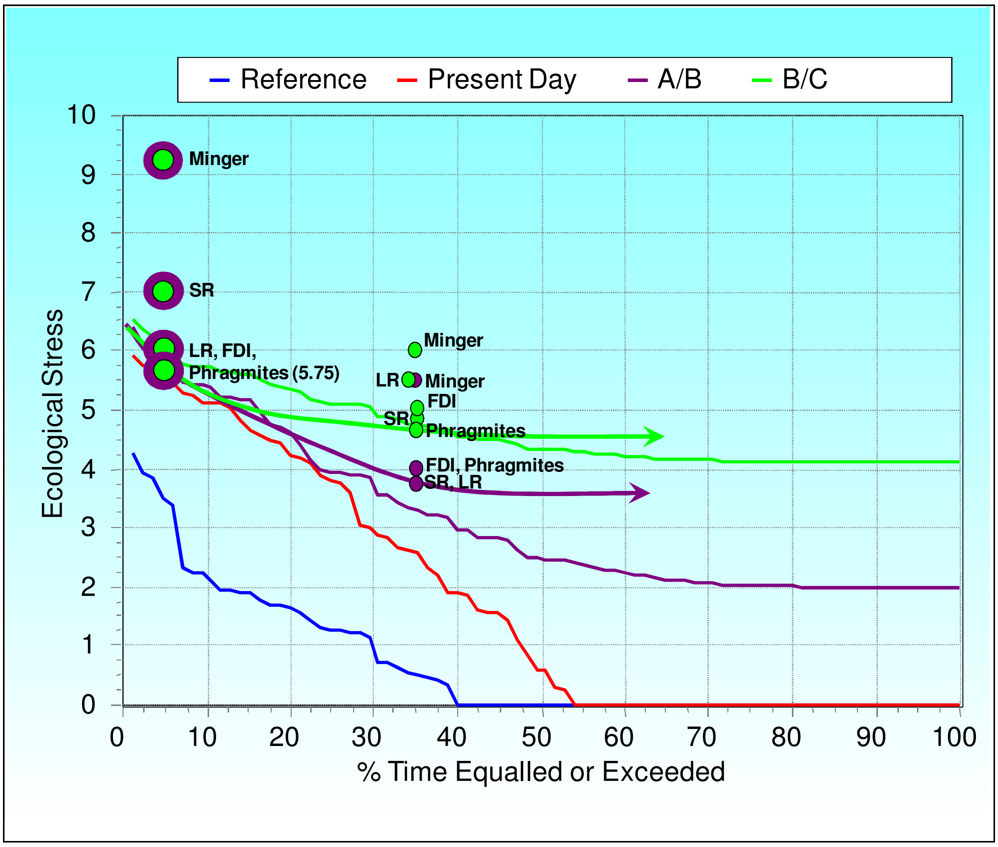

Figure 8–2 EWR 3: Stress duration curve for a A/B PES and REC and B/C AEC - WET season

Table 8.2 Summary of EWR 3 motivations

Month	% Stress duration	Component stress	Integrated stress	Flow m^3/s	Comment
PES and REC: A/B EcoStatus	**FISH: B**		**MACROINVERTEBRATES: B**		**RIP VEG: A/B**
Oct	5% drought	8 SR	8	1.46	Critical fast habitat is maintained to ensure survival of the SR guild.
	35% maintenance	6 SR	6	2.25	Highly stressed condition and maintenance of EC depends on the maintenance of wet season drought conditions.
Feb	5% drought	5 *Phragmites*	5.75	2.8	Obvious leaf wilting or vegetative parts begin unseasonal discolouration; flower/fruit abortion is widespread.
	35% maintenance	3 SR	3.8	7.1	Adequate critical habitat to maintain life stages and biological processes.
AEC: B/C EcoStatus		**FISH: C**	**MACROINVERTEBRATES: C**		**RIP VEG: B/C**
Oct	5% drought	8.9 SR	8.9	0.95	Critical fast habitat at reduced abundance than PES. Guild will occur at decreased FROC and abundance.
	35% maintenance	7.8 SR	7.8	0.67	Reduced occurrence of fast habitats, therefore fish occur in reduced abundance and FROC.
Feb	5% drought	5 *Phragmites*	5.75	2.8	See PES.
	35% maintenance	3 *Phragmites*	4.75	5.2	Leaf wilting/stress commences but is slight, and the population remains reproductively active.

8.3.2 Final low flow requirements

To produce the final results (Figure 8-3), the DRM results for the specific category are modified according to specialists' requirements (Figure 8-1 and 8-2). The following changes were required:

- Droughts were not changed.
- Seasonal distribution factor changes:
  - A/B EC: 1.5 for maintenance.
  - B/C EC: 2.1 for maintenance.

Dry season (October) **Wet season (February)**

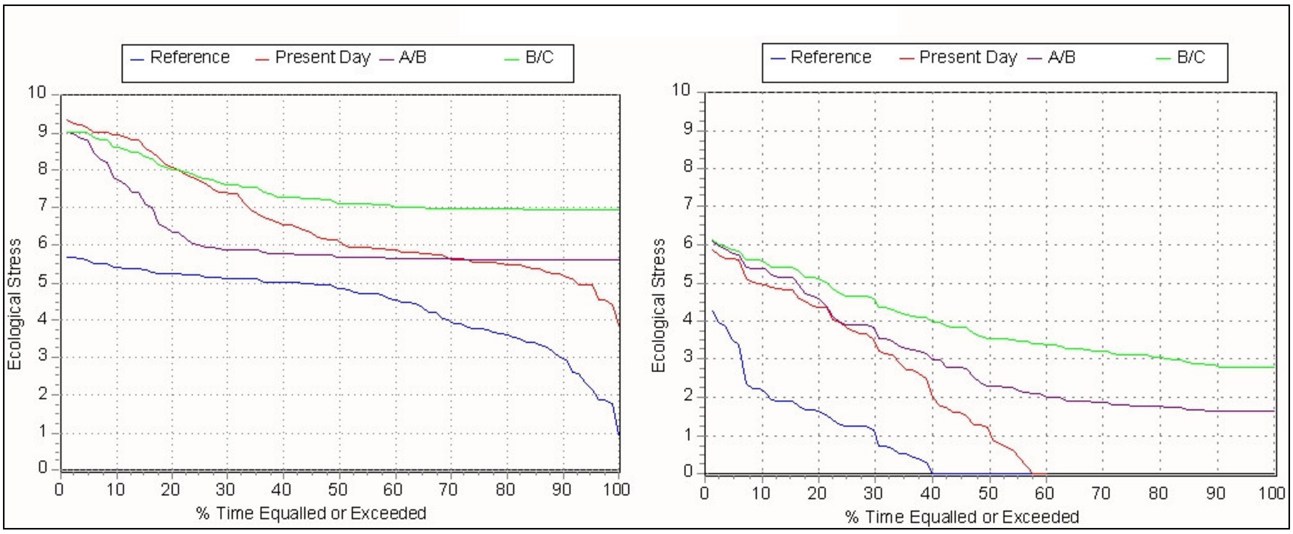

Figure 8–3 EWR 3: Final stress requirements for low flows

8.4 HIGH FLOW REQUIREMENTS

High low classes were identified as outlined in Section 4.4. Results are provided in Table 8.3 and detailed motivations provided in Table 8.4.

Table 8.3 Identification of instream functions addressed by the identified floods for geomorphology and riparian vegetation

FLOOD CLASS	FLOOD RANGE (m^3/s)	GEOMORPHOLOGY AND RIPARIAN VEGETATION MOTIVATION	Fish flood functions							Macroinvertebrate flood functions				
			Migration cues	Migration habitat (depth etc.)	Clean spawning substrate	Create spawning habitat	Create nursery areas	Resetting water quality	Inundate vegetation for spawning	Breeding and hatching cues	Clear fines	Scour substrate	Reach or inundate specific areas	Reset water quality
I	10 - 15	Macroinvertebrates. See Appendix D, Table D11.	√	√	√	√	√	√	√	√	√	√	√	√

FLOOD CLASS	FLOOD RANGE (m^3/s)	GEOMORPHOLOGY AND RIPARIAN VEGETATION MOTIVATION	Fish flood functions							Macroinvertebrate flood functions				
			Migration cues	Migration habitat (depth etc.)	Clean spawning substrate	Create spawning habitat	Create nursery areas	Resetting water quality	Inundate vegetation for spawning	Breeding and hatching cues	Clear fines	Scour substrate	Reach or inundate specific areas	Reset water quality
II	15 - 30	**Geomorphology:** This flow class is responsible for the transport of a large proportion of the fines (sands) component through the site, and would activate the gravels on the bed. **Vegetation:** Inundates half of reeds, but not to depths greater than about 50 cm. Inundates lower limit of *B. salicina* population, ensuring survival and recruitment opportunities. Inundates aquatic macrophytes (*Persecaria, Ludwigia*, and *Cyperus)*.	√	√	√	√	√	√	√	√	√	√	√	√
III	45 - 55	**Vegetation:** Inundates marginal zone, marginal zone riparian obligates and high density reedbeds. Activates the lower limit of *S. cordatum*. Also inundates a major portion of the *B. salicina* population.	√	√	√	√	√	√	√					
IV	75 - 100	**Geomorphology:** This important flow class is responsible for about 30% of both sand and gravel transport. Maintaining this flow category will scour the active channels of the reach. **Vegetation:** Maintains lower zone woody species (*N. oppositifolia and C. erythrophyllum*). Inundates lower portion of the lower zone and the majority of the reeds.	√	√	√	√	√	√	√					
V	150 +	**Vegetation:** Inundates the lower zone to the full extent and activates the upper zone.	√	√	√	√	√	√	√					
VI	250	**Geomorphology:** This large flood is responsible for the bulk of channel maintenance (specifically within these anastomosing reaches) - widening and deepening the channels and removing vegetation.	√	√	√	√	√	√	√					

Further information is provided in Appendix L, Table L11.

The number of high flow events required for each EC is provided in Table 8.4. The high flows were checked, using available daily hydrology.

Table 8.4 EWR 3: The recommended number of high flow events required

FLOOD RANGE (m^3/s)	FLOOD CLASS	INVERTEBRATES	FISH	VEGETATION	GEOMORPHOLOGY	FINAL (No of events)	MONTHS	DAILY AVERAGE (m^3/s)	DURATION (Days)
PES and REC SCENARIO: A/B									
I	10 - 15	4				4	Nov, Dec, Jan, Feb	8	3
II	15 - 30			4	4	4	Nov, Dec, Jan, Mar	20	4
III	45 -55			1		1	Mar	40	5
IV	75 - 100			1:2	1:2	1:2			
V	150 +			1:3+		1:3			
VI	250				1:5	1:5			

AEC SCENARIO: B/C									
I	10 - 15	3				3	Dec, Jan, Feb	8	3
II	15 - 30			3	3	3	Nov, Jan, Mar	20	4
III	45 -55			1		1	Feb	40	5
IV	75 - 100			1:2	1:2	1:2			
V	150 +			1:3+		1:3			
VI	250			1:5	1:5	1:5			

8.5 FINAL FLOW REQUIREMENTS

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

- An EWR table, which shows the results of high flows and low flows for each month separately (Table 8.5 – 8.7). Floods with a frequency higher than 1:1 is not included.
- An EWR rule table which provides the recommended EWR flows as a duration table, showing flows which should be provided when linked to a natural trigger (natural modelled hydrology in this case). EWR rules are supplied for total flows as well as for low flows only (Appendix L, Section L2.5).

Table 8.5 EWR table for PES and REC: A/B

Desktop version:		**2**	**Virgin MAR (MCM)**	**495.858**
BFI index	**0.499**	**Distribution type**		**Eastern Escarpment**
MONTH	**LOW FLOWS**		**HIGH FLOWS**	
	Maintenance (m^3/s)	**Drought (m^3/s)**	**Daily average (m^3/s) on top of base flow**	**Duration (days)**
OCTOBER	2.703	1.090		
NOVEMBER	3.362	1.234	8 20	3 4
DECEMBER	4.274	1.386	8 20	3 4
JANUARY	5.546	1.626	8 20	3 4
FEBRUARY	7.843	2.121	8	3
MARCH	7.508	1.995	20 40	4 5
APRIL	6.941	1.908		
MAY	5.794	1.673		
JUNE	5.120	1.565		
JULY	4.086	1.351		
AUGUST	3.326	1.208		
SEPTEMBER	2.881	1.143		
TOTAL MCM	155.440	47.960	31.847	
% OF VIRGIN	31.35	9.67	6.42	

Table 8.6 EWR table for AEC: B/C

Desktop version:		**2**	**Virgin MAR (MCM)**	**495.858**
BFI index	**0.499**	**Distribution type**		**Eastern Escarpment**
MONTH	**LOW FLOWS**		**HIGH FLOWS**	
	Maintenance (m^3/s)	**Drought (m^3/s)**	**Daily average (m^3/s) on top of base flow**	**Duration (days)**

OCTOBER	1.492	1.090		
NOVEMBER	1.982	1.234	20	4
DECEMBER	2.706	1.386	8	3
JANUARY	3.689	1.626	8 20	3 4
FEBRUARY	5.401	2.121	40	5
MARCH	5.205	1.995	20	4
APRIL	4.747	1.908		
MAY	3.881	1.673		
JUNE	3.340	1.565		
JULY	2.561	1.351		
AUGUST	1.974	1.208		
SEPTEMBER	1.610	1.143		
TOTAL MCM	100.945	47.960	26.933	
% OF VIRGIN	20.36	9.67	5.43	

A comparison between the Desktop Reserve Model estimates and the EWR results in terms of percentages of natural flow are provided in Table 8.7.

Table 8.7 Modifications made to the DRM for EWR 3

Changes	PES and REC A/B		AEC B/C	
	DRM	EWR	DRM	EWR
MLIFR - Maintenance low flow	40.0%	31.3%	24.5%	20.4%
DLIFR - Drought low flow	9.7%	9.7%	9.7%	9.7%
MHIFR - Maintenance high flow	9.8%	6.4%	7.7%	5.4%
Long-term % of virgin MAR	48.3%	37.0%	33.2%	27.1%

9 EWR 4: MAC MAC (MAC MAC RIVER) – DETERMINATION OF STRESS INDICES

NOTE: All supporting specialist information for EWR 4 is summarized in Volume 3, Appendix M.

9.1 INDICATOR SPECIES OR GROUP

9.1.1 Fish indicator group 1: Large rheophilic species (VNEL)

Varicorhinus nelspruitensis (VNEL): See Section 3.1.2 and Appendix J, Table J1.

9.1.2 Fish indicator group 2: Small rheophilic species (AURA, CANO)

Chiloglanis anoterus (CANO) and *Opsaridium peringueyi* (OPER): See Section 3.1.2 and Appendix J, Table J2.

9.1.3 Macroinvertebrate indicator taxa

Perlidae, Heptageniidae and Elmidae were selected as FDI indicator taxa. Refer to Section 5.1.3.

9.1.4 Riparian vegetation indicator species

One indicator species was selected:

- *Breonadia salicina:* See Section 5.1.4.

9.2 STRESS FLOW INDEX

The stress flow index is generated in terms of habitat and biotic response and is discussed below.

9.2.1 Habitat response

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

- 0 - Optimum habitat (fixed at the natural maximum base flow – calculated using the wettest flow month discharge at the maintenance percentage of 30% - 40% for the Mac Mac River at the EWR site).
- 10 - No flow (although there may still be surface water in pools).

The abundance of fish velocity-depth classes are provided in Appendix M, Table M1.

The instantaneous response of FDI taxa provides the % occurrence of various velocity-substrate classes under different flow conditions are provided in Appendix M, Table M3.

9.2.2 Biota response

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

The fish species response index is calculated using the fish habitat rating (cf Section 3.2.1) (Appendix M, Table M2) for each of the discharges evaluated for assessing habitat response. The FDI index is derived by considering the habitat response and % occurrence of habitat conditions at different flows. The FDI responses are described and coupled to a stress level (Appendix M, Table M4)

A riparian vegetation stress index is also provided (Appendix M, Table M5).

9.2.3 Integrated stress curve

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

The shaded species stress discharges in Table 9.1 indicate the discharge evaluated by specialists to determine the biota stress. The values that are not shaded are interpolated. The highest discharge representing a specific stress is used to define the integrated stress curve. Figure 9-1 illustrates this graphically.

In this specific case, the LR fish stress index represents the integrated stress index (these values are the highest flow for the stress). Therefore the blue line (representing the LR stress index) is lying 'beneath' the integrated stress line (black) (Figure 9-1).

Table 9.1 Species stress discharges used to determine biotic stress

Stress	Flow (m^3/s)				Integrated Flow (m^3/s)
	LR	SR	FDI	Minger *Breonadia*	
0	2.37	1.64	2.1	2.1	2.37
1	1.86	1.42	1.3	1.45	1.86
2	1.26	1.09	0.8	0.8	1.26
3	1.09	0.7	0.5	0.15	1.09
4	0.7	0.6	0.3	0.102	0.7
5	0.59	0.5	0.18	0.054	0.59
6	0.5	0.43	0.094	0.006	0.5
7	0.405	0.31	0.028	0.004	0.405
8	0.31	0.205	0.006	0.001	0.31
9	0.155	0.1	0.001	0.001	0.155
10	0	0	0.001	0.001	0.001

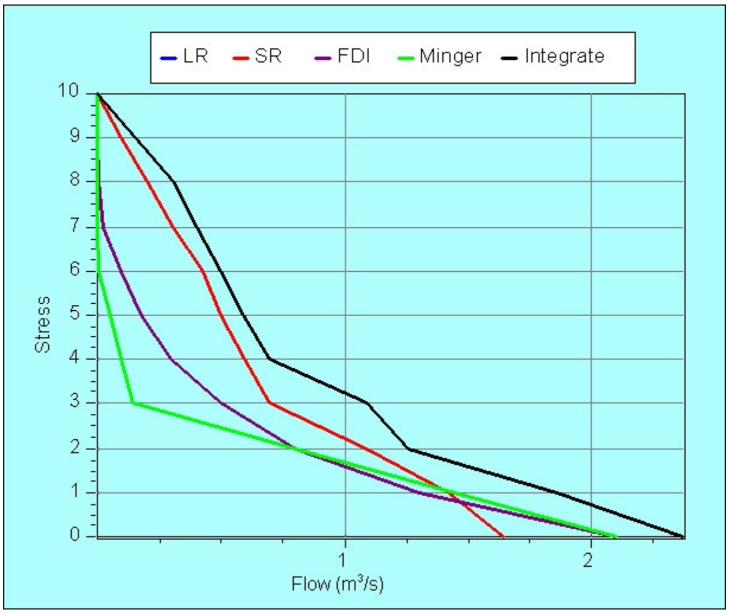

Figure 9–1 Component and integrated stress curves for EWR 4

Table 9.2 provides the summarised biotic response for the integrated stresses.

Table 9.2 Integrated stress and summarised habitat/biotic responses

Integrated stress	Flow m^3/s	Habitat and/or Biotic responses
0 (SR)	2.37	Fish guild habitats are at an optimum (5*). FDI habitat is heterogeneous and plentiful. Taxa abundant. Lower limit of *B. salicina* inundated. No water stress. Riparian vegetation: Adults with full vigour and at maximum reproductive capacity.
1 (SR)	1.86	Habitats are optimal for the SR guild. The LR habitat range from good – optimal.
2 (SR)	1.26	SR habitat is good – optimal. The LR habitat is good although spawning habitat is slightly impacted (3.5). Diverse FDI habitat of high quality. Majority of indicators persist in healthy state.
3 (SR)	1.09	SR habitat is still good although nursery habitat is slightly deteriorated (3.5*). All LR habitat is moderate although connectivity and water quality is still good. Critical FDI habitat reduced with moderate quality. Most indicator taxa persist at reduced abundances. Leaf wilting/stress commences, but is slight.
4 (SR)	0.7	SR spawning and connectivity habitat is still good, while the rest of the habitat is low to moderate. The LR spawning habitat is moderate while the rest of the habitat is low and connectivity is good.
5 (SR)	0.59	SR guild: Spawning and connectivity is moderate while the rest of the habitat is slightly worse than moderate (2.5). LR guild: Spawning habitat is low (1.5) while most of the other habitat is slightly better (2). Critical FDI habitat very reduced. Perlidae decline in abundance and occupy remaining fast flowing areas. Heptageniidae and Elmidae persist at low abundances.
6 (SR)	0.5	Critical FDI habitat reduced slightly. Abundances of Perlids and Heptageniids reduced.
7 (SR)	0.405	SR and LR habitat is very low with some connectivity.
8 (SR)	0.31	SR guild: Nursery habitat is very rare while the rest of the habitat is very low. Spawning and nursery habitat is very rare for the LR guild. Relative proportions of FDI flow habitat are very low. All life stages of Perlids and Heptageniids viable in limited areas, critical life stages of Perlids at risk.
9 (SR)	0.155	Critical FDI habitat very reduced; marginal vegetation lost. Perlidae persist in low numbers. Heptageniidae persist. Critical life stages of Perlidae at risk.
10 (SR)	0	Only pool dwelling species present. Standing water habitats only. Heptageniids no longer present. Unseasonal loss or mortality of above-ground parts (only minor portions of plants remain viable). Rootstocks/rhizomes of some species remain viable.

* Suitability rating 0 (not suitable) – 5 (highly suitable)

10 EWR 4: MAC MAC (MAC MAC RIVER): DETERMINATION OF EWR SCENARIOS

10.1 ECOCLASSIFICATION SUMMARY OF EWR 4

EWR 4 Mac Mac (Mac Mac River)

EIS: High
Rare and endangered fish and vegetation species. Species present intolerant to flow and flow related water quality changes.

PES: B
Forestry, exotic vegetation and wastewater input. Impacts are flow and non-flow related.

REC: A/B
The EIS at EWR 4 is high and the REC is therefore to improve the PES by improving the fish. Improved water quality required..

AEC down: C
Decreased low flows due to e.g. a weir or small dam in the upper catchment. This will result in embedded cobbles. Nutrients and temperature will increase. Increased exotic vegetation in the riparian zone.

Driver Components	PES Category	Trend	REC	AEC↓
HYDROLOGY	C		C	C
WATER QUALITY	A/B		A	B/C
GEOMORPHOLOGY	A	Stable	A	B
Response Components	**PES Category**	**Trend**	**REC**	**AEC↓**
FISH	B/C	Stable	B	C/D
MACRO INVERTEBRATES	A/B	Stable	A/B	B/C
INSTREAM	B		B	C
RIPARIAN VEGETATION	A/B	Negative	A/B	B/C
ECOSTATUS	B		A/B	C

10.2 HYDROLOGY

The highest and lowest low flow months selected as the key months are February (wet) and October (dry). The key assurance percentages for which stress requirements had to be set were:

- 95%: Representing droughts for both wet and dry months. This would represent 5% on the stress duration graphs.
- 65%: Representing maintenance flows for both wet and dry months. This would represent 35% on the stress duration graphs.

10.3 LOW FLOW REQUIREMENTS (IN TERMS OF STRESS)

The integrated stress index is used to identify required stress levels at specific durations for the wet and dry month/season. Specialist motivations for the stresses are provided in Appendix M, Section M2.1 - 2.3.

10.3.1 Low flow (in terms of stress) requirements

The fish, macroinvertebrate and riparian vegetation flow requirements for different Ecological Categories (ECs) are provided in Table 10.1, Figure 10-1 and 10-2. The results are plotted for the wet and dry season on stress duration graphs and compared to the DRM low flow estimates for the same range of ECs. The stress requirements (as a 'hand drawn line') are illustrated in Figures 10-1 and 10-2.

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

Summarised motivations for the final requirements are provided in Table 10.2.

Table 10.1 Species and integrates stress requirements as well as the final integrated stress and flow requirement

Duration	LR stress	Integ stress	SR stress	Integ stress	FDI stress	Integ stress	*B. salicina* (Minger) stress	Integ stress	FINAL* (Integ stress)	FLOW (m^3/s)
PES and REC: B EcoStatus			**FISH: B/C**		**MACROINVERTEBRATES: A/B**				**RIP VEG: A/B**	
DRY SEASON										
5%	8.5	8.5	8	8.8	6	9.5	6	10	**8.5**	**0.2**
35%	6.5	6.5	6.5	7.5	4	8.1	4	9.5	**6.5**	**0.45**
WET SEASON										
5%	6	6	6	6.9	4	8.1	5	9.75	**6**	**0.5**
35%	3	3	2.5	3.5	2	3.9	2	3.75	**3**	**1.09**
AEC↓: C EcoStatus			**FISH: C/D**		**MACROINVERTEBRATES: B/C**				**RIP VEG: B/C**	
DRY SEASON										
35%	7.5	7.5	7.5	8.3	5	9	Not assessed. AEC is related to alien vegetation.		**7.5**	**0.35**
WET SEASON										
35%	5	5	4.5	5.3	3	6	As above.		**5**	**0.59**

- Final refers to the final stress selected as the EWR requirement, usually the lowest integrated stress. In some cases, vegetation was ignored due to the much lower confidence in the requirements.

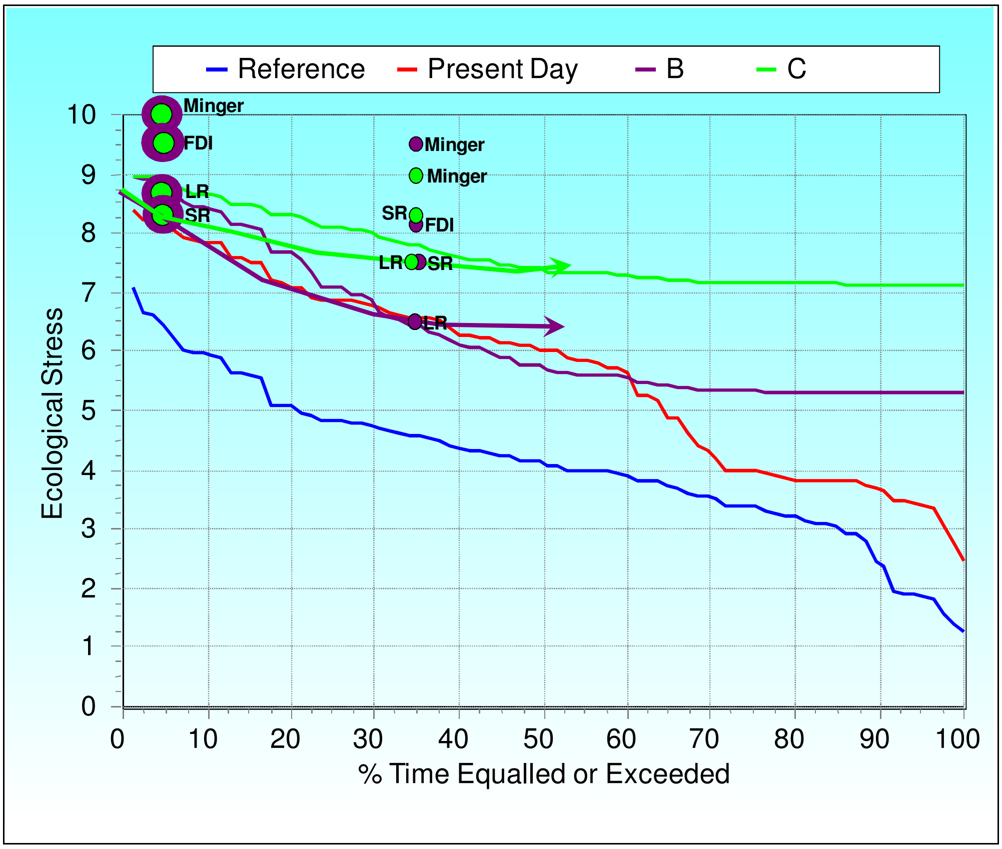

Figure 10–1 EWR 4: Stress duration curve for a B PES and REC and C AEC - DRY season

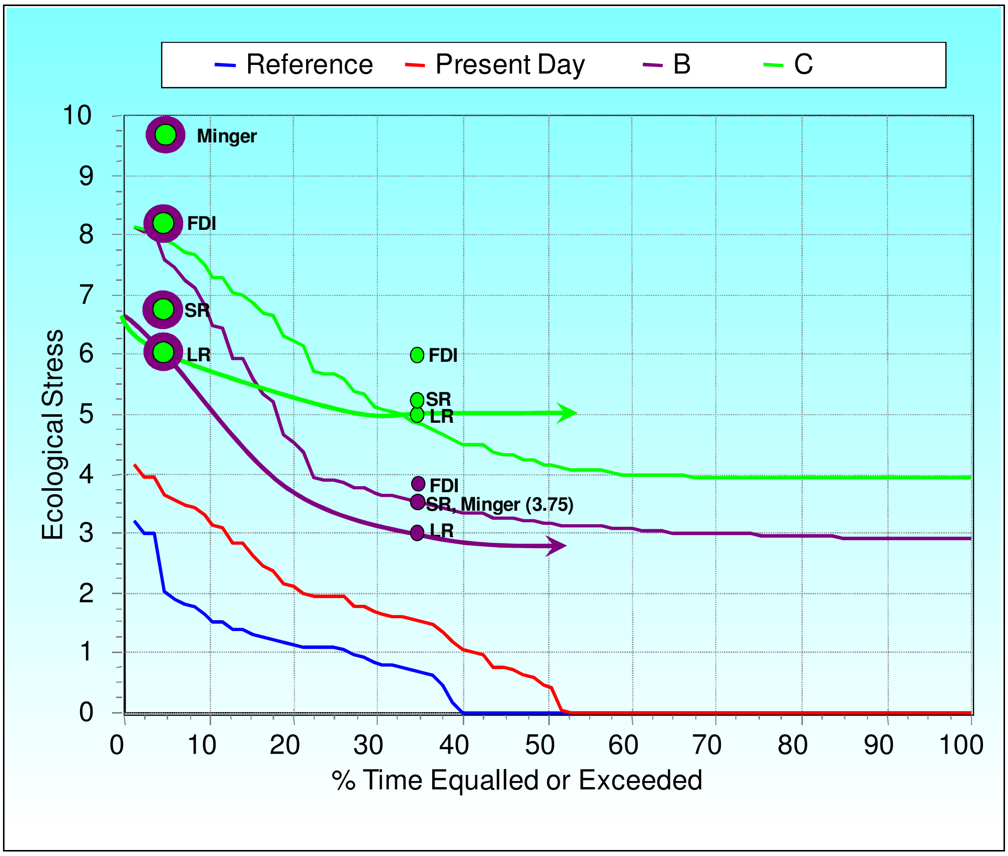

Figure 10–2 EWR 4: Stress duration curve for a B PES and REC and C AEC - WET season

Table 10.2 Summary of EWR 4 motivations

Month	% Stress duration	Component stress	Integrated stress	Flow m^3/s	Comment
PES and REC: B EcoStatus		**FISH: B/C**		**MACROINVERTEBRATES: A/B**	**RIP VEG: A/B**
Oct	5% - drought	8.5 LR	8.5	0.2	Limited FS and FI to maintain fish.
	35% maintenance	6.5 LR	6.5	0.45	Most critical habitat will be maintained and adequate for fish survival.
Feb	5% - drought	6 LR	6	0.5	Reduced spawning habitat, but sufficient to maintain all life stages and survival of fish.
	35% maintenance	3 SR	3	1.09	Adequate critical habitat to maintain life stages and biological processes.
AEC↓: C EcoStatus		**FISH: C/D**		**MACROINVERTEBRATES: B/C**	**RIP VEG: B/C**
Oct	5% - drought	8.5 LR	8.5	0.2	See PES.
	35% maintenance	7.5 LR	7.5	0.35	Reduced occurrence of fast habitats, therefore fish occur in reduced abundance and FROC.
Feb	5% - drought	6 LR	6	0.5	See PES.
	35% maintenance	5 LR	5	0.59	Fast habitats are reduced but adequate to maintain life stages at a reduced abundance and FROC.

10.3.2 Final low flow requirements

To produce the final results (Figure 10-3), the DRM results for the specific category are modified according to specialists' requirements (Figure 10-1 and 10-2). The following changes were required:

- Seasonal distribution factor changes:

- B EC: 1.22 for maintenance; 1.65 for drought.
- C EC: manual reduction of wet season flows by about 0.04 cm^3/s. No change to droughts.

Dry season (October) **Wet season (February)**

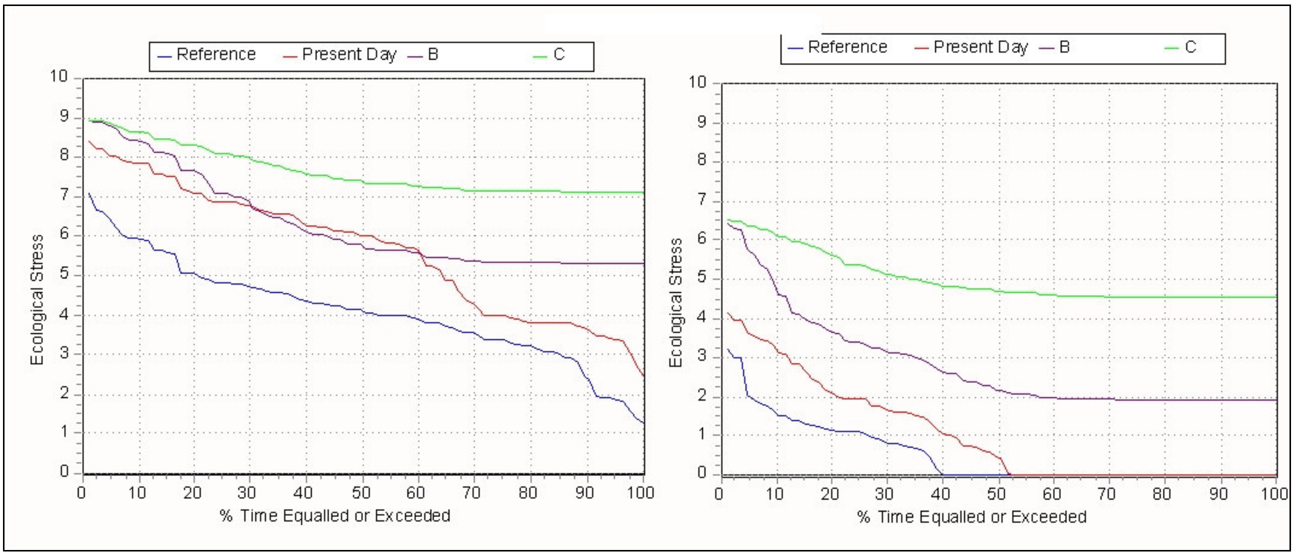

Figure 10–3 EWR 4: Final stress requirements for low flows

10.4 HIGH FLOW REQUIREMENTS

High low classes were identified as outlined in Section 4.4. Results are provided in Table 10.3 and detailed motivations provided in Table 10.4.

Table 10.3 Identification of instream functions addressed by the identified floods for geomorphology and riparian vegetation

FLOOD CLASS	FLOOD RANGE (m^3/s)	GEOMORPHOLOGY AND RIPARIAN VEGETATION MOTIVATION	Fish flood functions							Macroinvertebrate flood functions					
			Migration cues	Migration habitat (depth etc.)	Clean spawning substrate	Create spawning habitat	Create nursery areas	Resetting water quality	Inundate vegetation for spawning	Breeding and hatching cues	Clear fines	Scour substrate	Reach or inundate specific areas	Reset water quality	Migration cues
I	3 - 5	**Geomorphology:** This flow class initiates movement of the smaller (50 mm) gravels at the site, and would scour any accumulated fines. **Vegetation:** Maintains marginal zone riparian obligates, activates the lower limit of *B. salicina,* and inundates marginal zone *S. cordatum.*	√	√	√	√	√	√	√	√	√	√	√	√	√
II	6 - 12	**Geomorphology:** This flow class initiates movement of the larger gravels (100 mm) and maintains bed mobility. **Vegetation:** Inundates the marginal zone and lower portion of the lower zone. Inundates *B. salicina, S. cordatum* (*Hydrochorous* species) and *Anthocleista grandiflora* (medium to low lying forest species) populations.	√	√	√	√	√	√	√	√	√	√	√	√	√

FLOOD CLASS	FLOOD RANGE (m^3/s)	GEOMORPHOLOGY AND RIPARIAN VEGETATION MOTIVATION	Fish flood functions							Macroinvertebrate flood functions					
			Migration cues	Migration habitat (depth etc.)	Clean spawning substrate	Create spawning habitat	Create nursery areas	Resetting water quality	Inundate vegetation for spawning	Breeding and hatching cues	Clear fines	Scour substrate	Reach or inundate specific areas	Reset water quality	Migration cues
III	25 - 35	**Vegetation:** Inundates the lower zone and activates the lower portion of the upper zone. Inundates facultative riparian species (often also moist forest species) in the upper portions of the lower zone *(F. sur)*.	√	√	√	√	√	√	√						
IV	70 +	**Geomorphology:** Inundates the lateral terrace and activates the ephemeral flood channel. Scours the bed and moves the cobbles within the active channel. **Vegetation:** Inundates the upper zone woody species (kloof and forest species with some facultative riparian species; also historic *B. salicina* population). Inundates the lower zone and the lower portion of the upper zone.	√	√	√	√	√	√	√						

Further information is provided in Appendix M, Table M11.

The number of high flow events required for each EC is provided in Table 10.4. The high flows were checked, using available daily hydrology.

Table 10.4 EWR 4: The recommended number of high flow events required

FLOOD RANGE (m^3/s)	FLOOD CLASS	INVERTEBRATES	FISH	VEGETATION	GEOMORPHOLOGY	FINAL (No of events)	MONTHS	DAILY AVERAGE (m^3/s)	DURATION (Days)
PES and REC SCENARIO: B									
I	3 - 5	4		4		4	Nov, Dec, Jan, Mar	4	3
II	6 – 12	1		1		1	Feb	15	4
III	25 - 35			1:2		1:2			
IV	70 +			1:3+	1:10	1:3			
AEC SCENARIO: C									
I	3 - 5	3		4		4	Nov, Dec, Jan, Mar	4	3
II	6 – 12			1		1	Feb	15	4
III	25 - 35			1:2		1:2			
IV	70 +			1:3+	1:10	1:3			

10.5 FINAL FLOW REQUIREMENTS

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

- An EWR table, which shows the results of high flows and low flows for each month separately (Table 10.5 – 10.7). Floods with a frequency higher than 1:1 is not included.

- An EWR rule table which provides the recommended EWR flows as a duration table, showing flows which should be provided when linked to a natural trigger (natural modelled hydrology in this case). EWR rules are supplied for total flows as well as for low flows only (Appendix M, Section M2.5).

Table 10.5 EWR table for PES and REC: B

Desktop version:		2	Virgin MAR (MCM)	65.782
BFI index	0.499	Distribution type		Eastern Escarpment
MONTH	LOW FLOWS		HIGH FLOWS	
	Maintenance (m^3/s)	Drought (m^3/s)	Daily average (m^3/s) on top of base flow	Duration (days)
OCTOBER	0.047	0.160		
NOVEMBER	0.561	0.200	4	3
DECEMBER	0.675	0.254	4	3
JANUARY	0.836	0.329	4	3
FEBRUARY	1.133	0.459	15	4
MARCH	1.098	0.449	4	3
APRIL	1.053	0.427		
MAY	0.915	0.365		
JUNE	0.840	0.329		
JULY	0.682	0.258		
AUGUST	0.565	0.204		
SEPTEMBER	0.500	0.172		
TOTAL MCM	24.435	9.442	5.210	
% OF VIRGIN	37.15	14.35	7.92	

Table 10.6 EWR table for AEC: C

Desktop version:		2	Virgin MAR (MCM)	65.782
BFI index	0.5	Distribution type		Eastern Escarpment
MONTH	LOW FLOWS		HIGH FLOWS	
	Maintenance (m^3/s)	Drought (m^3/s)	Daily average (m^3/s) on top of base flow	Duration (days)
OCTOBER	0.281	0.160		
NOVEMBER	0.319	0.200	4	3
DECEMBER	0.350	0.254	4	3
JANUARY	0.400	0.329	4	3
FEBRUARY	0.500	0.459	15	4
MARCH	0.460	0.449	4	3
APRIL	0.460	0.427		
MAY	0.420	0.365		
JUNE	0.400	0.329		
JULY	0.362	0.258		
AUGUST	0.317	0.204		
SEPTEMBER	0.296	0.172		
TOTAL MCM	11.970	9.442	5.210	
% OF VIRGIN	18.20	14.35	7.92	

A comparison between the Desktop Reserve Model estimates and the EWR results in terms of percentages of natural flow are provided in Table 10.7.

Table 10.7 Modifications made to the DRM for EWR 4

Changes	PES and REC A/B		AEC B/C	
	DRM	EWR	DRM	EWR
MLIFR - Maintenance low flow	40.0%	31.3%	24.5%	20.4%
DLIFR - Drought low flow	9.7%	9.7%	9.7%	9.7%
MHIFR - Maintenance high flow	9.8%	6.4%	7.7%	5.4%
Long-term % of virgin MAR	48.3%	37.0%	33.2%	27.1%

11 EWR 5: MARITE (MARITE RIVER) – DETERMINATION OF STRESS INDICES

NOTE: All supporting specialist information for EWR 5 is summarized in Volume 3, Appendix N.

11.1 INDICATOR SPECIES OR GROUP

11.1.1 Fish indicator group 1: Large rheophilic species (VNEL)

Varicorhinus nelspruitensis (VNEL): See Section 3.1.2 and Appendix J, Table J1.

11.1.2 Fish indicator group 2: Small rheophilic species (AURA, CANO, OPER)

Chiloglanis anoterus (CANO) and *Opsaridium peringueyi* (OPER): See Section 3.1.2 and Appendix J, Table J2.

11.1.3 Macroinvertebrate indicator taxa

Perlidae, Heptageniidae and Elmidae were selected as FDI indicator taxa. Refer to Section 5.1.3.

11.1.4 Riparian vegetation indicator species

Two indicator species was selected:
- *Breonadia salicina:* See Section 5.1.4.
- *Phragmites mauritianus:* See Section 3.1.4.

11.2 STRESS FLOW INDEX

The stress flow index is generated in terms of habitat and biotic response and is discussed below.

11.2.1 Habitat response

The habitat flow index is described separately for fish, macroinvertebrates and riparian vegetation as an instantaneous response of habitat to flow in terms of a 0 – 10 index relevant for the specific site where:
- 0 - Optimum habitat (fixed at the natural maximum base flow – calculated using the wettest flow month discharge at the maintenance percentage of 35% - 40% for the Marite River at the EWR site).
- 10 - No flow (although there may still be surface water in pools).

The abundance of fish velocity-depth classes are provided in Appendix N, Table N1.

The instantaneous response of FDI taxa provides the % occurrence of various velocity-substrate classes under different flow conditions are provided in Appendix N, Table N3).

11.2.2 Biota response

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

The fish species response index is calculated using the fish habitat rating (cf Section 3.2.1) (Appendix N, Table N2) for each of the discharges evaluated for assessing habitat response. The FDI index is derived by considering the habitat response and % occurrence of habitat conditions at different flows. The FDI responses are described and coupled to a stress level (Appendix N, Table N4)

A riparian vegetation stress index is also provided (Appendix N, Table N5).

11.2.3 Integrated stress curve

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

The shaded species stress discharges in Table 11.1 indicate the discharge evaluated by specialists to determine the biota stress. The values that are not shaded are interpolated. The highest discharge representing a specific stress is used to define the integrated stress curve. Figure 11-1 illustrates this graphically.

In this specific case, the LR fish stress index represents the integrated stress index (these values are the highest flow for a stress) for stress 3 - 10. Therefore the blue line (representing the LR stress index) is lying 'beneath' the integrated stress line (black) (Figure 11-1).

Table 11.1 Species stress discharges used to determine biotic stress

Stress	Flow (m^3/s)					Integrated Flow (m^3/s)
	LR	SR	FDI	Reed *Phragmites*	Minger *Breonadia*	
0	4.89	4.89	3.9	4.9	3.45	4.9
1	3.44	3.44	3.3	3.647	2.597	3.647
2	2.05	2.35	2.7	2.393	1.743	2.7
3	1.78	1.33	1.33	1.14	0.89	1.78
4	1.375	0.97	1.01	0.887	0.707	1.375
5	0.97	0.81	0.69	0.633	0.523	0.97
6	0.69	0.69	0.44	0.38	0.34	0.69
7	0.5	0.5	0.29	0.26	0.2	0.5
8	0.35	0.3	0.11	0.14	0.06	0.35
9	0.29	0.2	0.05	0.071	0.03	0.29
10	0	0	0	0	0	0

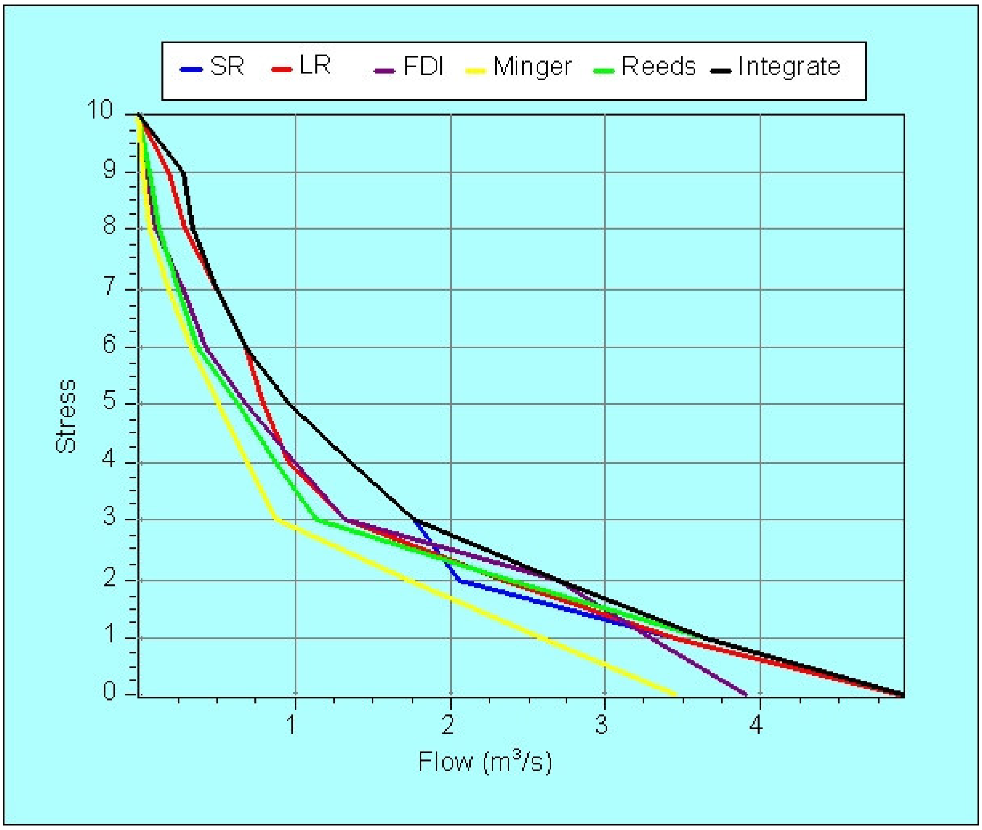

Figure 11–1 Component and integrated stress curves for EWR 5

Table 11.2 provides the summarised biotic response for the integrated stresses.

Table 11.2 Integrated stress and summarised habitat/biotic responses

Integrated stress	Flow m^3/s	Habitat and/or Biotic responses
0 (Reeds)	4.9	Fish guild habitats are at an optimum (5[*]). All FDI habitat in excess. Taxa abundant. *Phragmites* adults with full vigour and at maximum reproductive capacity.
1 (Reeds)	3.647	Fish habitats are slightly less (4.5)[*] with nursery, connectivity and water quality still at an optimal. FDI habitat plentiful. *Breonadia* adults with full vigour and at maximum reproductive capacity.
2 (FDI)	2.7	Fish habitats are good (4) with nursery, connectivity and water quality still at an optimal. All FDI indicator taxa present, but the Perlidae and Heptageniidae are less abundant.
3 (LR)	1.78	Fish spawning, abundance and cover habitat is moderate while rest of habitat is good – optimal. Critical FDI habitat reduced with moderate quality. Most indicator taxa persist at reduced abundances. Leaf wilting/stress commences, but is slight.
4 (LR)	1.375	Fish spawning habitat for both guilds have deteriorated (2.5). Abundance and cover for the SR guild is low (2.5) and moderate (3) for the LR guild while the rest of the habitats for both guilds. Reduced FDI critical habitat and quality. *Phragmites*: Leaf wilting/stress commences, but is slight.
5 (LR)	0.97	Nursery habitat for both guilds is moderate, while the rest of the habitats are low (2). Connectivity for the SR guild is good (4) and moderate – good (3.5) for the LR guild. All life stages of Perlidae, Elmidae and Heptageniidae are viable in limited areas, critical life stages of some sensitive rheophilic species at risk.
6 (LR)	0.69	Nursery habitat is the same as above but the rest of the habitat occurrences have deteriorated (1.5) Critical FDI habitat limited. Critical life-stages of sensitive indicator taxa at risk or non-viable.
7 (LR)	0.5	Fish habitat as above albeit slightly reduced. LS spawning habitat is rare (0.5).
8 (LR)	0.35	LR spawning habitat is absent, while cover and abundance is very rare (0.5). SR spawning habitat is rare while rest of habitat is very low. Elmidae and Heptageniidae persist but at very low numbers. All life stages of most rheophilic taxa at risk or non-viable. Riparian vegetation: Unseasonal thinning or partial mortality of above-ground parts (majority of the plant/s remains viable, but water stressed).

Integrated stress	Flow m^3/s	Habitat and/or Biotic responses
9 (LR)	0.29	Fish habitat as above with a reduction in water quality and connectivity. Critical FDI habitat residual and of low quality. Elmidae and Heptageniidae persist but at very low numbers. All life stages of most rheophilic taxa at risk or non-viable.
10	0	Only pool dwelling species present. Only hyporheic refugia, no surface water. Widespread and complete mortality of population.

* Suitability rating 0 (not suitable) – 5 (highly suitable)

12 EWR 5: MARITE (MARITE RIVER) - DETERMINATION OF EWR SCENARIOS

12.1 ECOCLASSIFICATION SUMMARY OF EWR 5

EWR 5 Marite (Marite River)

EIS: High.
Rare, endangered and unique biota. Species richness high and species intolerant to flow and flow related water quality changes present.
PES: B/C
Increased low flows and landuse activities. Impacts mostly flow related
REC: B
The EIS is high; therefore the REC is an improvement of the PES. More natural distribution of flows required. Reduce grazing and trampling, remove exotic vegetation.
AEC down: C/D
No flow releases for the EWR, less dilution and less floods due to e.g. direct abstraction from the dam. More nutrients and toxics present. Sandier river, some riffles and bedrock areas in the reach will be lost, vegetation encroachment on bars and banks and embedded cobbles. Increased aliens, removal, grazing, trampling.

Driver Components	PES Category	Trend	REC	AEC↓
HYDROLOGY	C			D
WATER QUALITY	B		B	C
GEOMORPHOLOGY	C	Negative	C	D
Response Components	**PES Category**	**Trend**	**REC**	**AEC↓**
FISH	B/C	Negative	B	C/D
MACRO INVERTEBRATES	B/C	Stable	B	C
INSTREAM	B/C		B	C/D
RIPARIAN VEGETATION	B/C	Negative	B	C/D
ECOSTATUS	B/C		B	C/D

12.2 HYDROLOGY

The highest and lowest low flow months selected as the key months are February (wet) and October (dry). The key assurance percentages for which stress requirements had to be set were:

- 95%: Representing droughts for both wet and dry months. This would represent 5% on the stress duration graphs.
- 65%: Representing maintenance flows for both wet and dry months. This would represent 35% on the stress duration graphs.

12.3 LOW FLOW REQUIREMENTS (IN TERMS OF STRESS)

The integrated stress index is used to identify required stress levels at specific durations for the wet and dry month/season. Specialist motivations for the stresses are provided in Appendix F, Section N2.1 - 2.3.

12.3.1 Low flow (in terms of stress) requirements

The fish, macroinvertebrate and riparian vegetation flow requirements for different Ecological Categories (ECs) are provided in Table 12.1, Figure 12-1 and 12-2. The results are plotted for the wet and dry season on stress duration graphs and compared to the DRM low flow estimates for the same range of ECs. The stress requirements (as a ‘hand drawn line’) are illustrated in Figures 12-1 and 12-2.

For easier reference the range of ECs are colour coded in the Tables and Figures:

PES: Green REC: Purple AEC: Yellow

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

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

Duration	LR stress	Integ stress	SR stress	Integ stress	FDI stress	Integ stress	*Phragmites* (Reeds) stress	Integ stress	*B. salicina* (Minger) stress	Integ stress	FINAL* (Integ stress)	FLOW (m^3/s)
PES: B/C EcoStatus				**FISH: B/C**		**MACROINVERTEBRATES: B/C**				**RIP VEG: B/C**		
DRY SEASON												
5%	8.5	8.5	9	9.3	8	9.6	7	9.25	6	8.5	**8.5**	**0.32**
35%	7.5	7.5	7	7	6	7.2	5	6.5	4.5	6.5	**6.5**	**0.6**
WET SEASON												
5%	6.5	6.5	7.5	7.5	6	7.2	5	6.5	5	7	**6.5**	**0.6**
35%	3	3	3	4.1	4	4.9	2	2.5	2	3	**3**	**1.78**
REC: B EcoStatus				**FISH: B**		**MACROINVERTEBRATES: B**				**RIP VEG: B**		
DRY SEASON												
35%	6.5	6.5	5.5	5.8	5	6	Not assessed. Improvements are non-flow related.				**5.8**	**0.75**
WET SEASON												
35%	2	2.8	2.5	2.8	3	4.1	As above.				**2.8**	**1.9**
AEC: C/D EcoStatus				**FISH: C/D**			**MACROINVERTEBRATES: C**			**RIP VEG: C/D**		
DRY SEASON												
35%	8	8	8	9	7	8.9	Not assessed. AEC is related to non-flow related impacts.				**8**	**0.35**
WET SEASON												
35%	4.5	4.5	4.5	5.4	5	6	As above.				**4.5**	**1.2**

* Final refers to the final stress selected as the EWR requirement, usually the lowest integrated stress. In some cases, vegetation was ignored due to the much lower confidence in the requirements.

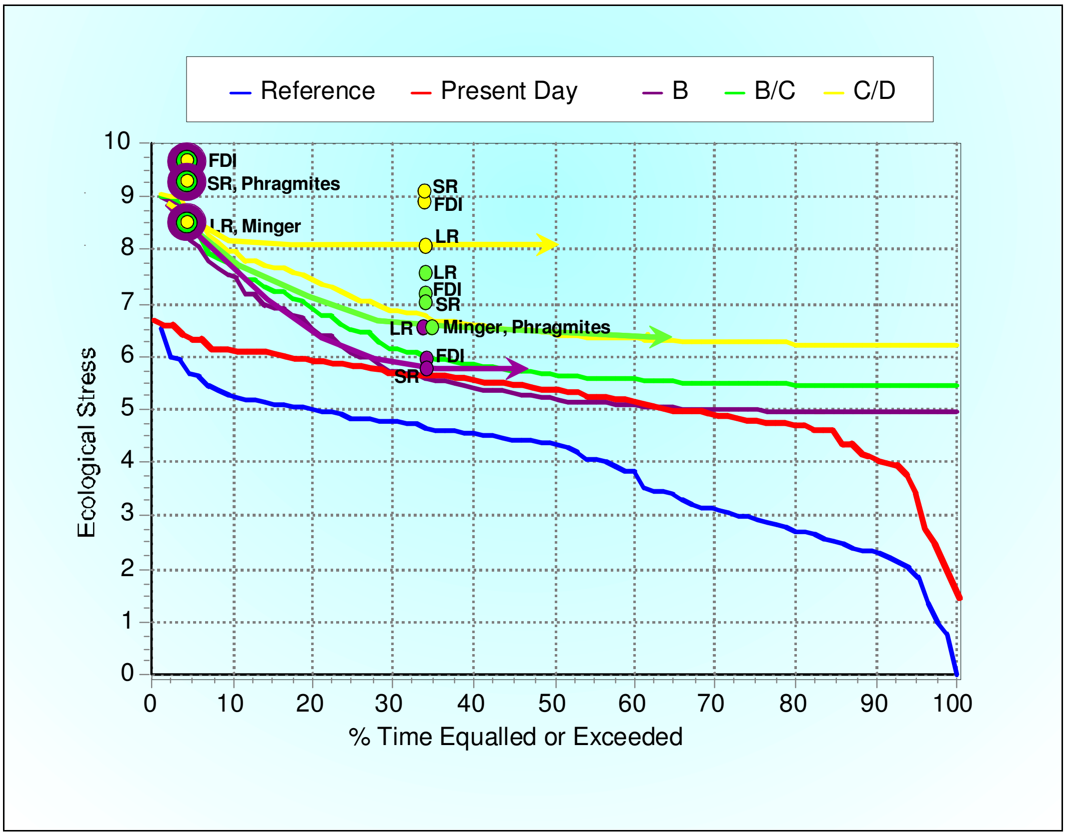

Figure 12–1 EWR 5: Stress duration curve for a B/C PES, B REC and C/D AEC - DRY season

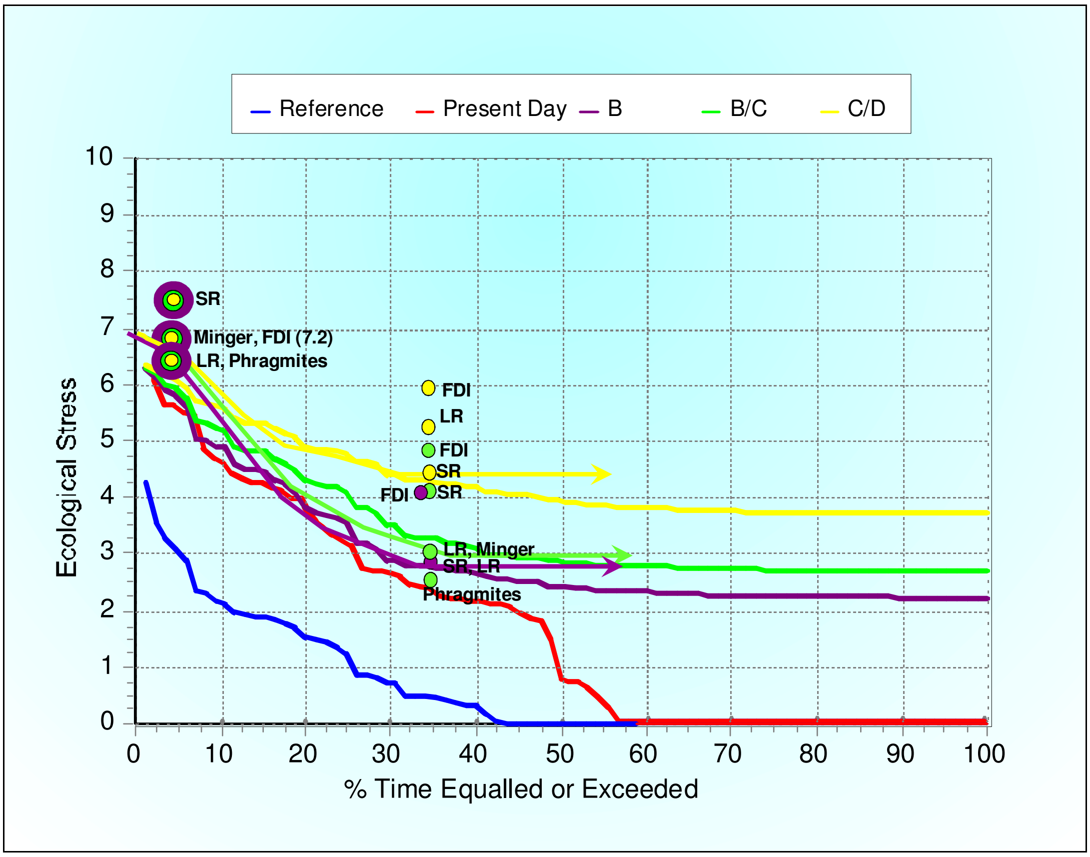

Figure 12–2 EWR 5: Stress duration curve for a B/C PES, B REC and C/D AEC - WET season

Table 12.2 Summary of EWR 5 motivations

Month	% Stress duration	Component stress	Integrated stress	Flow m^3/s	Comment
PES: B/C EcoStatus	**FISH: B/C**	**MACROINVERTEBRATES: B/C**			**RIP VEG: B/C**
Oct	5% drought	8.5 LR	8.5	0.32	Limited critical habitat present to ensure survival of LR guild.
	35% maintenance	4.5 *Breonadia*	6.5	0.6	Leaf wilting/stress commences but is slight, and flower/fruit abortion commences although unlikely to occur in dry season).
Feb	5% drought	6.5 LR	6	0.6	Critical habitat greatly reduced but adequate for spawning.
	35% maintenance	3 LR	3	1.78	Maintenance of critical habitat required for most life stages and biological processes.
REC: B EcoStatus	**FISH: B**	**MACROINVERTEBRATES: B**			**RIP VEG: B**
Oct	5% drought	8.5 LR	8.5	0.32	See PES.
	35% maintenance	5.5 SR	5.8	0.75	Improved habitat and therefore improved abundance and FROC.
Feb	5% drought	6.5 LR	6	0.6	See PES.
	35% maintenance	2 LR	2.8	1.9	Improved spawning and nursery habitat for guild.
AEC: C/D EcoStatus	**FISH: C/D**			**MACROINVERTEBRATES: C**	**RIP VEG: C/D**
Oct	5% drought	8.5 LR	8.5	0.32	See PES.
	35% maintenance	8 LR	8	0.35	Limited critical habitat available and therefore reduced abundance and FROC of guild.
Feb	5% drought	6.5 LR	6	0.6	See PES.
	35% maintenance	4.5 LR	4.5	1.2	Some critical habitat available to maintain life stages at reduced abundance and FROC.

12.3.2 Final low flow requirements

To produce the final results (Figure 12-3), the DRM results for the specific category are modified according to specialists' requirements (Figure 12-1 and 12-2). The following changes were required:

- Seasonal distribution factor changes:
  - B EC: 1.1 for maintenance; 0.57 for drought.
  - B/C EC: 1.5 for maintenance; 0.57 for drought.
  - C/D EC: 1.2 for maintenance; 0.57 for drought.

Dry season (October) **Wet season (February)**

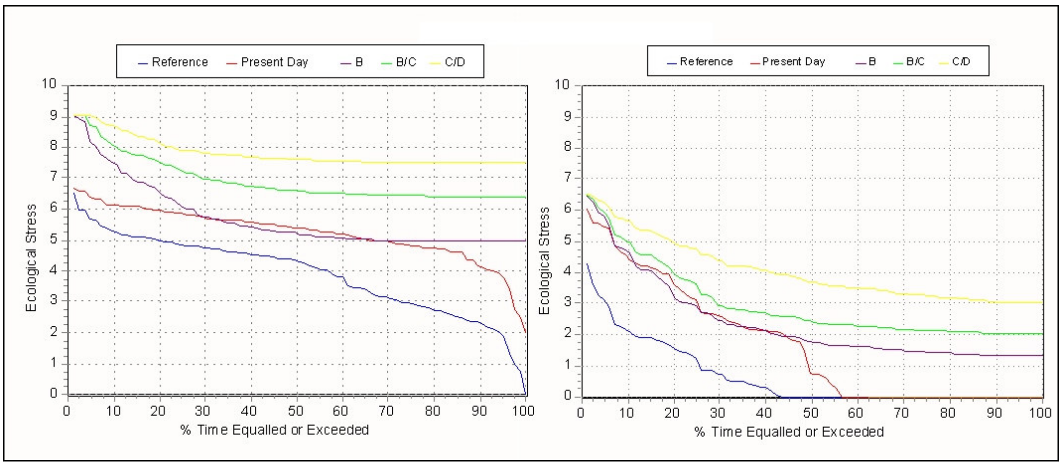

Figure 12–3 EWR 5: Final stress requirements for low flows

12.4 HIGH FLOW REQUIREMENTS

High low classes were identified as outlined in Section 4.4. Results are provided in Table 12.3 and detailed motivations provided in Table 12.4.

Table 12.3 Identification of instream functions addressed by the identified floods for geomorphology and riparian vegetation

FLOOD CLASS	FLOOD RANGE (m^3/s)	GEOMORPHOLOGY AND RIPARIAN VEGETATION MOTIVATION	Fish flood functions							Macroinvertebrate flood functions				
			Migration cues	Migration habitat (depth etc.)	Clean spawning substrate	Create spawning habitat	Create nursery areas	Resetting water quality	Inundate vegetation for spawning	Breeding and hatching cues	Clear fines	Scour substrate	Reach or inundate specific areas	Reset water quality
I	4 - 6	**Geomorphology:** This flow class represents an important component of fines (sand) transport for this site. Maintenance of the transport of sands through the site will prevent excessive bed aggradation and smothering of bedrock/boulders on the bed. It also inundates and activates the lower beach areas on the island. **Vegetation:** Inundates the marginal zone, marginal zone obligates and 30 - 50% of *B. salicina* and *P. mauritianus* populations. Activates *Ishaemum* and *Setaria* grasses and ensures lower level *Syzigium sp* recruit survival.	√	√	√	√	√	√	√	√	√		√	√
II	8 - 18	**Geomorphology:** This flow class is the effective discharge for the fines (sands) at the site; maintaining these flows will, as above, enable the bedrock influence to be maintained in the reach. These flows also inundate most of the island, as well as the seasonal channel. **Vegetation:** Inundates marginal zone and lower portion of the lower zone, *Ludwigia, Persecaria*, *C. dives*, and about 50% of *P. mauritianus, B. salicina* and riparian grasses *(Ishaemum* and *Setaria).* Ensures survival of lower level *S. cordatum* recruits and ensures additional recruitment opportunities. Activates the lower zone terraces and backwaters (channel/pools).	√	√	√	√	√	√	√		√	√	√	√
III	28 - 42	**Geomorphology:** This flow class is the effective discharge for the larger gravels (60 mm) within the reach; maintaining clean bed conditions (and clean gravels within the fast flowing sections). The flow will also scour the seasonal channel and activate the upper ephemeral channel. **Vegetation:** Inundates the majority of the lower zone and floods back channels/pools. Inundates *B. salicina* population and facilitates *Syzigium sp* recruitment in the lower zone. Floods lower zone riparian grasses *(Setaria* and *Ishaemum).*	√	√	√	√	√	√	√					
IV	80 +	**Geomorphology:** This flow class is important for gravels activation and transport, as well as for scouring the upper ephemeral channel and inundating terrace areas at the site. **Vegetation:** Inundates the lower zone and the lower portion of the upper zone. Activates the upper limit of *S. cordatum* and maintains *N. oppositifolia* and *C. erythrophyllum* populations.	√	√	√	√	√	√	√					
V	250 +	**Vegetation:** Activates upper zone terraces. Activates and inundates *C. erythrophyllum* and *T. sericea.*	√	√	√	√	√	√	√					

Further information is provided in Appendix N, Table N10.

The number of high flow events required for each EC is provided in Table 12.4. The high flows were checked, using available daily hydrology.

Table 12.4 EWR 5: The recommended number of high flow events required

FLOOD CLASS	FLOOD RANGE (m^3/s)	INVERTEBRATES	FISH	VEGETATION	GEOMORPHOLOGY	FINAL (No of events)	MONTHS	DAILY AVERAGE (m^3/s)	DURATION (Days)
PES SCENARIO: B/C									
I	4 - 6			4	4	4	Nov, Dec, Feb, Mar	4	3
II	8 - 18			1	2	2	Dec, Jan	8	4
III	28 - 42			1:2	1:2	1:2	Feb	25	5
IV	80 +			1:3	1:5	1:3			
V	250 +			1:5+		1:5			
REC SCENARIO: B									
I	4 - 6			4	5	5	Nov, Dec, Jan, Feb, Mar	4	3
II	8 - 18			1	2	2	Dec, Jan	8	4
III	28 - 42			1:2	1:2	1:2	Feb	25	5
IV	80 +			1:3	1:5	1:3			
V	250 +			1:5+		1:5			
AEC SCENARIO: C/D									
I	4 - 6			3	3	3	Nov, Dec, Mar	4	3
II	8 - 18			1	1	1	Jan	8	4
III	28 - 42			1:2	1:2	1:2	Feb	25	5
IV	80 +			1:3	1:5	1:3			
V	250 +			1:5+		1:5			

12.5 FINAL FLOW REQUIREMENTS

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

- An EWR table, which shows the results of high flows and low flows for each month separately (Table 12.5 – 12.7). Floods with a frequency higher than 1:1 is not included.
- An EWR rule table which provides the recommended EWR flows as a duration table, showing flows which should be provided when linked to a natural trigger (natural modelled hydrology in this case). EWR rules are supplied for total flows as well as for low flows only (Appendix N, Section N2.5).

Table 12.5 EWR table for PES: B/C

Desktop version:		2	Virgin MAR (MCM)	157.094
BFI index	**0.436**	**Distribution type**		**Eastern Escarpment**
MONTH	**LOW FLOWS**		**HIGH FLOWS**	
	Maintenance (m^3/s)	**Drought (m^3/s)**	**Daily average (m^3/s) on top of base flow**	**Duration (days)**
OCTOBER	0.491	0.277		

Desktop version:		2	Virgin MAR (MCM)	157.094
BFI index	**0.436**	**Distribution type**		**Eastern Escarpment**
MONTH	**LOW FLOWS**		**HIGH FLOWS**	
	Maintenance (m^3/s)	**Drought (m^3/s)**	**Daily average (m^3/s) on top of base flow**	**Duration (days)**
NOVEMBER	0.650	0.317	4	3
DECEMBER	0.904	0.366	4 8	3 4
JANUARY	1.247	0.440	8	4
FEBRUARY	1.849	0.587	4 25	3 5
MARCH	1.783	0.555	4	3
APRIL	1.553	0.511		
MAY	1.163	0.422		
JUNE	0.970	0.386		
JULY	0.752	0.333		
AUGUST	0.608	0.302		
SEPTEMBER	0.521	0.290		
TOTAL MCM	32.657	12.537	10.524	
% OF VIRGIN	20.79	7.98	6.70	

Table 12.6 EWR table for REC: B

Desktop version:		2	Virgin MAR (MCM)	157.094
BFI index	**0.436**	**Distribution type**		**Eastern Escarpment**
MONTH	**LOW FLOWS**		**HIGH FLOWS**	
	Maintenance (m^3/s)	**Drought (m^3/s)**	**Daily average (m^3/s) on top of base flow**	**Duration (days)**
OCTOBER	0.826	0.277		
NOVEMBER	1.030	0.317	4	3
DECEMBER	1.336	0.366	4 8	3 4
JANUARY	1.759	0.440	4 8	3 4
FEBRUARY	2.525	0.587	4 25	3 5
MARCH	2.421	0.555	4	3
APRIL	2.143	0.511		
MAY	1.655	0.422		
JUNE	1.424	0.386		
JULY	1.149	0.333		
AUGUST	0.970	0.302		
SEPTEMBER	0.871	0.290		
TOTAL MCM	47.376	12.537	11.157	
% OF VIRGIN	30.16	7.98	7.10	

Table 12.7 EWR table for AEC: C/D

Desktop version:		2	Virgin MAR (MCM)	157.094
BFI index	**0.436**	**Distribution type**		**Eastern Escarpment**
MONTH	**LOW FLOWS**		**HIGH FLOWS**	
	Maintenance (m^3/s)	**Drought (m^3/s)**	**Daily average (m^3/s) on top of base flow**	**Duration (days)**
OCTOBER	0.258	0.277		
NOVEMBER	0.327	0.317	4	3
DECEMBER	0.432	0.366	4	3
JANUARY	0.576	0.440	8	4
FEBRUARY	0.835	0.587	25	5

Desktop version:		2	Virgin MAR (MCM)	157.094
BFI index	**0.436**	**Distribution type**		**Eastern Escarpment**
MONTH	**LOW FLOWS**		**HIGH FLOWS**	
	Maintenance (m^3/s)	**Drought (m^3/s)**	**Daily average (m^3/s) on top of base flow**	**Duration (days)**
MARCH	0.802	0.555	4	3
APRIL	0.706	0.511		
MAY	0.541	0.422		
JUNE	0.461	0.386		
JULY	0.368	0.333		
AUGUST	0.307	0.302		
SEPTEMBER	0.272	0.290		
TOTAL MCM	15.393	12.537	8.437	
% OF VIRGIN	9.80	7.98	5.37	

A comparison between the Desktop Reserve Model estimates and the EWR results in terms of percentages of natural flow are provided in Table 12.8.

Table 12.8 Modifications made to the DRM for EWR 5

Changes	PES B/C		REC B		AEC C/D	
	DRM	**EWR**	**DRM**	**EWR**	**DRM**	**EWR**
MLIFR - Maintenance low flow	21.9%	20.8%	27.4%	30.2%	12.3%	9.8%
DLIFR - Drought low flow	8.5%	8.0%	8.5%	8.0%	8.5%	8.0%
MHIFR - Maintenance high flow	8.5%	6.5%	9.3%	7.1%	7.1%	5.4%
Long-term % of virgin MAR	31.2%	28.2%	36.2%	36.3%	24.9%	19.8%

13 EWR 6: MUTLUMUVI (MUTLUMUVI RIVER) – DETERMINATION OF STRESS INDICES

NOTE: All supporting specialist information for EWR 6 is summarized in Volume 3, Appendix O.

13.1 INDICATOR SPECIES OR GROUP

13.1.1 Fish indicator group 1: Small rheophilic species (CANO)

Chiloglanis anoterus (CANO): See Section 3.1.2 and Appendix J, Table J2.

13.1.2 Fish indicator group 2: Large semi-rheophilic species (BMAR)

Labeobarbus marequensis (BMAR): See Section 7.1.2 and Appendix L, Table L1.

13.1.3 Macroinvertebrate indicator taxa

A number of flow FDI taxa were selected on the basis of their sensitivity to changes in velocity and water quality. Only taxa that occur commonly at the site were selected. The taxa used were the:

- Caddisfly family: Hydropsychidae also preferring velocities between 0.3 and 0.6 m/s.
- Mayfly family: Heptageniidae – Refer to Section 5.1.3.

13.1.4 Riparian vegetation indicator species

Two indicator species was selected:

- *Breonadia salicina:* See Section 5.1.4.
- *Phragmites mauritianus:* See Section 3.1.4.

13.2 STRESS FLOW INDEX

The stress flow index is generated in terms of habitat and biotic response and is discussed below.

13.2.1 Habitat response

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

- 0 – Optimum habitat (fixed at the natural maximum base flow – calculated using the wettest flow month discharge at the maintenance percentage of 60% for the Mutlumuvi River at the EWR site).
- 10 - No flow (although there may still be surface water in pools).

The abundance of fish velocity-depth classes are provided in Appendix O, Table O1.

The instantaneous response of FDI taxa provides the % occurrence of various velocity-substrate classes under different flow conditions are provided in Appendix O, Table O3).

13.2.2 Biota response

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

The fish species response index is calculated using the fish habitat rating (cf Section 3.2.1) (Appendix O, Table O2) for each of the discharges evaluated for assessing habitat response. The FDI index is derived by considering the habitat response and % occurrence of habitat conditions at different flows. The FDI responses are described and coupled to a stress level (Appendix O, Table O4).

A riparian vegetation stress index is also provided (Appendix O, Table O5).

13.2.3 Integrated stress curve

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

The shaded species stress discharges in Table 13.1 indicate the discharge evaluated by specialists to determine the biota stress. The values that are not shaded are interpolated. The highest discharge representing a specific stress is used to define the integrated stress curve. Figure 13-1 illustrates this graphically.

Table 13.1 Species stress discharges used to determine biotic stress

Stress	Flow (m^3/s)					Integrated Flow (m^3/s)
	SR	LSR	FDI	Minger *Breonadia*	Reed *Phragmites*	
0	1.14	1.14	1.14	1.6	1.04	1.6
1	0.985	0.83	1.04	1.25	0.847	1.25
2	0.83	0.73	0.93	0.9	0.653	0.93
3	0.73	0.685	0.83	0.55	0.46	0.83
4	0.64	0.64	0.78	0.42	0.34	0.78
5	0.595	0.46	0.73	0.29	0.22	0.73
6	0.55	0.38	0.64	0.16	0.1	0.64
7	0.46	0.3	0.3	0.08	0.056	0.46
8	0.38	0.16	0.05	0	0.012	0.38
9	0.163	0.05	0.012	0	0.007	0.163
10	0	0	0	0	0	0

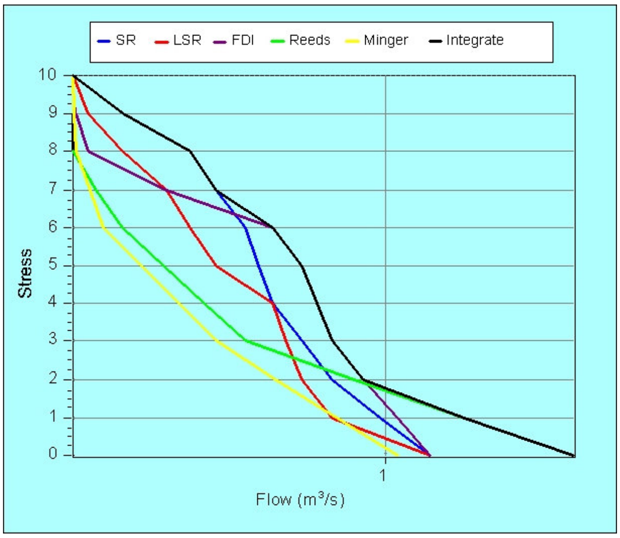

Figure 13–1 Component and integrated stress curves for EWR 6

Table 13.2 provides the summarised biotic response for the integrated stresses.

Table 13.2 Integrated stress and summarised habitat/biotic responses

Integrated stress	Flow m^3/s	Habitat and/or Biotic responses
0 (Minger)	1.6	Fish guild habitats are at an optimum (5*). All FDI habitat in excess. Taxa abundant. *Phragmites* adults with full vigour and at maximum reproductive capacity.
1 (Minger)	1.25	Fish guilds as above. FDI taxa as above.
2 (Minger)	0.93	Fish as above. Critical FDI habitat sufficient. All indicator taxa present, but Hydropsychidae and Heptageniidae are less abundant.
3 (FDI)	0.83	Fish habitat is good with optimal water quality. Reduced FDI critical habitat and quality. Leaf wilting/stress commences, but is slight. All indicator taxa present, but Heptageniidae and Hydropsychidae are much less abundant.
4 (FDI)	0.78	All life stages of Heptageniidae and Hydropsychidae are viable in limited areas, critical life stages of some sensitive rheophilic species at risk.
5 (FDI)	0.73	SR guild: Moderate habitat with good connectivity and water quality. LSR guild spawning habitat is low (2.5) with other habitats good. Critical FDI habitat limited. Critical life-stages of sensitive indicator taxa at risk or non-viable.
6 (FDI)	0.64	SR guild: Low (2.5) habitat with moderate connectivity and good water quality. LSR guild: Low spawning habitat with good nursery habitat and water quality and other habitat occurrences moderate. Critical habitat very reduced. Heptageniidae and Hydropsychidae occur in very low numbers, critical stages of sensitive rheophilic species non-viable, and at risk for some less sensitive species.
7 (SR)	0.46	SR guild: Spawning habitat rare (0.5), other habitat very low and moderate connectivity and water quality. LSR guild: Spawning habitat is rare, while nursery habitat and water quality is moderate and the rest of the habitat very low (1.5). Critical FDI habitat residual. *Breonadia*: Leaf wilting/stress commences, but is slight.
8 (SR)	0.38	Spawning habitat for both guilds is absent. LSR habitat is low (2.5) while nursery habitat is rare for SR guild and other habitats are low – very low (1 – 2). Critical FDI habitat absent. Heptageniidae and Hydropsychidae persist but at very low numbers. All life stages of most rheophilic taxa at risk or non-viable. Riparian vegetation: Unseasonal thinning or partial mortality of above-ground parts (majority of the plant/s remains viable, but water stressed).
9 (SR)	0.163	SR spawning and nursery habitat absent while rest of habitat is very low. LSR spawning habitat is absent and rest of habitat is very low. *Breonadia*: Unseasonal thinning or partial mortality of above-ground parts (majority of the plant/s remains viable, but water stressed).
10	0	Spawning habitat is absent while other habitat is very rare (0.5). Standing water only. Indicator taxa no longer present. Inverts: Widespread and complete mortality of population.

* Suitability rating 0 (not suitable) – 5 (highly suitable)

14 EWR 6: MUTLUMUVI (MUTLUMUVI RIVER) - DETERMINATION OF EWR SCENARIOS

14.1 ECOCLASSIFICATION SUMMARY OF EWR 6

EWR 6 Mutlumuvi (Mutlumuvi River)

EIS: High
Rare, endangered and unique biota. Taxon species richness high and species intolerant to flow and flow related water quality changes present.
PES: C
Abstraction, forestry, informal settlements and landuse activities. Impacts flow and non-flow related.
REC: B
The EIS is high and improvement requires improved system operation which improves the low flow regime.
AEC down: C/D
Decreased low flows and longer periods of zero flows. Increased algal growth. Less moderate floods will cause some impact on sedimentation. The reedbeds will become less dense and Matumi will disappear.

Driver Components	PES Category	Trend	REC	AEC↓
HYDROLOGY	C			
WATER QUALITY	B/C		B	C/D
GEOMORPHOLOGY	C	Stable	C	D
Response Components	**PES Category**	**Trend**	**AEC ↑**	**AEC↓**
FISH	C	Stable	B	D
MACRO INVERTEBRATES	B/C	Negative	B	C
INSTREAM	C		B	C/D
RIPARIAN VEGETATION	C	Negative	B	D
ECOSTATUS	C		B	C/D

14.2 HYDROLOGY

The highest and lowest low flow months selected as the key months are February (wet) and October (dry). The key assurance percentages for which stress requirements had to be set were:

- 95%: Representing droughts for both wet and dry months. This would represent 5% on the stress duration graphs.
- 40%: Representing maintenance flows for both wet and dry months. This would represent 60% on the stress duration graphs.

14.3 LOW FLOW REQUIREMENTS (IN TERMS OF STRESS)

Hydrology provided for the Sand catchment is extremely unreliable due to the lack of gauges and information in the system. Only one gauge in the lower Sand River is functional. The operation of local small weirs, dams and irrigation canals is also not clear. This resulted in the hydrology being changed based on some anecdotal information, and some of it after the EWR workshop, resulting in many EWRs having to be re-evaluated.

The integrated stress index is used to identify required stress levels at specific durations for the wet and dry month/season. Specialist motivations for the stresses are provided in Appendix O, Section O2.1 – 2.3.

14.3.1 Low flow (in terms of stress) requirements

The fish, macroinvertebrate and riparian vegetation flow requirements for different Ecological Categories (ECs) are provided in Table 14.1, Figure 14-1 and 14-2. The results are plotted for the Wet and Dry Season on stress duration graphs and compared to the DRM low flow estimates for the same range of ECs. The stress requirements (as a ‘hand drawn line’) are illustrated in Figures 14-1 and 14-2.

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

Summarised motivations for the final requirements are provided in Table 14.2.

Table 14.1 Species and integrates stress requirements as well as the final integrated stress and flow requirement

Duration	SR stress	Integ stress	LSR stress	Integ stress	FDI stress	Integ stress	*B. salicina* (Minger) stress	Integ stress	*Phragmites* (Reeds) stress	Integ stress	FINAL* (Integ stress)	FLOW (m^3/s)
PES: C EcoStatus				**FISH: C**		**MACROINVERTEBRATES: B/C**					**RIP VEG: C**	
						DRY SEASON						
5%	10	10	10	10	9	9.9	6	9.5	7	9.5	**10**	**0**
60%	9	9	8	9	8	9.6	5	8.75	5.5	8.75	**9**	**0.163**
						WET SEASON						
5%	8	8	7	8.5	8	9.6	5.5	8.75	5	8.75	**8**	**0.38**
60%	3.5	5.5	3	5.5	6	6	2	6	2.5	4.7	**5.5**	**0.685**
REC: B EcoStatus				**FISH: B**		**MACROINVERTEBRATES: B**					**RIP VEG: B**	
						DRY SEASON						
5%	9.5	9.5	9.9	9.9	9	9.9	Not assessed. Improvements are based on non related flow issues.				**9.5**	**0.082**
60%	8.5	8.5	7	8.5	7.5	9					**8.5**	**0.27**
						WET SEASON						
60%	2	3	2	5	5	5	As above.				**3**	**0.83**
AEC: C/D EcoStatus				**FISH: C/D**			**MACROINVERTEBRATES: C**				**RIP VEG: C/D**	
						DRY SEASON						
60%	9.5	9.5	8.5	9.5	8.5	9.75	6	9.5	6.5	9.25	**9.5**	**0.082**
						WET SEASON						
60%	5	6.2	5	7	7	8.4	3.5	7.5	3.5	7	**6.2**	**0.622**

* Final refers to the final stress selected as the EWR requirement, usually the lowest integrated stress. In some cases, vegetation was ignored due to the much lower confidence in the requirements.

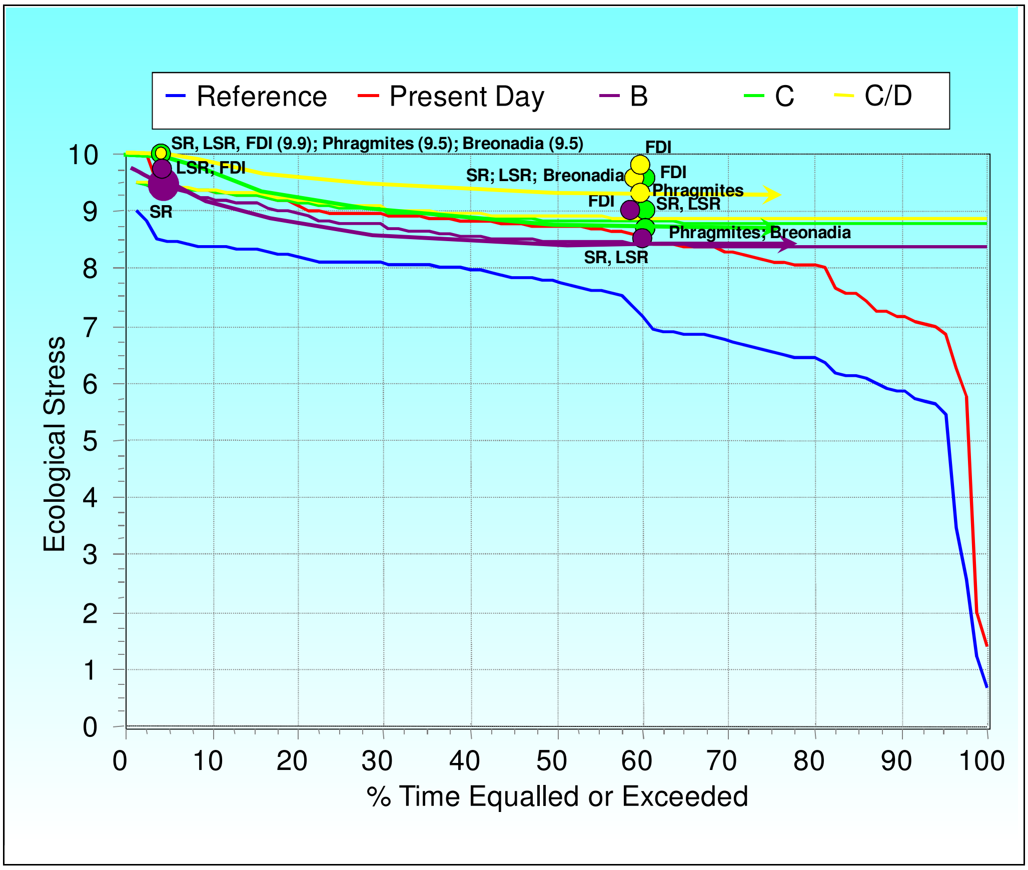

Figure 14–1 EWR 6: Stress duration curve for a C PES, B REC and C/D AEC - DRY season

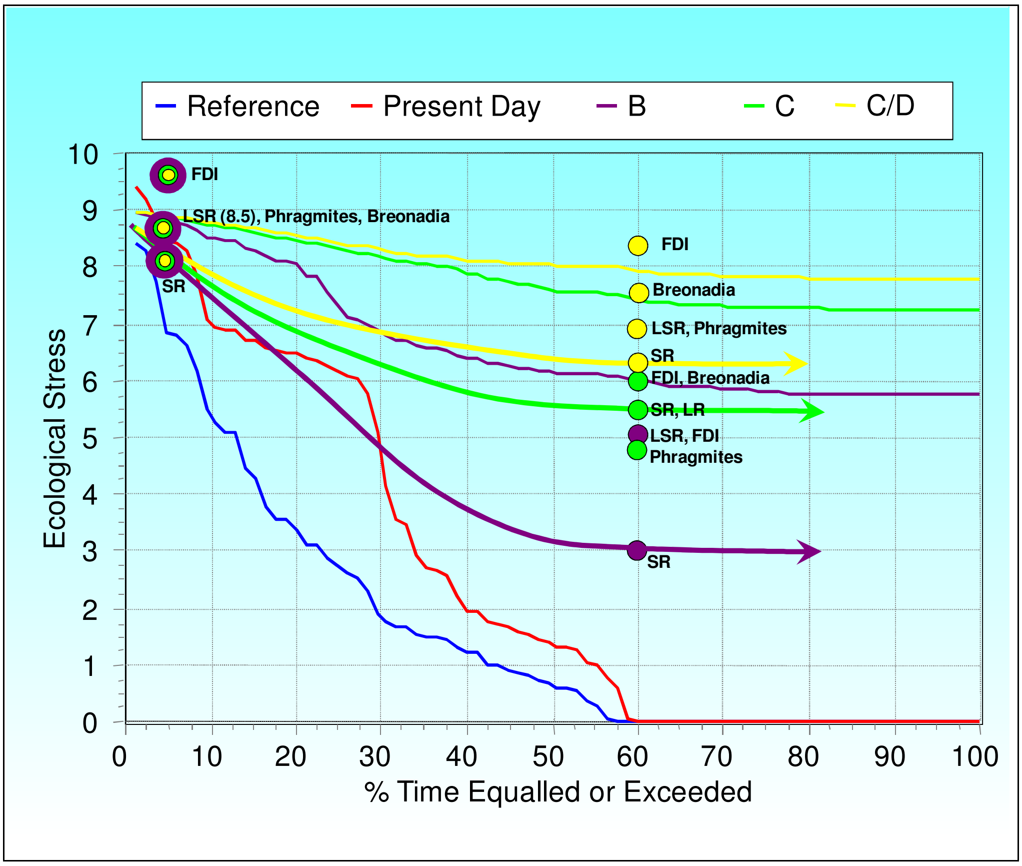

Figure 14–2 EWR 6: Stress duration curve for a C PES, B REC and C/D AEC - WET season

Table 14.2 Summary of EWR 6 motivations

Month	% Stress duration	Component stress	Integrated stress	Flow m³/s	Comment
PES: C EcoStatus	**FISH: C**		**MACROINVERTEBRATES: B/C**		**RIP VEG: C**
Oct	5% - drought	10 SR	10	0	Prolonged periods of zero flows. Guild however still survives and seeks refuge upstream where perennial flow is present. PES will be maintained if connectivity and wet season flows are ensured.
	60% maintenance	9 SR	9	0.163	Adequate habitats available for the survival of the guild although fast habitats are absent.
Feb	5% - drought	8 SR	8	0.38	Critical habitat greatly reduced but adequate for spawning. Refuge in tributaries if spawning not possible.
	60% maintenance	3 SR	5.5	0.685	Maintenance of critical habitat required for most life stages and biological processes.
REC: B EcoStatus	**FISH: B**		**MACROINVERTEBRATES: B**		**RIP VEG: B**
Oct	5% - drought	9.5 SR	9.5	0.082	Guild survives and seeks refuge upstream where perennial flow is present.
	60% - maintenance	8.5 SR	8.5	0.27	Improved habitat and therefore improved abundance and FROC.
Feb	5% - drought	8 SR	8	0.38	See PES.
	60% maintenance	3 SR	3	0.83	Improved spawning and nursery habitat for guild.
AEC: C/D EcoStatus	**FISH: D**		**MACROINVERTEBRATES: C/D**		**RIP VEG: D**
Oct	5% - drought	10 SR	10	0	See PES.
	60% - maintenance	9.5 SR	9.5	0.082	Limited habitat available for guild. However, the guild will be highly stressed and may be eradicated from reach.
Feb	5% - drought	8 SR	8	0.38	See PES.
	60% maintenance	5 SR	6.2	0.622	Some fast habitat available but more reduced than PES. Abundance and FROC will reduce.

14.3.2 Final low flow requirements

To produce the final results (Figure 14-3), the DRM results for the specific category are modified according to specialists' requirements (Figure 14-1 and 14-2). The following changes were required:

- Seasonal distribution factor changes:
  - B EC: 0.97 for maintenance; 1.65 for drought.
  - C EC: 1.2 for maintenance; 1.65 for drought.
  - C/D EC: 2.6 for maintenance; 1.65 for drought.
- Seasonal distribution changes revisions based on manual adjustments

Dry season (October) **Wet season (February)**

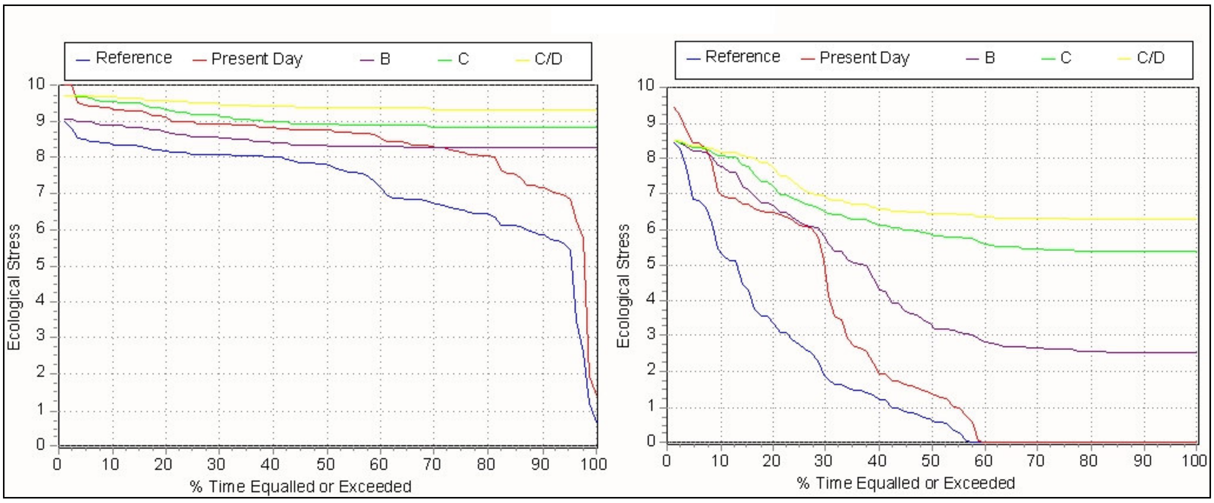

Figure 14–3 EWR 6: Final stress requirements for low flows

14.4 HIGH FLOW REQUIREMENTS

High low classes were identified as outlined in Section 4.4. Results are provided in Table 14.3 and detailed motivations provided in Table 14.4.

Table 14.3 Identification of instream functions addressed by the identified floods for geomorphology and riparian vegetation

FLOOD CLASS	FLOOD RANGE (m^3/s)	GEOMORPHOLOGY AND RIPARIAN VEGETATION MOTIVATION	Fish flood functions							Macroinvertebrate flood functions				
			Migration cues	Migration habitat (depth etc)	Clean spawning substrate	Create spawning habitat	Create nursery areas	Resetting water quality	Inundate vegetation for spawning	Breeding and hatching cues	Clear fines	Scour substrate	Reach or inundate specific areas	Reset water quality
I	1.6 - 2.5	**Geomorphology:** This flow class will scour fines (sand) from the beds of the two main active channels, as well as activate the seasonal channel. **Vegetation:** Inundates the marginal zone. Inundates *B. salicina* and facilitates their recruitment. Inundates 50 - 60% reedbeds, *Setaria, Cyperus* species and about half the population of *S. mucronata*. Activates seasonal channels.	√	√	√	√	√	√	√	√	√		√	√
II	10 - 12	**Geomorphology:** This flow class will inundate the island and lateral bar areas; as well as scour the active and seasonal channels. These flows would also initiate gravel and small cobble movement, preventing embeddedness. **Vegetation:** Inundates marginal zone and lower half of lower zone and seasonal channels. Inundates large proportion of *P. mauritianus* and all marginal zone riparian obligates.	√	√	√	√	√	√	√		√	√	√	√
III	16 - 30	**Vegetation:** Inundates the lower zone and floods seasonal channels and backwaters. Inundates *S. cordatum, B. salicina, S. mucronata, C. dives* and *P. mauritianus.*	√	√	√	√	√	√	√					

FLOOD CLASS	FLOOD RANGE (m^3/s)	GEOMORPHOLOGY AND RIPARIAN VEGETATION MOTIVATION	Fish flood functions							Macroinvertebrate flood functions				
			Migration cues	Migration habitat (depth etc)	Clean spawning substrate	Create spawning habitat	Create nursery areas	Resetting water quality	Inundate vegetation for spawning	Breeding and hatching cues	Clear fines	Scour substrate	Reach or inundate specific areas	Reset water quality
IV	50 +	**Geomorphology:** These floods would transport most of the gravels and small cobbles through the reach. **Vegetation:** Activates upper zone terrace and inundates lower portion of the upper zone. Maintains *C. erythrophyllum* and *D. mespiliformis* populations.	√	√	√	√	√	√	√					
V	190 +	**Vegetation:** Inundates major portion of upper zone and *D. mespiliformis.*	√	√	√	√	√	√	√					

Further information is provided in Appendix O, Table O10.

The number of high flow events required for each EC is provided in Table 14.4. The high flows were checked, using available daily hydrology.

Table 14.4 EWR 6: The recommended number of high flow events required

FLOOD CLASS	FLOOD RANGE (m^3/s)	INVERTEBRATES	FISH	VEGETATION	GEOMORPHOLOGY	FINAL (No of events)	MONTHS	DAILY AVERAGE (m^3/s)	DURATION (Days)
PES SCENARIO: C									
I	1.6 - 2.5			4	3	4	Nov, Dec, Jan, Mar	1.6	3
II	10 - 12			1	1	1	Feb	10	4
III	16 - 30			1:2		1:2			
IV	50 +			1:3	1:3	1:3			
V	190 +			1:5+		1:5			
REC SCENARIO: B									
I	1.6 - 2.5			4	4	4	Nov, Dec, Jan, Mar	1.6	3
II	10 - 12			1	1	1		10	4
III	16 - 30			1:2		1:2			
IV	50 +			1:3	1:3	1:3			
V	190 +			1:5+		1:5			
AEC SCENARIO: C/D									
I	1.6 - 2.5			3	2	3	Nov, Dec, Mar	1.6	3
II	10 - 12			1	1	1	Feb	10	4
III	16 - 30			1:2		1:2			
IV	50 +			1:3	1:3	1:3			
V	190 +			1:5+		1:5			

14.5 FINAL FLOW REQUIREMENTS

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

- An EWR table, which shows the results of high flows and low flows for each month separately (Table 14.5 – 14.7). Floods with a frequency higher than 1:1 is not included.
- An EWR rule table which provides the recommended EWR flows as a duration table, showing flows which should be provided when linked to a natural trigger (natural modelled hydrology in this case). EWR rules are supplied for total flows as well as for low flows only (Appendix O, Section O2.5).

Table 14.5 EWR table for PES: C

Desktop version:		2	Virgin MAR (MCM)	45.007
BFI index	0.473	Distribution type		Eastern Escarpment
MONTH	LOW FLOWS		HIGH FLOWS	
	Maintenance (m^3/s)	Drought (m^3/s)	Daily average (m^3/s) on top of base flow	Duration (days)
OCTOBER	0.140	0.040		
NOVEMBER	0.180	0.070	1.6	3
DECEMBER	0.260	0.110	1.6	3
JANUARY	0.370	0.160	1.6	3
FEBRUARY	0.520	0.260	10	4
MARCH	0.500	0.270	1.6	3
APRIL	0.450	0.240		
MAY	0.370	0.180		
JUNE	0.330	0.160		
JULY	0.280	0.120		
AUGUST	0.240	0.100		
SEPTEMBER	0.180	0.070		
TOTAL MCM	9.998	4.654	2.810	
% OF VIRGIN	22.21	10.34	6.24	

Table 14.6 EWR table for REC: B

Desktop version:		2	Virgin MAR (MCM)	45.007
BFI index	0.473	Distribution type		Eastern Escarpment
MONTH	LOW FLOWS		HIGH FLOWS	
	Maintenance (m^3/s)	Drought (m^3/s)	Daily average (m^3/s) on top of base flow	Duration (days)
OCTOBER	0.270	0.150		
NOVEMBER	0.300	0.160	1.6	3
DECEMBER	0.280	0.170	1.6	3
JANUARY	0.510	0.190	1.6	3
FEBRUARY	0.740	0.272		
MARCH	0.733	0.271	1.6	3
APRIL	0.660	0.243		
MAY	0.520	0.185		
JUNE	0.460	0.175		
JULY	0.420	0.170		
AUGUST	0.350	0.160		
SEPTEMBER	0.300	0.150		
TOTAL MCM	14.506	6.016	2.810	
% OF VIRGIN	32.23	13.37	6.24	

Table 14.7 EWR table for AEC: C/D

Desktop version:		2	Virgin MAR (MCM)	45.007
BFI index	0.473	Distribution type		Eastern Escarpment
MONTH	LOW FLOWS		HIGH FLOWS	
	Maint[1] (m^3/s)	Drought (m^3/s)	Daily average (m^3/s) on top of base flow	Duration (days)
OCTOBER	0.065	0.040		
NOVEMBER	0.080	0.070	1.6	3
DECEMBER	0.120	0.110	1.6	3
JANUARY	0.240	0.160		
FEBRUARY	0.370	0.260	10	4
MARCH	0.360	0.270	1.6	3
APRIL	0.320	0.240		
MAY	0.260	0.180		
JUNE	0.210	0.160		
JULY	0.160	0.120		
AUGUST	0.120	0.100		
SEPTEMBER	0.080	0.070		
TOTAL MCM	6.232	4.654	2.561	
% OF VIRGIN	13.85	10.34	5.69	

A comparison between the Desktop Reserve Model estimates and the EWR results in terms of percentages of natural flow are provided in Table 14.8.

Table 14.8 Modifications made to the DRM for EWR 6

Changes	PES C		REC B		AEC C/D	
	DRM	EWR	DRM	EWR	DRM	EWR
MLIFR - Maintenance low flow	15.5%	22.2%	26.7%	32.2%	12.0%	13.8%
DLIFR - Drought low flow	8.2%	10.3%	8.2%	13.4%	8.2%	10.3%
MHIFR - Maintenance high flow	8.0%	6.3%	9.5%	6.3%	7.3%	5.7%
Long-term % of virgin MAR	26.6%	32.4%	35.8%	38.6%	24.6%	25.7%

15 EWR 7: THULANDZITEKA (THULANDZITEKA RIVER) – DETERMINATION OF STRESS INDICES

NOTE: All supporting specialist information for EWR 7 is summarized in Volume 3, Appendix P.

15.1 INDICATOR SPECIES OR GROUP

15.1.1 Fish indicator group 1: Small rheophilic species (CANO)

Chiloglanis anoterus (CANO): See Section 3.1.2 and Appendix J, Table J2.

15.1.2 Fish indicator group 2: Large semi-rheophilic species (BMAR)

Labeobarbus marequensis (BMAR): See Section 7.1.2 and Appendix L, Table L1.

15.1.3 Macroinvertebrate indicator taxa

Perlidae, Heptageniidae and Elmidae were selected as indicator FDI taxa. Refer to Section 5.1.3.

15.1.4 Riparian vegetation indicator species

One indicator species was selected:

- *Phragmites mauritianus:* See Section 3.1.4.

15.2 STRESS FLOW INDEX

The stress flow index is generated in terms of habitat and biotic response and is discussed below.

15.2.1 Habitat response

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

- 0 – Optimum habitat (fixed at the natural maximum base flow – calculated using the wettest flow month discharge at the maintenance percentage of 60% for the Tlulandziteka River at the EWR site).
- 10 - No flow (although there may still be surface water in pools).

The abundance of fish velocity-depth classes are provided in Appendix P, Table P1.

The instantaneous response of FDI taxa provides the % occurrence of various velocity-substrate classes under different flow conditions are provided in Appendix P, Table P3)..

15.2.2 Biota response

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

The fish species response index is calculated using the fish habitat rating (cf Section 3.2.1) (Appendix P, Table P2) for each of the discharges evaluated for assessing habitat response. The FDI index is derived by considering the habitat response and % occurrence of habitat conditions at different flows. The FDI responses are described and coupled to a stress level (Appendix P, Table P4).

A riparian vegetation stress index is also provided (Appendix P, Table P5).

15.2.3 Integrated stress curve

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

The shaded species stress discharges in Table 15.1 indicate the discharge evaluated by specialists to determine the biota stress. The values that are not shaded are interpolated. The highest discharge representing a specific stress is used to define the integrated stress curve. Figure 15-1 illustrates this graphically.

Table 15.1 Species stress discharges used to determine biotic stress

Stress	Flow (m^3/s)				Integrated Flow (m^3/s)
	SR	LSR	FDI	Reed *Phragmites*	
0	0.683	0.68	0.5	0.7	0.7
1	0.5	0.5	0.36	0.523	0.523
2	0.43	0.43	0.29	0.347	0.43
3	0.36	0.395	0.24	0.17	0.395
4	0.24	0.36	0.15	0.123	0.36
5	0.19	0.24	0.083	0.077	0.24
6	0.17	0.19	0.044	0.03	0.19
7	0.15	0.15	0.013	0.015	0.15
8	0.11	0.07	0.006	0	0.11
9	0.07	0.04	0.002	0	0.07
10	0	0	0	0	0

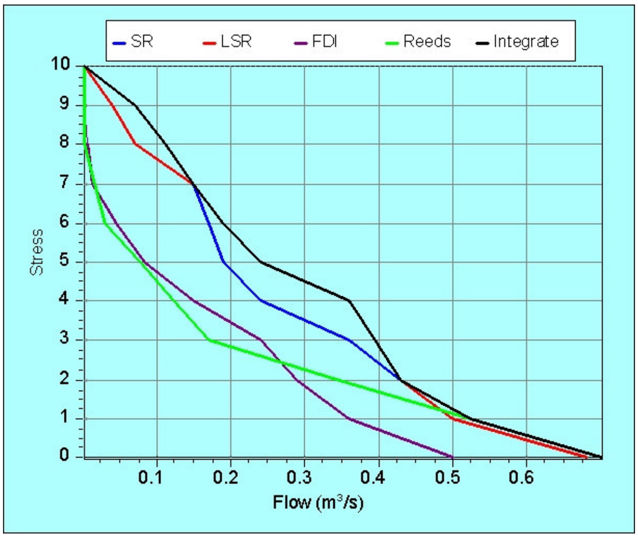

Figure 15–1 Component and integrated stress curves for EWR 7

Table 15.2 provides the summarised biotic response for the integrated stresses.

Table 15.2 Integrated stress and summarised habitat/biotic responses

Integrated stress	Flow m^3/s	Habitat and/or Biotic responses
0 (Reeds)	0.7	Fish guild habitats are at an optimum (5*). All FDI habitat in excess. Taxa abundant. *Phragmites* adults with full vigour and at maximum reproductive capacity.
1 (Reeds)	0.523	FDI habitat plentiful. Taxa abundant.
2 (SR)	0.43	SR spawning, cover and abundance is moderate and other habitat is good. LSR guild: Spawning habitat is moderate while rest of habitat is good.
3 (LR)	0.395	SR guild as above with a slight reduction in all habitat occurrences. LSR spawning and connectivity habitat is low with good abundance and cover and moderate nursery habitat and water quality.
4 (LR)	0.36	Fish guilds as above. Critical FDI habitat sufficient. All indicator taxa present, but the Perlidae are less abundant.
5 (LR)	0.24	SR nursery, water quality and connectivity habitat is moderate while rest of habitat is low. LSR spawning habitat is very low, connectivity low and the rest of the habitat is moderate. Reduced FDI critical habitat. All indicator taxa present, but the Perlidae, Heptageniidae and Elmidae are less abundant.
6 (LR)	0.19	SR guild: Spawning habitat is very low (1) with a slight reduction in rest of habitat occurrences. LSR guild: Spawning habitat is very rare (0.5) with rest of habitat in low occurrence. Leaf wilting/stress commences, but is slight. Up to 80 cm rooting depth for upper limit, lower limit at water level on average.
7 (LR)	0.15	SR spawning habitat is very rare and absent for LSR guild. LSR habitat is generally low while SR habitat is very low. Critical FDI habitat limited and of moderate quality. Riparian vegetation as above.
8 (SR)	0.11	Spawning habitat for both guilds are absent, while rest of habitat is very low. No critical FDI habitat present. Perlidae, Elmidae and Heptageniidae persist but at very low numbers. All life stages of most rheophilic taxa at risk or non-viable.
9 (SR)	0.07	Fish habitat is as above but with a reduction in all habitat occurrences. Unseasonal thinning or partial mortality of above-ground parts (majority of the plant/s remains viable, but water stressed).
10	0	Only pool dwelling species present. Standing water only. Indicator taxa no longer present. Widespread and complete mortality of population.

* Suitability rating 0 (not suitable) – 5 (highly suitable)

16 EWR 7: THULANDZITEKA (THULANDZITEKA RIVER) - DETERMINATION OF EWR SCENARIOS

16.1 ECOCLASSIFICATION SUMMARY OF EWR 7

EWR 7 Tlulandziteka (Tlulandziteka River)

EIS: Moderate
Rare and endangered species, high taxon richness, species intolerant to flow and flow related water quality changes.
PES: C
Forestry, abstraction, flow modification and poor landuse management. Impacts flow and non-flow related.
REC: C
Due to the moderate EIS, the REC = the PES.
AEC Up: B
Improved flows through fixing of canals, rehabilitation of forestry areas and improved management of canal system and landuse. Remove exotic vegetation, minimise agricultural disturbance and remove unused orchards.
AEC Down: D
Increased use of the dam with less spills, i.e. less floods. More abstraction and forestry. Nutrients, temperature, oxygen, and turbidity levels will change. Increase in bed height, more subsurface flows and sediment with resulting decrease in riffles and shallower pools. More reeds, alien vegetation and more removal.

Driver Components	PES & REC Category	Trend	AEC ↑	AEC↓
HYDROLOGY	A?			D
WATER QUALITY	C		B	D
GEOMORPHOLOGY	C/D	Stable	C	D
Response Components	**PES &REC Category**	**Trend**	**AEC ↑**	**AEC↓**
FISH	C	Stable	B	D
MACRO INVERTEBRATES	B/C	Negative	B	C/D
INSTREAM	C		B	D
RIPARIAN VEGETATION	C	Negative	B	D
ECOSTATUS	C		B	D

16.2 HYDROLOGY

The highest and lowest low flow months selected as the key months are February (wet) and October (dry). The key assurance percentages for which stress requirements had to be set were:

- 95%: Representing droughts for both wet and dry months. This would represent 5% on the stress duration graphs.
- 40%: Representing maintenance flows for both wet and dry months. This would represent 60% on the stress duration graphs.

16.3 LOW FLOW REQUIREMENTS (IN TERMS OF STRESS)

Hydrology provided for the Sand catchment is extremely unreliable due to the lack of gauges and information in the system. Only one gauge in the lower Sand River is functional. The operation of local small weirs, dams and irrigation canals is also not clear. This resulted in the hydrology being changed based on some anecdotal information, and some of it after the EWR workshop, resulting in many EWRs having to be re-evaluated.

The integrated stress index is used to identify required stress levels at specific durations for the wet and dry month/season. Specialist motivations for the stresses are provided in Appendix P, Section P2.1 – 2.3.

16.3.1 Low flow (in terms of stress) requirements

The fish, macroinvertebrate and riparian vegetation flow requirements for different Ecological Categories (ECs) are provided in Table 16.1, Figure 16-1 and 16-2. The results are plotted for the Wet and Dry Season on stress duration graphs and compared to the DRM low flow estimates for the same range of ECs. The stress requirements (as a 'hand drawn line') are illustrated in Figures 16-1 and 16-2.

For easier reference the range of ECs are colour coded in the Tables and Figures:

PES and REC: Green AEC up: Purple AEC down: Yellow

Summarised motivations for the final requirements are provided in Table 16.2.

Table 16.1 Species and integrates stress requirements as well as the final integrated stress and flow requirement

Duration	SR stress	Integ stress	LSR stress	Integ stress	FDI stress	Integ stress	*Phragmites* (Reeds) stress	Integ stress	FINAL* (Integ stress)	FLOW (m^3/s)
PES and REC: C EcoStatus			**FISH: C**		**MACROINVERTEBRATES: B/C**				**RIP VEG: C**	
					DRY SEASON					
5%	10	10	10	10	10	10	7	9.75	**10**	**0**
60%	8.5	8.5	7[1]	7[1]	5	8.5	5	8.75	**8.5**	**0.09**
					WET SEASON					
5%	7	7	6	6	6	9.2	5	8.75	**6**	**0.19**
60%	3.5	4.5	4	4	3	5	2	4.5	**4**	**0.36**
AEC up: B EcoStatus			**FISH: B**		**MACROINVERTEBRATES: B**				**RIP VEG: B**	
					DRY SEASON					
5%	8.5	8.5[2]	8.5	9.3	6	9.2	Not assessed. Improvements are non-flow related.		**9.3**	**0.05**
60%	5	6	6	6	4	7			**7**	**0.15**
					WET SEASON					
60%	2.5	3.2	3	3	2	4.5	As above.		**3**	**0.395**
AEC down: D EcoStatus			**FISH: D**		**MACROINVERTEBRATES: C**				**RIP VEG: D**	
					DRY SEASON					
60%	9.2	9.2	8.5	9.3	6	9.2	6	9.5	**9.2**	**0.056**
					WET SEASON					
60%	5.5	6.2	5	5	4	7	2.5	4.75	**5**	**0.24**

* Final refers to the final stress selected as the EWR requirement, usually the lowest integrated stress. In some cases, vegetation was ignored due to the much lower confidence in the requirements.

1 During refinement it was identified that the SR guild stress was the most critical indicator and the LSR guild stress was not adjusted.

2 During refinement it was identified that the LSR guild stress was the most critical indicator and the SR guild stress was not taken into account.

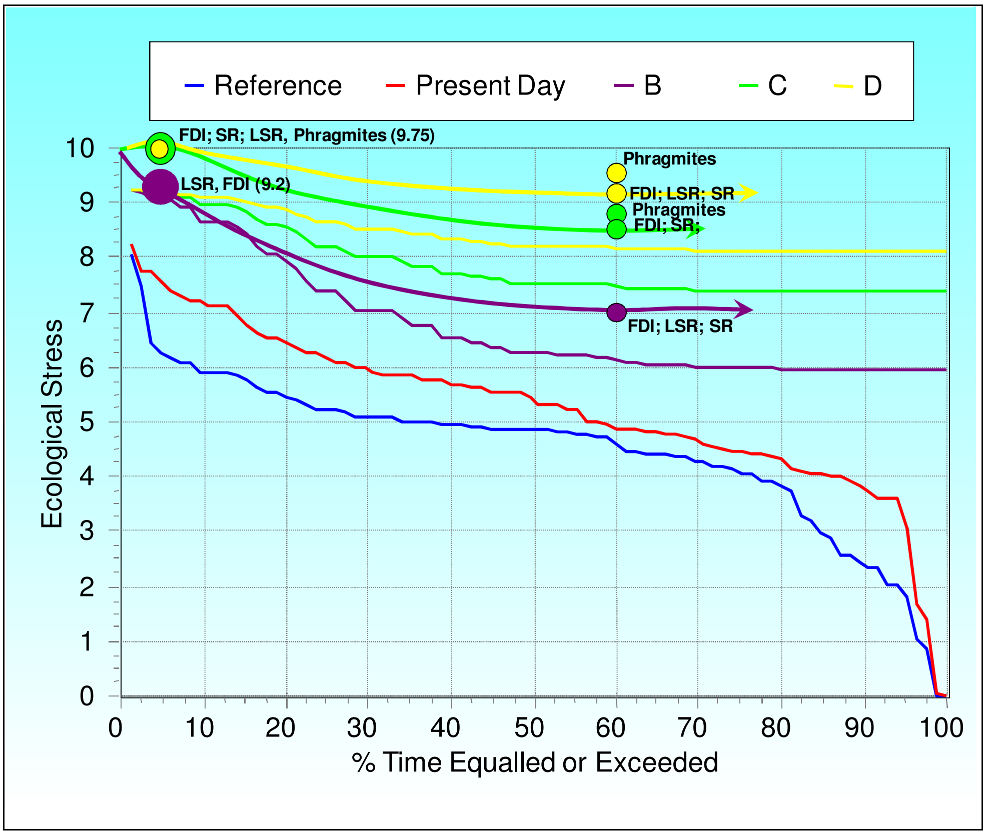

Figure 16–1 EWR 7: Stress duration curve for a C PES and REC, B AEC up and D AEC down - DRY season

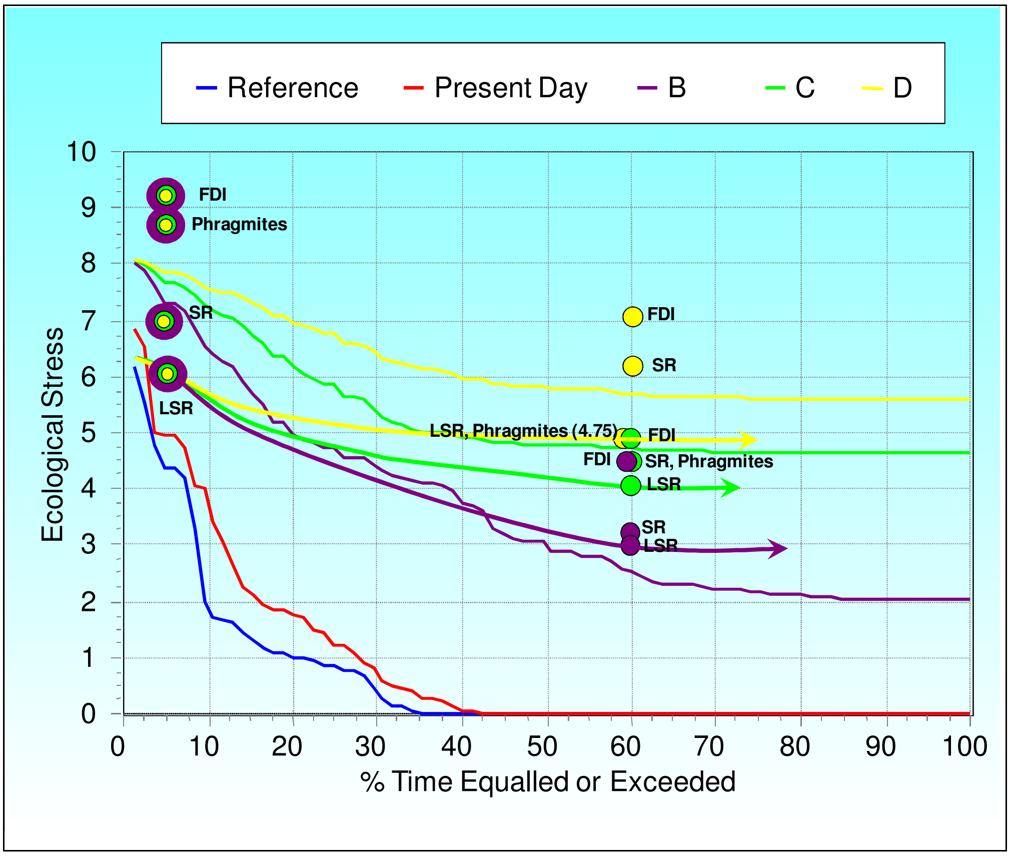

Figure 16–2 EWR 7: Stress duration curve for a C PES and REC, B AEC up and D AEC down - WET season

Table 16.2 Summary of EWR 7 motivations

Month	% Stress duration	Component stress	Integrated stress	Flow m³/s	Comment
PES: C EcoStatus	**FISH: C**		**MACROINVERTEBRATES: B/C**		**RIP VEG: C**
Oct	5% drought	10 SR	10	0	Prolonged periods of zero flows. Guild however still survives and seeks refuge upstream where perennial flow is present. PES will be maintained if connectivity and wet season flows are ensured.
	60% maintenance	8.5 SR	8.5	0.09	Some FS habitat available but FI and FD habitat absent. Available habitat should just be adequate to maintain the PES.
Feb	5% drought	6 LSR	6	0.19	This fish guild will have much reduced spawning habitats, but it should be adequate to maintain some habitats to meet requirements of all life stages to ensure survival of these species and allow recovery after drought period.
	60% maintenance	4 LSR	4	0.36	Critical spawning habitats will be maintained and adequate habitat for rest of life stages.
REC: B EcoStatus	**FISH: B**		**MACROINVERTEBRATES: B**		**RIP VEG: B**
Oct	5% drought	8.5 LSR	9.3	0.05	Adequate critical refuge areas are available for survival.
	60% maintenance	4 FDI	7	0.19	Suitable habitat that will allow for overwintering without significant detrimental impacts.
Feb	5% drought	6 LSR	6	0.19	See PES.
	60% maintenance	3 LSR	3	0.395	Fast habitats available with improvement in abundance of spawning and nursery habita.
AEC: C/D EcoStatus	**FISH: D**		**MACROINVERTEBRATES: C/D**		**RIP VEG: D**
Oct	5% drought	10 SR	10	0	See PES.
	60% maintenance	9.2 SR	9.2	0.056	Limited fast habitat available leading to reduced abundance and FROC.
Feb	5% drought	6 LSR	6	0.19	See PES.
	60% maintenance	5 LSR	5	0.24	Limited fast habitat available to maintain life stages at reduced abundance and FROC.

16.3.2 Final low flow requirements

To produce the final results (Figure 16-3), the DRM results for the specific category are modified according to specialists' requirements (Figure 16-1 and 16-2). The following changes were required:

- Seasonal distribution factor changes based on manual adjustments:
  - B EC: 0.72 for maintenance; 0.72 for drought.
  - C EC: 0.82 for maintenance.
  - D EC: maintenance and drought flows are similar based on distribution and flow.

Dry season (October) **Wet season (February)**

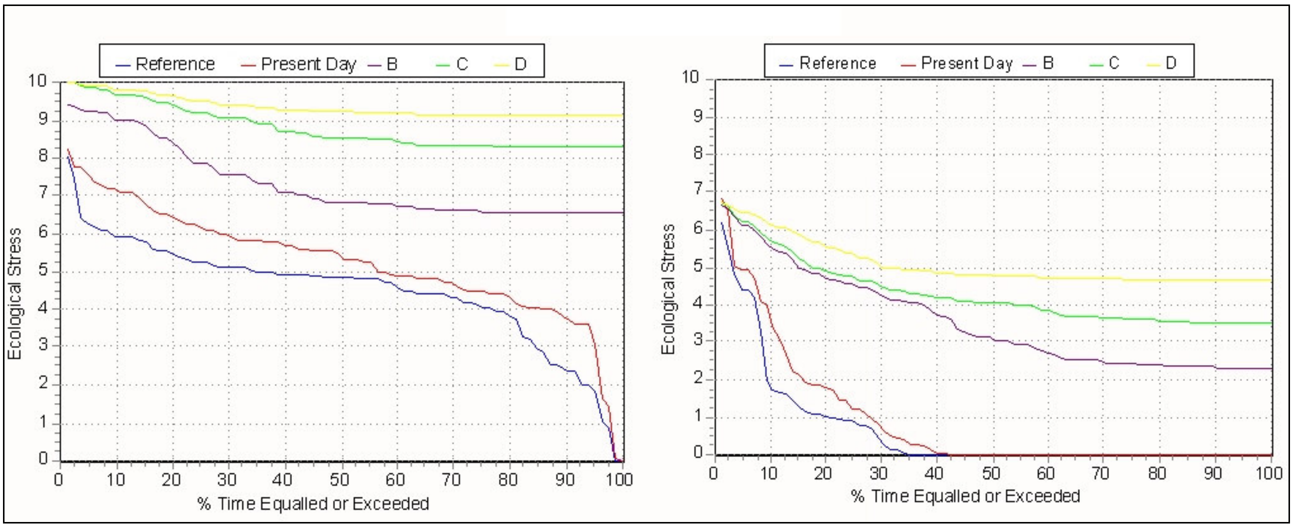

Figure 16–3 EWR 7: Final stress requirements for low flows

16.4 HIGH FLOW REQUIREMENTS

High low classes were identified as outlined in Section 4.4. Results are provided in Table 16.3 and detailed motivations provided in Table 16.4.

Table 16.3 Identification of instream functions addressed by the identified floods for geomorphology and riparian vegetation

FLOOD CLASS	FLOOD RANGE (m^3/s)	GEOMORPHOLOGY AND RIPARIAN VEGETATION MOTIVATION	Fish flood functions							Macroinvertebrate flood functions				
			Migration cues	Migration habitat (depth etc)	Clean spawning substrate	Create spawning habitat	Create nursery areas	Resetting water quality	Inundate vegetation for spawning	Breeding and hatching cues	Clear fines	Scour substrate	Reach or inundate specific areas	Reset water quality
I	1.6 - 2.5	**Vegetation:** Inundates the marginal zone, *Salix mucronata* and about 50% of the reedbeds.	√	√	√	√	√	√	√	√	√		√	√
II	4 - 9	**Geomorphology:** This flow transports some of the sand through the reach, and may allow the currently incised; narrowed active channel to widen. **Vegetation:** Inundates the marginal zone and lower portion of the lower zone. Activates lower zone low lying areas and backwaters and maintains *Cyperus* species in these depressions. Reduces terrestrialization on the lower zone: inundates current *Acacia sieberiana* population. Also inundates *P. mauritianus*.	√	√	√	√	√	√	√		√	√	√	√
III	15 Ave	**Geomorphology:** This flow will activate and turn over the gravels along the riffle sections of the bed.	√	√	√	√	√	√	√			√		
IV	28 Ave	**Geomorphology:** This flow class will activate and scour the ephemeral channel at the back of the macro-channel, and the peak of this flow should inundate sections of the large terrace area.	√	√	√	√	√	√	√					
V	68 +	**Geomorphology:** This large, infrequent flood will inundate and activate the terrace; scour the active and ephemeral channel. **Vegetation:** Activates the upper zone terrace and fills the lower zone backwater channel. Inundates the lower	√	√	√	√	√	√	√					

FLOOD CLASS	FLOOD RANGE (m^3/s)	GEOMORPHOLOGY AND RIPARIAN VEGETATION MOTIVATION	Fish flood functions: Migration cues	Migration habitat (depth etc)	Clean spawning substrate	Create spawning habitat	Create nursery areas	Resetting water quality	Inundate vegetation for spawning	Macroinvertebrate flood functions: Breeding and hatching cues	Clear fines	Scour substrate	Reach or inundate specific areas	Reset water quality
		zone. Activates and inundates the *C. erythrophyllum* population on the upper zone.												

Further information is provided in Appendix P, Table P10.

The number of high flow events required for each EC is provided in Table 16.4. The high flows were checked, using available daily hydrology.

Table 16.4 EWR 7: The recommended number of high flow events required

FLOOD CLASS	FLOOD RANGE (m^3/s)	INVERTEBRATES	FISH	VEGETATION	GEOMORPHOLOGY	FINAL (No of events)	MONTHS	DAILY AVERAGE (m^3/s)	DURATION (Days)
PES SCENARIO: C									
I	1.6 - 2.5			4		4	Nov, Dec, Jan, Mar	1.5	3
II	4 - 9			1	3	1	Jan	4	3
III	15 Ave				1	1	Feb	9	4
IV	28 Ave				1:2	1:2			
V	68 +			1:3+	1:10	1:3	Wet		
REC SCENARIO: B									
I	1.6 - 2.5					4	Nov, Dec, Jan, Mar	1.5	3
II	4 - 9				4	2	Dec, Jan	4	3
III	15 Ave				1	1	Feb	9	4
IV	28 Ave				1:2	1:2			
V	68 +				1:10	1:10			
AEC SCENARIO: D									
I	1.6 - 2.5			3		3	Nov, Dec, Jan, Mar	1.5	3
II	4 - 9			1	2	1	Jan	4	3
III	15 Ave				1	1	Feb	9	4
IV	28 Ave				1:3	1:03			
V	68 +			1:3+	1:10	1:10	Wet		

16.5 FINAL FLOW REQUIREMENTS

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

- An EWR table, which shows the results of high flows and low flows for each month separately (Table 16.5 – 16.7). Floods with a frequency higher than 1:1 is not included.
- An EWR rule table which provides the recommended EWR flows as a duration table, showing flows which should be provided when linked to a natural trigger (natural modelled hydrology in this case). EWR rules are supplied for total flows as well as for low flows only (Appendix P, Section P2.5).

Table 16.5 EWR table for PES: C

Desktop version:		**2**	**Virgin MAR (MCM)**	**28.896**
BFI index	**0.472**	**Distribution type**		**Eastern Escarpment**
MONTH	**LOW FLOWS**		**HIGH FLOWS**	
	Maintenance (m^3/s)	**Drought (m^3/s)**	**Daily average (m^3/s) on top of base flow**	**Duration (days)**
OCTOBER	0.07	0		
NOVEMBER	0.07	0	1.5	3
DECEMBER	0.12	0.05	1.5	3
JANUARY	0.2	0.1	1.5 4	3 3
FEBRUARY	0.26	0.14	9	4
MARCH	0.27	0.16	1.5	3
APRIL	0.25	0.12		
MAY	0.2	0.09		
JUNE	0.18	0.06		
JULY	0.15	0.04		
AUGUST	0.1	0.02		
SEPTEMBER	0.08	0		
TOTAL MCM	5.105	2.037	3.188	
% OF VIRGIN	17.67	7.05	11.03	

Table 16.6 EWR table for REC: B

Desktop version:		**2**	**Virgin MAR (MCM)**	**28.896**
BFI index	**0.472**	**Distribution type**		**Eastern Escarpment**
MONTH	**LOW FLOWS**		**HIGH FLOWS**	
	Maintenance (m^3/s)	**Drought (m^3/s)**	**Daily average (m^3/s) on top of base flow**	**Duration (days)**
OCTOBER	0.14	0.04		
NOVEMBER	0.17	0.06	1.5	3
DECEMBER	0.21	0.08	1.5 4	3 3
JANUARY	0.26	0.11	1.5 4	3 3
FEBRUARY	0.36	0.15	9	4
MARCH	0.35	0.16	1.5	3
APRIL	0.33	0.15		
MAY	0.28	0.12		
JUNE	0.24	0.11		
JULY	0.22	0.1		
AUGUST	0.2	0.08		
SEPTEMBER	0.16	0.07		
TOTAL MCM	7.65	3.22	3.81	
% OF VIRGIN	26.47	11.15	13.19	

Table 16.7 EWR table for AEC: D

Desktop version:		2	Virgin MAR (MCM)	28.896
BFI index	0.472	Distribution type		Eastern Escarpment
MONTH	LOW FLOWS		HIGH FLOWS	
	Maintenance (m^3/s)	Drought (m^3/s)	Daily average (m^3/s) on top of base flow	Duration (days)
OCTOBER	0.03	0		
NOVEMBER	0.05	0	1.5	3
DECEMBER	0.07	0.05	1.5	3
JANUARY	0.11	0.1	1.5 4	3 3
FEBRUARY	0.14	0.14	9	4
MARCH	0.14	0.16	1.5	3
APRIL	0.12	0.12		
MAY	0.1	0.09		
JUNE	0.09	0.06		
JULY	0.08	0.04		
AUGUST	0.06	0.02		
SEPTEMBER	0.05	0		
TOTAL MCM	2.72	2.037	2.955	
% OF VIRGIN	9.42	7.05	10.23	

A comparison between the Desktop Reserve Model estimates and the EWR results in terms of percentages of natural flow are provided in Table 16.8.

Table 16.8 Modifications made to the DRM for EWR 7

Changes	PES C		REC B		AEC D	
	DRM	EWR	DRM	EWR	DRM	EWR
MLIFR - Maintenance low flow	15.6%	17.7%	26.8%	26.5%	8.3%	9.4%
DLIFR - Drought low flow	8.3%	7.1%	8.3%	11.2%	8.3%	7.1%
MHIFR - Maintenance high flow	7.9%	11%	9.6%	13.2%	6.9%	10.2%
Long-term % of virgin MAR	26.6%	31.7%	35.8%	39.4%	22.0%	26.9%

17 EWR 8: LOWER SAND (SAND RIVER) - DETERMINATION OF STRESS INDICES

NOTE: All supporting specialist information for EWR 8 is summarized in Volume 3, Appendix Q.

17.1 INDICATOR SPECIES OR GROUP

17.1.1 Fish indicator group 1: Small rheophilic species (CANO)

Chiloglanis anoterus (CANO): See Section 3.1.2 and Appendix J, Table J2.

17.1.2 Fish indicator group 2: Large semi-rheophilic species (BMAR)

Labeobarbus marequensis (BMAR): See Section 7.1.2 and Appendix L, Table L1.

17.1.3 Macroinvertebrate indicator taxa

FDI taxa: Heptageniidae was selected as indicator taxa. This was the only FDI indicator that occurred reasonably commonly at the site at the time of sampling. Refer to Section 5.1.3.

Marginal Vegetation macroinvertebrate (MVI) taxa: One macroinvertebrate taxon, Atyidae, was selected on the basis of its preference for the marginal vegetation (in or out of flow) habitat, and its sensitivity to the disappearance thereof. Only taxa that occur commonly at the site can be selected as indicators.

17.1.4 Riparian vegetation indicator species

Two indicator species was selected:

- *Phragmites mauritianus:* See Section 3.1.4.
- *Breonadia salicina:* See Section 3.1.4.

Only *Breonadia* was used at this site as it was more sensitive to flow related changes than *Phragmites*.

17.2 STRESS FLOW INDEX

The stress flow index is generated in terms of habitat and biotic response and is discussed below.

17.2.1 Habitat response

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

- 0 – Optimum habitat (fixed at the natural maximum base flow – calculated using the wettest flow month discharge at the maintenance percentage of 60% for the Sand River at the EWR site).
- 10 - No flow (although there may still be surface water in pools).

Specific results for the fish indicator species are summarised in Appendix Q, Table Q1 and in Appendix Q, Table Q3 for the FDI and MVI taxa.

17.2.2 Biota response

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

The fish species response index is calculated using the fish habitat rating (cf Section 3.2.1) (Appendix Q, Table Q2) for each of the discharges evaluated for assessing habitat response. The FDI and MVI index is derived by considering the habitat response and % occurrence of habitat conditions at different flows. The FDI and MVI responses are described and coupled to a stress level (Appendix Q, Table Q4 and Q5)

A riparian vegetation stress index is also provided (Appendix Q, Table Q6).

17.2.3 Integrated stress curve

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

The shaded species stress discharges in Table 17.1 indicate the discharge evaluated by specialists to determine the biota stress. The values that are not shaded are interpolated. The highest discharge representing a specific stress is used to define the integrated stress curve. Figure 17-1 illustrates this graphically.

Table 17.1 Species stress discharges used to determine biotic stress

Stress	Flow (m^3/s)						Integrated Flow (m^3/s)
	SR	LSR	FDI	MVI	Reed *Phragmites*	Minger Breonadia	
0	4.71	4.71	5.2	5.2	2.9	2.8	5.2
1	3.12	3.915	3.73	3.73	2.5		3.915
2	2.33	3.12	2.33	2.33	2.1		3.12
3	1.98	2.33	1.85	1.85	1.7	1.14	2.33
4	1.63	1.63	1.24	1.24	1.367		1.63
5	1.34	1.34	0.77	0.77	1.033		1.34
6	1.24	1.24	0.1	0.1	0.7	0.15	1.24
7	0.59	0.59	0.006	0.006	0.365		0.59
8	0.51	0.51	0.002	0.002	0.03	0.03	0.51
9	0.21	0.21	0	0	0.015		0.21
10	0	0	0	0	0	0	0

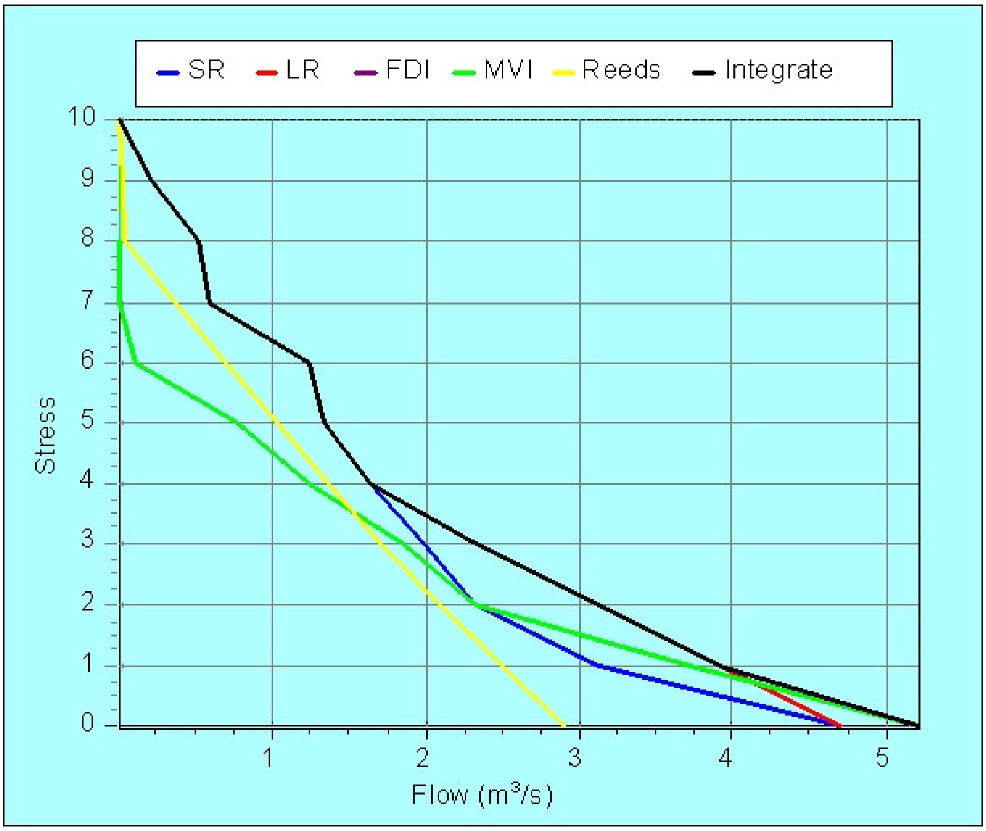

Figure 17–1 Component and integrated stress curves for EWR 8

Table 17.2 provides the summarised biotic response for the integrated stresses.

Table 17.2 Integrated stress and summarised habitat/biotic responses

Integrated stress	Flow m^3/s	Habitat and/or Biotic responses
0 (Inverts)	5.2	Fish guild habitats are at an optimum (5*). All macroinvertebrate habitat in excess. Taxa abundant. *Phragmites* adults with full vigour and at maximum reproductive capacity.
1 (LR)	3.915	Fish guilds as above. Macroinvertebrate habitat plentiful. Taxa abundant. Vegetation as above.
2 (LR)	3.12	SR guild: All habitats slightly less than optimal (4.5) with good spawning habitat (4). LSR guild: Habitats are mostly good with nursery habitat and water quality at 4.5. Macroinvertebrates as above. Vegetation as above.
3 (LR)	2.33	SR guild: Nursery habitat, connectivity and water quality is good (4 – 4.5) while rest of habitats are slightly better than moderate (3.5). LSR guild: Spawning habitat moderate (3), with slightly better abundance, cover and connectivity (3.5). Nursery habitat and water quality is good. Critical macroinvertebrate habitat sufficient. Heptageniidae and more sensitive FDI persist, Atyidae are abundant.
4 (LR)	1.63	SR guild: All habitat is moderate. LSR guild: Spawning habitat has deteriorated (2.5) while rest of habitat is medium. Leaf wilting/stress commences, but is slight. Up to 80 cm rooting depth for upper limit, lower limit at water level on average.
5 (LR)	1.34	SR: Nursery habitat, connectivity and water quality is moderate while rest of habitat is slightly lower (2.5). LSR guild: Spawning and cover is low (2), while rest of habitat is moderate.
6 (LR)	1.24	SR guild: All habitat occurrence is low (2 – 2.5). LSR guild: Spawning, cover and abundance have deteriorated (1.5) while rest of habitats are at low (2.5) occurrence. Macroinvertebrates: Fast and moderately fast flow habitat reduced. Heptageniidae present at lower abundances. More flow sensitive taxa present at lower abundances. All life stages viable in limited areas. Atyidae life stages viable in limited areas and critical life stages at risk.
7 (LR)	0.59	SR guild: Nursery habitat, connectivity and water quality is low while rest of habitats are very low.

Integrated stress	Flow m³/s	Habitat and/or Biotic responses
		LSR guild: Spawning habitat is very rare (0.5) and abundance and cover is very low (1).
8 (LR)	0.51	SR guild: Abundance, cover and connectivity is very rare, while rest of habitats are very low – low. LSR guild: Spawning habitat absent with very low occurrence of other habitat types with some nursery habitat.
9 (LR)	0.21	SR guild: All habitat is very rare with very low nursery habitat. LSR guild: Spawning habitat is absent with very rare occurrence of other habitat types. Unseasonal thinning or partial mortality of above-ground parts (majority of the plant/s remains viable, but water stressed).
10	0	Only pool dwelling species present. Standing water only. Indicator taxa no longer present. Widespread and complete mortality of population.

* Suitability rating 0 (not suitable) – 5 (highly suitable)

18 EWR 8: LOWER SAND (SAND RIVER) - DETERMINATION OF EWR SCENARIOS

18.1 ECOCLASSIFICATION SUMMARY OF EWR 8

EWR 8 Lower Sand (Sand River)

EIS: High
Rare and endangered species, high taxon richness and species intolerant to flow and flow related water quality changes. Situated in KNP
PES: B
Abstraction, dams, weirs, poor landuse management. Impacts are flow and non-flow related.
REC: B
Although the EIS is High, the PES is already in a B therefore the REC = PES. Improve the macroinvertebrate EC by increasing low flows.
AEC down: C
More decreased low flows and longer periods of no flow.

Driver Components	PES Category	Trend	REC	AEC↓
HYDROLOGY	C?		C	D?
WATER QUALITY	B		B	C
GEOMORPHOLOGY	C	Negative	C	Lower C
Response Components	**PES Category**	**Trend**	**REC**	**AEC↓**
FISH	B	Stable	B	C
MACRO INVERTEBRATES	C	Negative	B	C/D
INSTREAM	B/C		B	C
RIPARIAN VEGETATION	B	Stable	B	B/C
ECOSTATUS	B	Negative	B	C

18.2 HYDROLOGY

The highest and lowest low flow months selected as the key months are February (wet) and October (dry). The key assurance percentages for which stress requirements had to be set were:

- 95%: Representing droughts for both wet and dry months. This would represent 5% on the stress duration graphs.
- 40%: Representing maintenance flows for both wet and dry months. This would represent 60% on the stress duration graphs.

18.3 LOW FLOW REQUIREMENTS (IN TERMS OF STRESS)

Hydrology provided for the Sand catchment is extremely unreliable due to the lack of gauges and information in the system. Only one gauge in the lower Sand River is functional. The operation of local small weirs, dams and irrigation canals is also not clear. This resulted in the hydrology being changed based on some anecdotal information, and some of it after the EWR workshop, resulting in many EWRs having to be re-evaluated.

The fish and macroinvertebrate flow requirements for different Ecological Categories (ECs) are provided in Table 18.1, Figure 18-1 and 18-2. The results are plotted for the Wet and Dry Season on stress duration graphs and compared to the DRM low flow estimates for the same range of ECs. The stress requirements (as a 'hand drawn line') are illustrated in Figures 18-1 and 18-2.

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

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

Table 18.1 Species and integrates stress requirements as well as the final integrated stress and flow requirement

Duration	SR stress	Integ stress	LSR stress	Integ stress	FDI stress	Integ stress	MVI stress	Integ stress	FINAL* (Integ stress)	FLOW (m^3/s)
PES and REC: C EcoStatus				**FISH: C**	**MACROINVERTEBRATES: C (PES), B (REC)**				**RIP VEG: B**	
					DRY SEASON					
5%	9.75	9.75	9.75	9.75	10	10	8	10	**10**	**0**
60%	8.5	8.5	8.5	8.5	6	9.4	6	9.4	**8.5**	**0.36**
					WET SEASON					
5%	9	9	9	9	6	9.4	7	10	**10**	**0**
60%	3	3.5	3	3	2	3	3	3.8	**3**	**2.33**
AEC: C EcoStatus			**FISH: C**		**MACROINVERTEBRATES: C/D**				**RIP VEG: B/C**	
					DRY SEASON					
60%	9.5	9.5	9.5	9.5	6	9.4	7	10	**9.4**	**0.36**
					WET SEASON					
60%	5	5	5	5	4	6	5	7	**5**	**1.34**

* Final refers to the final stress selected as the EWR requirement, usually the lowest integrated stress. In this case, vegetation stress was ignored due to the much lower confidence in the requirements.
NOTE: For this site the low flow requirements for riparian vegetation were not included due to low confidence in the results.

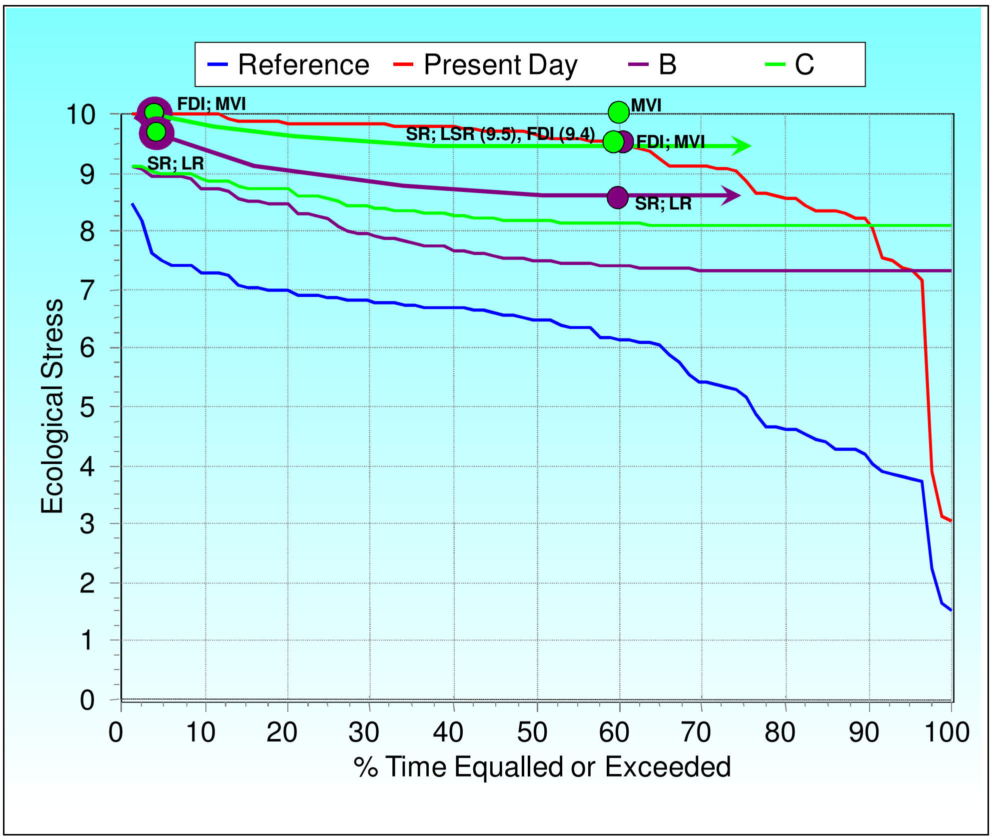

Figure 18–1 EWR 8: Stress duration curve for a B REC and C AEC - DRY season

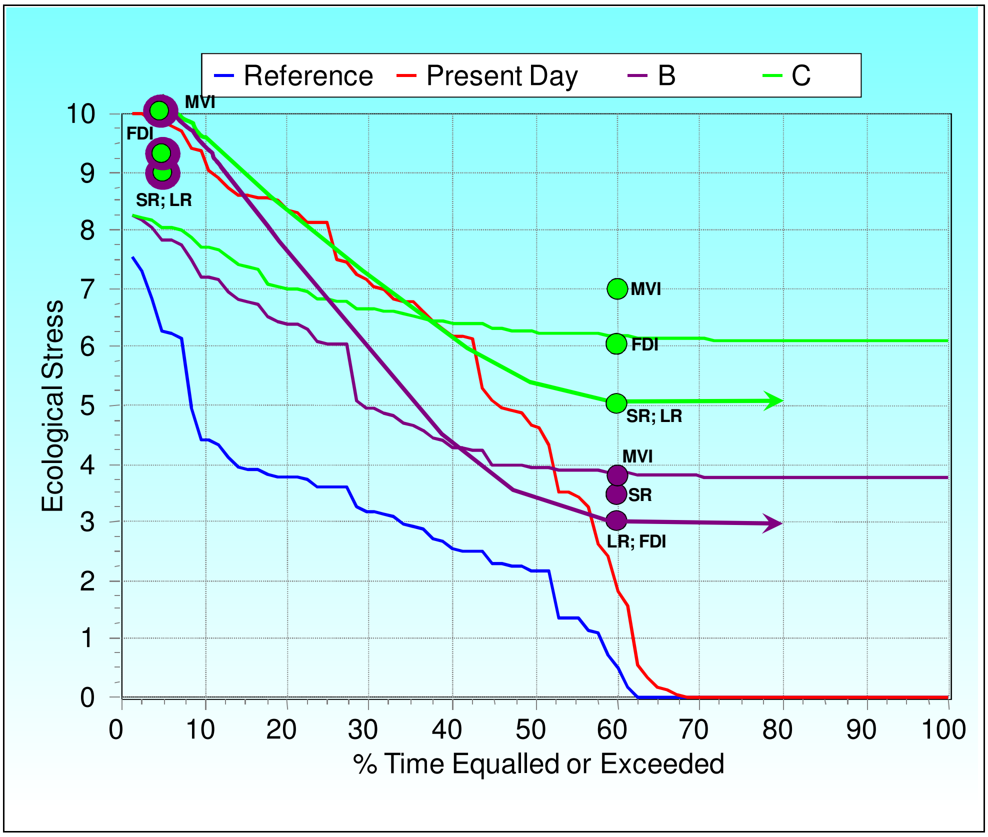

Figure 18–2 EWR 8: Stress duration curve for a B REC and C AEC - WET season

Table 18.2 Summary of EWR 8 motivations

Month	% Stress duration	Component stress	Integrated stress	Flow m^3/s	Comment
PES and REC: C EcoStatus		**FISH: C**		**MACROINVERTEBRATES: B/C**	**RIP VEG: C**
Oct	5% drought	10 MVI	10	0	Pools will persist in the channel, and these will be fringed with MV. Atyidae will persist in this habitat, in very low abundances.
	60% maintenance	8.5 SR	8.5	0.36	Some FS and very limited FI will be present while no FD habitats will be available. This habitat composition should be adequate to provide the most critical habitats for the survival of species within this fish guild during the dry season.
Feb	5% drought	7 MVI	10	0	Adequate depth is present in channel and vegetation to ensure survival of taxa.
	60% maintenance	2 FDI	3	0.36	FDI taxa are abundant as critical habitats are present.
AEC: C EcoStatus	**FISH: C**			**MACROINVERTEBRATES: C/D**	**RIP VEG: B/C**
Oct	5% drought	10 MVI	10	0	See PES.
	60% maintenance	6 FDI	9.4	0.36	FDI persist in low numbers but will survive.
Feb	5% drought	7 MVI	10	0	See PES.
	60% maintenance	5 SR	5	1.34	Limited fast habitat available. Reduced abundance and FROC.

18.3.1 Final low flow requirements

To produce the final results (Figure 18-3), the DRM results for the specific category are modified according to specialists' requirements (Figure 18-1 and 18-2). The following changes were required:

- Drought flows were manually changed with a seasonal distribution between 0 (Oct) and 0.3 (Mar).
- Monthly assurance rules changed:
  - Shape factor 5 for dry and 6 for wet season.
  - Low flow max increased to 140 for dry and 145 for wet season.
  - Lower shift changed to 10 for dry and 15 for wet season.
- Revisions involved large changes to the shape of the seasonal distribution to lower the dry season flows.

Dry season (October) **Wet season (February)**

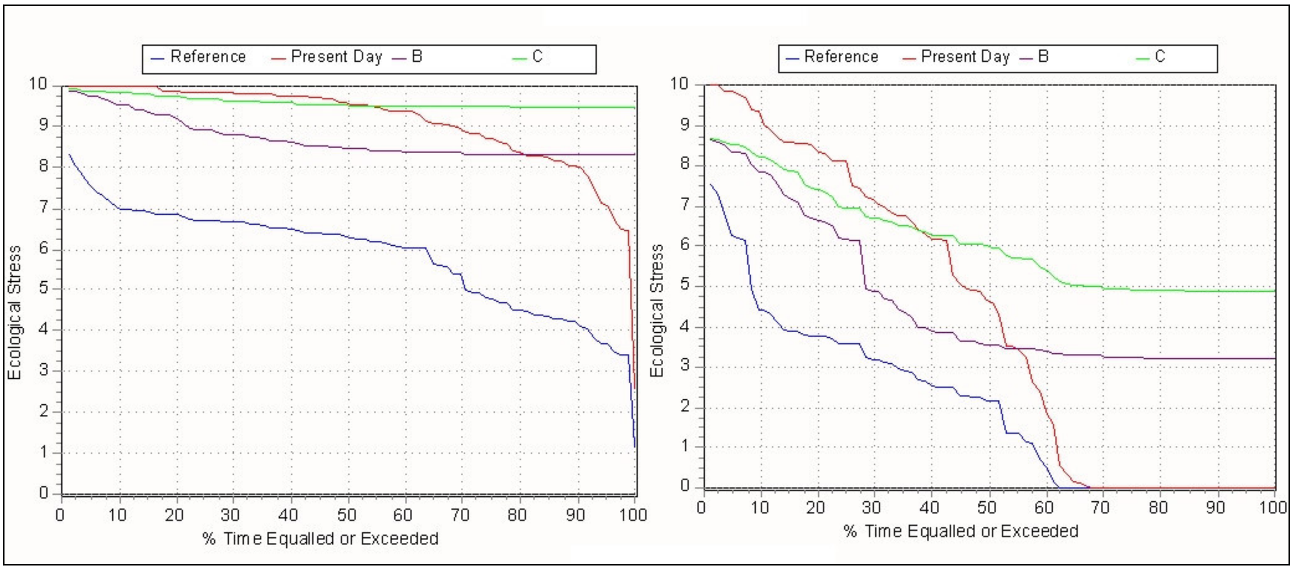

Figure 18–3 EWR 8: Final stress requirements for low flows

18.4 HIGH FLOW REQUIREMENTS

High low classes were identified as outlined in Section 4.4. Results are provided in Table 18.3 and detailed motivations provided in Table 18.4.

Table 18.3 Identification of instream functions addressed by the identified floods for geomorphology and riparian vegetation

FLOOD CLASS	FLOOD RANGE (m^3/s)	GEOMORPHOLOGY AND RIPARIAN VEGETATION MOTIVATION	Fish flood functions							Macroinvertebrate flood functions				
			Migration cues	Migration habitat (depth etc)	Clean spawning substrate	Create spawning habitat	Create nursery areas	Resetting water quality	Inundate vegetation for spawning	Breeding and hatching cues	Clear fines	Scour substrate	Reach or inundate specific areas	Reset water quality
I	4 - 7	**Vegetation:** Activates seasonal channels. Inundates *Persecaria, Cyperus* and about half of the reeds. Maintains reedbeds and macro channel floor shrubs.	√	√	√	√	√	√	√	√		√	√	√
II	30 - 65	**Vegetation:** Inundates the lower zone and bars on the lower upper zone. Maintains lower-level reeds and shrubs, and lower-level *C. erythrophyllum* and *N. oppositifolia.*	√	√	√	√	√	√	√	√		√	√	√
V	150 +	**Geomorphology:** This flow class is the geomorphologically effective discharge - it is responsible for nearly half of all the transport of sands (1 and 2 mm) at this site. These results are confirmed by the morphological cues - this discharge will inundate and maintain the large, extensive lateral bar which runs through the reach (on the right bank at this site). **Vegetation:** Activates and inundates the upper zone terrace with *P. mauritianus, C. erythrophyllum, N. oppositifolia, G. sennegalensis,* and *D. mespiliformis.* Activates ephemeral channels.	√	√	√	√	√	√	√					

Further information is provided in Appendix Q, Table Q12.

The number of high flow events required for each EC is provided in Table 18.4. The high flows were checked, using available daily hydrology.

Table 18.4 EWR 8: The recommended number of high flow events required

FLOOD CLASS	FLOOD RANGE (m^3/s)	INVERTEBRATES	FISH	VEGETATION	GEOMORPHOLOGY	FINAL (No of events)	MONTHS	DAILY AVERAGE (m^3/s)	DURATION (Days)
PES and REC SCENARIO: B									
I	1.6 - 2.5			4		4	Nov, Dec, Jan, Mar	5	4
II	4 - 9			1		1	Feb	30	5
III	15 Ave								
IV	28 Ave								
V	68 +			1:3	1:2	1:2			

FLOOD CLASS	FLOOD RANGE (m^3/s)	INVERTEBRATES	FISH	VEGETATION	GEOMORPHOLOGY	FINAL (No of events)	MONTHS	DAILY AVERAGE (m^3/s)	DURATION (Days)
AEC SCENARIO: C									
I	1.6 - 2.5			3		3	Dec, Jan, Mar	5	4
II	4 - 9			1		1	Feb	30	5
III	15 Ave								
IV	28 Ave								
V	68 +			1:3	1:3	1:3			

18.5 FINAL FLOW REQUIREMENTS

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

- An EWR table, which shows the results of high flows and low flows for each month separately (Table 18.5 – 18.6). Floods with a frequency higher than 1:1 is not included.
- An EWR rule table which provides the recommended EWR flows as a duration table, showing flows which should be provided when linked to a natural trigger (natural modelled hydrology in this case). EWR rules are supplied for total flows as well as for low flows only (Appendix Q, Section Q2.5).

Table 18.5 EWR table for REC: B

Desktop version:		**2**	**Virgin MAR (MCM)**	**133.6**
BFI index	**0.425**	**Distribution type**		**Eastern Escarpment**
MONTH	**LOW FLOWS**		**HIGH FLOWS**	
	Maintenance (m^3/s)	**Drought (m^3/s)**	**Daily average (m^3/s) on top of base flow**	**Duration (days)**
OCTOBER	0.26	0		
NOVEMBER	0.34	0.05	5	4
DECEMBER	0.56	0.1	5	4
JANUARY	0.9	0.2	5	4
FEBRUARY	1.63	0.3	30	5
MARCH	1.52	0.3	5	4
APRIL	1.17	0.25		
MAY	0.72	0.2		
JUNE	0.62	0.15		
JULY	0.5	0.1		
AUGUST	0.39	0.05		
SEPTEMBER	0.3	0.02		
TOTAL MCM	23.23	4.49	9.77	
% OF VIRGIN	17.39	3.36	7.31	

1 Maintenance

Table 18.6 EWR table for AEC: C

Desktop version:		2	Virgin MAR (MCM)	133.6
BFI index	0.425	Distribution type		Eastern Escarpment
MONTH	LOW FLOWS		HIGH FLOWS	
	Maintenance (m^3/s)	Drought (m^3/s)	Daily average (m^3/s) on top of base flow	Duration (days)
OCTOBER	0.349	0.000		
NOVEMBER	0.388	0.050		
DECEMBER	0.469	0.100	5	4
JANUARY	0.606	0.200	5	4
FEBRUARY	0.927	0.300	30	5
MARCH	0.857	0.300	5	4
APRIL	0.723	0.250		
MAY	0.535	0.200		
JUNE	0.501	0.150		
JULY	0.443	0.100		
AUGUST	0.401	0.050		
SEPTEMBER	0.375	0.020		
TOTAL MCM	17.196	4.488	8.865	
% OF VIRGIN	12.87	3.36	6.63	

A comparison between the Desktop Reserve Model estimates and the EWR results in terms of percentages of natural flow are provided in Table 18.7.

Table 18.7 Modifications made to the DRM for EWR 8

Changes	REC B		AEC C	
	DRM	EWR	DRM	EWR
MLIFR - Maintenance low flow	22.1%	17.1%	12.9%	9.5%
DLIFR - Drought low flow	6.5%	3.4%	6.5%	3.4%
MHIFR - Maintenance high flow	11.2%	7.3%	9.2%	6.6%
Long-term % of virgin MAR	31.8%	25.3%	24.4%	18.4%

19 CONCLUSIONS AND RECOMMENDATIONS

The following process was followed to identify realistic recommendations:

- Identify the confidences associated with the low and high flow results; and
- based on this, make realistic recommendations on any work that can be undertaken to improve the confidences.
- Evaluate whether these recommendations can be accommodated in a monitoring programme that should follow EWR assessments or whether specific work is required.

19.1 SUMMARY OF FINAL RESULTS

The final flow requirements are expressed as a percentage of the natural MAR in Table 19.1. The natural MARs are provided below:

EWR 1 140.2 MCM
EWR 2 262.1 MCM
EWR 3 495.9 MCM
EWR 4 65.8 MCM
EWR 5 157.1 MCM
EWR 6 45 MCM
EWR 7 28.9 MCM
EWR 8 133.6 MCM

Table 19.1 Summary of results as a percentage of the natural MAR

EWR site	EC[1]	Maintenance low flows (%nMAR)	Drought low flows (%nMAR)	High flows (%nMAR)	Long term mean (% nMAR)
EWR 1	B/C PES	33.2	12.1	5.3	37.8
	B REC	44.1	12.1	6.1	46.3
	C/D AEC	20.7	12.1	4.5	31
EWR 2	B/C PES	19.8	11.1	4.4	28
	B REC	31.1	11.1	5	35.7
	C/D AEC	12.5	11.1	3.6	22.1
EWR 3	A/B REC	31.3	9.7	6.4	37
	B/C AEC	20.4	9.7	5.4	27.1
EWR 4	A/B PES	31.3	9.7	6.4	37
	B/C AEC	20.4	9.7	5.4	27.1
EWR 5	B/C PES	20.8	8	6.5	28.2
	B REC	30.2	8	7.1	36.3
	C/D AEC	9.8	8	5.4	19.8
EWR 6	C PES	22.2	10.3	6.3	32.4
	B AEC	32.2	13.4	6.3	38.6
	C/D AEC	13.8	10.3	5.7	25.7
EWR 7	C PES	17.7	7.1	11	31.7
	B AEC	26.5	11.2	13.2	39.4
	D AEC	9.4	7.1	10.2	26.9
EWR 8	B PES[2]/REC	17.4	3.4	7.3	25.3
	C AEC	9.5	3.4	6.6	18.4

1 Refer to Report 26/8/3/10/12/009 (DWA, 2009).
2 The attainable and realistic objective was to maintain the PES, but improve the macroinvertebrate EC by improving low flows.

19.2 CONFIDENCES

19.2.1 Confidence in low flow EWR

The question that the confidences should answer is the following:

> 'How confident are you that the low flow (with the associated high flows) recommended will achieve the EC?'

To determine the confidence, one should consider:

- The quality of available data; and
- whether your requirement represents the critical requirement. For example, if the macroinvertebrate stress requirement of a 4 at 30% was the final recommendation, and fish was 7 at 30%, then fish should have very high confidence that the recommended flow will achieve the EC. This is because the fish will receive more flow than required for fish, so even if the fish data availability and understanding of habitat requirements are of low confidence, the confidence that this much higher requirement that is being recommended based on invertebrates will cater for fish requirements should result in a high confidence that the EC will be maintained/achieved.

The low flow confidence evaluation is representative of the component (fish or macroinvertebrates) confidence which drove the flow requirement. If both drove the flow requirement, then an average of the confidence will be provided.

Table 19.2 provides the confidence for the low flow biotic components (fish, macroinvertebrates and riparian vegetation). The shaded green columns indicate which of these components dictated the final requirements. The final confidence is representative of these requirements where:

1 (very low confidence) 2 (low confidence) 3 (medium confidence)
4 (high confidence) 5 (very high confidence)

These ratings are applicable to all confidences.

Table 19.2 Confidence in low flows for biotic responses

EWR SITE	FISH	MACROINVERTEBRATES	RIPARIAN VEGETATION	COMMENT	OVERALL CONFIDENCE
EWR 1	3.5	4	4	**Fish:** The dry and wet season flows are mostly driven by the large rheophilic fish species. It is estimated that the required flows should provide adequate habitat for all life stages of the large rheophilic indicator guild to sustain viable assemblages and maintain the fish within the required ecological category. The requirements for the second fish indicator guild (small rheophilic species) will be equalled and in many cases exceeded, ensuring adequate flows for the requirements of this group. The requirements and habitat preferences of different life stages of the species is in general well documented and where required, deficiencies were addressed by information of similar species. The data and information gathered regarding these indicator species during this study at the EWR site was excellent.	**3.5**
				Macroinvertebrates: Requirements for the other components higher than macroinvertebrates, therefore high confidence that ECs will be achieved.	

EWR SITE	FISH	MACROINVERTEBRATES	RIPARIAN VEGETATION	COMMENT	OVERALL CONFIDENCE
				Riparian vegetation: Lower because obligate and sensitive riparian plant species were not common at lower levels of the site (along the transect). However, high confidence that integrated stress flow will achieve vegetation objectives since integrated flow is higher than riparian vegetation requirement.	
EWR 2	3.5	4	2.5	**Fish:** The dry and wet season flows are mostly driven by the LR guild. It is estimated that the required flows should provide adequate habitats for all life stages of this guild to sustain viable assemblages and maintain the fish within the required EC. The requirements for the second fish indicator guild (SR) will be equalled and in many cases exceeded, ensuring adequate flows for the requirements of this group. The requirements and habitat preferences of different life stages of the species is in general well documented and where required, deficiencies were addressed by information of similar species. The data and information gathered regarding these indicator species during this study at the EWR site was excellent.	**3.5**
				Macroinvertebrates: The macroinvertebrates are not driving the low flows during both the dry and wet seasons; however the requirements are very close to the overall requirements for the REC. The flows provided are more than those requested and will allow enough habitats for all three indicator taxa. Only two data sets were available for this site.	
				Riparian vegetation: The placing of the site was such that there was a lack of flow sensitive riparian obligates along the profile that were not affected by impacts at the site (vegetation removal, mowing and shading). Obligates along the back channel were maintained by upstream connectivity and hydraulic ratings could not be used to assess flows.	
EWR 3	4	4	3	**Fish:** Flow requirements are driven by the fish requirements. The requirements and habitat preferences of different life stages of the indicator species is well documented while very good data on these species were also gathered at this EWR site during the present study. The use of both a cross-section and 2D hydraulic information approach furthermore improved the confidence of assessing the habitat compositions at different flows for the indicator species.	**4**
				Macroinvertebrates: Requirements for the other components higher than macroinvertebrates, therefore high confidence that ECs will be achieved.	
				Riparian vegetation: hydraulic confidence higher for low flows but complex channel morphology at this site. There were sufficient vegetation survey points (obligate or preferential riparian species) to assess low flow requirements. Different bed heights/depths (since there are 4 active channels) also complicate interpretation of hydraulic data.	
EWR 4	4	4.5	3.5	**Fish:** Requested flows for both the PES and AEC for both wet and dry seasons are driven by the requirements of the LR species. The flows set should be adequate to create favourable habitat for al requirements of different life stages of this fish guild. Flows generally exceed the requirements for the SR species and their requirements should therefore definitely be met. The requirements and habitat preferences of different life stages of the species is in general well documented and where required, deficiencies were addressed by information of similar species. The data and information gathered regarding these indicator species during this study at the EWR site was excellent.	**4**
				Macroinvertebrates: Requirements for the other components higher than macroinvertebrates, therefore high confidence that ECs will be achieved.	
				Riparian vegetation: Hydraulic confidence moderate for low flows. There were sufficient vegetation survey points (obligate or preferential riparian species) to assess low flow requirements.	
EWR 5	4	4	4.5	**Fish:** Requested flows for PES and REC are driven by fish requirements (varying between two indicator groups) and the flows set should be adequate to create critical habitat for al requirements of different life stages. Two indicator groups were used (LS and SR guild), covering a range of habitats and flows that should be adequate to sustain all fish species expected at site. Requirements of different life stages of the indicator guild for fish should also be met during both the wet and dry season. The requirements and habitat preferences of different life stages of the indicator species are well documented. The data and information gathered regarding these species during the current study at this EWR site is good. In some cases the requested flows were driven by requirements for riparian vegetation, and the flow requirements for fish were exceeded, and should therefore be more than adequate for maintenance within those ECs.	**4**
				Macroinvertebrates: Requirements for the other components higher than macroinvertebrates, therefore high confidence that ECs will be achieved.	
				Riparian vegetation: Hydraulic confidence high for low flows. There were sufficient vegetation survey points (obligate or preferential riparian species) to assess low flow requirements.	

EWR SITE	FISH	MACROINVERTEBRATES	RIPARIAN VEGETATION	COMMENT	OVERALL CONFIDENCE
EWR 6	3	4.5	4	**Fish:** The PES dry season and wet maintenance flows are driven by requirements of riparian vegetation, and should therefore exceed the fish requirements and ensure adequate habitats for maintenance within the PES. The AEC are driven by fish requirements (varying between two indicator groups) and the flows set should be adequate to create critical habitat for all requirements of different life stages. Two indicator groups were used (LR and SR guild), covering a range of habitats and flows that should be adequate to sustain all fish species expected at site. Requirements of different life stages of the indicator guild for fish should also be met during both the wet and dry season. The requirements and habitat preferences of different life stages of the indicator species are well documented while good data on these species were also gathered at this EWR site during the present study. The cross-section not falling within the critical (fast) habitats of the site and running predominantly through a deeper area decreased the confidence of the hydraulic information, and thus fish habitat availability at different flows.	3.5
				Macroinvertebrates: The recommended flows are driven by fish and are considerably more than what was required by the macroinvertebrates. Although there is only limited data available for this site, it is highly unlikely that the macroinvertebrates will not attain the required categories for the specified flows.	
				Riparian vegetation: Hydraulic confidence moderate for low flows. There were sufficient vegetation survey points (obligate or preferential riparian species) to assess low flow requirements.	
EWR 7	2.5	2.5	4	**Fish:** Limited information available for this site. Good indicators were present however.	2.5
				Macroinvertebrates: Macroinvertebrates are driving the flows and due to the lack of information at this sites and the seasonality of the system, the confidence is low..	
				Riparian vegetation: Hydraulic confidence high for low flows. There were sufficient vegetation survey points (obligate or preferential riparian species) to assess low flow requirements.	
EWR 8	**3**	**3**	**4**	**Fish:** The dry season flows for the PES and AEC are driven by riparian vegetation and macroinvertebrates and therefore exceeds the requirements for fish at the site, and should be adequate to provide the required habitats. Wet season flows are driven by the requirements of the fish guilds at the site. Two indicator groups were used (SR and LS guild), covering a range of habitats and flows that should be adequate to sustain all fish species expected at site. Requirements of different life stages of the indicator guild for fish should also be met. The requirements and habitat preferences of different life stages of the indicator species are well documented. The data and information gathered regarding these species during the current study at this EWR site is good.	**3**
				Macroinvertebrates: The alluvial nature of the site makes it difficult to interpret, and taking into account that the EWR is driven by macroinvertebrate requirements, the confidence is only moderate.	
				Riparian vegetation: Hydraulic confidence high for low flows. There were sufficient vegetation survey points (obligate or preferential riparian species) to assess low flow requirements.	

19.2.2 Confidence in high flow EWR

The question that the confidences should answer is the following:
'How confident are you that the high flow (with the associated high flows) recommended will achieve the EC?'

To determine the confidence, one should consider

- The quality of available data; and
- whether the vegetation requirement was increased to cater for a larger requirement recommended for geomorphology. Then the riparian vegetation confidence could be high as more water is provided.

The high flow confidence (Table 19.3) represents an average of the riparian vegetation and geomorphology confidence as these two components determine the flood requirements.

Table 19.3 Confidence in high flows

EWR SITE	FISH	MACROINVERTEBRATES	RIPARIAN VEGETATION	GEOMORPHOLOGY	COMMENT	HIGH FLOWS
EWR 1	4.5	3	4	2.5	**Fish:** The recommended floods are adequate in terms of frequency, size and duration to provide various functions regarding fish migration, creation of migration, spawning habitats and nursery areas. **Macroinvertebrates:** The recommended floods are adequate in terms of frequency, size and duration to provide various functions (clearing fines, scouring the substrate, providing breeding and hatching cues and flooding the vegetation to provide extra habitat. **Riparian vegetation:** Sufficient vegetation survey points (obligate and preferential riparian species) to assess flow requirements despite denudation of the site due to picnic site. **Geomorphology:** Although there are terraces at the site, these are not paired. The site is on a bend and thus the terraces may not be associated with the effective discharges, so there is little confidence in the morphological cues. The available hydrology for the site has been derived from a gauge near Sabie town which is upstream of a number of tributary confluences. Although there is a long record for the gauge (40 years), it seems likely that the gauge is not recording the larger floods (i.e. is either under-estimating or the gauge drowns out). For these reasons the confidence in the hydrological data, and thus the results of the PBMT, are moderate.	**3.3**
EWR 2	4.5	3	3	3	**Fish:** The recommended floods are adequate in terms of frequency, size and duration to provide various functions regarding fish migration, creation of migration, spawning habitats and nursery areas. **Macroinvertebrates:** The recommended floods are adequate in terms of frequency, size and duration to provide various functions (clearing fines, scouring the substrate, providing breeding and hatching cues and flooding the vegetation to provide extra habitat. **Riparian vegetation:** There were sufficient vegetation survey points (obligate or preferential riparian species) to assess flood requirements although marked changes in vegetation structure occurred at the site due to removal. **Geomorphology:** There is a long (40 year) flow record for the gauge near the site. There is a floodplain morphological cue; but no paired terraces are present. The presence of the floodplain also results in lower confidence of the high flow/flood hydraulics, since flow direction changes and is then difficult to predict. For these reasons the confidence in the hydrological data, and thus the results of the PBMT, are moderate.	**3**
EWR 3	4.5	3	4	4	**Fish:** The recommended floods are adequate in terms of frequency, size and duration to provide the various flood functions required for fish migration, creation of adequate depths/connectivity for migration, spawning habitats and for nursery areas. Receding limb of higher floods classes also provide important functions. **Macroinvertebrates:** The recommended floods are adequate in terms of frequency, size and duration to provide various functions (clearing fines, scouring the substrate, providing breeding and hatching cues and flooding the vegetation to provide extra habitat. **Riparian vegetation:** There were sufficient vegetation survey points (obligate or preferential riparian species) to assess flood requirements. Different bed heights/depths (since there are 4 active channels) also complicate interpretation of hydraulic data. Extensive data on this site is available **Geomorphology:** The available hydrological record for the site is relatively short with gaps. Additionally, the years which are within this record include the extremely wet 1996 and 2000 (very large flood) years as well as the very low flow years of the 1990's and early 2000's. Due to the bedrock nature of the site, there are no reliable morphological cues which can be used to indicate required flows. However extensive research into the geomorphological dynamics of these river systems (including the author's PhD research) has provided significant insight in the behaviour and maintenance of these anastomosing reaches of the river. These anastomosing sections have been shown to depend on extremely large floods for channel maintenance, and the large floods are shown to be required for channel maintenance and scour.	**4**
EWR 4	4.5	3	3	1.5	**Fish:** The recommended floods are adequate in terms of frequency, size and duration to provide various functions regarding fish migration, creation of migration, spawning habitats and nursery areas. Receding limb of higher floods classes also provide important functions. **Macroinvertebrates:** The recommended floods are adequate in terms of frequency, size and duration to provide various functions (clearing fines, scouring the substrate, providing breeding and hatching cues and flooding the vegetation to provide extra habitat. **Riparian vegetation:** Sufficient vegetation survey points to assess flow requirements.	**2.3**

EWR SITE	FISH	MACROINVERTEBRATES	RIPARIAN VEGETATION	GEOMORPHOLOGY	COMMENT	HIGH FLOWS
					Geomorphology: The available hydrological record for the site is extremely unreliable – the only observed data is derived from a gauge very far upstream, and the flows recorded at this gauge do not represent the flow conditions at the site. Due to the bedrock nature of the channel form at the site, there are very poor morphological cues which can be used to set flows. Flow requirements were thus estimated using the bed material (sediment characteristics) within the active channel, and the largest (Class V) flood estimated from the alluvial bar and ephemeral flood channel adjacent to the active channel. Confidence is extremely low due to lack of morphological cues and the absence of PBMT modelling results (due to a lack of daily hydrological data for the site).	
EWR 5	4	3	3.5	2	**Fish:** The recommended floods are adequate in terms of frequency, size and duration to provide various functions regarding fish migration, creation of migration, spawning habitats and nursery areas. Receding limb of higher floods classes also provide important functions.	**2.8**
					Macroinvertebrates: The recommended floods are adequate in terms of frequency, size and duration to provide various functions (clearing fines, scouring the substrate, providing breeding and hatching cues and flooding the vegetation to provide extra habitat.	
					Riparian vegetation: Sufficient vegetation survey points to assess flow requirements.	
					Geomorphology: Confidence is moderate because, due to the absence of available daily hydrological data, it was not possible to undertake PBMT modelling to identify the geomorphologically effective flows for the site. Additionally, the morphological cues (paired terraces etc) for the identification of geomorphologically significant or effective flows are weak. However these factors are ameliorated because the main issue at the site (given the bed characteristics observed) would be to maintain fines transport through the site to prevent the smothering of the cobbles and boulders immediately up- and downstream. Flows to ensure this have been estimated and requested as above.	
EWR 6	3.5	4	4	1.5	**Fish:** The recommended floods are estimated to be adequate in terms of frequency, size and duration to provide various functions regarding fish migration, creation of migration, spawning habitats and nursery areas. Receding limb of higher floods classes also provide important functions	**2.8**
					Macroinvertebrates: The recommended floods are adequate in terms of frequency, size and duration to provide various functions (clearing fines, scouring the substrate, flushing out the Thiaridae and flooding the vegetation to provide extra habitat.	
					Riparian vegetation: Sufficient vegetation obligate survey points to assess flow requirements.	
					Geomorphology: The site is located in a bedrock anastomosing reach. There are two main channels and a seasonal channel on the cross-section. Overall confidence in the flows for geomorphology is moderate to low because: • The site is completely bedrock dominated and morphological cues are not reliable. • The confidence in high flow hydraulics is medium to low; and • no daily hydrological data were available to enable PBMT to be undertaken, so it was not possible to determine the geomorphologically effective (channel maintenance) flows for the site.	
EWR 7	4	4	3	1.5	**Fish:** The recommended floods are estimated to be adequate in terms of frequency, size and duration to provide various functions regarding fish migration, creation of migration, spawning habitats and nursery areas. Receding limb of higher floods classes also provide important functions	**2.3**
					Macroinvertebrates: The recommended floods are adequate in terms of frequency, size and duration to satisfy the required functions, namely clearing fines, scouring the substrate, inundating the marginal vegetation and improving the water quality.	
					Riparian vegetation: Vegetation survey points (riparian indicators) to assess flow requirements scanty at this site.	
					Geomorphology: There is an extensive paired terrace upstream of the cross-section; part of which extends into the cross-section area (on the left bank). At the far left extent of the cross-section is an ephemeral flood channel. The active channel itself is incised, and width dramatically reduced from the historic condition. Overall confidence in the flows for geomorphology is low because: • The site is immediately upstream of a bridge and the macro-channel morphology is likely to have been affected so cues for inter-annual floods are not clear. • The active channel is incised so small (intra-annual) floods are not clear. • The confidence in high flow hydraulics is moderate; and • no daily hydrological data are available to enable PBMT to be undertaken, so it was not possible to determine the geomorphologically effective (channel maintenance) flows for the site.	
EWR 8	**4**	3	4	4	**Fish:** The recommended floods are estimated to be adequate in terms of frequency, size and duration to provide various functions regarding fish migration, creation of migration, spawning habitats and nursery areas. Receding limb of higher floods classes also provide important functions	**4**
					Macroinvertebrates: The recommended floods are adequate in terms of frequency, size and duration to satisfy the required functions, namely clearing fines, scouring the substrate, inundating the marginal vegetation and improving the water quality.	

EWR SITE	FISH	MACROINVERTEBRATES	RIPARIAN VEGETATION	GEOMORPHOLOGY	COMMENT	HIGH FLOWS
					Riparian vegetation: Sufficient riparian vegetation survey points to assess flow requirements.	
					Geomorphology: There is an extensive terrace on the right bank of on the cross-section. This runs far up- and downstream from the site. It is not paired due to the large bedrock boulder on the right bank. Potential bed material transport modelling indicated that the effective discharge class, responsibly for about 40% of the transport of the 1 mm and 2 mm sands at the site, is 1 - 0.1%. This flow duration class is represented by a discharge of approximately 160 m^3/s. This flow corresponds precisely with the extensive lateral bar at the site (see below). The sediment transport results are thus confirmed by the morphological cues at the site, and thus our confidence at this site is very high. There were no further cues or other important discharges (in terms of sediment transport) that were evident for this site.	

19.2.3 Hydrology confidence

Note: if natural hydrology is used to guide requirements, then that confidence will carry a higher weight than normal. Hydrology confidence is provided from the perspective of its usefulness to EWR assessments. This will be different than the confidence in the hydrology for water resources management and planning. The scale of requirements is very different, and that is why high confidence hydrology for water resource management purposes often does not provide sufficient confidence for EWR assessment. The confidence in hydrology for the respective EWR sites is provided in Table 19.4.

Table 19.4 Confidence in hydrology

EWR site	Natural hydrology	Present hydrology	Observed hydrology	Local knowledge / information	Comment	confidence: Median	confidence: Average
EWR 1	3	2	1	3	There is no gauge anywhere close to the site to be really useful. Due to the fact that the Sabie is not seen as stressed, much less effort was spent on verifying present use than on the Crocodile system. Some uncertainty therefore exists with regards to the modeled present day hydrology.	2.5	2.25
EWR 2	3	2	4	3	A gauge exists upstream of the site and provides useful information for calibration purposes and flood determination.	3	3
EWR 3	3	3	3	4	The site is further downstream and the hydrology was not compared to previous detailed daily hydrology undertaken. Present hydrology probably more realistic as further in the system and the culminating impact of users easier to deal with. The gauge is far from the site, but still useful. As the site has been extensively studied and surveyed, extensive local information can be obtained.	3	3.25
EWR 4	3	1	0	0	A gauge very far upstream of the site exists. There is uncertainty on the forest usage and upstream activities. This results in an overall low confidence in the hydrology.	0.5	1
EWR 5	4	1	2	3	The very low confidence in present hydrology is based on the discrepancies on the actual operation on the dam, and the rules built into the yield model. Most of the information on the operation of the dam was word of mouth. The upstream gauge is upstream of tributaries and not that useful. Local information due to the site having been often surveyed before is reasonable.	2.5	2.5
EWR 6	1	1	0	1	The whole Sand Catchment is represented by one gauge. With the forestry and huge rural community in the catchment, as well as various small water schemes all in various states of disrepair, modeling hydrology is extremely complex. Uncertainty exists regarding the perenniality of the system. Local knowledge is based on extensive travel in the area 10 13 years ago.	1	0.75

EWR site	Natural hydrology	Present hydrology	Observed hydrology	Local knowledge / information	Comment	confidence: Median	confidence: Average
EWR 7	2	1	0	0	See above.	0.5	0.75
EWR 8	2	1	0	3	See above.	1.5	1.5

19.2.4 Overall confidence

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

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

Colour coding of confidences in Table 19.5 – 19.6 are as follows:

Green: High to Very High
Yellow: Medium to high
Red: Very low to Medium

Table 19.5 Overall Confidence in EWR Results

EWR SITE	HYDROLOGY	LOW FLOWS				HIGH FLOWS			
		BIOLOGICAL RESPONSES	HYDRAULICS	EWR SITE	Comment	BIOLOGICAL RESPONSES	HYDRAULICS	EWR SITE	Comment
EWR 1	2.5	3.5	3.5	**3.5**	Moderate - High confidence for both biophysical and hydraulic aspects. Hydraulics is not of higher confidence due to EWR being below the measured minimum discharge and the presence of non-uniform flow conditions.	3.3	3	**3**	Moderate confidence due to hydraulics where flood requirements is above the measured maximum discharge and the presence of non-uniform conditions.
EWR 2	3	3.5	3.5	**3.5**	Moderate - High confidence for both biophysical and hydraulic aspects. Hydraulics is not of higher confidence due to some of the EWR recommendations being below the measured minimum.	3	3	**3**	Moderate confidence. The hydraulics is complex as during flood conditions various channels form in a floodplain on a bend.
EWR 3	3	4	3.5	**3.5**	Moderate - High confidence for hydraulics due to uncertainty with low flow 2-D modelling.	4	4	**4**	The site is complex with multi-distributary channels, however the flood recommendations are below the highest measured flow.

EWR SITE	HYDROLOGY	LOW FLOWS				HIGH FLOWS			
		BIOLOGICAL RESPONSES	HYDRAULICS	EWR SITE	Comment	BIOLOGICAL RESPONSES	HYDRAULICS	EWR SITE	Comment
EWR 4	0.5	4	4	4	High confidence for both hydraulics and biophysical aspects.	2.3	3	2.3	Moderate confidence for hydraulics due to downstream bridge that can cause back-up during flooding conditions. Biophysical confidence lower due to the lack of geomorphological cues and a nearby gauge with reliable data.
EWR 5	2.5	4	3.5	3.5	Two channels at different stages[1] and some flows recommended lower than measured discharge.	2.8	3	3	Confidence related to lack of hydrological data and geomorphological cues at the site and moderate hydraulic confidence as flood recommendations are mostly above measured maximum.
EWR 6	1	3.5	4	3.5	Lower confidence in the fish than the other components, mostly due to the position of the cross-section which does not represent the most critical habitats for fish.	2.8	3	3	Complex hydraulic site. Bedrock nature of site - lack of geomorphological cues and hydrological information.
EWR 7	0.5	2.5	3.5	2.5	The site was approached at a rapid level and only one biological survey was undertaken. Confidence therefore relates to lack of surveyed and any historical information. Only one low flow hydraulic point was available.	2.3	3	2.3	Geomorphological confidence low due to lack of a gauge, no hydrology, paired terraces, bedrock and lack of cues. Only one hydraulic measurement at the bottom of the high flow range was available.
EWR 8	1.5	3	2	2	Although this is an old EWR site, the cross-section had to be moved as the previous one was overgrown with reeds. Previous hydraulic data could not be used. Minimal measurements at low flows were available and the bed and channel is mobile. There is backup from bedrock and uncertainty with the flow class modelling.	4	3	3	Confidence due to the hydraulics is moderate as recommended floods are above the measured maximum and vegetation resistance in the channel is problematic.

1 The height of the surface of a river or other fluctuating body of water above a set point e.g. *at flood stage* (http://www.answers.com/topic/stage).

19.3 RECOMMENDATIONS

The biological confidences for low flows range from Moderate - High to High for all the sites except for EWR 7 and EWR 8. EWR 7 was at a Rapid level for surveys and due to the lack of historical information and the once-of survey, the confidence is Low - Moderate. EWR 8 has a moderate confidence which is due to the alluvial nature of the system and the lack of information on hydrology. No further work apart from monitoring within the Ecological Water Resource Monitoring Programme (EWRMP) is envisioned at any of the sites. If EWR 7 becomes an EWRM site, one additional survey might be required to establish the baseline prior to monitoring.

The overall confidences in the low flows are Low at EWR 7 and 8, and range from Moderate - High to High at the other sites. The Low confidence at EWR 7 is related to low confidence in the instream biota (see above). The Low confidence at EWR 8 is due to the lack of measured discharge information used to calibrate low flow hydraulics. To improve the overall confidence in the low flow requirements, the following must be undertaken:

- Measurements at very low flows to calibrate the hydraulic modelling will be required.
- The hydraulic modelling will have to be redone.
- If the rating relationships are different, ecologists might have to review requirements.

The biophysical confidence in the high flows range from Low - Moderate to High. The lower range of confidences is all associated with a lack of geomorphological confidence in the recommended high flows related to the nature of the site and lack of hydrological information. This information cannot be obtained by additional work, so no further biophysical work is recommended.

The high flow confidence ranged from Low - Moderate to High. Apart from the geomorphological problems, no hydraulic confidence is below Moderate. Further work is therefore not recommended as it would not be of any use improving hydraulic confidence if the geomorphological confidence cannot be improved in any case. Also, high flows cannot be managed at any of the sites apart from EWR 5.

One of the major issues that also influence the confidence is the lack of good hydrological information in the Sand River System. Unless additional gauges are established, this situation will continue. It is strongly recommended that more hydrological information be collected at gauges or rated sections.

It is strongly recommended that an EWRMP is initiated as soon as possible. The information gathered during this study is suitable for the baseline, but if too much time relapses between the baseline and monitoring, new surveys and EcoClassification process will have to be undertaken. It must be noted that an Instream Flow Requirement study was undertaken during 1996 at a Comprehensive level. However, no monitoring was undertaken in the interim and therefore the 1996 information is now historical information and could not be used for a baseline. The Marite and downstream Sabie River were also the first systems where the IFRs (or EWRs as they are known now) were implemented.

NOTE: No monitoring was initiated, and no audit of the implementation took place, therefore no information on the success of the implementation is available. Due to lack of support and capacity, the implementation system is apparently not functioning anymore.

Lastly, EWRM will be difficult to successfully implement without the additional hydrological stations. Causes of problems cannot be identified unless there is hydrological information that is available close to EWR sites.

The recommendations are summarised in Table 19.6.

Table 19.6 Summary of recommendations required to improve confidences

EWR sites	Low flow confidence	High flow confidence	Recommendations
EWR 1	3.5	3	EWRM.
EWR 2	3.5	3	EWRM.
EWR 3	3.5	4	EWRM.
EWR 4	4	2.3	EWRM.
EWR 5	3.5	3	EWRM.
EWR 6	3.5	3	Hydrological monitoring. EWRM.
EWR 7	2.5	2.3	Hydrological monitoring. EWRM.
EWR 8	2	3	Additional low flow hydraulic information for calibration purposes. Hydrological monitoring. EWRM.

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