

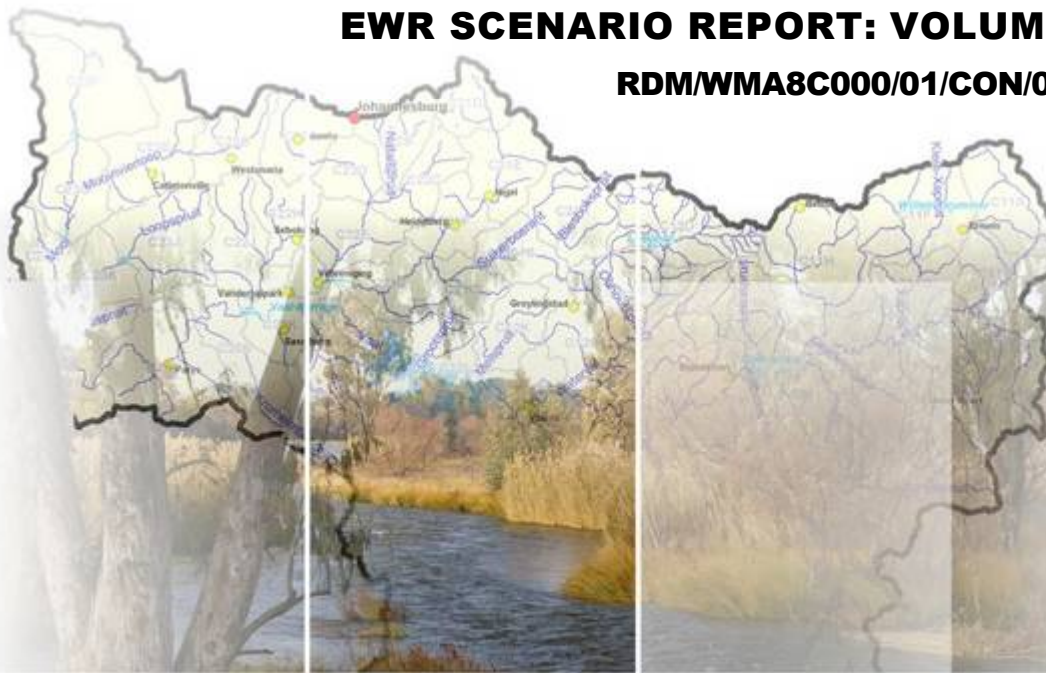
COMPREHENSIVE RESERVE DETERMINATION

INTEGRATED VAAL RIVER SYSTEM

SURFACE WATER

EWR SCENARIO REPORT: VOLUME 1

RDM/WMA8C000/01/CON/0209



TECHNICAL COMPONENT: UPPER VAAL

NOVEMBER 2009

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REPUBLIC OF SOUTH AFRICA

COMPREHENSIVE RESERVE DETERMINATION STUDY OF THE INTEGRATED VAAL RIVER SYSTEM

UPPER VAAL WATER MANAGEMENT AREA TECHNICAL COMPONENT: EWR SCENARIO REPORT: VOLUME 1

Report number: RDM/WMA8C000/01/CON/0209

NOVEMBER 2009

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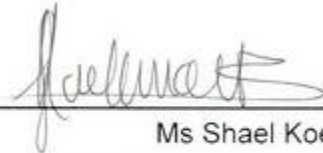
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EXECUTIVE SUMMARY

INTRODUCTION

In order for the Department of Water Affairs (DWA) to make informed decisions regarding the authorization of future water use and the magnitude of the impacts of the present and proposed developments in the Vaal River System, higher levels of confidence is needed for the Reserve Determination within this study area. Therefore a Comprehensive Reserve determination study within Water Management Area (WMA) 8 has been undertaken to provide input to the Reconciliation studies and the integrated water quality management plan recently undertaken by the National Water Resources Planning Directorate (D: NWRP) of the DWAF.

STUDY AREA

The Upper Vaal WMA is one of three WMAs in the Vaal River catchment, which is the drainage area of the Vaal River from its headwaters to the confluence of the Vaal and Orange Rivers (DWAF, 2004).

The Upper Vaal WMA includes *inter alia* the Vaal, Klip, Wilge, Liebenbergsvlei and Mooi Rivers and extends to the confluence of the Mooi and Vaal Rivers. It covers a catchment area of 55 565 km². The locality and characteristics of the Ecological Water Requirement (EWR) sites are provided in the Table below.

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 2). Volume 2 will only be made available electronically.

APPROACH

Comprehensive EWR sites: EWR 2, 3, 6, 7, 8, and 9

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.

Comprehensive EWR sites: 10, 11, 1, 4 and 5

During the Ecological Water Requirement (EWR) scenario assessment of the Upper Vaal, 5 EWR sites were identified as having more flows than natural. Therefore the standard Habitat Flow Stressor Response method approach could not be applied to these sites to determine low flow requirements for the EWR scenarios. The HFSR method was refined to cater for these situations by Ms Delana Louw with input from all the specialists and the general approach is provided in detail in Chapter 14.

Rapid EWR sites: RE-EWR 1 and 2

RE-EWR 1 and 2 was assessed at Rapid level for low flows and therefore the HFSR method for setting low flows were not applied to this site. The Reserve was estimated using the Hughes Desktop Reserve Model for the Ecological Category (EC) set. Therefore for the low flow requirements, the estimated Reserve was verified and the DRM was adjusted if needed. High flows were set using the standard Comprehensive approach.

EWR site number	EWR site name	River	National RHP site	Co-ordinates		EcoRegion (Level II)	Geomorphic Zone	Altitude (m)	RU	Quaternary	Hydrological gauge
				Latitude	Longitude						
EWR 1	Uitkoms	Vaal	C1Geel_Unspe	-26.8728	29.61384	11.05	Lowland	1570	MRU Vaal B	C11J	C1H007
EWR 2	Grootdraai	Vaal	C1Vaal Braks	-26.9211	29.27929	11.03	Lowland	1537	MRU Vaal C	C11L	C1H019
EWR 3	Gladdedrift	Vaal	C1Vaal-Villie	-26.99087	28.72971	11.03	Lowland	1487	MRU Vaal C	C12H	C1H012
EWR 4	De Neys	Vaal	C2Vaal-Deny	-26.84262	28.1123	11.03	Lower Foothills	1445	MRU Vaal D	C22F	C2H122
EWR 5	Skandinavia	Vaal		-26.93243	27.01367	11.08	Lowland	1309	MRU Vaal E	C23L	C2H018
EWR 6	Klip	Klip	C1Klip-Unspe2	-27.36166	29.48503	11.06	Lower Foothills	1593	MRU Klip C	C13D	
EWR 7	Upper Wilge	Wilge		-28.20185	29.55827	11.03	Lowland	1692	MRU Wilge A	C81A	Redmans Werf 319
EWR 8	Bavaria	Wilge	C8Wilg-Belwh	-27.80017	28.76778	11.03	Lowland	1573	MRU Wilge B	C82C	C8H028
EWR 9	Suikerbos US	Suikerbosrand	C2Suik-Dehoe	-26.6467	28.38197	11.01	Lower Foothills	1509	RU Suiker A	C21C	
EWR 10	Suikerbos DS	Suikerbosrand	Close to C2Suik-Badfo	-26.68137	28.16798	11.01	Lowland	1453	RU Suiker B	C21G	
EWR 11	Blesbokspruit	Blesbokspruit	C2Bles-Marai (locality incorrect)	-26.47892	28.42488	11.03	Lower Foothills	1528	RU Bles A	C21F	
Rapid Level sites											
RE-EWR 1	Klein Vaal	Klein Vaal	C1KVaal-unspe	-26.9128	30.17497	11.02	Lower Foothills	1620	MRU Kvaal A	C11C	
RE-EWR 2	Mooi	Mooi	Close to C2Mooi-Klerk	-26.2587	27.15973	11.01	Lower Foothills	1457	RU Mooi B	C23G	

RESULTS

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

EWR site	EC	Maintenance low flows (%nMAR)	Drought low flows (%nMAR)	High flows (%nMAR)	Long term mean (% nMAR)
Virgin MARs					
EWR 2	C PES, REC	6.6	1.1	7	12.7
	B AEC up	11.3	1.1	7.6	16.2
	C/D AEC down	3.1	1.1	6.2	9.5
EWR 3	C PES, REC	10.6	0.9	3.7	14.6
	B AEC up	20.4	1.8	4.3	22.7
	C/D AEC down	4.5	0.9	3.2	8.8
EWR 6	B/C PES, REC	18.4	18.4	8.1	23.4
	C AEC down	8.8	1.7	6.5	14.9
EWR 7	B/C PES, REC	34.8	2.8	13.2	24
	C AEC down	19.6	2.8	5.1	25.8
EWR 8	C PES, REC	5.1	1.2	6.6	11.5
	B/C AEC up	6.6	1.2	7	12.6
	D AEC down	3.1	1.2	5.7	9.7
EWR 9	C PES	14.1	5.8	6.6	21.1
	B/C REC	27.1	5.8	7.3	31.4
EWR 1	B/C PES, REC	35.7	1.8	9.7	40.5
Present Day (PD) MAR					
EWR 10	C/D PES, REC	30.1	17.1	4.3	41.1
	C AEC down	29.3	11.6	4.1	33.6
EWR 11	D PES (DRM D)	12.4	9.2	5.7	25.9
	D REC (DRM C)	14.1	7.1	5.7	21.2
EWR 4	Could not be generated.				
EWR 5	Could not be generated.				

CONCLUSIONS AND RECOMMENDATIONS

A summary of confidences for all the sites are given below. Red cells indicate low confidence, yellow cells indicate medium confidence and green cells indicate high confidence.

Site	Hydrology	Biological responses Low flows	Hydraulic: Low Flows	OVERALL: LOW FLOWS	COMMENT	Biophysical responses: High flows	Hydraulics: High Flows	OVERALL: HIGH FLOWS	COMMENT
EWR 2	3	3.5	4	3.5	Macroinvertebrate requirements result in a slightly lower confidence than the fish due to uncertainties on the influence of water quality on the biota response.	3	4	3.5	High flow medium confidence due to the upstream dam and impact on sediment as well as the lack of morphological cues.
EWR 3	3	4	4	4	Biological responses medium due. Two-dimensional hydraulic modelling was undertaken. The hydraulic requirements for low flows largely within the range of measured flows.	3.5	5	3.5	Medium to high confidence due to bedrock nature of the site and lack of geomorphological cues.
EWR 6	1.9	4	3	3	Hydraulics: No measured flows between 0.003 and 1.0 m ³ /s. As many of the low flow requirements are within this range, the confidence is medium.	3.5	3	3	Hydraulics a medium confidence due to the lack of measured flows in the range of high flow recommendations.

Site	Hydrology	Biological responses Low flows	Hydraulic: Low Flows	OVERALL: LOW FLOWS	COMMENT	Biophysical responses: High flows	Hydraulics: High Flows	OVERALL: HIGH FLOWS	COMMENT
EWR 7	2.8	2	2.5	2	Hydraulics is low confidence as there is uncertainty whether zero flows equate to zero depth. Only one low flow measurement was available. The biota confidence is also low due to the fact that macroinvertebrate requirements are based on depth – however, no flow dependant macroinvertebrates are present.	3.8	3	3	Complex site with floodplain and wetland components.
EWR 8	2.4	4	3	3	Hydraulics: Complex site. Non-horizontal water surfaces. No measurements in the range of most low flow requirements.	3.8	5	4	Hydraulics of very high confidence as a suitable range of measured flows exists.
EWR 9	1.8	4	4	4	Hydraulically this is a complex site with non-horizontal water surfaces. As a suitable range of flows were measured in the high flow range, the confidence is high. The biota confidence medium to high due to	3	3	3	Hydraulically this is a complex site with only a single high flow measurement. The bedrock nature of the site and lack of geomorphological cues resulted in a moderate confidence for the biophysical responses.
EWR 10	2.5	2.8	3	3	Low flows set are below measurements for hydraulic calibrations. There is also uncertainty for flow class modelling. The medium confidence for the biota is due to the complexity of the water quality issues and the higher flows than natural.	4	4	4	Suitable range of measured flows for high flows resulting in high confidence for the hydraulics.
EWR 11	2.3	4	2.5	2.5	The low flows fall below the recommendations and the hydraulic confidence is therefore medium to high.	4	5	4	Suitable range of measured high flows result in very high confidence for the hydraulics.
EWR 1	2.9	4	2.5	2.5	The site is hydraulically complex. Most requirements fall below the measured minimum flow. There are also non-uniform flow conditions and uncertainty regarding the flow class modelling.	4	4	4	Hydraulics: Two of the three high flows fall within the range of measured flows.
EWR 4	2.8	1	3.5	1	Hydraulics: Recommendations are below measured minimum flows. There are non-uniform flow conditions and non-horizontal water surfaces and therefore uncertainty in the flow class modelling. The very low confidence of the biota is due to the macroinvertebrate uncertainty in their recommendations. The change in seasonality, water quality issues and increased flows in some seasons are difficult to interpret.	2.3	3	2.3	Low to Medium confidence due to the uncertainty in the geomorphological requirements due to the nature of the site, the effect of the Vaal Dam and the response in terms of habitat to the flood recommendations made.
EWR 5	2.8	3	3.5	3	Hydraulics: The recommendations are below the measured minimum. Non-uniform flow conditions exist. There is uncertainty for flow class modelling. See above for confidence motivation for biota.	4	3.5	3.5	The flood requirements are above the measured maximum resulting in a medium to high confidence only.

Recommendations are determined based on the possibility and necessity of improving confidence. Considering the above confidences, the recommendations are summarised in the table below.

EWR sites	Low flow confidence	High flow confidence	Recommendations
2	3.5	3.5	EWRM.
3	4	3.5	EWRM.
6	3	3	EWRM. If any improvement is required at this site, it is firstly recommended that a better idea of the present hydrological regime is obtained.
7	2	3	The wetland as a whole must be addressed and this would require the floodplain to be surveyed and hydraulics to be supplied for the whole floodplain.
8	3	4	EWRM.
9	4	3	EWRM.
10	3	4	EWRM.
11	2.5	4	EWRM.
1	2.5	4	EWRM.
4	1	2.3	EWRM.
5	3	3.5	EWRM.

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APPENDIX E	Supporting information for the determination of stress indices and EWR scenarios of EWR 7: Upper Wilge
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APPENDIX G	Supporting information for the determination of stress indices and EWR scenarios of EWR 9: Suikerbos US
APPENDIX H	Supporting information for the determination of stress indices and EWR scenarios of EWR 10: Suikerbos DS
APPENDIX I	Supporting information for the determination of stress indices and EWR scenarios of EWR 11: Blesbokspruit
APPENDIX J	Supporting information for the determination of stress indices and EWR scenarios of EWR 1: Uitkoms
APPENDIX K	Supporting information for the determination of stress indices and EWR scenarios of EWR 4: De Neys
APPENDIX L	Supporting information for the determination of stress indices and EWR scenarios of EWR 5: Scandinavia

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: NWRP	Directorate: National Water Resource Planning
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
FFHA	Fish Flow Habitat Assessment model
FI	Fast intermediate fish habitat
FROC	Frequency of Occurrence
FS	Fast shallow fish habitat
HFSR	Habitat Flow Stressor Response
Integ	Integrated
LIM	Limnophilic fish species
LSR	Large semi-rheophilic fish species
MAR	Mean Annual Runoff
MCM	Million Cubic Meters
MHIFR	Maintenance high flow
MLIFR	Maintenance low flow
MVI	Marginal vegetation macroinvertebrate
MV	Marginal vegetation
Quat	Quaternary catchment
PD	Present Day
PES	Present Ecological State
REC	Recommended Ecological Category
RHP	River Health Programme
RU	Resource Unit
SD	Slow deep fish habitat
SPATSIM	Spatial and Time Series Information Modelling
SSR	Small semi-rheophilic fish species
SS	Slow shallow fish habitat
Veg	Vegetation
WMA	Water Management Area

1 BACKGROUND AND INTRODUCTION

1.1 BACKGROUND

In order for the Department of Water Affairs (DWA) to make informed decisions regarding the authorization of future water use and the magnitude of the impacts of the present and proposed developments in the Vaal River System, higher levels of confidence is needed for the Reserve Determination within this study area. Therefore a Comprehensive Reserve determination study within Water Management Area (WMA) 8 has been undertaken to provide input to the Reconciliation studies and the integrated water quality management plan recently undertaken by the National Water Resources Planning Directorate (D: NWRP) of the DWA.

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.

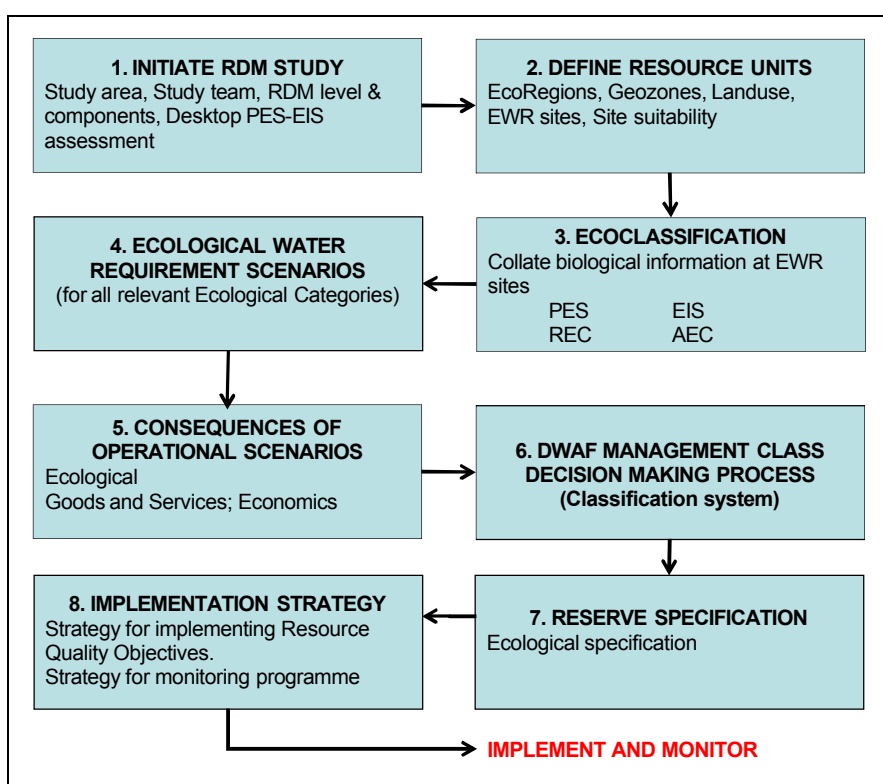


Figure 1.1 The 8-step Ecological Reserve procedure (adapted from DWAF, 1999)

1.2 STUDY AREA

The Upper Vaal WMA is one of three WMAs in the Vaal River catchment, which is the drainage area of the Vaal River from its headwaters to the confluence of the Vaal and Orange Rivers (DWAF, 2004).

The Upper Vaal WMA includes *inter alia* the Vaal, Klip, Wilge, Liebenbergsvlei and Mooi Rivers and extends to the confluence of the Mooi and Vaal Rivers. It covers a catchment area of 55 565 km². The locality and characteristics of the Ecological Water Requirement (EWR) sites are provided in Table 1.1 and Figure 1.2. Information on site selection and the Management Resource Units (MRUs) are provided in DWAF (2008) (Report RDM/WMA8C000/01/CON/0208).

Table 1.1 Locality of EWR sites for the Upper Vaal River system

EWR site number	EWR site name	River	National RHP site	Co-ordinates		EcoRegion (Level II)	Geomorphic Zone	Altitude (m)	RU	Quaternary	Hydrological gauge
				Latitude	Longitude						
EWR 1	Uitkoms	Vaal	C1Geel_Unspe	-26.8728	29.61384	11.05	Lowland	1570	MRU Vaal B	C11J	C1H007
EWR 2	Grootdraai	Vaal	C1Vaal Braks	-26.9211	29.27929	11.03	Lowland	1537	MRU Vaal C	C11L	C1H019
EWR 3	Gladdedrift	Vaal	C1Vaal-Villie	-26.99087	28.72971	11.03	Lowland	1487	MRU Vaal C	C12H	C1H012
EWR 4	De Neys	Vaal	C2Vaal-Deny	-26.84262	28.1123	11.03	Lower Foothills	1445	MRU Vaal D	C22F	C2H122
EWR 5	Scandinavia	Vaal		-26.93243	27.01367	11.08	Lowland	1309	MRU Vaal E	C23L	C2H018
EWR 6	Klip	Klip	C1Klip-Unspe2	-27.36166	29.48503	11.06	Lower Foothills	1593	MRU Klip C	C13D	
EWR 7	Upper Wilge	Wilge		-28.20185	29.55827	11.03	Lowland	1692	MRU Wilge A	C81A	Redmans Werf 319
EWR 8	Bavaria	Wilge	C8Wilg-Belwh	-27.80017	28.76778	11.03	Lowland	1573	MRU Wilge B	C82C	C8H028
EWR 9	Suikerbos US	Suikerbosrand	C2Suik-Dehoe	-26.6467	28.38197	11.01	Lower Foothills	1509	RU Suiker A	C21C	
EWR 10	Suikerbos DS	Suikerbosrand	Close to C2Suik-Badfo	-26.68137	28.16798	11.01	Lowland	1453	RU Suiker B	C21G	
EWR 11	Blesbokspruit	Blesbokspruit	C2Bles-Marai (locality incorrect)	-26.47892	28.42488	11.03	Lower Foothills	1528	RU Bles A	C21F	
Rapid Level sites											
RE-EWR 1	Klein Vaal	Klein Vaal	C1KVaal-unspe	-26.9128	30.17497	11.02	Lower Foothills	1620	MRU Kvaal A	C11C	
RE-EWR 2	Mooi	Mooi	Close to C2Mooi-Klerk	-26.2587	27.15973	11.01	Lower Foothills	1457	RU Mooi B	C23G	

1 River Health Programme

2 Resource Unit

3 Quaternary catchment

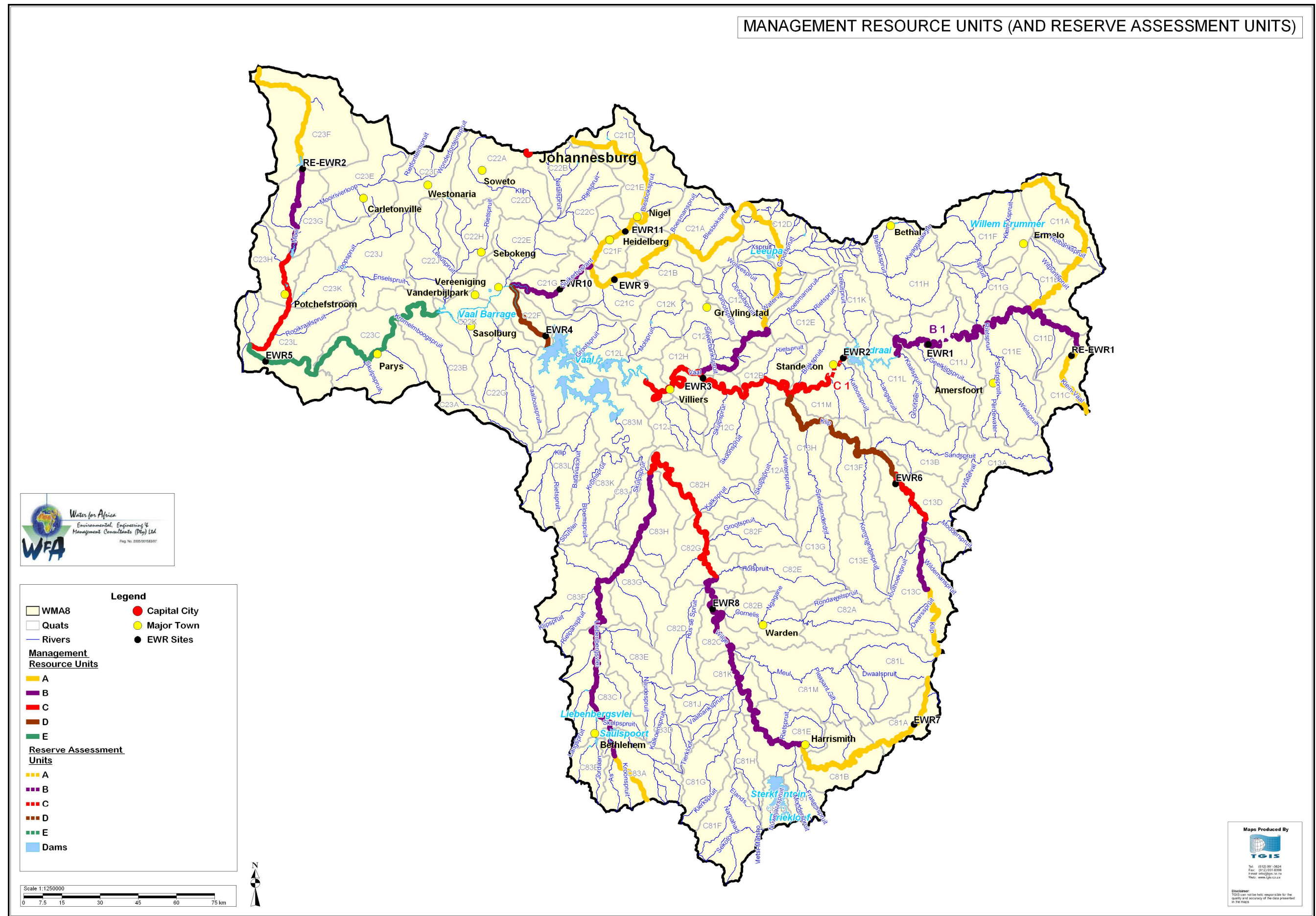


Figure 1.2 Locality of EWR sites and Management Resource Units

1.3 METHODOLOGY FOR SETTING RIVERINE EWR SCENARIOS

SPATSIM (Spatial and Time Series Information Modelling) (Hughes and Forsythe, 2006) was used as a framework for the hydrological information used within the process, and to capture the EWR results.

Comprehensive EWR sites

The approach summarised in Section 1.3.1 was applied to EWR 2, 3, 6, 7, 8 and 9. During the Ecological Water Requirement (EWR) scenario assessment of the Upper Vaal, 5 EWR sites were identified as having more flows than natural with:

- EWR 10 and EWR 11 having more flows than natural during all seasons.
- EWR 4 and EWR 5 having more flows than natural during the dry season with seasonal reversal (i.e. present flows are much lower than natural during the wet season).
- EWR 1 having more flows than natural during the dry season only – the present flows in the wet season are similar than natural.

Therefore the standard Habitat Flow Stressor Response method (HFSR) (IWR S2S, 2004) could not be applied to these sites to determine low flow requirements for the EWR scenarios. The HFSR method was refined to cater for these situations by Ms Delana Louw with input from all the specialists and the general approach is provided in detail in Chapter 14.

Rapid EWR sites

RE-EWR 1 and 2 was assessed at a Rapid level 3 for low flows and therefore the HFSR method for setting low flows were not applied to these sites. The Reserve was estimated using the Hughes Desktop Reserve Model (DRM) (DWAf, 1999) for the Ecological Category (EC) set. Therefore for the low flow requirements, the estimated Reserve was verified and the DRM was adjusted if needed. High flows were set using the standard Comprehensive approach.

1.3.1 Low flows

The Habitat Flow Stressor Response method (HFSR) (IWR S2S, 2004) was used to set low flows, a method adjusted from the Building Block Methodology (BBM; King and Louw, 1998). The objective is to supply a relationship between an index of stress (0 to 10) and habitat availability during different flow conditions. This information is required for the determination of required stresses for different Ecological Categories (ECs). The information on habitat collated during the course of the study, as well as the hydraulics, was used to determine the stress indices. These indices form the basis for the determination of low flows for the EWR scenarios using the Habitat Flow Stressor Response method.

1.3.2 High flows

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

- Flood ranges for each flood class and the geomorphology and riparian vegetation functions are identified and tabled by the relevant specialists.
- These are provided to the instream specialists who indicate;
 - 0 which instream function these floods cater for,
 - 0 whether additional instream functions apart from the generic list are required,
 - 0 whether any instream functions are not necessary and can be deleted from the list,

- 0 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.
 - The floods are evaluated by the hydrologist to determine whether they are realistic. A nearby gauge if available is used for this.
 - The hydrologist then determines the daily average and documents the months in which the floods are spaced.

1.4 PURPOSE OF THE REPORT

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 RDM/WMA8C000/01/CON/0109; 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.

1.5 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 Volume 2, which contains the relevant supporting specialist information. Volume two will be provided in electronic format only.

Chapter 1: Introduction

This chapter.

Chapter 2, 4, 6, 8, 10, 12, 15, 17, 19, 21, 23: Determination of stress indices

The stress indices for all physical and biological components at each comprehensive EWR site are provided.

Chapter 3, 5, 7, 9, 11, 13, 16, 18, 20, 22, 24: Determination of EWR scenarios

These chapters provide results of different EWR scenarios with respect to low and high flows for the respective comprehensive 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 14: Application of HFSR: Present flows more than natural

This chapter provides the approach to determining the low flow requirements of 5 comprehensive EWR sites where present day flows were more than natural.

Chapter 25, 26: Determination of low and high flow requirements of the Rapid EWR sites

The results of the low and high flow requirements are provided.

Chapter 27: Conclusions and Recommendations

The results are summarised and recommendations are made.

Chapter 28: References

2 EWR 2: GROOTDRAAI (VAAL RIVER) - DETERMINATION OF STRESS INDICES

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

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

2.1 INDICATOR SPECIES OR GROUP

2.1.1 Fish indicator group 1: Large semi-rheophilic species (BAEN, BKIM)

Two indicator species were selected representing two different groups for this EWR site. As a result of the absence of any true rheophilic fish species in this system, *Labeobarbus aeneus* (BAEN) was selected as a representative of a large semi-rheophilic (LSR) species. Additional information is provided in Appendix B, Table B1. Although *Labeobarbus kimberleyensis* (BKIM), another large semi-rheophilic species, reach bigger lengths, there were very small differences in stress between these two species related to habitat changes. As more information is available regarding the biology and different life-stage requirements of BAEN, this species was selected as the preferred indicator species for LSR.

2.1.2 Fish indicator group 2: Small semi-rheophilic species (BANO)

Barbus anoplus (BANO) was used as species representing small semi-rheophilic species (SSR). This group was used as a second indicator group due to its different habitat requirement and preferences when compared to the large semi-rheophilic. Additional information is provided in Appendix B, Table B2. BANO require inundated vegetation for spawning purposes, which may require higher flows than the large-semi rheophilic species which spawn within the riffle/rapid habitats.

2.1.3 Macroinvertebrate indicator taxa

Flow dependant (FDI) cobble dwelling macroinvertebrate 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 and include:

- Hydropsychid caddisflies and Simuliidae (i.e. common, flow dependent taxa). The minimum depth requirements for these taxa are 10 cm, and maximum depths are about 30 cm. The optimal current speeds are 0.4 m/s. These taxa are not sensitive to deterioration in water quality, and are expected to tolerate wide fluctuations in flow and water quality conditions.

2.1.4 Riparian vegetation indicator species¹

Indicator species included:

- *Cyperus marginatus*: Obligate riparian sedge that occurs in both the marginal and lower zones. Can form colonies in marshy areas and riverbanks. Rhizomatous, does not self seed.
- *Gomphostigma virgatum*: A perennial shrub which can attain 2.6 m. A woody riparian obligate occurring frequently in the marginal zone and prefers running water. Associated with inundated cobble and rocky streambeds. Flowers Dec - Mar.
- *Miscanthus junceus*: Grows on riverbanks and in vleis, often in standing water, mostly associated with coarse sandy soil. A dense, robust, perennial grass. Flowers from Nov – Jun.

2.2 STRESS FLOW INDEX

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

2.2.1 Habitat response

Habitat response is used to derive the biota's response to provide a biota stress index and represents the instantaneous response of habitat to flow changes, based on a site specific 0 – 10 scale for instream biota where:

- 0 – Optimum habitat (fixed at the natural maximum baseflow – calculated using the wettest flow month discharge at the maintenance % of 50 – 60% for the Vaal 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 B, Table B1.

The instantaneous response of flow dependent macroinvertebrate (FDI) taxa provides the % occurrence of various velocity-substrate classes under different flow conditions are provided in Appendix B, Table B3).

2.2.2 Biota response

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

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

The fish species response index is calculated using the fish habitat rating (cf Section 2.2.1) (Appendix B, Table B2) for each of the discharges evaluated for assessing habitat response. The macroinvertebrate (FDI) index is derived by considering the habitat response and % occurrence of

¹ The vegetation indicator species were used for the verification of low flows only. This is applicable to all sites.

habitat conditions at different flows. The FDI responses are described and coupled to a stress level (Appendix B, Table B4).

2.2.3 Integrated stress curve

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

The shaded species stress discharges in Table 2.1 indicate the discharges 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 2-1 illustrates this graphically.

In this specific case, the SSR fish stress index represents the integrated stress index (these values are the highest flow for a stress) for stress 0 – 7.3, therefore the red curve (representing the SSR stress index) is lying 'beneath' the integrated stress line (black) (Figure 2.1).

Table 2.1 Species stress discharges used to determine biotic stress

Stress	Flow (m ³ /s)			Integrated Flow (m ³ /s)
	SSR	LSR	FDI	
0	10	7.4	3.7	10
1	7.4	5.5	2.6	7.4
2	5.5	3.4	1.1	5.5
3	3.4	2.45	0.8	3.4
4	1.5	1.5	0.5	1.5
5	0.9	0.9	0.3	0.9
6	0.65	0.65	0.2	0.65
7	0.4	0.4	0.1	0.4
8	0.15	0.275	0.027	0.275
9	0.076	0.15	0.001	0.15
10	0.001	0.001	0.001	0

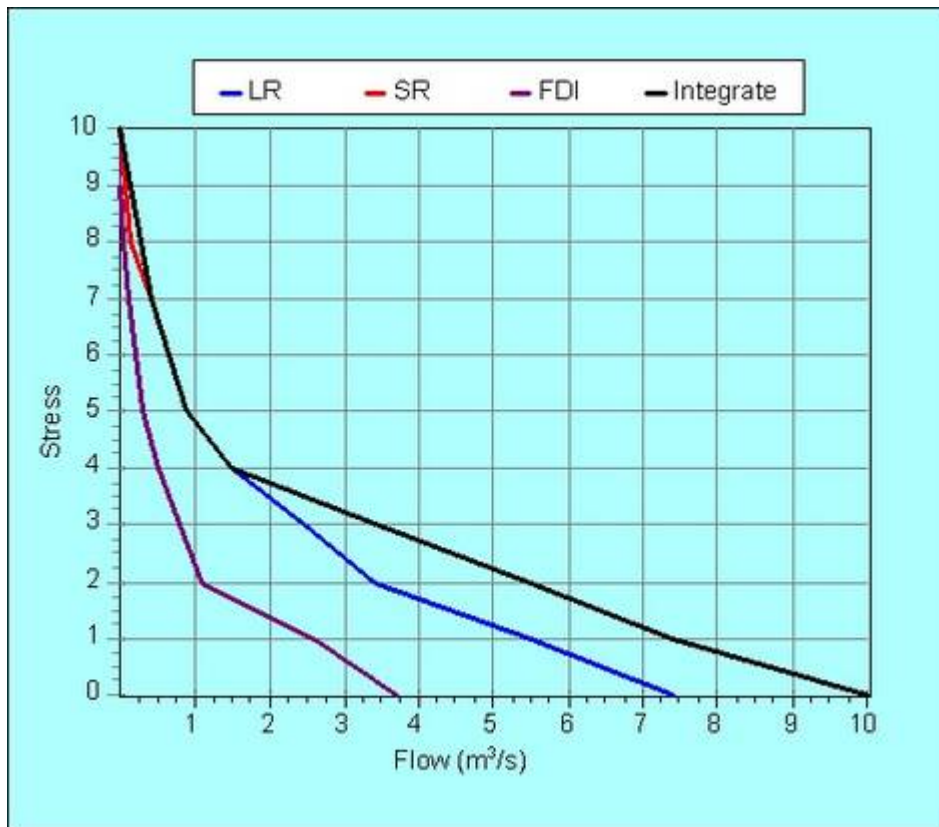


Figure 2.1 Component and integrated stress curves for EWR 2

Table 2.2 provides the summarised biotic response for the integrated stresses.

Table 2.2 Integrated stress and summarised habitat/biotic responses

Integrated stress	Flow m³/s	Habitat and/or Biotic responses
0 (SSR)	10	Fish guild: All habitats optimal (5 ⁺).
1 (SSR)	7.4	SSR guild: Water quality and abundance is optimal, Cover and connectivity is good (4) while spawning and nursery habitats are moderate (3). LSR guild: All habitats are optimal.
2 (SSR)	5.5	SSR guild: Habitats as above with nursery and spawning habitats low (2). LSR guild: All habitats are slightly less than optima (4.5).
3 (SSR)	3.4	SSR guild: Connectivity, water quality spawning and nursery habitat as above. Abundance is good and cover moderate. LSR guild: All habitat is good (4 – 4.5). All FDI habitats in excess, and taxa are very abundant and healthy.
4 (SSR)	1.5	SSR guild: Spawning and nursery habitats are very low (1) with rest of habitat moderate and water quality good. LSR guild: Spawning and nursery habitats are low (2.5) while rest of habitat occurrence is moderate and water quality good.
5 (SSR)	0.9	SSR guild: All habitat occurrence is moderate although spawning and nursery is very low (1). LSR guild: Connectivity and water quality is moderate while rest of habitats are low (2.5). Critical FDI habitats sufficient. Most rheophilic species persist, but slight (80 %) reduction.
6 (SSR)	0.65	Reduced FDI critical habitat. Most rheophilic species persist, but abundances reduced.
7 (SSR)	0.4	SSR guild: Spawning and nursery habitats are very rare (0.5) and rest of habitat occurrence is low. LSR guild: Spawning and nursery habitats are very rare, abundance and cover are very low (1.5) while connectivity and water quality is low. Critical FDI habitats limited. All life stages viable in limited areas, critical life stages of some sensitive rheophilic species at risk.

Integrated stress	Flow m ³ /s	Habitat and/or Biotic responses
8 (LSR)	0.275	Fish guild habitats are as above. Critical FDI habitat very reduced. Critical life-stages of sensitive rheophilic species at risk or non-viable.
9 (LSR)	0.15	SSR guild: Spawning, nursery and abundance are very rare. Connectivity and cover is very low with low water quality. LSR guild: Spawning and nursery habitats are absent, with very low cover. Rest of habitat occurrence is very rare. No critical FDI habitat. Some rheophilic species persist, but most disappear. All life-stages of sensitive rheophilic species at risk or non-viable.
10	0	Only pool dwelling species present. Only hyporheic refugia, no surface water for FDIs. Indicator taxa no longer present.

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

3 EWR 2: GROOTDRAAI (VAAL RIVER) - DETERMINATION OF EWR SCENARIOS

3.1 ECOCLASSIFICATION SUMMARY OF EWR 2

EWR 2 Grootdraai (Vaal River)				
<p>EIS: MODERATE PES: C Combination of flow and non-flow related impacts. Impacts mostly related to changes in flow regime due to Grootdraai Dam. REC: C Maintain the PES due to the MODERATE EIS rating. However note that there is rare and endangered <i>Labeobarbus kimberleyensis</i> present which warrants improvement of the fish EC. AEC up: B This ecological scenario is important due to the presence of <i>L. kimberleyensis</i>. Change in the operation of Grootdraai Dam, which includes the release of flows (base flows) with more natural seasonal patterns and the release of moderate floods to remove fines and no bottom releases. AEC down: C/D Less spilling (i.e. less floods) and decreased base flows. Increased bottom releases.</p>				
Driver Components	PES and REC Category	Trend	AEC↑	AEC↓
HYDROLOGY	D			
WATER QUALITY	B/C	Negative	B	B/C
GEOMORPHOLOGY	D	Stable	D	D/E
Response Components	PES Category	Trend	AEC↑	AEC↓
FISH	C	Stable	B	D
MACRO INVERTEBRATES	C	Stable	B/C	C/D
INSTREAM	C		B/C	C/D
RIPARIAN VEGETATION	B/C	Stable	B	C
ECOSTATUS	C		B	C/D

3.2 HYDROLOGY

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

- 95%: Representing droughts for both wet and dry months. This would represent 5% on the stress duration graphs.
- 45%: Representing maintenance flows for both wet and dry months. This would represent 55% on the stress duration graphs.
- Any additional points which had specific significance in terms of flow or stress requirements.

3.3 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 B, Section B2.1 – 2.2.

The fish and macroinvertebrate flow requirements for different Ecological Categories (ECs) are provided in Table 3.1 and Figure 3.1 and 3.2. 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 3.1 and 3.2.

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 3.2.

Table 3.1 Species and integrates stress requirements as well as the final integrated stress and flow requirements

Duration	LSR stress	Integ stress	SSR stress	Integ stress	FDI stress	Integ. stress	FINAL* (Integrated stress)*	FLOW (m ³ /s)
PES and REC C EcoStatus			FISH: C			MACROINVERTEBRATES: C		
DRY SEASON								
5%	9	9	10	10	5.5	9	9	0.15
55%	6	6	8	9.2	4	7	6	0.65
WET SEASON								
5%	7	7	8	9.2	3.5	7	7	0.4
55%	5	5	6	6	2	3.8	3.8	1.88
AEC UP: B EcoStatus			FISH: B			MACROINVERTEBRATES: B/C		
DRY SEASON								
55%	Same as for PES.				3	5.3	5.3	0.825
WET SEASON								
55%	Same as for PES.				1.5	3.5	3.5	2.45
AEC DOWN: C/D EcoStatus			FISH: D			MACROINVERTEBRATES: C/D		
DRY SEASON								
55%	7	7	10	10	5	7.6	7	0.4
WET SEASON								
55%	6	6	8	9.2	3	5.3	5.3	0.825

* Final refers to the final stress selected as the EWR requirement, i.e., the lowest integrated stress.

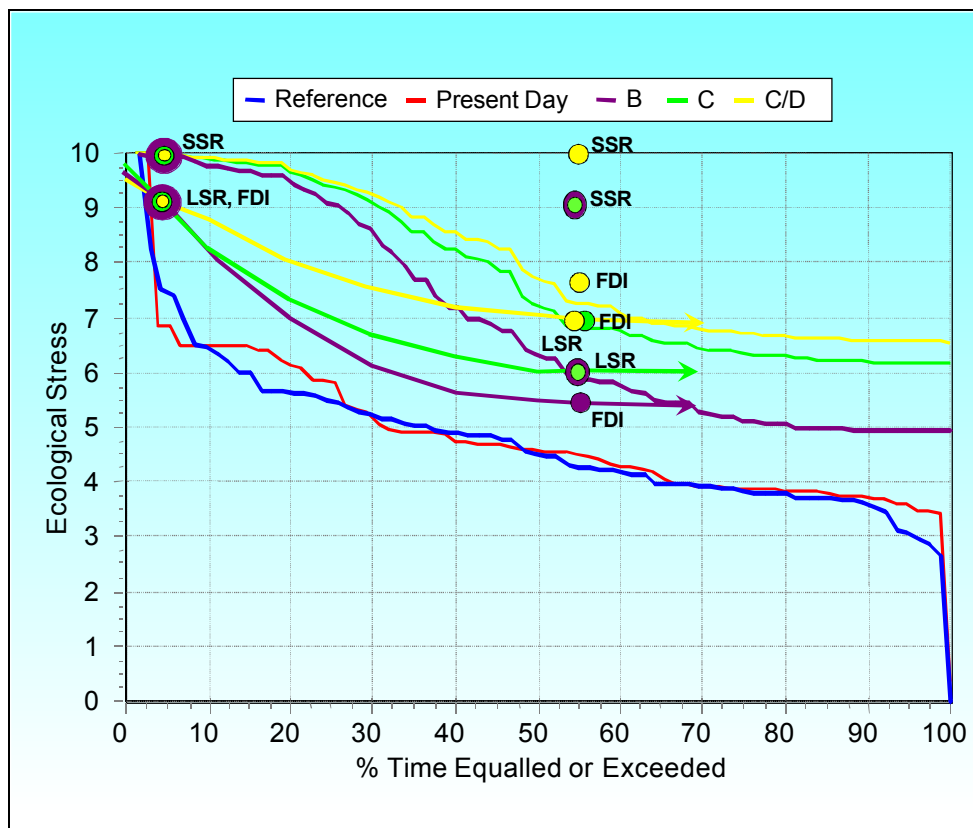


Figure 3.1 EWR 2: Stress Duration Curve for a C PES and REC, B AEC up and C/D AEC down - DRY season

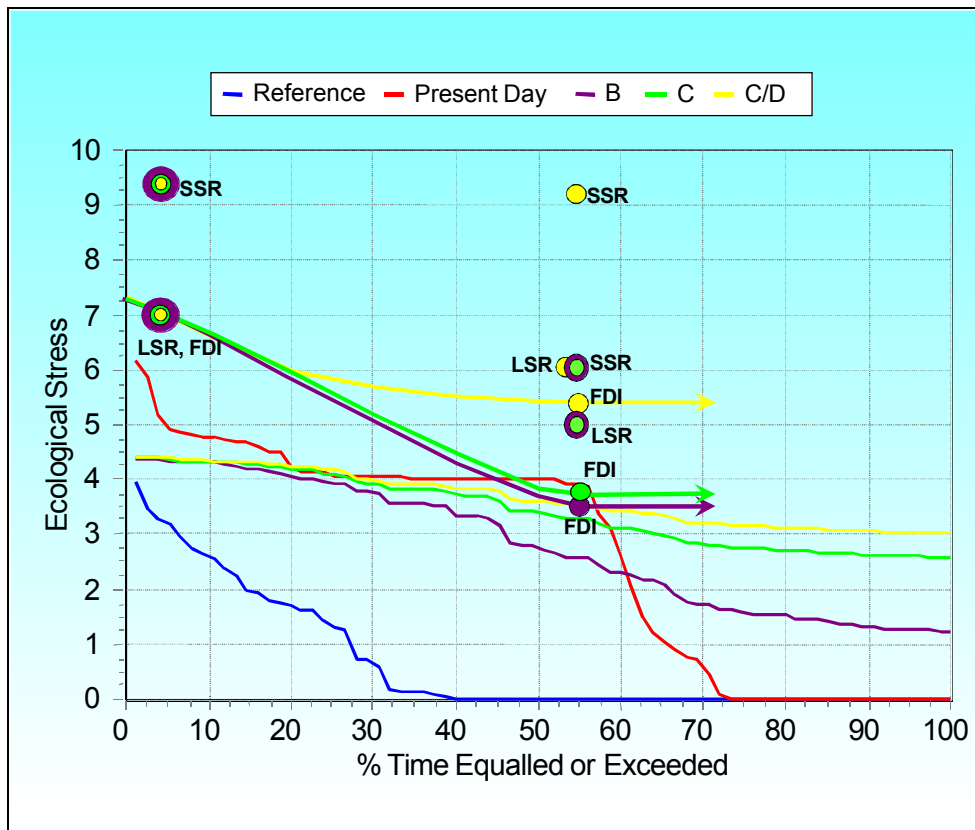


Figure 3.2 EWR 2: Stress Duration Curve for a C PES and REC, B AEC up and C/D AEC down - WET season

Table 3.2 Summary of EWR 2 motivations

Month	% Stress duration	Component stress	Integrated stress	Flow m ³ /s	Comment ¹
PES and REC: C EcoStatus					
FISH: C					
MACROINVERTEBRATES: C					
Aug	5% drought	9 LSR	9	0.15	At these flows critical habitat (Slow Deep (SD) and Slow Shallow (SS) are maintained to ensure survival of adults. Some FS in very low abundance is present to ensure juvenile survival and to maintain adequate oxygen levels in the pools.
	55% maintenance	6 LSR	6	0.65	Fast Deep (FD) habitats will be lost under this stress level, but adequate Fast Intermediate (FI) and Fast Shallow (FS) will be maintained to meet the requirements of the juveniles. SD with adequate depth should also be maintained to meet the requirements of adults, as well as juveniles
Feb	5% drought	7 LSR	7	0.4	Some critical FS habitats should be available for some period to enable spawning, egg and larvae development. Limited FS and adequate SD habitats should be maintained under these conditions for the survival of juveniles and adults during this period.
	55% maintenance	2 FDI	3.8	1.88	Average depth needed for wet season maintenance is 0.21 m, and average current velocity is 0.34 m/s. This will provide suitable habitats during summer.
AEC UP: B EcoStatus					
FISH: B					
MACROINVERTEBRATES: B/C					
Aug	5% drought	9 LSR	9	0.15	See PES.
	55% maintenance	3 FDI	5.3	0.825	Average depth needed for dry season maintenance is 0.19 m, and average current velocity is 0.29 m/s.
Feb	5% drought	7 LSR	7	0.4	See PES.

Month	% Stress duration	Component stress	Integrated stress	Flow m ³ /s	Comment ¹
	55% maintenance	1.5 FDI	3.5	2.45	Average depth needed for wet season maintenance is 0.26 m, and average current velocity is 0.41 m/s (Spp Stress 1.5).
AEC DOWN: C/D EcoStatus		FISH: D		MACROINVERTEBRATES: C/D	
Aug	5% drought	9 LSR	9	0.15	See PES.
	55% maintenance	7 LSR	7	0.4	Very low abundance of fast habitats (approximately 20 % FS and FI), which would reduce the survival of especially juvenile BAEN, which has a preference for fast habitats. Decreased flows will also reduce the depth of SD habitats, which are important survival habitats for overwintering of juvenile and adult BAEN, as adequate depth is required in SD to buffer temperature fluctuations in dry (cold) season, which will result in decreased FROC and abundance of BAEN.
Feb	5% drought	7 LSR	7	0.4	See PES
	55% maintenance	5.3 FDI	5.3	0.825	Average depth needed for wet season maintenance is 0.34 m, and average current velocity is 0.29 m/s

1 Applicable to all sites: For macroinvertebrates (FDI) the available indicator species at all sites in the Upper Vaal catchment tolerate wide fluctuations in flow and water quality conditions, and this makes it difficult to motivate for specific flow durations on the basis of indicator species alone. The assessment of macroinvertebrates requirements for all sites was therefore based largely on professional judgement of how overall macroinvertebrate biodiversity would respond to changes in hydraulic biotope availability. In general, a high diversity of macroinvertebrates can be expected when there are natural seasonal fluctuating water levels; when current speeds exceed 0.4 m/s; when depths exceed about 30 cm; and when there is an abundance of marginal vegetation.

The above flows were checked by the riparian vegetation specialist to ensure that these requirements are adequate to achieve the EC in which the marginal vegetation should be, as well as any other flow dependant vegetation that could occur.

The vegetation indicators used were *Cyperus marginatus* and *Gomphostigma* species. The resulting conditions of the vegetation indicators to the required low flows are described below. In conclusion, the low flows would maintain the PES and REC of the riparian vegetation (Table 3.3).

Table 3.3 Verification of the low flow requirements to maintain the vegetation EC

PES and REC: RIPARIAN VEGETATION EC C (ECOSTATUS B/C)	
Dry Season maintenance	Flows are sufficient to activate the lower limits of <i>Cyperus marginatus</i> rhizomes on the marginal zone, and facilitate survival of <i>Gomphostigma</i> (50 cm).
Dry Season drought	<i>Cyperus marginatus</i> rhizome level remains activated for survival. Water level is 0.07 m below rhizomes and 0.59 m below <i>Gomphostigma</i> rooting level.
Wet Season maintenance	This flow inundates the marginal zone sedges by 7 cm, which is sufficient to sustain summer functionality e.g. flowering.
Wet Season drought	Sufficient to activate the lower limits of <i>C. marginatus</i> rhizomes on the marginal zone, and facilitate survival of <i>Gomphostigma</i> (0.55 m below root level).
AEC up: RIPARIAN VEGETATION EC: B (ECOSTATUS B)	
Dry Season maintenance	Sufficient to inundate lower limit of <i>C. marginatus</i> on the marginal zone. This is likely to cause fatality and reduce the width of the marginal zone, which is a move toward reference.
Wet Season maintenance	Same effect as dry season base flow: nearly 10 cm inundation at rhizome level of current sedges.
AEC down: RIPARIAN VEGETATION EC: C/D (ECOSTATUS C)	
Dry Season maintenance	Reduced from PES flow requirements. The lower limit of sedges on the marginal zone likely to expand towards the

instream channel, with replacement of sedges in the upper portions of the lower with grasses as water stress causes loss of vigour and fatalities.

Wet Season maintenance

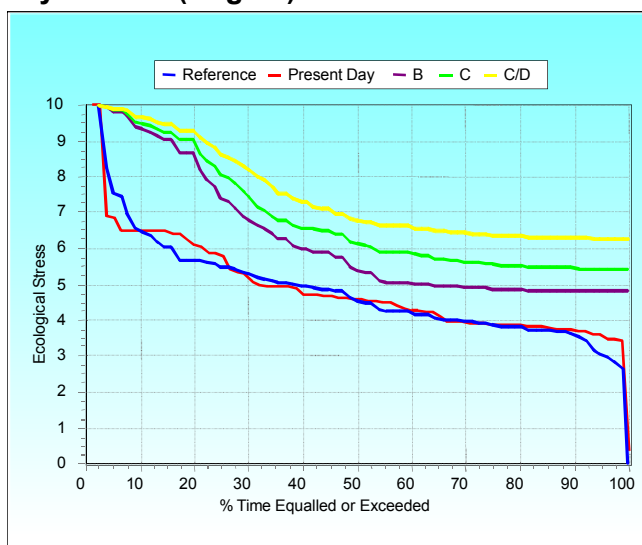
Will inundate marginal zone sufficiently to maintain vigour and density of the expanded zone.

3.3.1 Final low flow requirements

To produce the final results (Figure 3.3), the DRM results for the specific category are modified according to specialists’ requirements (Figure 3.1 and 3.2). 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 changes for C, B and C/D EC.
 - o August: Changed from 8 – 6. No changes for Feb.
 - o All upper shift values were set at 100%.
- AEC up: B
 - o Distribution factors: 0.42 for maintenance.
- PES and REC:C and AEC down: C/D
 - o Distribution factors could not be adjusted enough and was changed manually.

Dry Season (August)



Wet Season (February)

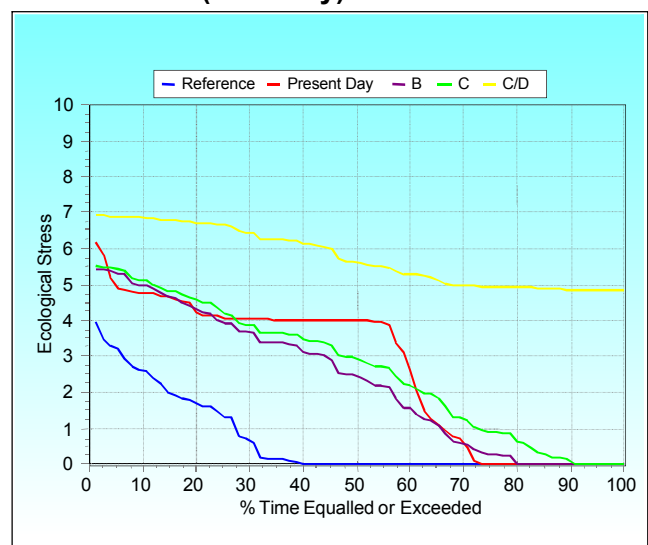


Figure 3.3 EWR 2: Final stress requirements for low flows

3.4 HIGH FLOW REQUIREMENTS

The high flow classes are identified as follows:

- The geomorphologist and riparian vegetation specialist identify the range of flood classes required and list the functions of each flood.
- The instream specialists then indicate which of the instream flooding functions are addressed by the floods identified for geomorphology and riparian vegetation (indicated by a ✓ in Table 3.4.
- Any of the floods required by the instream biota and not addressed by the floods already identified, must then be described (in terms of ranges and functions) for the instream biota.

Results are provided in Table 3.4 and detailed motivations provided in Table 3.5.

Table 3.4 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 and spawning	Migration habitat (depth etc.)	Clean spawning substrate	Create nursery areas	Resetting water quality	Inundate vegetation for spawning	Breeding and hatching cues	Clear fines	Scour substrate	Reach or inundate specific areas
I	4	Vegetation: <i>Gomphostigma</i> maintenance.	✓	✓	✓		✓			✓		
II	6 - 10	Vegetation: Activates marginal zone sedges. Maintains instream woody vegetation.	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
III	11 - 50	Geomorphology: Responsible for more than 50% of transport of fines/gravels. Vegetation: Activation of lower zone sedges, inundation of marginal zone.	✓	✓	✓	✓	✓	✓				
IV	70 - 100	Geomorphology: Scour activates cobbles. Vegetation: Maintain <i>Schoenoplectus</i> (sedge) on lower/upper zone interface.	✓	✓	✓	✓	✓	✓				

Further information is provided in Appendix B, Table B8.

The number of high flow events required for each EC is provided in Table 3.5. No observed daily data was available to check flood requirements against.

Table 3.5 EWR 2: The recommended number of high flow events required

FLOOD CLASS	FLOOD RANGE (m ³ /s)	INVERTEBRATES	FISH	VEGETATION	GEOMORPHOLOGY	FINAL (Frequency)	MONTHS	DAILY AVERAGE	DURATION
PES and REC SCENARIO: C									
I	4	6	6	6		6	Oct, Nov, Dec, Jan, Feb, Mar	2	3
II	6 - 10	4	4	4	4	4	Nov, Dec, Feb, Mar	7	5
III	11 - 50		1	1	1	1	Feb	30	5
IV	70 - 100		1:2	1:2	1:2	1:2	Jan	80	6
AEC up SCENARIO: B									
I	4	6	6	6		6	Oct, Nov, Dec, Jan, Feb, Mar	2	3
II	6 - 10	6	6	6	6	6	Oct, Nov, Dec, Jan, Feb, Mar	7	5
III	11 - 50		1	1	1	1	Feb	30	5
IV	70 - 100		1:2	1:2	1:2	1:2	Jan	80	6
AEC down SCENARIO: C/D									
I	2 - 4	4	4	4		4	Nov, Dec, Feb, Mar	2	3

FLOOD CLASS	FLOOD RANGE (m ³ /s)	INVERTEBRATES	FISH	VEGETATION	GEOMORPHOLOGY	FINAL (Frequency)	MONTHS	DAILY AVERAGE	DURATION
II	6 - 10	2	2	2	2	2	Dec, Feb	7	5
III	11 - 50		1:2	1:2	1:2	1:2	Feb	30	5
IV	70 - 100		1:3	1:3	1:3	1:3	Jan	80	6

The reach is between two large dams, so the floods are not set for the site per se (since there are no tributary inputs between the dam and the site), but instead for the reach.

3.5 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 3.6 – 3.8). Floods with a frequency higher than 1:1 is not included;
- The EWR rule table, which provides the EWR recommended flows as a duration table, showing flows that should be provided when linked to a natural trigger (natural hydrology). An EWR rule table is supplied for the low flows only, and for low and high flows combined (Appendix B, Section B2.4).

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

Table 3.6 EWR table for PES and REC: C

Desktop version:		2	Virgin MAR (MCM)	457.683
BFI	0.287	Distribution type		Vaal
MONTH	LOW FLOWS		HIGH FLOWS	
	Maintenance (m ³ /s)	Drought (m ³ /s)	Daily average (m ³ /s) on top of base flow	Duration (days)
OCTOBER	0.700	0.116	2	3
NOVEMBER	1.000	0.219	2 7	3 5
DECEMBER	1.200	0.281	2 7	3 5
JANUARY	1.350	0.309	2 80	3 6
FEBRUARY	1.750	0.422	2 7 30	3 5 5
MARCH	1.300	0.285	2 7	3 5
APRIL	1.000	0.194		
MAY	0.800	0.000		
JUNE	0.700	0.000		
JULY	0.600	0.000		
AUGUST	0.550	0.000		
SEPTEMBER	0.600	0.071		
TOTAL MCM	30.197	4.930	32.073	
% OF VIRGIN	6.60	1.08	7.01	
Total IFR	62.270			
% of MAR	13.61			

Table 3.7 EWR table for AEC up: B

Desktop version:		2	Virgin MAR (MCM)	457.683
BFI	0.287	Distribution type		Vaal
MONTH	LOW FLOWS		HIGH FLOWS	
	Maintenance (m ³ /s)	Drought (m ³ /s)	Daily average (m ³ /s) on top of base flow	Duration (days)
OCTOBER	1.151	0.116	2 7	3 5
NOVEMBER	1.875	0.219	2 7	3 5
DECEMBER	2.296	0.281	2 7	3 5
JANUARY	2.490	0.309	2 7 80	3 5 6
FEBRUARY	3.306	0.422	2 7 30	3 5 5
MARCH	2.319	0.285	2 7	3 5
APRIL	1.703	0.194		
MAY	1.188	0.000		
JUNE	0.974	0.000		
JULY	0.895	0.000		
AUGUST	0.799	0.000		
SEPTEMBER	0.856	0.071		
TOTAL MCM	51.847	4.930	34.948	
% OF VIRGIN	11.33	1.08	7.64	
Total IFR	86.8			
% of MAR	19			

Table 3.8 EWR table for AEC down: C/D

Desktop version:		2	Virgin MAR (MCM)	457.683
BFI	0.287	Distribution type		Vaal
MONTH	LOW FLOWS		HIGH FLOWS	
	Maintenance (m ³ /s)	Drought (m ³ /s)	Daily average (m ³ /s) on top of base flow	Duration (days)
OCTOBER	0.400	0.116		
NOVEMBER	0.480	0.219	2	3
DECEMBER	0.520	0.281	2 7	3 5
JANUARY	0.540	0.309	80	6
FEBRUARY	0.650	0.422	2 7 30	3 5 5
MARCH	0.520	0.285	2	3
APRIL	0.470	0.194		
MAY	0.400	0.000		
JUNE	0.400	0.000		
JULY	0.350	0.000		
AUGUST	0.350	0.000		
SEPTEMBER	0.390	0.071		
TOTAL MCM	14.332	4.930	28.574	
% OF VIRGIN	3.13	1.08	6.24	
Total IFR	42.91			
% of MAR	9.37			

A comparison between the differences in terms of percentages of the various types of flow blocks are provided in Table 3.9.

Table 3.9 Modifications made to the DRM for EWR 2

Changes	PES and REC C		AEC up B		AEC down C/D	
	DRM	EWR	DRM	EWR	DRM	EWR
MLIFR - Maintenance low flow	9.1%	6.6%	15.9%	11.3%	6.6%	3.1%
DLIFR - Drought low flow	2.9%	1.1%	2.9%	1.1%	2.9%	1.1%
MHIFR - Maintenance high flow	10.9%	7.0%	1.1%	7.6%	9.8%	6.2%
Long-term % of virgin MAR	17.6%	12.7%	24.1%	16.2%	15.4%	9.5%

4 EWR 3: GLADDEDRIFT (VAAL RIVER) - DETERMINATION OF STRESS INDICES

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

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

4.1 INDICATOR SPECIES OR GROUP

4.1.1 Fish indicator group 1: Large semi-rheophilic species (BAEN, BKIM)

Indicator species: *Labeobarbus aeneus* (BAEN) and *Labeobarbus kimberleyensis* (BKIM). Refer to Section 2.1.1 and Appendix C, Table C1.

4.1.2 Macroinvertebrate indicator taxa

Indicator taxa: Hydropsychid caddisflies and Simuliidae. Refer to Section 2.1.3.

4.1.3 Riparian vegetation indicator species

Indicator species: *Cyperus marginatus* and *Gomphostigma virgatum*. Refer to Section 2.1.4.

4.2 STRESS FLOW INDEX

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

4.2.1 Habitat response

Habitat response is used to derive the biota's response to provide a biota stress index and represents the instantaneous response of habitat to flow changes, based on a site specific 0 – 10 scale for instream biota where:

- 0 – Optimum habitat (fixed at the natural maximum baseflow – calculated using the wettest flow month discharge at the maintenance % of 50 – 60% for the Vaal 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 C, Table C1.

The instantaneous response of flow dependent macroinvertebrate (FDI) taxa provides the % occurrence of various velocity-substrate classes under different flow conditions are provided in Appendix C, Table C3).

4.2.2 Biota response

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

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

The fish species response index is calculated using the fish habitat rating (cf Section 2.2.1) (Appendix C, Table C2) 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 C, Table C4).

4.2.3 Integrated stress curve

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

The shaded species stress discharges in Table 4.1 indicate the discharges 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 4.1 illustrates this graphically.

In this specific case, the LSR fish stress index represents the integrated stress index (these values are the highest flow for a stress), therefore the blue curve (representing the LSR stress index) is lying 'beneath' the integrated stress line (black) (Figure 4.1).

Table 4.1 Species stress discharges used to determine biotic stress

Stress	Flow (m ³ /s)		Integrated Flow (m ³ /s)
	LSR	FDI	
0	30	30	30
1	18.5	8	18.5
2	13.29	6	13.29
3	10.16	4	10.16
4	6.93	2	6.93
5	4.85	0.8	4.85
6	2.31	0.5	2.31
7	1.27	0.1	1.27
8	0.71	0.04	0.71
9	0.14	0.03	0.14
10	0	0	0

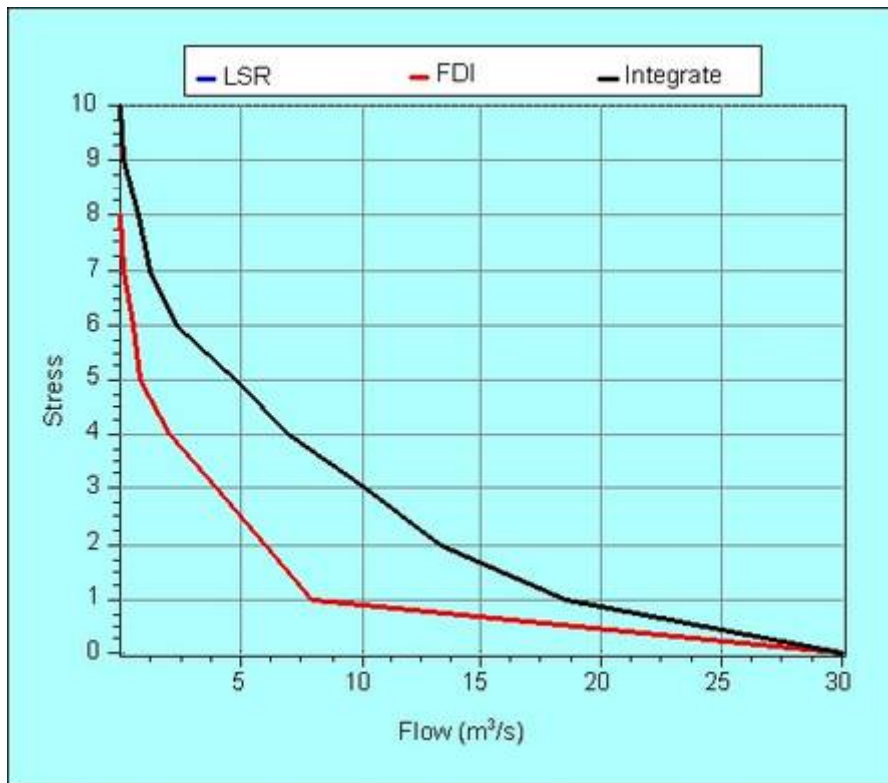


Figure 4.1 Component and integrated stress curves for EWR 3

Table 4.2 provides the summarised biotic response for the integrated stresses.

Table 4.2 Integrated stress and summarised habitat/biotic responses

Integrated stress	Flow M ³ /s	Habitat and/or Biotic responses
0 (LSR)	30	All fish habitats are optimal (5 [*]). All FDIs very abundant and healthy.
1 (LSR)	18.5	All fish habitat is optimal or slightly less than optimal (4.5).
2 (LSR)	13.29	Nursery habitat for LSR is optimal while rest of habitats are good (4 – 4.5).
3 (LSR)	10.16	Fish: Abundance and cover is moderate (3) while rest of habitats is good.
4 (LSR)	6.93	Fish: Spawning, connectivity and water quality is moderate (3 – 3.5) and nursery habitat is good. Abundance and cover is low (2.5). FDI: Critical habitats sufficient. Most rheophilic species persist, but slight (80 %) reduction.
5 (LSR)	4.85	Fish: Abundance and cover is low (2) while rest of habitat is moderate (3). FDI: Reduced critical habitats. Most rheophilic species persist, but abundances reduced.
6 (LSR)	2.31	FDI: Critical habitats limited. All life stages viable in limited areas, critical life stages of some sensitive rheophilic species at risk.
7 (LSR)	1.27	Fish: Spawning, nursery and connectivity is low (2) while water quality, abundance and cover is very low (1.5).
8 (LSR)	0.71	FDI: Critical habitat very reduced. Critical life-stages of sensitive rheophilic species at risk or non-viable.
9 (LSR)	0.14	Fish: Spawning habitat is absent and abundance, cover and water quality is very rare (0.5). Nursery and connectivity is very low. FDI: No critical habitat. Some rheophilic species persist, but most disappear. All life-stages of sensitive rheophilic species at risk or non-viable.
10	0	Only pool dwelling species present. Only hyporheic refugia, no surface water for FDIs. Indicator taxa no longer present.

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

5 EWR 3: GLADDEDRIFT (VAAL RIVER) - DETERMINATION OF EWR SCENARIOS

5.1 ECOCLASSIFICATION SUMMARY OF EWR 3

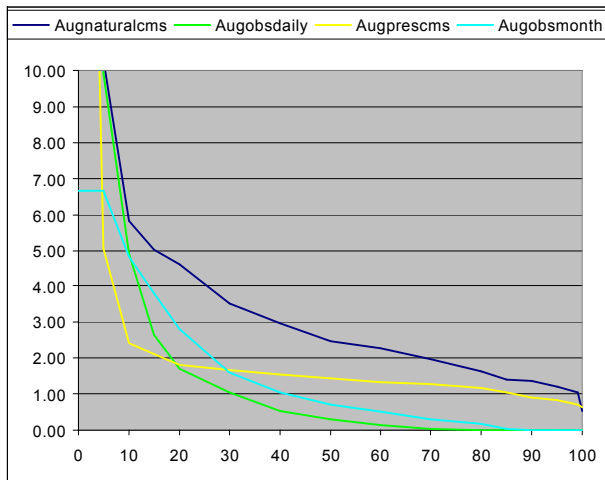
EWR 3 Gladdedrft (Vaal River)					
<p>EIS: MODERATE PES: C Combination of flow and non-flow related impacts. Impacts mostly related to changes in flow regime due to Grootdraai Dam, illegal irrigation, livestock farming and vegetation removal.</p> <p>REC: C Maintain the PES due to the MODERATE EIS rating. However note that there is rare and endangered <i>Labeobarbus kimberleyensis</i> present which warrants improvement of the fish EC.</p> <p>AEC Up: B Improved base flows (no zero flows), and increased frequency of moderate floods. Improved water quality due to improved flow regime. Removal of cattle grazing in the marginal zone.</p> <p>AEC Down: C/D Increased duration of zero flow periods. Decreased frequency of floods. Very low base flows in the dry season when flowing.</p>	Driver Components	PES and REC Category	Trend	AEC↑	AEC↓
	HYDROLOGY	C			
	WATER QUALITY	C	Stable	B/C	D
	GEOMORPHOLOGY	C	Stable	C	D
	Response Components	PES Category	Trend	AEC↑	AEC↓
	FISH	C	Stable	B	D
	MACRO INVERTEBRATES	C	Stable	B/C	D
	INSTREAM	C		B	D
	RIPARIAN VEGETATION	C	Stable	B	C
	ECOSTATUS	C		B	C/D

5.2 HYDROLOGY

The modelled present hydrology was compared to the observed record. What was of concern is that the observed hydrology indicates zero flows for about 30% of the time in August, compared to no zero flows in the modelled present (Figure 5.1). There are also major differences in the low flows. The differences are probably due to the following:

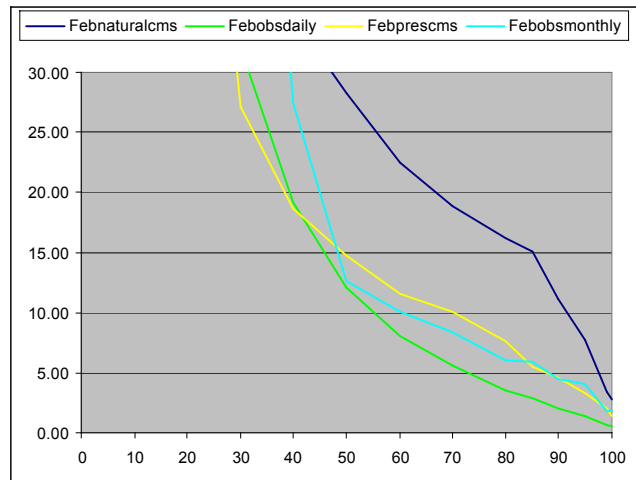
- The observed data from gauge C2H012 starts in September 1984.
- The modelled present day hydrology is only available up to 1994. There was therefore only 10 years of overlap with the observed data which results in the two data sets not being comparable. The high flow of approximately 31m³/s which appeared in the present day data was modelled in the period outside of the observed data.

Dry Season (August)



Augnaturalcms: Modelled natural hydrology in m³/s for Aug
 Augprescms: Modelled present hydrology in m³/s for Aug

Wet Season (February)



Febobsdaily: Daily observed flow in m³/s for Aug
 Febobsmonthly: Monthly observed hydrology in m³/s for Aug

Figure 5.1 Flow duration graphs showing the hydrology for the dry season

Therefore the following regarding the hydrology at EWR 3 was concluded. The biota occurring at the site, is in part a result of the hydrology as represented by the observed flows and not the modelled present day flows. One therefore has to consider the observed flows rather than the present day flows when determining flow requirements.

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

- 95%: Representing droughts for both wet and dry months. This would represent 5% on the stress duration graphs.
- 50%: Representing maintenance flows for both wet and dry months. This would represent 50% on the stress duration graphs.
- Any additional points which had specific significance in terms of flow or stress requirements.

5.3 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 C, Section C2.1 – 2.2.

The fish and macroinvertebrate flow requirements for different Ecological Categories (ECs) are provided in Table 5.1 and Figure 5.1 and 5.2. 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 5.1 and 5.2.

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 5.2.

Table 5.1 Species and integrates stress requirements as well as the final integrated stress and flow requirements

Duration	LSR stress	Integ stress	FDI stress	Integ. stress	FINAL* (Integrated stress)*	FLOW (m ³ /s)
PES and REC: C EcoStatus:		FISH: C		MACROINVERTEBRATES: C		
DRY SEASON						
5%	10	10	10	10	10	0
30%	9.3	9.3	7	9.3	9.3	0.098
50%	8.4	8.4			8.4	0.48
WET SEASON						
5%	6.9	6.9	6	8.2	6.9	1.37
30%	4.5	4.5	2	4.6	4.5	5.89
50%	3.2	3.2			3.2	9.51
AEC UP: B EcoStatus:		FISH: B		MACROINVERTEBRATES: B/C		
DRY SEASON						
0.1%	9.56	9.56			9.56	0.062
5%			8	9.7	9.7	0.042
10%	9.28	9.28			9.28	0.101
30%	8	8			8	0.71
50%	7.26	7.26	5.5	8.2	7.26	1.124
WET SEASON						
0.1%	6.9	6.9			6.93	1.374
10%	4.5	4.5			4.5	5.89
30%	2.3	2.3			2.32	12.351
50%	1.8	1.8	1.6	4	1.83	14.332
AEC DOWN: C/D EcoStatus:		FISH: D		MACROINVERTEBRATES: D		
DRY SEASON						
10%	10	10			10	0.001
30%	10	10			10	0.001
50%	9.07	9.07	8	9.7	9.07	0.13
WET SEASON						
10%	6.2	6.2			6.2	2.102
30%	5.2	5.2			5.2	4.342
50%	4.8	4.8	4	6	4.8	5.266

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

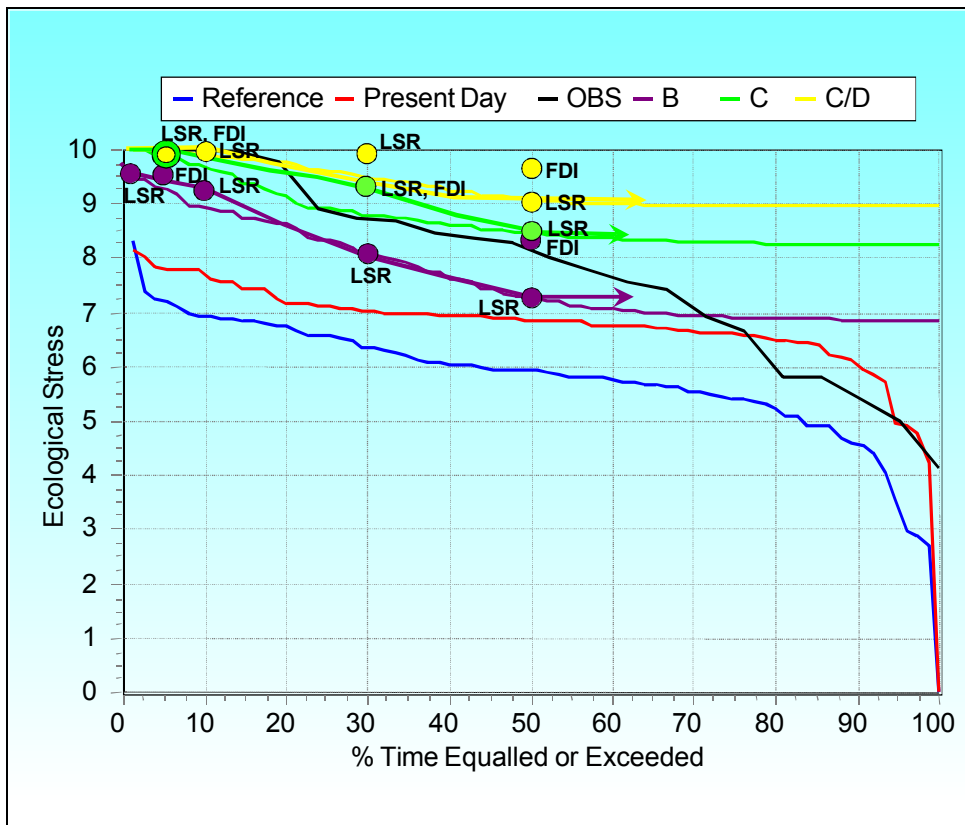


Figure 5.2 EWR 3: Stress Duration Curve for a C PES and REC, B AEC up and C/D AEC down - DRY season

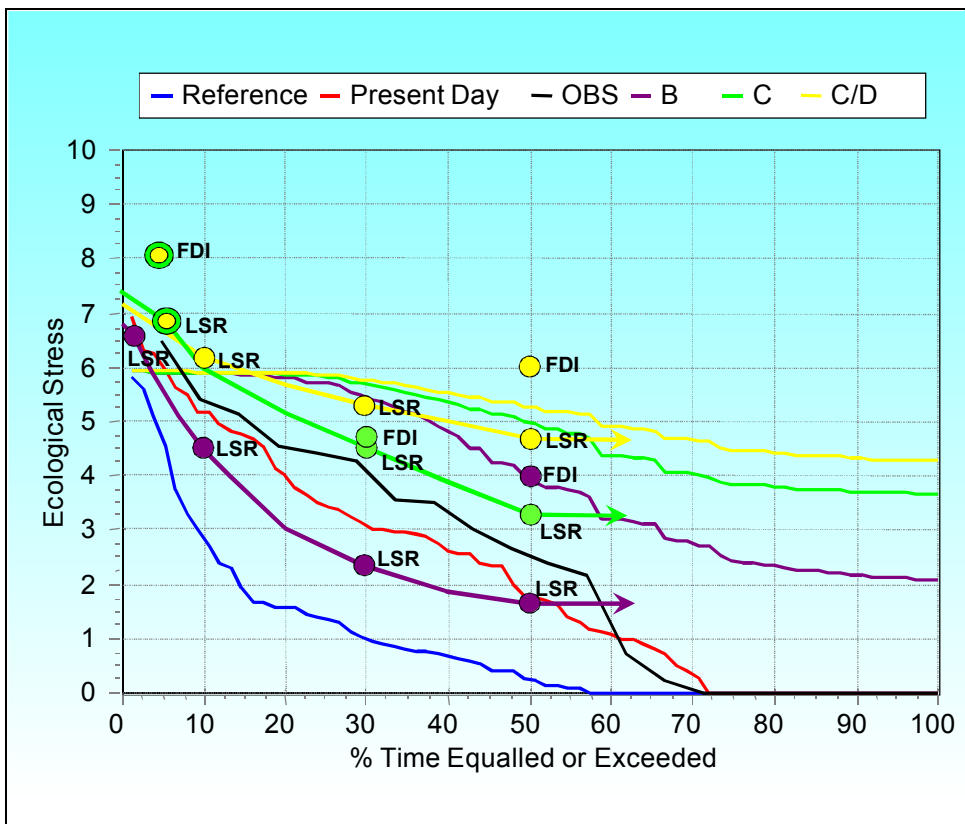


Figure 5.3 EWR 3: Stress Duration Curve for a C PES and REC, B AEC up and C/D AEC down - WET season

Table 5.2 Summary of EWR 3 motivations

Month	% Stress duration	Component stress	Integrated stress	Flow m ³ /s	Comment ¹
PES and REC: C EcoStatus:		FISH: C		MACROINVERTEBRATES: C	
Aug	5% drought	10 LSR	10	0.001	Habitat is unsuitable for any life stages of the LSR species, however it is estimated that they will take refuge in pools or downstream reaches or rivers and recolonise this section when conditions improve.
	30%	9.3 LSR	9.3	0.098	8% of optimal dry season habitat suitability is present and will maintain the guild.
Feb	5% drought	6.9 LSR	6.9	1.37	At this stress 3% of the optimal wet season habitat is suitable. Very low to low habitat suitability but should allow this guild to survive these critical periods and maintain some level of recruitment.
	30%	4.5 LSR	4.5	5.89	At this stress 32% of the optimal wet season habitat is suitable. It is estimated that these habitat conditions should be adequate to maintain this guild within this reach during the dry season.
AEC UP: B EcoStatus:		FISH: B		MACROINVERTEBRATES: B/C	
Aug	5% drought	8 FDI	9.7	0.042	Average depth needed for dry season drought is 0.15 m, and average current velocity is 0.008 m/s. Wetted perimeter is significantly reduced (11.59 m). All current speeds are very slow.
	30%	8 LSR	8	0.71	At this stress 57% of the optimal wet season habitat is suitable. It is estimated that these habitat conditions should be adequate to maintain this guild within this reach during the dry season.
Feb	30%	2.3 LSR	2.3	12.351	At this stress 85% of the optimal wet season habitat is suitable. It is estimated that these habitat conditions should be adequate to maintain this guild within this reach during the dry season.
AEC DOWN: C/D EcoStatus:		FISH: D		MACROINVERTEBRATES: D	
Aug	5% drought	10 LSR	10	0.001	See PES.
	30%	10 LSR	10	0.001	Total habitat suitability would be 0% of what can be expected under natural conditions, resulting in very poor status of this fish assemblage during the dry period.
Feb	5% drought	6.9 LSR	6.9	1.37	See PES.
	30%	5.2 LSR	5.2	4.342	Total habitat suitability would be 52.5% of what can be expected under natural conditions, adequate to maintain this fish guild in a D EC in the wet season.

¹ See Chapter 3, Table 3.2.

The above flows were checked by the riparian vegetation specialist to ensure that these requirements are adequate to achieve the EC in which the marginal vegetation should be, as well as any other flow dependant vegetation that could occur.

The vegetation indicators used were the marginal zone. The resulting conditions of the marginal zone to the required low flows are described below. In conclusion, the low flows would maintain the PES and REC of the riparian vegetation (Table 5.3)

Table 5.3 Verification of the low flow requirements to maintain the vegetation

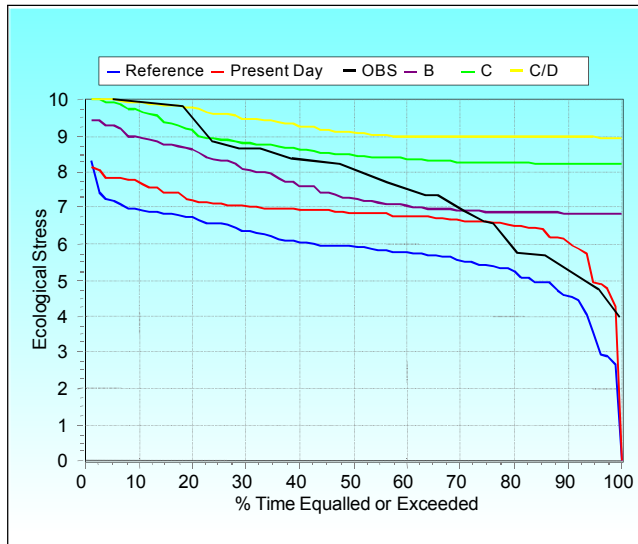
PES and REC: RIPARIAN VEGETATION EC C (ECOSTATUS C)
<p>Dry Season maintenance No inundation of marginal zone vegetation but survival likely.</p> <p>Wet Season maintenance Portions of all marginal zone vegetation remain inundated. Flow sufficient to maintain PES.</p>
AEC down: RIPARIAN VEGETATION EC: C (ECOSTATUS C/D)
<p>Dry Season maintenance Mortality of marginal zone riparian obligates at upper limits. Marginal zone shrinkage will occur.</p> <p>Wet Season maintenance Portions of all marginal zone vegetation remain inundated. Flow sufficient to maintain the AEC will result from dry season changes.</p>

5.3.1 Final low flow requirements

To produce the final results (Figure 5.4), the DRM results for the specific category are modified according to specialists' requirements (Figure 5.1 and 5.2). 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 changes for C, B and C/D EC.
 - 0 Shape values changed to 5 for Jan, Feb and Mar. Other months: 6.
 - 0 All upper shift values were set at 100% for wet season and 98% for dry season.
- AEC up: B
 - 0 Distribution factor: 2.8 for drought.
 - 0 Distribution factor: 1.9 for maintenance.
 - 0 Other distribution factors were set to 4.05 and all but Feb drought flows reduced (to 0 in dry season).
- PES and REC: C
 - 0 Distribution factor: 2.9 for maintenance.
- AEC down: C/D
 - 0 Distribution factor could not be set higher than 5 and Jan, Feb, Mar flows were manually adjusted to 2.4, 3.5 and 2.2 with Aug at 0.1.

Dry Season (August)



Wet Season (February)

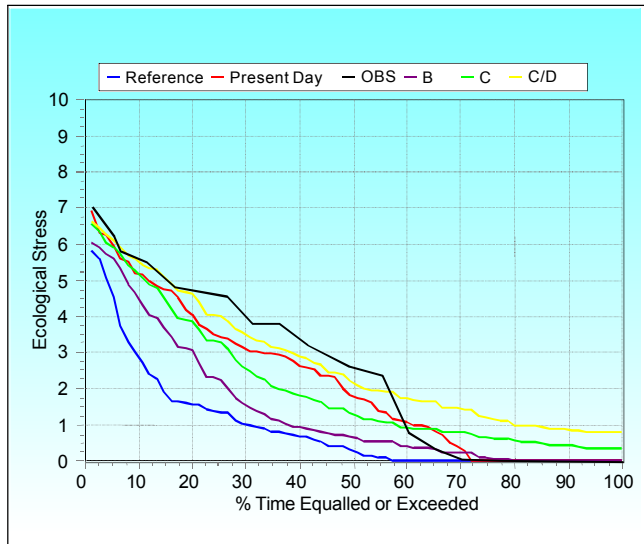


Figure 5.4 EWR 3: Final stress requirements for low flows

5.4 HIGH FLOW REQUIREMENTS

The high flow classes are identified as follows:

- The geomorphologist and riparian vegetation specialist identify the range of flood classes required and list the functions of each flood.
- The instream specialists then indicate which of the instream flooding functions are addressed by the floods identified for geomorphology and riparian vegetation (indicated by a ✓ in Table 5.4.
- Any of the floods required by the instream biota and not addressed by the floods already identified, must then be described (in terms of ranges and functions) for the instream biota.

Results are provided in Table 5.4 and detailed motivations provided in Table 5.5.

Table 5.4 Checklist of Geomorphology and Riparian vegetation floods and which cater for instream biota flood requirements

FLOOD CLASS	FLOOD RANGE (m ³ /s)	GEOMORPHOLOGY AND RIPARIAN VEGETATION MOTIVATION	Fish flood functions					Macroinvertebrate flood functions			
			Migration cues and spawning	Migration habitat (depth etc.)	Clean spawning substrate	Create nursery areas	Resetting water quality	Inundate vegetation for spawning	Breeding and hatching cues	Clear fines	Scour substrate
I	20 (ave)	Geomorphology: This flow class is responsible for more than 20% of the fines and gravels at the site. Vegetation: floods the marginal zone and approx 50% marginal zone riparian obligate species (activation & maintenance in wet season).	✓	✓	✓	✓	✓	✓	✓	✓	✓

II	(40 - 80) 60 (ave)	Geomorphology: This flow class is responsible for more than 30% of the fines and gravels at the site. Vegetation: Floods the marginal zone and inundates about 50% of the lower zone. <i>Gomphostigma</i> , <i>Persecaria</i> and <i>Cyperus marginatus</i> populations completely flooded; majority of <i>Rumex</i> flooded.	✓	✓	✓	✓	✓	✓	✓	✓	✓
III	100 - 130	Vegetation: Floods the lower zone and lower portions of the upper zone. Activates terrestrial grasses.	✓	✓	✓	✓	✓				
IV	200 (ave)	Geomorphology: This flow class is responsible for more than 35% of the gravels at the site, and would activate the cobbles and boulders at the site.	✓	✓	✓	✓	✓				

Further information is provided in Appendix C, Table C7.

The number of high flow events required for each EC is provided in Table 5.4. No observed daily data was available to check flood requirements against.

Table 5.5 EWR 3: The recommended number of high flow events required

FLOOD CLASS	FLOOD RANGE (m ³ /s)	INVERTEBRATES	FISH	VEGETATION	GEOMORPHOLOGY	FINAL (Frequency)	MONTHS	DAILY AVERAGE	DURATION
PES and REC SCENARIO: C									
I	4	6	6	6		6	Oct, Nov, Dec, Jan, Feb, Mar	2	3
II	6 - 10	4	4	4	4	4	Nov, Dec, Feb, Mar	7	5
III	11 - 50		1	1	1	1	Feb	30	5
IV	70 - 100		1:2	1:2	1:2	1:2	Jan	80	6
AEC up SCENARIO: B									
I	4	6	6	6		6	Oct, Nov, Dec, Jan, Feb, Mar	2	3
II	6 - 10	6	6	6	6	6	Oct, Nov, Dec, Jan, Feb, Mar	7	5
III	11 - 50		1	1	1	1	Feb	30	5
IV	70 - 100		1:2	1:2	1:2	1:2	Jan	80	6
AEC down SCENARIO: C/D									
I	2 - 4	4	4	4		4	Nov, Dec, Feb, Mar	2	3
II	6 - 10	2	2	2	2	2	Dec, Feb	7	5
III	11 - 50		1:2	1:2	1:2	1:2	Feb	30	5
IV	70 - 100		1:3	1:3	1:3	1:3	Jan	80	6

5.5 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 5.6 – 5.8). Floods with a frequency higher than 1:1 is not included;
- The EWR rule table, which provides the EWR recommended flows as a duration table, showing flows that should be provided when linked to a natural trigger (natural hydrology). An EWR rule table is supplied for the low flows only, and for low and high flows combined (Appendix C, Section C2.4).

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

Table 5.6 EWR table for PES and REC: C

Desktop version:		2	Virgin MAR (MCM)	858.100
BFI	0.3	Distribution type		Vaal
MONTH	LOW FLOWS		HIGH FLOWS	
	Maintenance (m ³ /s)	Drought (m ³ /s)	Daily average (m ³ /s) on top of base flow	Duration (days)
OCTOBER	1.775	0.100		
NOVEMBER	3.591	0.300		
DECEMBER	4.540	0.400	20	4
JANUARY	5.229	0.500	20	4
FEBRUARY	7.501	0.800	80	6
MARCH	5.002	0.500	20	4
APRIL	3.204	0.300		
MAY	1.559	0.100		
JUNE	0.776	0.050		
JULY	0.687	0.000		
AUGUST	0.400	0.000		
SEPTEMBER	0.554	0.000		
TOTAL MCM	90.610	7.906		32.054
% OF VIRGIN	10.56	0.92		3.74
Total IFR				122.67
% of MAR				14.29

Table 5.7 EWR table for AEC up: B

Desktop version:		2	Virgin MAR (MCM)	858.100
BFI	0.3	Distribution type		Vaal
MONTH	LOW FLOWS		HIGH FLOWS	
	Maintenance (m ³ /s)	Drought (m ³ /s)	Daily average (m ³ /s) on top of base flow	Duration (days)
OCTOBER	3.575	0.303		
NOVEMBER	6.859	0.611	20	6
DECEMBER	8.555	0.772	20	6
JANUARY	9.795	0.889	20	6
FEBRUARY	13.928	1.274	80	6
MARCH	9.386	0.850	20	6
APRIL	6.162	0.546		
MAY	3.186	0.267		
JUNE	1.789	0.134		
JULY	1.616	0.119		
AUGUST	1.100	0.070		
SEPTEMBER	1.390	0.096		
TOTAL MCM	175.356	15.436		36.634
% OF VIRGIN	20.44	1.80		4.27
Total IFR				212
% of MAR				24.7

Table 5.8 EWR table for AEC down: C/D

Desktop version:		2	Virgin MAR (MCM)	858.100
BFI	0.3	Distribution type		Vaal
MONTH	LOW FLOWS		HIGH FLOWS	
	Maintenance (m ³ /s)	Drought (m ³ /s)	Daily average (m ³ /s) on top of base flow	Duration (days)
OCTOBER	0.695	0.100		
NOVEMBER	1.478	0.300		
DECEMBER	1.891	0.400	20	6
JANUARY	2.400	0.500		
FEBRUARY	3.500	0.800	80	6
MARCH	2.200	0.500	20	6
APRIL	1.311	0.300		
MAY	0.601	0.100		
JUNE	0.260	0.050		
JULY	0.224	0.000		
AUGUST	0.100	0.000		
SEPTEMBER	0.165	0.000		
TOTAL MCM	38.522	7.906	27.475	
% OF VIRGIN	4.49	0.92	3.20	
Total IFR	66.0			
% of MAR	7.69			

A comparison between the differences in terms of percentages of the various types of flow blocks are provided in Table 5.9.

Table 5.9 Modifications made to the DRM for EWR 3

Changes	PES and REC C		AEC up: B		AEC down: C/D	
	DRM	EWR	DRM	EWR	DRM	EWR
MLIFR - Maintenance low flow	9.6%	10.6%	16.6%	20.4%	7.0%	4.5%
DLIFR - Drought low flow	3.8%	0.9%	3.8%	1.8%	3.8%	0.9%
MHIFR - Maintenance high flow	10.7%	3.7%	13.8%	4.3%	9.6%	3.2%
Long-term % of virgin MAR	18.1%	14.6%	24.5%	22.7%	15.9%	8.8%

6 EWR 6: KLIP (KLIP RIVER) - DETERMINATION OF STRESS INDICES

NOTE: All supporting specialist information for EWR 6 is summarized in Volume 2, Appendix D.

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

6.1 INDICATOR SPECIES OR GROUP

6.1.1 Fish indicator group 1: Large semi-rheophilic species (BAEN, BKIM)

Indicator species: *Labeobarbus aeneus* (BAEN) and *Labeobarbus kimberleyensis* (BKIM). Refer to Section 2.1.1 and Appendix B, Table B1.

6.1.2 Fish indicator group 2: Small semi-rheophilic species (BANO)

Indicator species: *Barbus anoplus* (BANO). Refer to Section 2.1.1 and Appendix B, Table B2.

6.1.3 Macroinvertebrate indicator taxa

Indicator taxa: Perlidae and Psephenidae (i.e., sensitive, flow dependent taxa). The minimum depth requirements for these taxa are 15 cm, and the optimal current speeds are 0.6 m/s. These taxa are sensitive to deterioration in water quality, and are not expected to tolerate wide fluctuations in flow and water quality conditions.

6.1.4 Riparian vegetation indicator species

Indicator species included:

- *Cyperus marginatus* and *Miscanthus junceus*: Refer to section 2.1.4.
- *Persecaria* spp.: Perennial herbs or shrubs which occur in moist areas near swamps, rivers and on floodplains. Can form floating mats and common in the marginal and lower zones. Riparian obligates. Can flower throughout the year.

6.2 STRESS FLOW INDEX

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

6.2.1 Habitat response

Habitat response is used to derive the biota's response to provide a biota stress index and represents the instantaneous response of habitat to flow changes, based on a site specific 0 – 10 scale for instream biota where:

- 0 – Optimum habitat (fixed at the natural maximum baseflow – calculated using the wettest flow month discharge at the maintenance % of 50 – 60% for the Klip 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 D, Table D1.

The instantaneous response of flow dependent macroinvertebrate (FDI) taxa provides the % occurrence of various velocity-substrate classes under different flow conditions are provided in Appendix D, Table D3).

6.2.2 Biota response

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

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

The fish species response index is calculated using the fish habitat rating (cf Section 2.2.1) (Appendix D, Table D2) 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 D, Table D4).

6.2.3 Integrated stress curve

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

The shaded species stress discharges in Table 6.1 indicate the discharges 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 6.1 illustrates this graphically.

In this specific case, the LSR fish stress index represents the integrated stress index (these values are the highest flow for a stress), therefore the blue curve (representing the LSR stress index) is lying 'beneath' the integrated stress line (black) (Figure 6.1).

Table 6.1 Species stress discharges used to determine biotic stress

Stress	Flow (m ³ /s)			Integrated Flow (m ³ /s)
	SSR	LSR	FDI	
0	1.95	1.95	2.7	2.7
1	1.335	1.335	1.6	1.6
2	0.72	0.72	0.9	0.9
3	0.57	0.57	0.6	0.57
4	0.427	0.14	0.4	0.427
5	0.283	0.1	0.3	0.3
6	0.14	0.02	0.1	0.14
7	0.1	0.15	0.024	0.1
8	0.06	0.01	0.003	0.06
9	0.02	0.006	0.001	0.02
10	0.001	0.001	0.001	0.001

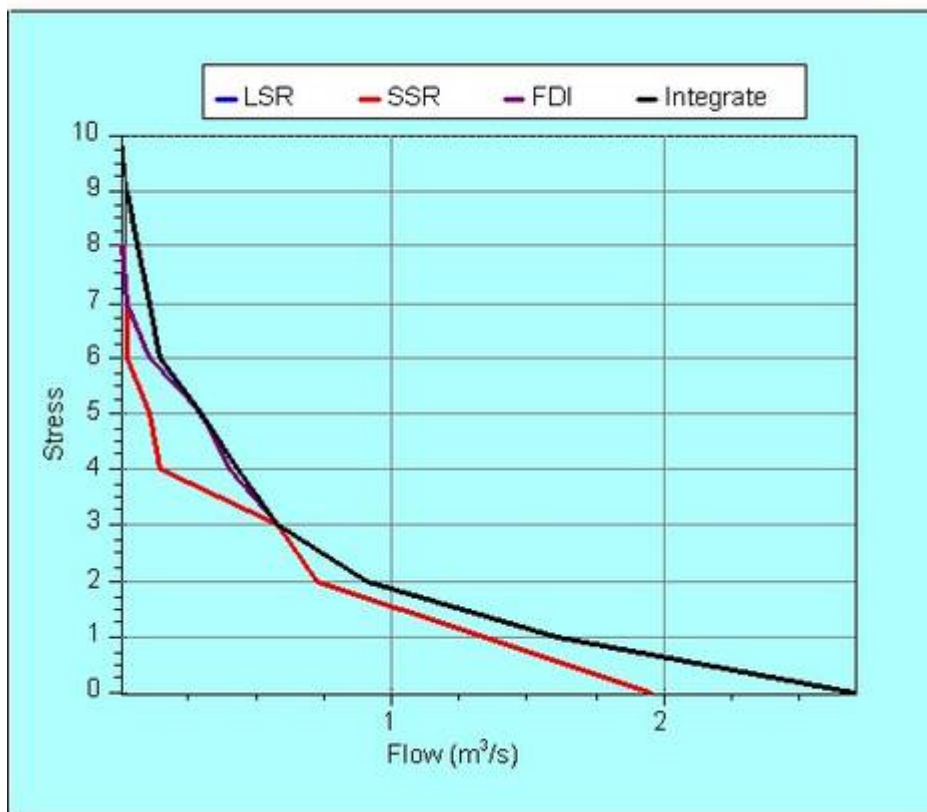


Figure 6.1 Component and integrated stress curves for EWR 6

Table 6.2 provides the summarised biotic response for the integrated stresses.

Table 6.2 Integrated stress and summarised habitat/biotic responses

Integrated stress	Flow m ³ /s	Habitat and/or Biotic responses
0 (FDI)	2.7	Fish guild: All habitats optimal (5 ⁺). All FDI habitats in excess. All FDIs very abundant and healthy.
1 (FDI)	1.6	FDI: All habitats plentiful. 90 % rheophilic species persist.
2 (FDI)	0.9	Critical FDI habitats sufficient. Most rheophilic species persist, but slight (80 %) reduction
3 (LSR)	0.572	SSR guild: Spawning and nursery habitat very low (1.5), abundance and water quality good (4) while connectivity is moderate. LSR guild: All habitats are good (4) and abundance is moderate (3). Reduced critical FDI habitat. Most rheophilic species persist, but abundances reduced.
4 (SSR)	0.427	Fish: Critical habitats limited. All life stages viable in limited areas, critical life stages of some sensitive rheophilic species at risk.
5 (FDI)	0.3	Critical FDI habitat very reduced. Critical life-stages of sensitive rheophilic species at risk or non-viable.
6 (SSR)	0.14	SSR guild: Abundance and cover is good. Water quality is moderate, connectivity is low (2) and spawning and nursery habitat is very low (1). LSR guild: All habitats are low with spawning and nursery slightly lower at 1.5.
7 (SSR)	0.1	SSR guild: Abundance and water quality is moderate while connectivity is low. Spawning and nursery habitat is very low and cover is good. LSR guild: Spawning and nursery habitat is very rare (0.5) while rest of habitats is very low with low water quality. Critical FDI habitat residual. Sensitive rheophilic species rare, critical stages of sensitive rheophilic species non-viable and at risk for some less sensitive species.
8 (SSR)	0.06	
9 (SSR)	0.02	SSR guild: Spawning and nursery habitat is very rare and abundance and water quality is low, connectivity very low and abundance moderate. LSR guild: All habitats are absent and water quality is much deteriorated (0.5). No critical FDI habitat. Some rheophilic species persist, but most disappear. All life-stages of sensitive rheophilic species at risk or non-viable.
10	0	Only pool dwelling species present. Only hyporheic refugia, no surface water for FDIs. Indicator taxa no longer present.

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

7 EWR 6: KLIP (KLIP RIVER) - DETERMINATION OF EWR SCENARIOS

7.1 ECOCLASSIFICATION SUMMARY OF EWR 6

EWR 6 Klip (Klip River)					
<p>EIS: MODERATE PES: B/C Combination of flow and non-flow related impacts. Flow related impacts include reduced base flows and moderate floods due to weirs and farm dams. Non-flow related impacts include agriculture, cattle grazing, and alien vegetation. The sole reason for the PES not being a B EcoStatus is the current vegetation EC (B/C EC) due to the high proportion of exotic species</p> <p>REC: B/C The EIS at EWR 6 is MODERATE and the REC is to maintain the PES.</p> <p>AEC up: B A B EC can be achieved by removal of alien vegetation. Improving flows will not improve the vegetation.</p> <p>AEC down: C The scenario includes decreased low flows and zero flows and decreased moderate floods and deteriorated water quality.</p>		Driver Components	PES and REC Category	Trend	AEC ↓
		HYDROLOGY	C		
		WATER QUALITY	B/C	Negative	C
		GEOMORPHOLOGY	B	Stable	C
		Response Components	PES Category	Trend	AEC ↓
		FISH	B	Stable	C
		MACRO INVERTEBRATES	B	Stable	C
		INSTREAM	B		C
		RIPARIAN VEGETATION	B/C	Stable	C
		ECOSTATUS	B/C		C

7.2 HYDROLOGY

The modelled present day hydrology shows higher flows than natural during the dry season, drought periods. This is impossible as the river is known to virtually stop flowing during the dry season as was experienced by EWR specialists during the course of this study. This was also confirmed by the farmers. The reasons for this anomaly are:

- There are gauges close to the EWR site to calibrate the hydrology.
- Present use is highly likely inaccurate due to illegal abstraction and illegal dams.
- Present use is grouped together and scaled back according to area to the EWR site – there was no information available to do this any other way.
- The present hydrology is representative of 1994 only.

It is therefore suspected that the present use in the hydrological model is underestimated and that more flows than natural is the result of irrigation return flow. Since this situation is not what is happening on the ground, the modelled present day hydrology had to be largely ignored, especially during the dry season.

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

- 95%: Representing droughts for both wet and dry months. This would represent 5% on the stress duration graphs.
- 45%: Representing maintenance flows for both wet and dry months. This would represent 55% on the stress duration graphs.
- Any additional points which had specific significance in terms of flow or stress requirements.

7.3 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 D, Section D2.1 – 2.2.

The fish and macroinvertebrate flow requirements for different Ecological Categories (ECs) are provided in Table 7.1 and Figure 7.1 and 7.2. 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 7.1 and 7.2.

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

PES and REC: **Purple** AEC down: **Green**

Summarised motivations for the final requirements are provided in Table 7.2.

Table 7.1 Species and integrates stress requirements as well as the final integrated stress and flow requirements

Duration	LSR stress	Integ stress	SSR stress	Integ stress	FDI stress	Integ. stress	FINAL* (Integrated stress)*	FLOW (m ³ /s)
PES and REC: B/C EcoStatus			FISH: B			MACROINVERTEBRATES: B		
DRY SEASON								
5%	9	9	9	10	8	9.5	9	0.02
20%					6.5	8	8	0.06
55%	6.5	6.5	7	7	6	7	6.5	0.12
WET SEASON								
5%	6.5	6.5	5.5	9	6	7	6.5	0.12
20%					4.5	4.5	4.5	0.364
55%	2.5	2.5	1.75	2.5	1	1	1	1.629
AEC down: C EcoStatus			FISH: C			MACROINVERTEBRATES: C		
DRY SEASON								
20%					6.5	8	8	0.06
55%	7	7	10	10	7.5	9.2	7	0.15
WET SEASON								
20%					5	5	5	0.358
55%	3	3	4.5	7	4	4	3	0.572

* Final refers to the final stress selected as the EWR requirement, i.e. the lowest integrated stress.

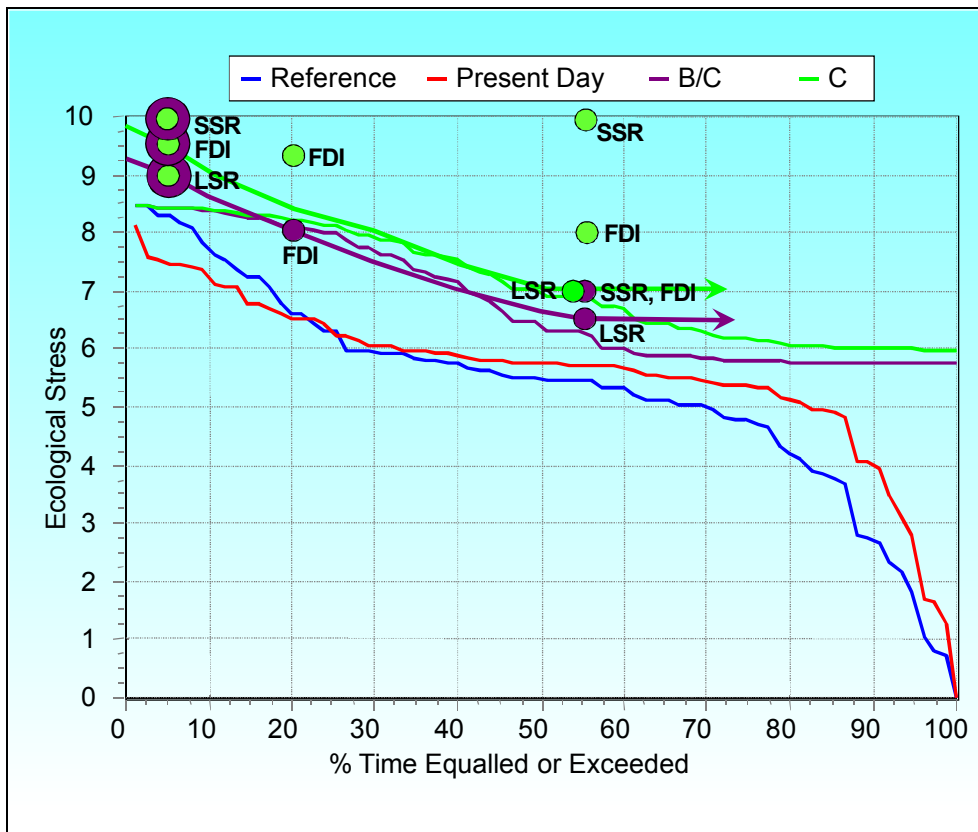


Figure 7.1 EWR 6: Stress Duration Curve for a B/C PES and REC, and C AEC down - DRY season

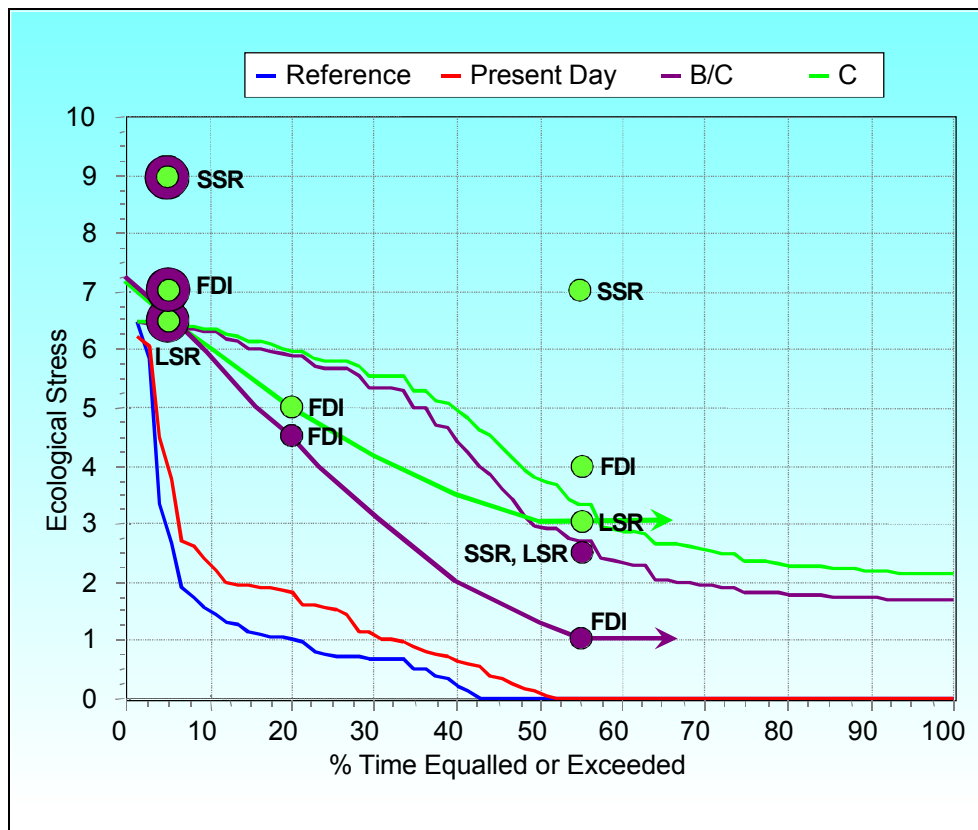


Figure 7.2 EWR 6: Stress Duration Curve for a B/C PES and REC, and C AEC down - WET season

Table 7.2 Summary of EWR 6 motivations

Month	% Stress duration	Component stress	Integrated stress	Flow m ³ /s	Comment ¹
PES and REC: B/C EcoStatus		FISH: B		MACROINVERTEBRATES: B	
Aug	5% drought	9 LSR	9	0.02	Refuge habitats critical for survival (SD and SS) will be maintained and the slight flows should at least maintain acceptable level of water quality for this moderately tolerant species.
	20%	6.5 FDI	8	0.06	Average depth needed is 0.07 m, and average current velocity is 0.08 m/s.
	55% maintenance	6.5 LSR	6.5	0.12	Very limited FS will be maintained, to allow for optimal survival habitat of juvenile BAEN. These flows will also ensure that adequate depth remains in the SD and SS (pools) for maintenance of especially adult BAEN in the reach.
Feb	5% drought	6.5 LSR	6.5	0.12	Some critical FS habitats should be available for some period to enable spawning, egg and larvae development. Very limited FS and adequate SD habitats should be available at the recommended stress level for the survival of juveniles and adults during this period.
	20%	4.5 FDI	4.5	0.364	Average depth needed is 0.15 m, and average current velocity is 0.22 m/s. Inflection point in wetted perimeter.
	55% maintenance	1 FDI	1	1.6	Average depth needed for wet season maintenance is 0.26 m, and average current velocity is 0.46 m/s (Spp Stress 1). This will inundate some marginal vegetation, and provide suitable habitats during summer.
AEC down: C EcoStatus		FISH: C		MACROINVERTEBRATES: C	
Aug	5% drought	9 LSR	9	0.02	See PES.
	20%	6.5 FDI	8	0.06	See PES.
	55% maintenance	7 LSR	7	0.15	Will result in very low abundance of FS habitats (no FI and FD), important for the survival of especially juvenile BAEN. Decreased flows will also reduce the depth of SD habitats, which are important survival habitats for over wintering of juvenile and adult BAEN, which will result in decreased FROC and abundance of BAEN.
Feb	5% drought	6.5 LSR	6.5	0.12	See PES.
	20%	5 FDI	5	0.358	Residual critical habitat (FCS) available, but insufficient current speeds for Perlidae.
	55% maintenance	3 LSR	3	0.572	Very limited FD habitats. Reduced FS and FI will however be available to allow for the requirements of the different life stages of BAEN during the wet season and would probably result in deterioration of the fish EC.

¹ See Chapter 3, Table 3.2.

The above flows were checked by the riparian vegetation specialist to ensure that these requirements are adequate to achieve the EC in which the marginal vegetation should be, as well as any other flow dependant vegetation that could occur.

The vegetation indicator used was *Cyperus marginatus*. The resulting conditions of the vegetation indicators to the required low flows are described below. In conclusion, the low flows would maintain the PES and REC of the riparian vegetation (Table 7.3).

Table 7.3 Verification of the low flow requirements to maintain the vegetation EC

PES and REC: RIPARIAN VEGETATION EC B/C (ECOSTATUS B/C)
Dry Season maintenance Sufficient to activate the lower limits of <i>C. marginatus</i> rhizomes on the marginal zone.

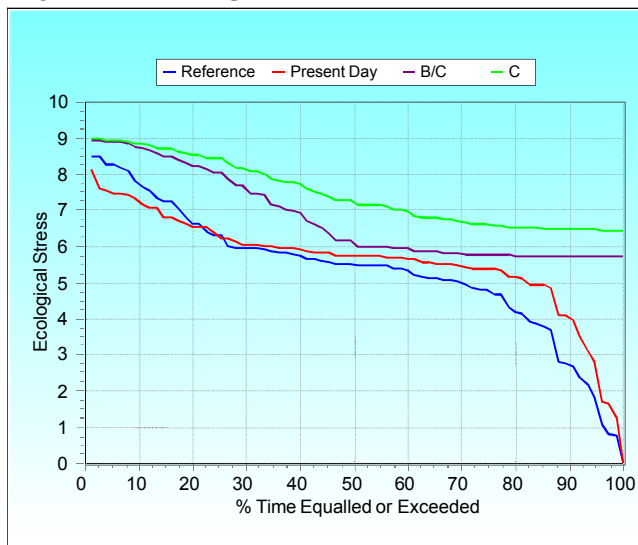
PES and REC: RIPARIAN VEGETATION EC B/C (ECOSTATUS B/C)
<p>Dry Season drought <i>C. marginatus</i> rhizome level remains activated for survival.</p> <p>Wet Season maintenance Inundates marginal zone sedges by 20 cm, which is sufficient to sustain summer functionality e.g. flowering.</p> <p>Wet Season drought Sufficient to activate the lower limits of <i>C. marginatus rhizomes</i> on the marginal zone.</p>
AEC down: RIPARIAN VEGETATION EC: C (ECOSTATUS C)
<p>Dry Season maintenance Unchanged from PES.</p> <p>Wet Season maintenance Lower limit of marginal zone sedges still remains inundated. Vegetation unlikely to change from PES.</p>

7.3.1 Final low flow requirements

To produce the final results (Figure 7.3), the DRM results for the specific category are modified according to specialists' requirements (Figure 7.1 and 7.2). 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 changes for B/C and C EC.
 - 0 Upper shift values for all months changed to 100%.
 - 0 Shape factor values for all months changed to 7.
- B/C EC
 - 0 Distribution factors: 1.5 for maintenance.
- C EC
 - 0 Distribution factors: 0.96 for maintenance.

Dry Season (August)



Wet Season (February)

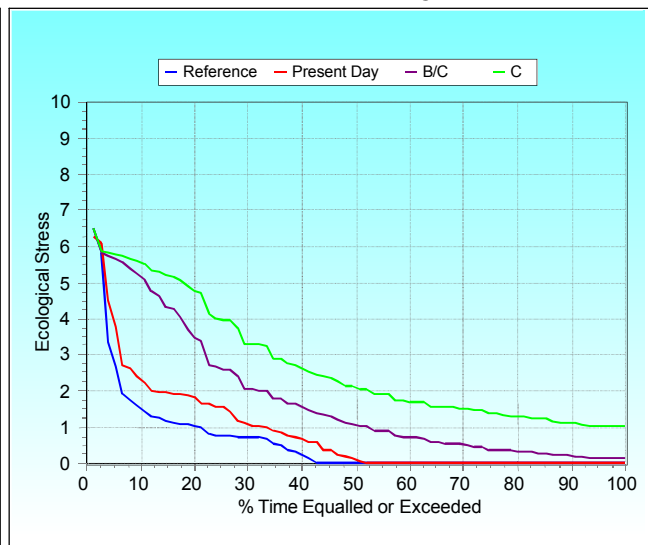


Figure 7.3 EWR 6: Final stress requirements for low flows

7.4 HIGH FLOW REQUIREMENTS

The high flow classes are identified as follows:

- The geomorphologist and riparian vegetation specialist identify the range of flood classes required and list the functions of each flood.
- The instream specialists then indicate which of the instream flooding functions are addressed by the floods identified for geomorphology and riparian vegetation (indicated by a ✓ in Table 7.4.
- Any of the floods required by the instream biota and not addressed by the floods already identified, must then be described (in terms of ranges and functions) for the instream biota.

Results are provided in Table 7.4 and detailed motivations provided in Table 7.5.

Table 7.4 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 and spawning	Migration habitat (depth etc.)	Clean spawning substrate	Create nursery areas	Resetting water quality	Inundate vegetation for spawning	Breeding and hatching cues	Clear fines	Scour substrate	Reach or inundate specific areas	Reset water quality	
I	5 – 7	Vegetation: Inundate marginal zone sedges.	✓	✓	✓	✓	✓	✓		✓				
II	10 -15	Geomorphology: Scours fines (2 mm sands) from the bed. Vegetation: Activates lower zone vegetation.	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
III	20 - 50	Geomorphology: This flow class accounts for the majority of both fines (2 mm sands) and coarser gravels (20 mm) transport. Vegetation: Activation/inundation of the <i>Miscanthus</i> grassland.	✓	✓		✓	✓	✓						
IV	> 90	Geomorphology: Transport of gravels (20 mm) and scour/movement of cobble bed elements. Vegetation: Promotes woody vegetation recruitment.	✓	✓		✓	✓	✓						

Further information is provided in Appendix D, Table D8.

The number of high flow events required for each EC is provided in Table 7.5. No observed daily data was available to check flood requirements against.

Table 7.5 EWR 6: The recommended number of high flow events required

FLOOD CLASS	FLOOD RANGE (m ³ /s)	INVERTEBRATES	FISH	VEGETATION	GEOMORPHOLOGY	FINAL (Frequency)	MONTHS	DAILY AVERAGE	DURATION
PES and REC SCENARIO: B/C									
I	5 – 7	6	6	4		6	Oct, Nov, Dec, Jan, Feb, Mar	5	3
II	10 -15	1	1	1	1	1	Jan	15	5

FLOOD CLASS	FLOOD RANGE (m ³ /s)	INVERTEBRATES	FISH	VEGETATION	GEOMORPHOLOGY	FINAL (Frequency)	MONTHS	DAILY AVERAGE	DURATION
III	20 - 50		1:2	1:2	1:2	1:2			
IV	> 90		1:5	1:5	1:3 to 1:5	1:5			
AEC down SCENARIO: C									
I	5 - 7	4	4	2		4	Nov, Dec, Jan, Feb,	5	3
II	10 -15			1:2	1:2	1:2	Jan	15	5
III	20 - 50			1:3	1:3	1:3			
IV	> 90			1:5	1:5	1:5			

7.5 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 7.6 – 7.7). Floods with a frequency higher than 1:1 is not included.
- The EWR rule table, which provides the EWR recommended flows as a duration table, showing flows that should be provided when linked to a natural trigger (natural hydrology). An EWR rule table is supplied for the low flows only, and for low and high flows combined (Appendix D, Section D2.4).

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

Table 7.6 EWR table for PES and REC: B/C

Desktop version:		2	Virgin MAR (MCM)	95.307
BFI	0.299	Distribution type		Vaal
MONTH	LOW FLOWS		HIGH FLOWS	
	Maintenance (m ³ /s)	Drought (m ³ /s)	Daily average (m ³ /s) on top of base flow	Duration (days)
OCTOBER	0.300	0.043		
NOVEMBER	0.600	0.072	5	3
DECEMBER	0.800	0.037	5	3
JANUARY	1.000	0.106	5 15	3 5
FEBRUARY	1.400	0.120	5	3
MARCH	0.950	0.093		
APRIL	0.600	0.019		
MAY	0.400	0.019		
JUNE	0.200	0.033		
JULY	0.200	0.028		
AUGUST	0.140	0.020		
SEPTEMBER	0.150	0.024		
TOTAL MCM	17.556	1.601	7.741	
% OF VIRGIN	18.42	1.68	8.12	
Total IFR	25.30			
% of MAR	26.54			

Table 7.7 EWR table for AEC down: C

Desktop version:		2	Virgin MAR (MCM)	95.307
BFI	0.299	Distribution type		Vaal
MONTH	LOW FLOWS		HIGH FLOWS	
	Maintenance (m ³ /s)	Drought (m ³ /s)	Daily average (m ³ /s) on top of base flow	Duration (days)
OCTOBER	0.15	0.043	5	3
NOVEMBER	0.3	0.072	5	3
DECEMBER	0.37	0.037	5	3
JANUARY	0.45	0.106	5 15	3 5
FEBRUARY	0.6	0.12	5	3
MARCH	0.42	0.093	5	3
APRIL	0.3	0.019		
MAY	0.2	0.019		
JUNE	0.14	0.033		
JULY	0.12	0.028		
AUGUST	0.085	0.02		
SEPTEMBER	0.1	0.024		
TOTAL MCM	8.85	1.601	6.186	
% OF VIRGIN	8.437	1.68	6.49	
Total IFR	14.62			
% of MAR	15.34			

A comparison between the differences in terms of percentages of the various types of flow blocks are provided in Table 7.8.

Table 7.8 Modifications made to the DRM for EWR 6

Changes	PES and REC B/C		AEC down C	
	DRM	EWR	DRM	EWR
MLIFR - Maintenance low flow	13.1%	18.4%	9.3%	8.8%
DLIFR - Drought low flow	2.1%	18.4%	2.1%	1.7%
MHIFR - Maintenance high flow	12.1%	8.1%	10.8%	6.5%
Long-term % of virgin MAR	20.4%	23.4%	17.3%	14.9%

8 EWR 7: UPPER WILGE (WILGE RIVER) - DETERMINATION OF STRESS INDICES

NOTE: All supporting specialist information for EWR 7 is summarized in Volume 2, Appendix E.

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

8.1 INDICATOR SPECIES OR GROUP

8.1.1 Fish indicator group 1: Small semi-rheophilic species (BANO, BPAL, BAEN)

All species present at this site are classified as small semi-rheophilic. It is thought that the large semi-rheophilic BAEN would not utilise this habitat for spawning and nursery areas, but juveniles and adults utilise it. The two small semi-rheophilic species, namely BANO and BPAL were therefore used as indicators to determine the stress for aspects such as spawning and nursery habitats, while all species were considered for abundance/cover, connectivity and flow related water quality metrics. Refer to Section 2.1.1 and Appendix B, Table B1 and B2.

8.1.2 Macroinvertebrate indicator taxa

Indicator taxa: Macroinvertebrates inhabiting marginal vegetation only (i.e., mainly Hemiptera). These taxa are not sensitive to deterioration in water quality, and are expected to tolerate wide fluctuations in flow and water quality conditions. The main consideration in setting flows was the depth that marginal vegetation was inundated (at least 10 cm), but allowing sufficient light penetration (less than 50 cm). Flow-dependent taxa were not found or expected within this oxbow dominated system.

8.1.3 Riparian vegetation indicator species

Indicator species included:

- *Persecaria* spp.: Refer to section 6.1.4.
- *Phragmites australis*: Hardy reed that is an obligate hydrophyte. Have a wide habitat tolerance, but optimal habitat and largest stands usually occur in the marginal zone and lower parts of the lower zone.

8.2 STRESS FLOW INDEX

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

8.2.1 Habitat response

Habitat response is used to derive the biota's response to provide a biota stress index and represents the instantaneous response of habitat to flow changes, based on a site specific 0 – 10 scale for instream biota where:

- 0 – Optimum habitat (fixed at the natural maximum baseflow – calculated using the wettest flow month discharge at the maintenance % of 50 – 60% for the Wilge 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 E, Table E1.

The instantaneous response of marginal vegetation macroinvertebrate (MVI) taxa provides the % occurrence of various velocity-substrate classes under different flow conditions are provided in Appendix E, Table E3).

8.2.2 Biota response

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

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

The fish species response index is calculated using the fish habitat rating (cf Section 2.2.1) (Appendix E, Table E2) for each of the discharges evaluated for assessing habitat response. The macroinvertebrate (MVI) index is derived by considering the habitat response and % occurrence of habitat conditions at different flows. The MVI responses are described and coupled to a stress level (Appendix E, Table E4).

8.2.3 Integrated stress curve

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

The shaded species stress discharges in Table 8.1 indicate the discharges 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 8.1 illustrates this graphically.

In this specific case, the SSR fish stress index represents the integrated stress index (these values are the highest flow for a stress), therefore the blue curve (representing the SSR stress index) is lying 'beneath' the integrated stress line (black) for stress 0 – 6.3 (Figure 8.1).

Table 8.1 Species stress discharges used to determine biotic stress

Stress	Flow (m ³ /s)		Integrated Flow (m ³ /s)
	SSR	MVI	
0	1.06	0.9	1.06
1	0.74	0.73	0.74
2	0.53	0.49	0.53
3	0.41	0.32	0.41
4	0.3	0.25	0.3
5	0.22	0.19	0.22
6	0.15	0.14	0.15
7	0.1	0.12	0.12
8	0.07	0.09	0.09
9	0.03	0.001	0.03
10	0	0	0

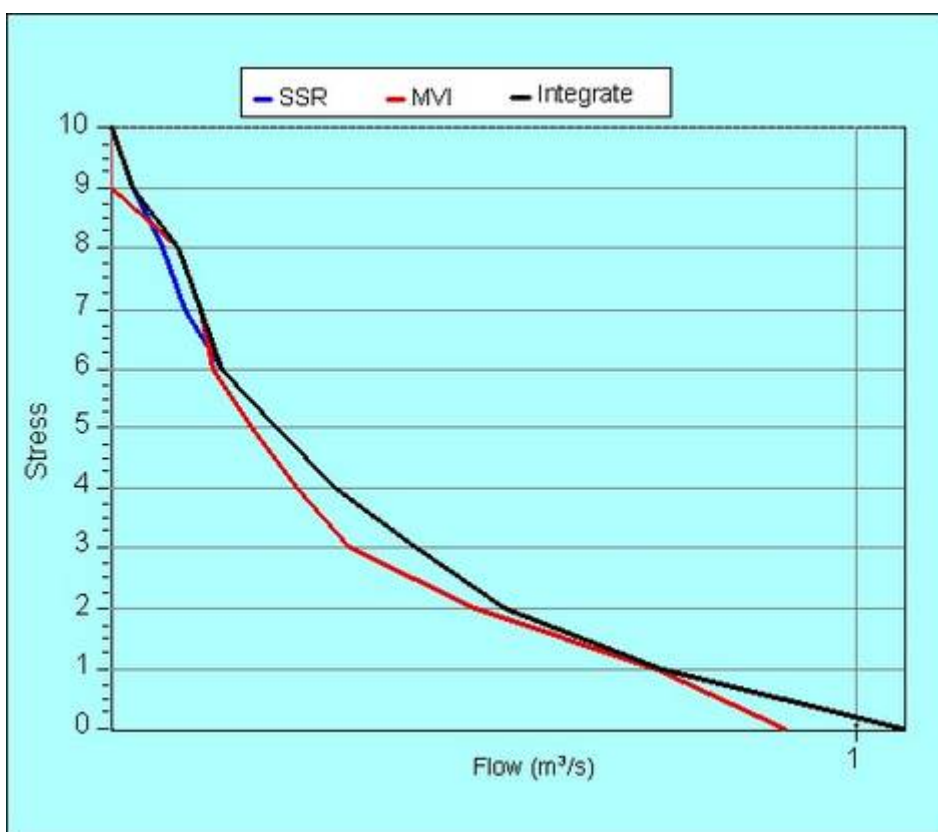


Figure 8.1 Component and integrated stress curves for EWR 7

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

Table 8.2 Integrated stress and summarised habitat/biotic responses

Integrated stress	Flow m ³ /s	Habitat and/or Biotic responses
0 (SSR)	1.06	All fish habitats are optimal (5 ⁺). All MVI habitats in excess. All flow dependent macroinvertebrates very abundant and healthy.
1 (SSR)	0.74	Fish habitats are good (4 – 4.5) and water quality is optimal. All MVI habitats plentiful. 90 % of taxa persist.
2 (SSR)	0.53	Critical MVI habitats sufficient. Most taxa persist, but slight (80 %) reduction.
3 (SSR)	0.41	
4 (SSR)	0.3	Spawning and nursery habitat is low (2.5) while cover and abundance is moderate (3) and connectivity and water quality is good (4). Reduced critical MVI habitat. Most rheophilic species persist, but abundances reduced.
5 (SSR)	0.22	Spawning habitat is very low (1). Nursery, cover and abundance is low (2 – 2.5), connectivity is good and water quality moderate. Critical MVI habitats limited. All life stages viable in limited areas, critical life stages of some sensitive rheophilic species at risk.
6 (SSR)	0.15	Critical MVI habitat residual. Sensitive rheophilic species rare, critical stages of sensitive rheophilic species non-viable and at risk for some less sensitive species.
7 (MVI)	0.12	Spawning habitat is absent and nursery habitat is very rare (0.5). Abundance and cover is very low (1.5) while connectivity is good and water quality low. No critical MVI habitat. Some rheophilic species persist, but most disappear. All life stages of sensitive rheophilic species at risk or non-viable.
8 (MVI)	0.09	Spawning habitat as above. Nursery, cover and abundance is very rare, connectivity moderate and water quality very low. MVI: Flowing water habitats residual. Some rheophilic species persist, but at very low numbers; All life stages of most rheophilic species at risk or non-viable.
9 (SSR)	0.03	Spawning and nursery habitats are absent with rest of habitat very rare and connectivity very low.
10	0	Only pool dwelling species present. Only hyporheic refugia, no surface water for FDIs. Indicator taxa no longer present.

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

9 EWR 7: UPPER WILGE (WILGE RIVER) - DETERMINATION OF EWR SCENARIOS

9.1 ECOCLASSIFICATION SUMMARY OF EWR 7

EWR 7 Upper Wilge (Wilge River)				
<p>EIS : HIGH There are rare and endangered species i.e. the flufftail crowned crane, bald ibis, and 11 red data vegetation species. There is a good diversity of habitats that include wetlands, flood plains, oxbow lakes and peat lands.</p> <p>PES: A/B Non-flow related impacts that include small dams for agriculture and exotic fish species (MSAL).</p> <p>REC A/B As the PES is also relatively high, the attainable and realistic objective is to maintain the PES even though a HIGH EIS would normally warrant improvement.</p> <p>AEC Down: C The scenario includes decreased low flows, some periods of zero flows and decreased moderate floods.</p>	Driver Components	PES and REC Category	Trend	AEC↓
	HYDROLOGY	A		
	WATER QUALITY	B	Negative B/C	-B
	GEOMORPHOLOGY	A	Negative B/C	B/C
	Response Components	PES Category	Trend	AEC↓
	FISH	B (D)	Negative D/E	C
	MACRO INVERTEBRATES	B	Stable	C/D
	INSTREAM	B		C
	RIPARIAN VEGETATION	A/B	Stable	B/C
	ECOSTATUS	A/B		C

9.2 HYDROLOGY

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

- 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.
- Any additional points which had specific significance in terms of flow or stress requirements.

9.3 LOW FLOW REQUIREMENTS (IN TERMS OF STRESS)

The integrated stress index is used to identify required stress levels at specific durations for the wet and dry month/season. Specialist motivations for the stresses are provided in Appendix E, Section E2.1 – 2.2.

The fish and macroinvertebrate flow requirements for different Ecological Categories (ECs) are provided in Table 9.1 and Figure 9.1 and 9.2. 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 9.1 and 9.2.

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

PES and REC: Purple

AEC down: Green

Summarised motivations for the final requirements are provided in Table 9.2.

Table 9.1 Species and integrates stress requirements as well as the final integrated stress and flow requirements

Duration	SSR stress	Integ stress	FDI stress	Integ. stress	FINAL* (Integrated stress)	FLOW (m ³ /s)
PES and REC: A/B EcoStatus		FISH: B		MACROINVERTEBRATES: B		
DRY SEASON						
5%	9.49	9.4	9	9.9	9.9	0.004
40%	7.25	8			8	0.09
60%			8.5	8.7	8.7	0.048
WET SEASON						
5%	5.3	5.75	6	6.3	6.3	0.141
40%	1.25	1.25			1.25	0.68
60%			1	1	1	0.74
AEC down: C EcoStatus		FISH: C		MACROINVERTEBRATES: C/D		
DRY SEASON						
40%	7.64	8.3			8.3	0.072
60%			9	9.8	9.8	0.007
WET SEASON						
40%	2.15	2.15			2.15	0.512
60%			3	3.8	3.8	0.322

* Final refers to the final stress selected as the EWR requirement, i.e. the lowest integrated stress.

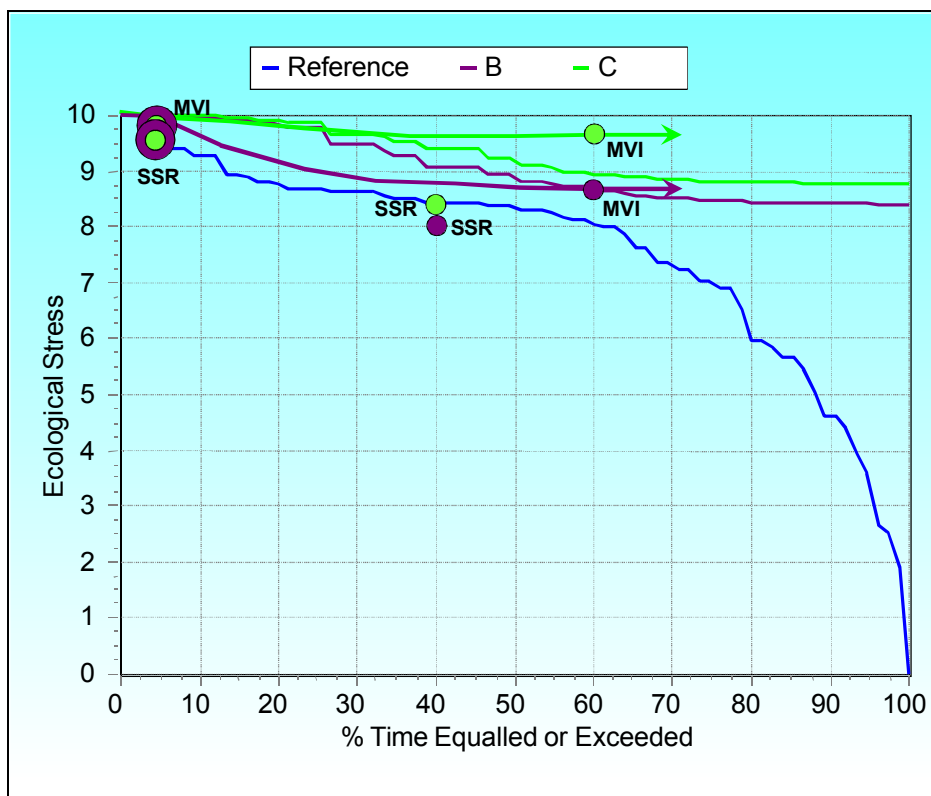


Figure 9.1 EWR 7: Stress Duration Curve for a A/B PES and REC, and C AEC down - DRY season

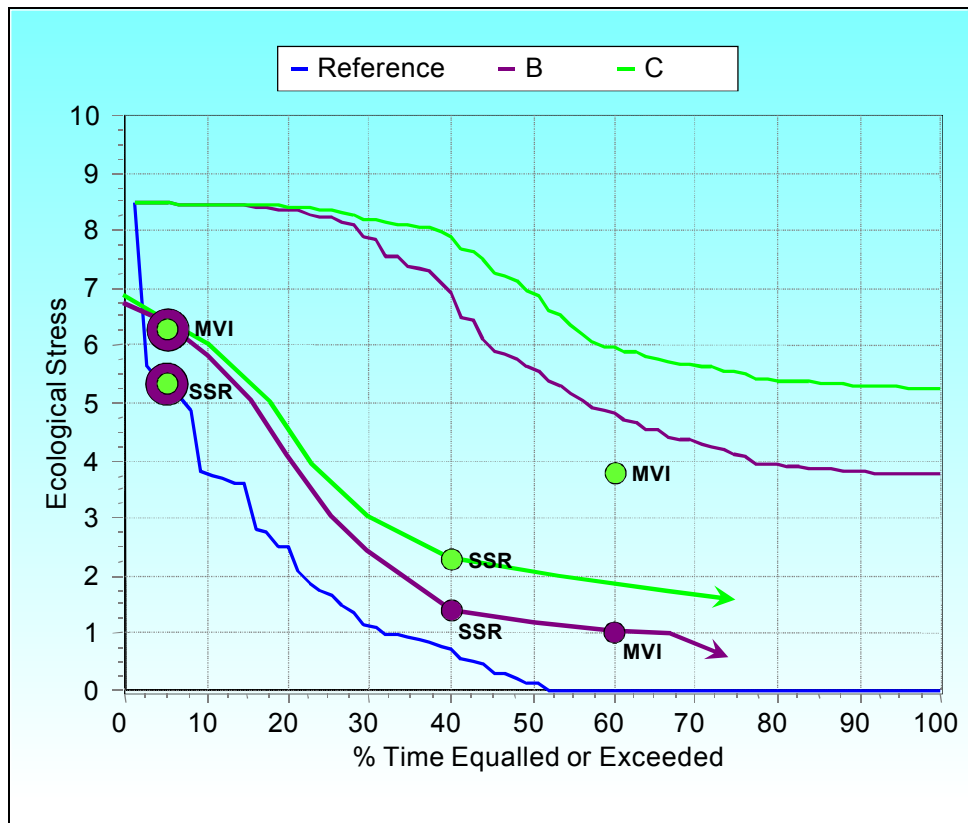


Figure 9.2 EWR 7: Stress Duration Curve for a A/B PES and REC, and C AEC down - WET season

Table 9.2 Summary of EWR 7 motivations

Month	% Stress duration	Component stress	Integrated stress	Flow m ³ /s	Comment ¹
PES: A/B EcoStatus		FISH: B		MACROINVERTEBRATES: B	
Aug	5% drought	9 MVI	9.9	0.004	Average depth needed for dry season drought is 10 cm, and maximum depth is 54 cm to ensure survival of MVI taxa.
	40%	7.25 SSR	8	0.09	The total habitat suitability would be adequate to sustain the semi-rheophilic fish species at this site and maintain it in the PES.
	60% maintenance	8.5 MVI	8.7	0.048	Average depth needed for dry season maintenance is 12 cm, and maximum depth is 60 cm, which is considered sufficient.
Feb	5% drought	6 MVI	6.3	0.141	Average depth needed for wet season drought is 0.13 m, and maximum depth is 0.78 m.
	40%	1.25 SSR	1.25	0.688	The habitat suitability will be 92% of the expected optimal wet season habitat suitability under natural conditions and adequate to maintain this guild within this reach.
	60% maintenance	1 MVI	1	0.74	Average depth needed for wet season maintenance is 0.34 m, and maximum depth is 1.2 m. This will provide suitable vegetation habitats during summer.
AEC down: C EcoStatus		FISH: C		MACROINVERTEBRATES: C/D	
Aug	5% drought	9 MVI	9.9	0.004	See PES.
	40%	8.3 SSR	8.3	0.072	Loss of suitable habitats for some life stages of the semi-rheophilic species.
	60% maintenance	9.8 FDI	9.8	0.024	Average depth needed for dry season maintenance is 0.1 m (i.e. some vegetation inundated).
Feb	5% drought	6 MVI	6.3	0.141	See PES.

Month	% Stress duration	Component stress	Integrated stress	Flow m ³ /s	Comment ¹
	40%	2.15 SSR	2.15	0.71	Reduced habitat availability for the different life stages of the semi-rheophilic species. Habitat suitability will be 82% of what can be expected during the dry season under natural flow conditions.
	60% maintenance	3 FDI	3.8	0.32	Average depth needed for wet season maintenance is 0.25 m. Crucial marginal vegetation present and abundant.

¹ See Chapter 3, Table 3.2.

The above flows were checked by the riparian vegetation specialist to ensure that these requirements are adequate to achieve the EC in which the marginal vegetation should be, as well as any other flow dependant vegetation that could occur.

The vegetation indicators used were *Persecaria* and *Phragmites* species. The resulting conditions of the vegetation indicators to the required low flows are described below. In conclusion, the low flows would maintain the PES and REC of the riparian vegetation (Table 9.3).

Table 9.3 Verification of the low flow requirements to maintain the vegetation EC

PES and REC: RIPARIAN VEGETATION EC A/B (ECOSTATUS A/B)
<p>Dry Season maintenance 20 – 50 cm rooting depth required to maintain marginal zone species. Survival is likely: PES will be met.</p> <p>Dry Season drought Likely to have mortality of <i>Persecaria</i> and <i>Phragmites</i> in the lower zone. Marginal zone vegetation shows high levels of water stress (30 cm rooting).</p> <p>Wet Season maintenance Sufficient flow to meet riparian requirement.</p> <p>Wet Season drought Marginal zone vegetation likely to abort fruiting and flowering, but survival will ensure PES maintenance.</p>
AEC down : RIPARIAN VEGETATION EC: B/C (ECOSTATUS C)
<p>Dry Season maintenance Sufficient flow to meet riparian requirement for AEC in dry season.</p> <p>Wet Season maintenance Sufficient flow to meet riparian requirement for AEC.</p>

9.3.1 Final low flow requirements

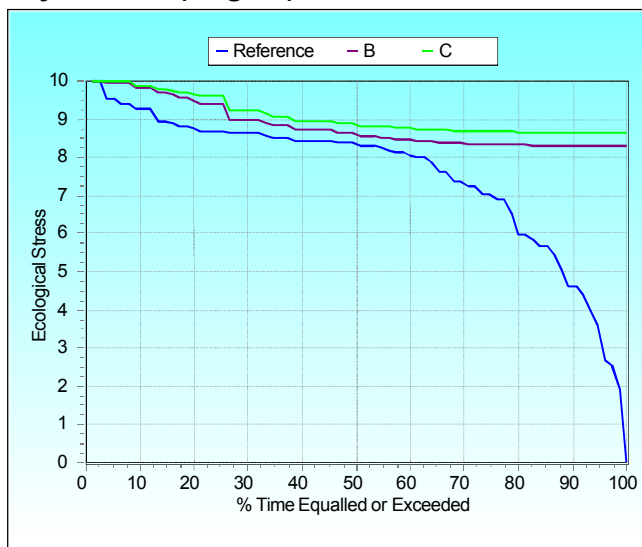
The DRM used the rules associated with a B EC which represents the Instream PES and REC. This would be more appropriate than the A/B EC (the EcoStatus) as the higher EcoStatus is due to the A/B EC for riparian vegetation which does not play a role in the determination of the EWRs.

To produce the final results (Figure 9.3), the DRM results for the specific category are modified according to specialists’ requirements (Figure 9.1 and 9.2). There are a range of options one can use to make these modifications, such as changing the total volume required for the year, 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 changes for B/C and C EC.
 - o Upper shift values: Set at 100% for WET; 98 for DRY.

- 0 Shape factor values: 5 for Jan, Feb and Mar; 6 for rest of months.
- B (A/B) EC
 - 0 Distribution factors: 2.3 for maintenance.
- C EC
 - 0 Distribution factors: 1.7 for maintenance.
- Some of the maintenance flows in other months reduced for the B and C EC to avoid being greater than natural.
- An additional edit was made to C EC for the three main wet season months Jan = 0.25, Feb = 0.4, and Mar = 0.28.
- Note that there are many periods when the requirements are close to natural.

Dry Season (August)



Wet Season (February)

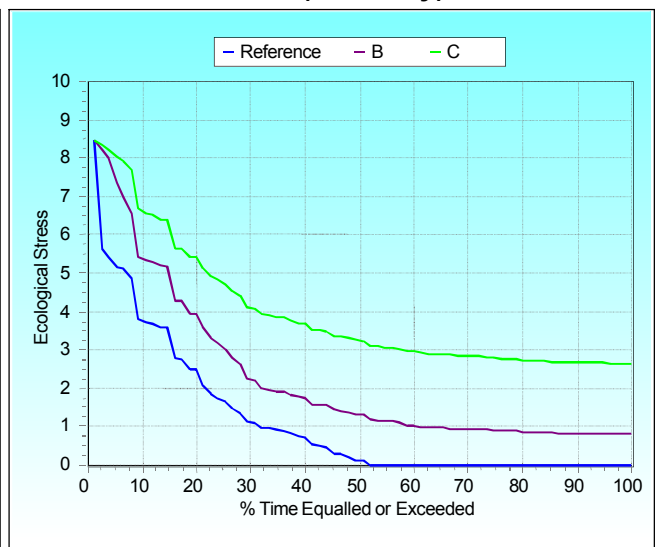


Figure 9.3 EWR 7: Final stress requirements for low flows

9.4 HIGH FLOW REQUIREMENTS

The high flow classes are identified as follows:

- The geomorphologist and riparian vegetation specialist identify the range of flood classes required and list the functions of each flood.
- The instream specialists then indicate which of the instream flooding functions are addressed by the floods identified for geomorphology and riparian vegetation (indicated by a ✓ in Table 9.4).
- Any of the floods required by the instream biota and not addressed by the floods already identified, must then be described (in terms of ranges and functions) for the instream biota.

Results are provided in Table 9.4 and detailed motivations provided in Table 9.5.

Table 9.4 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 and spawning	Migration habitat (depth etc.)	Clean spawning substrate	Create nursery areas	Resetting water quality	Inundate vegetation for spawning	Breeding and hatching cues	Clear fines	Scour substrate	Reach or inundate specific areas
II	2 - 3	Vegetation: Required to maintain in-channel obligate riparian vegetation (<i>Persecaria and Phragmites australis</i>)	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
III	8 - 9	Geomorphology: Breaches the levee and connects and recharges the ox-bow lake; inundates seasonal zone around lake. Vegetation: Required to breach the main channel upstream of the site in order to recharge oxbow lakes (which have specific and different communities from floodplain and channel) and flood lower lying floodplain grasses.	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
IV	< 11	Vegetation: Overtops the bank levees and recharges higher lying oxbow communities (which are also reliant on lateral inputs), also floods majority of floodplain grasses.	✓	✓	✓	✓	✓	✓				✓

Further information is provided in Appendix E, Table E7.

The number of high flow events required for each EC is provided in Table 9.5. No observed daily data was available to check flood requirements against.

Table 9.5 EWR 7: The recommended number of high flow events required

FLOOD CLASS	FLOOD RANGE (m ³ /s)	INVERTEBRATES	FISH	VEGETATION	GEOMORPHOLOGY	FINAL (Frequency)	MONTHS	DAILY AVERAGE	DURATION
PES and REC SCENARIO: A/B (B)									
I	1	6				6	Oct - Mar	0.5	2
II	2 - 3	4		4		4	Nov, Dec, Jan, Feb	1	2
III	8 - 9	2		2	> 2 (?)	>2	Dec, Jan	3	3
IV	< 11	1		1		1	Feb	5	3
AEC down SCENARIO: C									
I	1	3				3	Nov, Jan, Mar	0.5	2
II	2 - 3	4		2		2	Dec, Feb	1	2
III	8 - 9			1:1	1		Feb	5	3
IV	< 11			1:1			Summer		

9.5 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 9.6 – 9.7). Floods with a frequency higher than 1:1 is not included.
- The EWR rule table, which provides the EWR recommended flows as a duration table, showing flows that should be provided when linked to a natural trigger (natural hydrology). An EWR rule table is supplied for the low flows only, and for low and high flows combined (Appendix E, Section E2.4).

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

Table 9.6 EWR table for PES and REC: B

Desktop version:		2	Virgin MAR (MCM)	23.467
BFI	0.314	Distribution type		Vaal
MONTH	LOW FLOWS		HIGH FLOWS	
	Maintenance (m ³ /s)	Drought (m ³ /s)	Daily average (m ³ /s) on top of base flow	Duration (days)
OCTOBER	0.12	0	0.5	2
NOVEMBER	0.28	0.035	0.5 1	2 2
DECEMBER	0.36	0.041	0.5 1 3	2 2 3
JANUARY	0.44	0.047	0.5 1 3	2 2 3
FEBRUARY	0.62	0.062	0.5 1 5	2 2 3
MARCH	0.5	0.053	0.5	2
APRIL	0.32	0		
MAY	0.2	0		
JUNE	0.1	0		
JULY	0.06	0		
AUGUST	0.056	0		
SEPTEMBER	0.08	0.012		
TOTAL MCM	34.82	2.77	2.596	
% OF VIRGIN	8.171	0.649	11.06	
Total IFR	10.77			
% of MAR	45.88			

Table 9.7 EWR table for AEC down: C

Desktop version:		2	Virgin MAR (MCM)	23.467
BFI	0.314	Distribution type		Vaal
MONTH	LOW FLOWS		HIGH FLOWS	
	Maintenance (m ³ /s)	Drought (m ³ /s)	Daily average (m ³ /s) on top of base flow	Duration (days)
OCTOBER	0.07	0		
NOVEMBER	0.14	0.035	0.5	2
DECEMBER	0.18	0.041	1	2
JANUARY	0.25	0.047	0.5	2
FEBRUARY	0.4	0.062	1 5	2 3
MARCH	0.28	0.053	0.5	2
APRIL	0.17	0		
MAY	0.1	0		
JUNE	0.06	0		
JULY	0.04	0		
AUGUST	0.035	0		
SEPTEMBER	0.045	0.012		
TOTAL MCM	19.61	2.77		5.15
% OF VIRGIN	4.601	0.649		1.21
Total IFR			5.81	
% of MAR			24.76	

A comparison between the differences in terms of percentages of the various types of flow blocks are provided in Table 9.8.

Table 9.8 Modifications made to the DRM for EWR 7

Changes	PES and REC A/B		AEC down C	
	DRM	EWR	DRM	EWR
MLIFR - Maintenance low flow	17.2%	34.8%	9.9%	19.6%
DLIFR - Drought low flow	2.8%	2.8%	2.8%	2.8%
MHIFR - Maintenance high flow	13.2%	11.1%	10.6%	5.1%
Long-term % of virgin MAR	24%	42.2%	17.6%	25.8%

10 EWR 8: BAVARIA (WILGE RIVER) – DETERMINATION OF STRESS INDICES

NOTE: All supporting specialist information for EWR 8 is summarized in Volume 2, Appendix F.

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

10.1 INDICATOR SPECIES OR GROUP

10.1.1 Fish indicator group 1: Large semi-rheophilic species (BAEN, BKIM)

Indicator species: *Labeobarbus aeneus* (BAEN) and *Labeobarbus kimberleyensis* (BKIM). Refer to Section 2.1.1 and Appendix B, Table B1.

10.1.2 Fish indicator group 2: Small semi-rheophilic species (BANO)

Indicator species: *Barbus anoplus* (BANO). Refer to Section 2.1.1 and Appendix B, Table B2.

10.1.3 Macroinvertebrate indicator taxa

Indicator taxa: Hydropsychid caddisflies and blackflies (i.e. common flow-dependent taxa), as well as Leptophlebiidae. Refer to Section 2.1.3.

10.1.4 Riparian vegetation indicator species

Indicator species included:

- *Cyperus marginatus*: Refer to Section 2.1.4.
- *Persecaria* spp.: Refer to Section 6.1.4.
- *Crinum bulbispermum*: Occurs near rivers, streams, and seasonal pans. Robust deciduous bulbous plant, reaching up to 900 mm, solitary or in large colonies. Flowers Sep – Dec.

10.2 STRESS FLOW INDEX

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

10.2.1 Habitat response

Habitat response is used to derive the biota's response to provide a biota stress index and represents the instantaneous response of habitat to flow changes, based on a site specific 0 – 10 scale for instream biota where:

- 0 – Optimum habitat (fixed at the natural maximum baseflow – calculated using the wettest flow month discharge at the maintenance % of 50 – 60% for the Wilge 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 F, Table F1.

The instantaneous response of marginal vegetation macroinvertebrate (FDI) taxa provides the % occurrence of various velocity-substrate classes under different flow conditions are provided in Appendix F, Table F3).

10.2.2 Biota response

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

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

The fish species response index is calculated using the fish habitat rating (cf Section 2.2.1) (Appendix F, Table F2) 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 F, Table F4).

10.2.3 Integrated stress curve

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

The shaded species stress discharges in Table 10.1 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 10.1 illustrates this graphically.

Table 10.1 Species stress discharges used to determine biotic stress

Stress	Flow (m ³ /s)			Integrated Flow (m ³ /s)
	LSR	SSR	FDI	
0	25	25	12.48	25
1	6.8	15.9	10.03	15.9
2	5	6.8	7.96	7.96
3	2.9	2.9	6.77	6.77
4	1.8	0.6	2.4	2.4
5	1.23	0.42	1.03	1.23
6	0.6	0.24	0.35	0.6
7	0.42	0.015	0.02	0.42
8	0.24	0.009	0.004	0.24
9	0.015	0.003	0.003	0.015
10	0	0	0	0

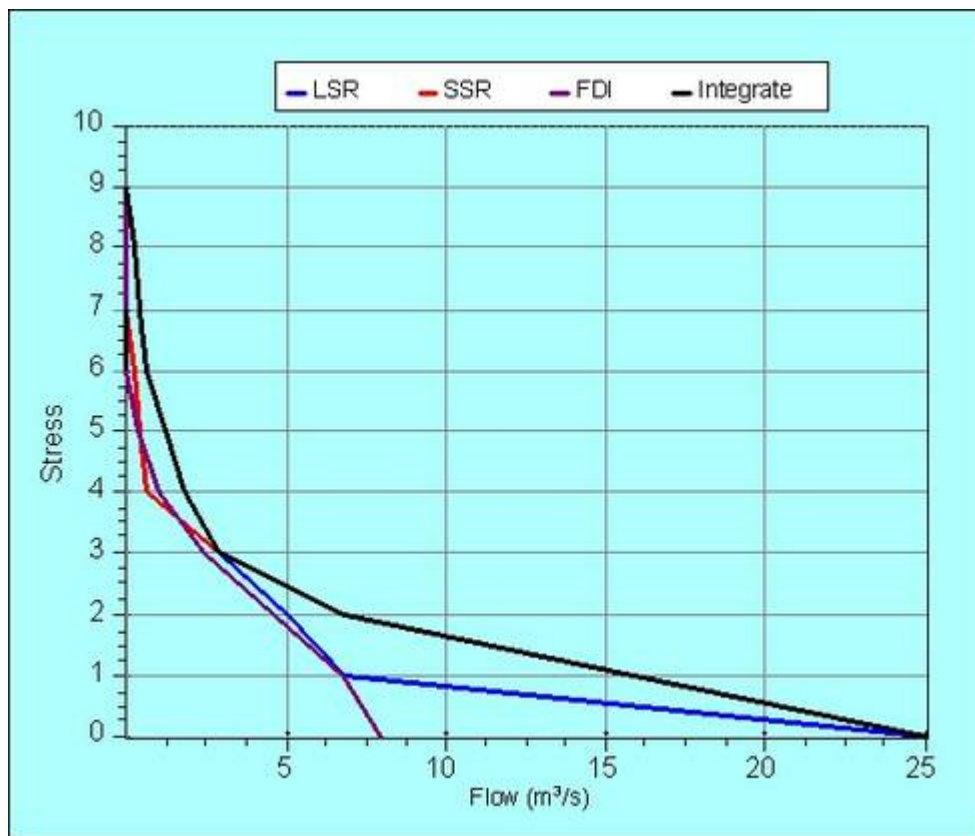


Figure 10.1 Component and integrated stress curves for EWR 8

Table 10.2 provides the summarised biotic response for the integrated stresses.

Table 10.2 Integrated stress and summarised habitat/biotic responses

Integrated stress	Flow m ³ /s	Habitat and/or Biotic responses
0 (LSR)	25	Fish guild: All habitats optimal (5 ⁺).
1 (SSR)	15.9	
2 (SSR)	7.96	
3 (LSR)	6.77	SSR: Spawning, nursery and cover is moderate (3) while rest of habitats are optimal. LSR: Spawning, nursery and water quality is optimal while rest of habitats are good (4.5).
4 (LSR)	2.4	SSR: Spawning and nursery habitats are low (2.5), cover is moderate and rest of habitats are good (4). LSR: Cover and connectivity is moderate (3 – 3.5) while rest of habitats are good (4).
5 (LSR)	1.23	SSR: As above. LSR: Abundance and water quality is moderate and rest of habitats are low (2 – 2.5). All FDI habitats are plentiful. All FDIs very abundant and healthy.
6 (LSR)	0.6	SSR: All habitats are moderate but spawning and nursery habitats are low. LSR: Spawning, nursery and connectivity is very low (1 – 1.5) while rest of habitats are low. Reduced critical FDI habitat. Most rheophilic species persist, but slight (80%) reduction.
7 (LSR)	0.42	Most rheophilic species persist, but abundances reduced.
8 (LSR)	0.24	SSR: All habitats are low. LSR: Spawning and nursery habitats are very rare (0.5) while water quality is very low and the rest of the habitats are very low. Critical FDI habitat very reduced. Critical life stages of sensitive rheophilic species at risk or non-viable.
9 (LSR)	0.015	SSR: Cover and water quality habitats are still low but rest of habitats are very low. LSR: Spawning and nursery habitats are absent while rest of habitats are very rare.

Integrated stress	Flow m ³ /s	Habitat and/or Biotic responses
		Flowing water habitats residual and of low quality for FDIs. Some rheophilic species persist, but at very low numbers. All life stages of most rheophilic species at risk or non-viable.
10	0	Only pool dwelling species present. Only hyporheic refugia, no surface water for FDIs. Indicator taxa no longer present.

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

11 EWR 8: BAVARIA (WILGE RIVER) - DETERMINATION OF EWR SCENARIOS

11.1 ECOCLASSIFICATION SUMMARY OF EWR 8

EWR 8 Bavaria (Wilge River)																																																													
<p>EIS: MODERATE PES: C Flow related impacts include alteration of hydrological regime due to interbasin transfers from Sterkfontein Dam, abstraction and agriculture. Non-flow related impacts include water quality problems, erosion and exotic species invasion.</p> <p>REC: C. Maintain the PES due to the MODERATE EIS rating.</p> <p>AEC Up: B/C Dry season base flow increase and no zero flows. Ongoing improved management of the Sterkfontein Dam releases. Reduced grazing, burning and removal of debris. Removal of MSAL (although highly impractical, without this removal, the fish EC will not improve).</p> <p>AEC Down: D Further decrease of base flows (e.g. an additional dam). Decrease in small moderate floods. Associated water quality deterioration.</p>			<table border="1"> <thead> <tr> <th>IHI</th> <th>Driver Components</th> <th>PES and REC Category</th> <th>Trend</th> <th>AEC ↑</th> <th>AEC ↓</th> </tr> </thead> <tbody> <tr> <td rowspan="3">I N S T R E A M</td> <td rowspan="3">R I P A R I A N</td> <td>HYDROLOGY</td> <td></td> <td></td> <td></td> </tr> <tr> <td>WATER QUALITY</td> <td>C</td> <td>Stable</td> <td>B/C C/D</td> </tr> <tr> <td>GEOMORPHOLOGY</td> <td>C</td> <td>Positive</td> <td>+C C/D</td> </tr> <tr> <td></td> <td>Response Components</td> <td>PES Category</td> <td>Trend</td> <td>AEC ↑</td> <td>AEC ↓</td> </tr> <tr> <td></td> <td>FISH</td> <td>C</td> <td>Stable</td> <td>B</td> <td>D</td> </tr> <tr> <td></td> <td>MACRO INVERTEBRATES</td> <td>C/D</td> <td>Stable</td> <td>C</td> <td>D</td> </tr> <tr> <td></td> <td>INSTREAM</td> <td>C</td> <td></td> <td>B/C</td> <td>D</td> </tr> <tr> <td></td> <td>RIPARIAN VEGETATION</td> <td>C</td> <td>Stable</td> <td>B/C</td> <td>D</td> </tr> <tr> <td></td> <td>ECOSTATUS</td> <td>C</td> <td></td> <td>B/C</td> <td>D</td> </tr> </tbody> </table>			IHI	Driver Components	PES and REC Category	Trend	AEC ↑	AEC ↓	I N S T R E A M	R I P A R I A N	HYDROLOGY				WATER QUALITY	C	Stable	B/C C/D	GEOMORPHOLOGY	C	Positive	+C C/D		Response Components	PES Category	Trend	AEC ↑	AEC ↓		FISH	C	Stable	B	D		MACRO INVERTEBRATES	C/D	Stable	C	D		INSTREAM	C		B/C	D		RIPARIAN VEGETATION	C	Stable	B/C	D		ECOSTATUS	C		B/C	D
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11.2 HYDROLOGY

The modelled present day hydrology shows higher flows than natural during the dry season. This can be due to the very infrequent releases from Sterkfontein Dam, or a modelling artefact of irrigation return flows. However, the modelled present day hydrology does not show any very low flows or zero flows. This is impossible as the river is known to virtually stop flowing during the dry season as was experienced by EWR specialists during the course of this study. This was also confirmed by the farmers. The reasons for this anomaly are:

- The gauges close to the EWR site will not measure very low flows accurately (rated section).
- Present use is highly likely inaccurate due to illegal abstraction.
- Present use is grouped together and scaled back according to area to the EWR site – there was no information available to do this any other way.
- The present hydrology is representative of 1994 only.

It is therefore suspected that the present use in the hydrological model is underestimated. Since this situation is not what is happening on the ground, the modelled present day hydrology had to be largely ignored, especially during the dry season.

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

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

- 45%: Representing maintenance flows for both wet and dry months. This would represent 55% on the stress duration graphs.
- Any additional points which had specific significance in terms of flow or stress requirements.

11.3 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 F2.1 – 2.2.

Note: An improvement in the base flows (closer to natural hydrological regime) or even a decrease in base flows will not result in a significant improvement or deterioration of the BANO assemblage (SSR guild). The primary impact on this species (and other small barb species at the site) is related to the presence of the predatory alien *Micropterus salmoides* (MSAL) and therefore the flow requirements for this guild were not assessed.

The fish and macroinvertebrate flow requirements for different Ecological Categories (ECs) are provided in Table 11.1 and Figure 11.1 and 11.2. 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 11.1 and 11.2.

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 11.2.

Table 11.1 Species and integrates stress requirements as well as the final integrated stress and flow requirements

Duration	LSR stress	Integ stress	FDI stress	Integ. stress	FINAL* (Integrated stress)	FLOW (m ³ /s)
PES and REC: C EcoStatus		FISH: C		MACROINVERTEBRATES: C/D		
DRY SEASON						
5%	9	9	6.5	9	9	0.015
55%	7.5	7.5	5.5	8.5	7.5	0.33
WET SEASON						
5%	7	7	5.5	8.5	7	0.42
55%	4.5	4.5	4	6.5	4.5	1.515
AEC up: B/C EcoStatus		FISH: B		MACROINVERTEBRATES: C		
DRY SEASON						
55%	Optimal conditions prevail at a C EcoStatus, therefore improved flows will not improve conditions for the LSR guild.	4	6.5	6.5	6.5	0.51
WET SEASON						

Duration	LSR stress	Integ stress	FDI stress	Integ. stress	FINAL* (Integrated stress)	FLOW (m ³ /s)
55%	As above.		3.5	4	4	1.8
AEC down: D EcoStatus		FISH: D		MACROINVERTEBRATES: D		
DRY SEASON						
55%	8	8	6	8.7	8	0.24
WET SEASON						
55%	5.75	5.75	5	8	5.75	0.758

* Final refers to the final stress selected as the EWR requirement, i.e. the lowest integrated stress

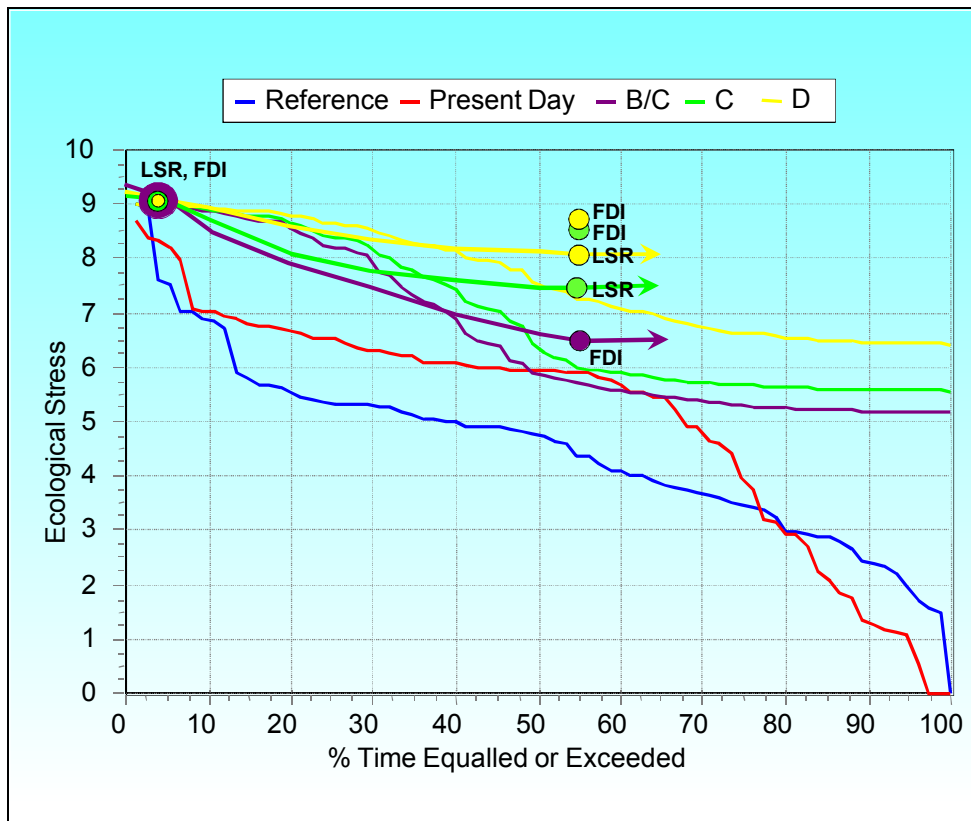


Figure 11.1 EWR 8: Stress Duration Curve for a C PES and REC, B/C AEC up and D AEC down - DRY season

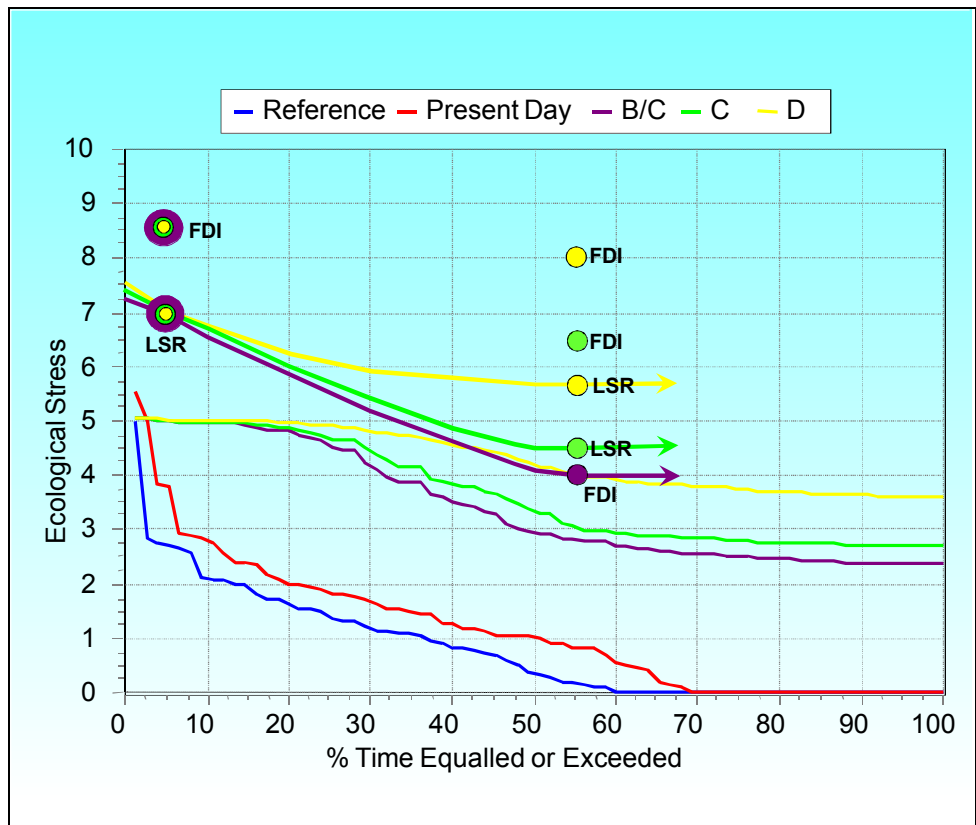


Figure 11.2 EWR 8: Stress Duration Curve for a C PES and REC, B/C AEC up and D AEC down - WET season

Table 11.2 Summary of EWR 8 motivations

Month	% Stress duration	Component stress	Integrated stress	Flow m ³ /s	Comment ¹
PES and REC: C EcoStatus				FISH: C	MACROINVERTEBRATES: C/D
Aug	5% drought	9 LSR	9	0.015	The most critical habitat for survival of this species during drought periods in the dry season (adequate depths in pools - both SD and SS) will be maintained. Some FS habitats (no FD and FI) for especially juvenile survival, and to maintain adequate oxygen levels in the pools will also be present.
	55% maintenance	7.5 LSR	7.5	0.33	Some fast habitat will be maintained (some FS, FI and limited FD) for adequate survival habitat for juveniles and feeding habitat for adults during the dry season. Some SD as refuge areas (especially at night by adults and juveniles to escape from extreme temperature fluctuations in shallow waters) will be maintained.
Feb	5% drought	7 LSR	7	0.42	At this recommended stress level, all the fast habitats (FD, FS and FI) will still be present, albeit in a very low abundance.
	55% maintenance	4.5 LSR	4.5	1.515	The recommended stress level should maintain adequate fast habitats (FS, FI and FD) to allow for the requirements for the different life stages.
AEC up: B/C EcoStatus				FISH: B	MACROINVERTEBRATES: C
Aug	5% drought	9 LSR	9	0.015	See PES.
	55% maintenance	4 FDI	6.5	0.51	Average depth needed for dry season maintenance is 0.22 m, and average current velocity is 0.22 m/s to ensure survival of FDIs.
Feb	5% drought	7 LSR	7	0.42	See PES.
	55% maintenance	3.5 FDI	4	1.8	Average depth needed for wet season maintenance is 0.27 m, and average current velocity is 0.26 m/s which will maintain FDIs.

Month	% Stress duration	Component stress	Integrated stress	Flow m ³ /s	Comment ¹
AEC down: D EcoStatus		FISH: D			MACROINVERTEBRATES: D
Aug	5% drought	9 LSR	9	0.015	See PES.
	55% maintenance	8 LSR	8	0.24	Limited FS and FI will still be available, but FD will be lost during the dry season. This should be adequate to sustain the BAEN assemblage, through the provision of FS for juveniles, and adequate flow to sustain pools and acceptable flow related water quality for all life stages. The decreased abundance and overall condition of preferred habitat of this species will result in decreased FROC and abundance of the guild.
Feb	5% drought	7 LSR	7	0.42	See PES.
	55% maintenance	5.75 LSR	5.75	0.7	Very limited fast habitats to maintain the different life stages of BAEN during the wet season. Decrease in abundance and condition of breeding, nursery and refuge habitats, as well as water quality deterioration as a result of decreased flows. Reduced depth of SD habitats will jeopardise the role these habitats play to provide refuge to juveniles and adults from night time temperature fluctuations.

¹ See Chapter 3, Table 3.2.

The above flows were checked by the riparian vegetation specialist to ensure that these requirements are adequate to achieve the EC in which the marginal vegetation should be, as well as any other flow dependant vegetation that could occur.

The vegetation indicators used were *C. marginatus*. The resulting conditions of the vegetation indicators to the required low flows are described below. In conclusion, the low flows would maintain the PES and REC of the riparian vegetation (Table 11.3).

Table 11.3 Verification of the low flow requirements to maintain the vegetation EC

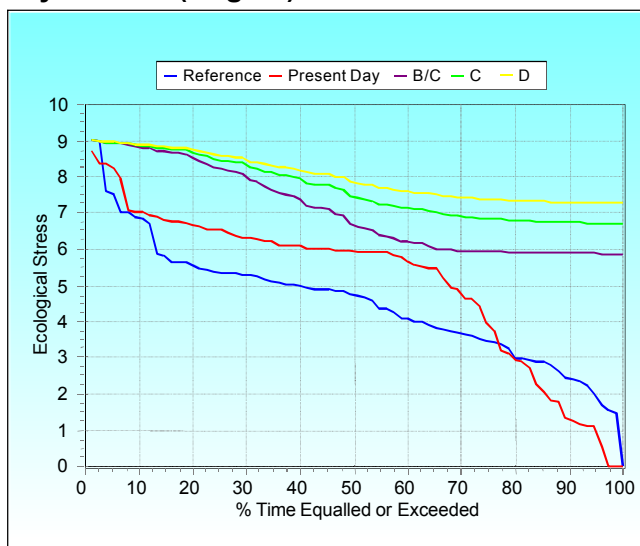
PES: RIPARIAN VEGETATION EC C (ECOSTATUS C)
<p>Dry Season maintenance The rhizome level of <i>C. marginatus</i> remains activated and survival is likely.</p> <p>Dry Season drought 30 cm below rooting level of lower limit of <i>C. marginatus</i>. Vegetation will display intense water stress and fatalities may occur.</p> <p>Wet Season maintenance Survival of the marginal zone is secure and the rhizomes remain activated.</p> <p>Wet Season drought Similar response to dry season maintenance.</p>
AEC up: RIPARIAN VEGETATION EC: B/C (ECOSTATUS B/C)
AEC up for vegetation requires mitigation of non-flow related impacts.
AEC down: RIPARIAN VEGETATION EC: D (ECOSTATUS D)
<p>Dry Season maintenance Riparian vegetation will exhibit water stress, and some fatalities may occur, but vegetation is likely to remain in PES (for vegetation).</p> <p>Wet Season maintenance Riparian vegetation will exhibit water stress, and some fatalities may occur, but vegetation likely to remain in PES (for vegetation).</p>

11.3.1 Final low flow requirements

To produce the final results (Figure 11.3), the DRM results for the specific category are modified according to specialists' requirements (Figure 11.1 and 11.2). 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 changes: All ECs.
 - 0 Upper shift values: Set at 100% for all months.
 - 0 Shape factor values: Set to 7 for all months.
- C EC
 - 0 Distribution factors: 0.7 for maintenance.
- B/C EC
 - 0 Distribution factors: 0.56 for maintenance.
- D EC
 - 0 Flows were set manually.

Dry Season (August)



Wet Season (February)

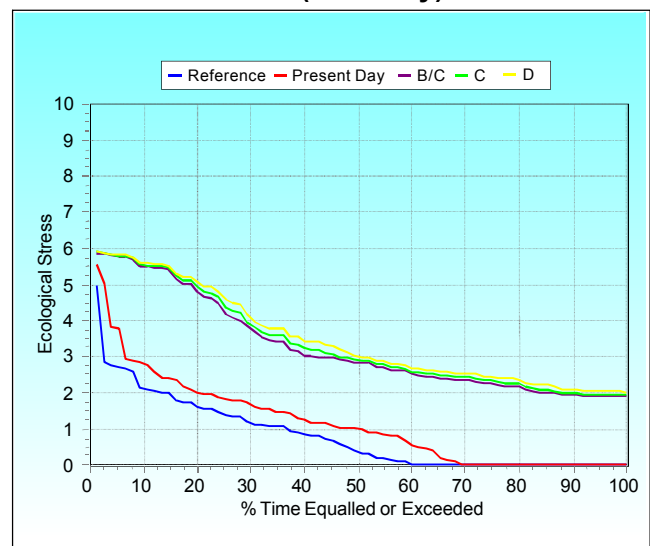


Figure 11.3 EWR 8: Final stress requirements for low flows

11.4 HIGH FLOW REQUIREMENTS

The high flow classes are identified as follows:

- The geomorphologist and riparian vegetation specialist identify the range of flood classes required and list the functions of each flood.
- The instream specialists then indicate which of the instream flooding functions are addressed by the floods identified for geomorphology and riparian vegetation (indicated by a ✓ in Table 11.4).
- Any of the floods required by the instream biota and not addressed by the floods already identified, must then be described (in terms of ranges and functions) for the instream biota.

Results are provided in Table 11.4 and detailed motivations provided in Table 11.5.

Table 11.4 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 & spawning	Migration habitat (depth etc.)	Clean spawning substrate	Create nursery areas	Resetting water quality	Inundate vegetation for spawning	Breeding and hatching cues	Clear fines	Scour substrate	Reach or inundate specific areas	Reset water quality
I	6 - 12	Vegetation: Inundates the marginal zone sedges and lower limits of the <i>Cyperus</i> .	✓	✓	✓	✓	✓	✓		✓			
II	15 – 30	Vegetation: Activates and inundates <i>Persecaria</i> population.	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
III	65 – 90	Geomorphology: This flow class accounts for about the transport of about one quarter of the fines (2 mm sands). Vegetation: Inundates the <i>Crinum</i> and <i>Cyperus</i> .	✓	✓	✓	✓	✓	✓					
IV	100 - 150	Geomorphology: Responsible for 50% of the transport of gravels and about 25% of the fines transported at this site, and would also clean the cobbles at the site and activates the backwater channel. Vegetation: Activates <i>Crinum</i> .	✓	✓	✓	✓	✓	✓					

Further information is provided in Appendix F, Table F8.

The number of high flow events required for each EC is provided in Table 11.5. No observed daily data was available to check flood requirements against.

Table 11.5 EWR 8: The recommended number of high flow events required

FLOOD CLASS	FLOOD RANGE (m ³ /s)	INVERTEBRATES	FISH	VEGETATION	GEOMORPHOLOGY	FINAL (Frequency)	MONTHS	DAILY AVERAGE	DURATION
PES and REC SCENARIO: C									
I	6 - 12	4	5	4		5	Oct, Nov, Dec, Jan, Feb	8	4
II	15 - 30	2	2	2		2	Dec, Feb	20	5
III	65 - 90			1	1	1	Jan	70	6
IV	100 - 150			1:2	1:2	1:2	Summer		
AEC↑ SCENARIO: B/C									
I	6 - 12	5	6	5		6	Oct, Nov, Dec, Jan, Feb, Mar	8	4
II	15 - 30	2	2	2		2	Dec, Feb	20	5
III	65 - 90			1	1:1.5 (2:3)	1	Jan	70	6
IV	100 - 150			1:2	1:2	1:2			
AEC↓ SCENARIO: D									
I	6 - 12	2	4	2		5	Oct, Nov, Dec, Jan, Feb	8	4
II	15 - 30	1	1	1		1	Feb	20	5

FLOOD CLASS	FLOOD RANGE (m ³ /s)	INVERTEBRATES	FISH	VEGETATION	GEOMORPHOLOGY	FINAL (Frequency)	MONTHS	DAILY AVERAGE	DURATION
III	65 - 90			1:2	1:2	1:2	Jan	70	6
IV	100 - 150			1:3	1:3	1:3			

11.5 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 11.6 – 11.8). Floods with a frequency higher than 1:1 is not included.
- The EWR rule table, which provides the EWR recommended flows as a duration table, showing flows that should be provided when linked to a natural trigger (natural hydrology). An EWR rule table is supplied for the low flows only, and for low and high flows combined (Appendix F, Section F2.4).

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

Table 11.6 EWR table for PES and REC: C

Desktop version:		2	Virgin MAR (MCM)	474.246
BFI	0.313	Distribution type		Vaal
MONTH	LOW FLOWS		HIGH FLOWS	
	Maintenance (m ³ /s)	Drought (m ³ /s)	Daily average (m ³ /s) on top of base flow	Duration (days)
OCTOBER	0.53	0.011	8	4
NOVEMBER	0.83	0.236	8	4
DECEMBER	0.97	0.274	8 20	4 5
JANUARY	1.1	0.316	8 70	4 6
FEBRUARY	1.4	0.422	8 20	4 5
MARCH	1.25	0.355		
APRIL	1	0.27		
MAY	0.65	0.06		
JUNE	0.45	0.031		
JULY	0.4	0.011		
AUGUST	0.33	0.015		
SEPTEMBER	0.4	0.118		
TOTAL MCM	24.341	5.510	31.469	
% OF VIRGIN	5.13	1.16	6.64	
Total IFR	64.45			
% of MAR	13.59			

Table 11.7 EWR table for AEC up: B/C

Desktop version:		2	Virgin MAR (MCM)	474.246
BFI	0.313	Distribution type		Vaal
MONTH	LOW FLOWS		HIGH FLOWS	
	Maintenance (m ³ /s)	Drought (m ³ /s)	Daily average (m ³ /s) on top of base flow	Duration (days)
OCTOBER	0.722	0.011	8	4
NOVEMBER	1.063	0.236	8	4
DECEMBER	1.212	0.274	8 20	4 5
JANUARY	1.375	0.316	8 70	4 6
FEBRUARY	1.807	0.422	8 20	4 5
MARCH	1.529	0.355	8	4
APRIL	1.201	0.27		
MAY	0.858	0.06		
JUNE	0.636	0.031		
JULY	0.546	0.011		
AUGUST	0.509	0.015		
SEPTEMBER	0.6	0.118		
TOTAL MCM	31.525	5.510	32.920	
% OF VIRGIN	6.65	1.16	6.94	
Total IFR	64.45			
% of MAR	13.59			

Table 11.8 EWR table for AEC down: D

Desktop version:		2	Virgin MAR (MCM)	474.246
BFI	0.313	Distribution type		Vaal
MONTH	LOW FLOWS		HIGH FLOWS	
	Maintenance (m ³ /s)	Drought (m ³ /s)	Daily average (m ³ /s) on top of base flow	Duration (days)
OCTOBER	0.32	0.011	8	4
NOVEMBER	0.5	0.236	8	4
DECEMBER	0.6	0.274	8	4
JANUARY	0.65	0.316	8 70	4 6
FEBRUARY	0.85	0.422	8 20	4 5
MARCH	0.72	0.355		
APRIL	0.6	0.27		
MAY	0.4	0.06		
JUNE	0.3	0.031		
JULY	0.24	0.011		
AUGUST	0.2	0.015		
SEPTEMBER	0.25	0.118		
TOTAL MCM	14.717	5.510	27.380	
% OF VIRGIN	3.10	1.16	5.77	
Total IFR	42.1			
% of MAR	8.88			

A comparison between the differences in terms of percentages of the various types of flow blocks are provided in Table 11.9.

Table 11.9 Modifications made to the DRM for EWR 8

Changes	PES and REC C		AEC up B/C		AEC down D	
	DRM	EWR	DRM	EWR	DRM	EWR
MLIFR - Maintenance low flow	9.9%	5.1%	13.8%	6.6%	4.5%	3.1%
DLIFR - Drought low flow	3.1%	1.2%	3.1%	1.2%	3.1%	1.2%
MHIFR - Maintenance high flow	10.6%	6.6%	11.7%	7.0%	8.9%	5.7%
Long-term % of virgin MAR	17.8%	11.5%	20.9%	12.6%	13.5%	9.7%

12 EWR 9: SUIKERBOS US (SUIKERBOSRAND RIVER) - DETERMINATION OF STRESS INDICES

NOTE: All supporting specialist information for EWR 9 is summarized in Volume 2, Appendix G.

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

12.1 INDICATOR SPECIES OR GROUP

12.1.1 Fish indicator group 1: Large semi-rheophilic species (BAEN, BKIM)

Indicator species: *Labeobarbus aeneus* (BAEN) and *Labeobarbus kimberleyensis* (BKIM). Refer to Section 2.1.1 and Appendix B, Table B1.

12.1.2 Fish indicator group 2: Small semi-rheophilic species (BANO)

Indicator species: *Barbus anoplus* (BANO). Refer to Section 2.1.1 and Appendix B, Table B2.

12.1.3 Macroinvertebrate indicator taxa

Indicator taxa: Hydropsychid caddisflies and blackflies. Refer to Section 2.1.3.

12.1.4 Riparian vegetation indicator species

Indicator species included:

- *Cyperus marginatus*: Refer to Section 2.1.4.
- *Gomphostigma virgatum*: Refer to Section 2.1.4.
- *Miscanthus junceus*: Refer to Section 2.1.4.
- *Persecaria* spp.: Refer to section 6.1.4.
- *Crinum bulbispermum*: Refer to section 10.1.4.
- *Salix mucronata*: A marginal and lower zone woody species. As an obligate riparian species it makes a good indicator of flow requirements and geomorphology.

12.2 STRESS FLOW INDEX

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

12.2.1 Habitat response

Habitat response is used to derive the biota's response to provide a biota stress index and represents the instantaneous response of habitat to flow changes, based on a site specific 0 – 10 scale for instream biota where:

- 0 – Optimum habitat (fixed at the natural maximum baseflow – calculated using the wettest flow month discharge at the maintenance % of 50 – 60% for the Vaal 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 G, Table G1.

The instantaneous response of flow dependent macroinvertebrate (FDI) taxa provides the % occurrence of various velocity-substrate classes under different flow conditions are provided in Appendix G, Table G3).

12.2.2 Biota response

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

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

The fish species response index is calculated using the fish habitat rating (cf Section 2.2.1) (Appendix G, Table G2) 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 G, Table G4).

12.2.3 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 12.1 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 12.1 illustrates this graphically.

In this specific case, the LSR fish stress index represents the integrated stress index (these values are the highest flow for a stress) for stress 4 – 10, therefore the blue curve (representing the LSR stress index) is lying 'beneath' the integrated stress line (black) (Figure 12.1).

Table 12.1 Species stress discharges used to determine biotic stress

Stress	Flow (m ³ /s)			Integrated Flow (m ³ /s)
	LSR	SSR	FDI	
0	0.8	0.8	1.726	1.726
1	0.3	0.55	1.05	1.05
2	0.25	0.3	0.5	0.5
3	0.21	0.235	0.28	0.28
4	0.17	0.17	0.1	0.17
5	0.14	0.11	0.086	0.14
6	0.11	0.095	0.03	0.11
7	0.08	0.08	0.015	0.08
8	0.06	0.06	0.003	0.06
9	0.04	0.04	0.001	0.04
10	0	0	0	0.001

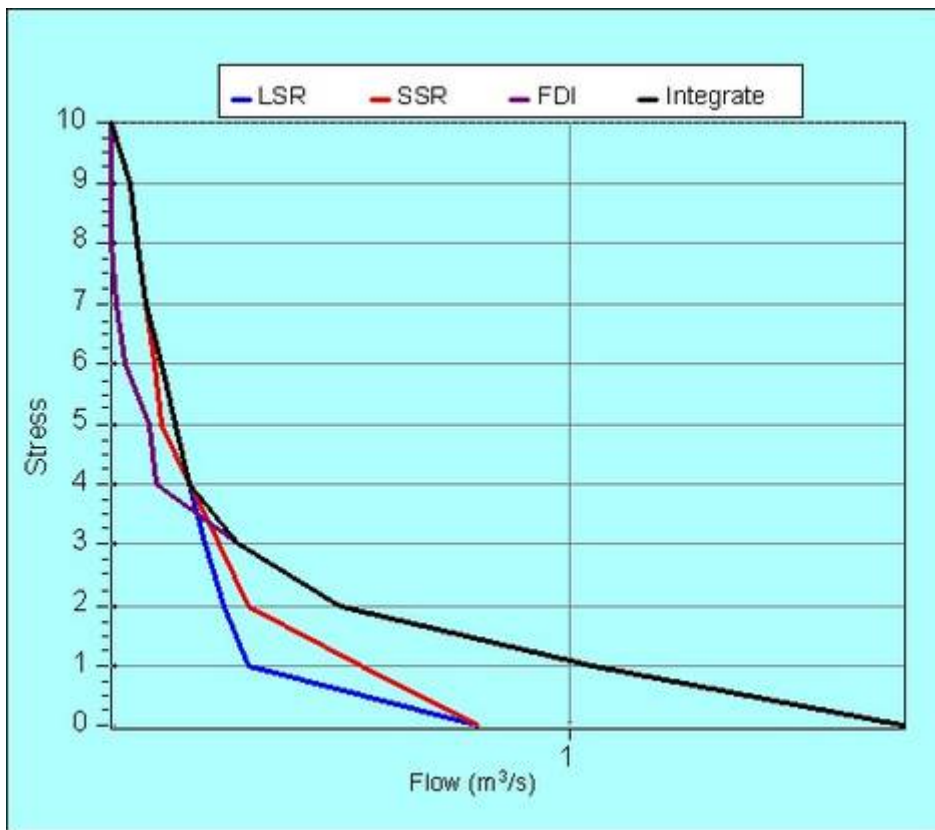


Figure 12.1 Component and integrated stress curves for EWR 9

Table 12.2 provides the summarised biotic response for the integrated stresses.

Table 12.2 Integrated stress and summarised habitat/biotic responses

Integrated stress	Flow m ³ /s	Habitat and/or Biotic responses
0 (FDI)	1.726	Fish guild: All habitats optimal (5 ⁺). All FDI habitats in excess. All flow dependent macroinvertebrates very abundant and healthy.
1 (FDI)	1.05	All FDI habitats plentiful. 90 % rheophilic species persist.
2 (FDI)	0.5	Critical FDI habitats sufficient. Most rheophilic species persist, but slight (80 %) reduction.
3 (FDI)	0.28	Reduced critical FDI habitat. Most rheophilic species persist, but abundances reduced.
4 (LSR)	0.17	Fish guild: Spawning and nursery habitats are low (2) while rest of habitats are moderate (3 – 3.5) and water quality is good (4).
5 (LSR)	0.14	
6 (LSR)	0.11	SSR guild; Spawning, nursery and cover is low (2), while abundance and connectivity is moderate and water quality is good. LSR guild: Spawning and nursery habitat is very low (1), cover and abundance is low and connectivity and water quality is moderate. Critical FDI habitats limited. All life stages viable in limited areas, critical life stages of some sensitive rheophilic species at risk.
7 (LSR)	0.08	SSR guild: Habitat abundance is low, water quality moderate and the rest of the habitats is very low (1). LSR guild: Spawning and nursery habitat is very rare (0.5) while the rest of the habitats is very low. Critical FDI habitat very reduced. Critical life-stages of sensitive rheophilic species at risk or non-viable.
8 (LSR)	0.06	
9 (LSR)	0.04	SSR guild: Abundance and water quality is very low and the rest of the habitats are very rare. LSR guild: Cover and water quality is very rare and the other habitats are absent.
10	0.001	Only pool dwelling species present. Only hyporheic refugia, no surface water for FDIs. Indicator taxa no longer present. Only. Mostly pool dwellers; all life stages of most rheophilic species non-viable.

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

13 EWR 9: SUIKERBOS US (SUIKERBOSRAND RIVER) - DETERMINATION OF EWR SCENARIOS

13.1 ECOCLASSIFICATION SUMMARY OF EWR 9

EWR 9 Suikerbos US (Suikerbosrand River)																												
<p>EIS: HIGH There are endangered species at this site, which includes <i>Labeobarbus kimberleyensis</i> and the Soweto Highveld grassland vegetation type (conservation status: endangered).</p> <p>PES: C Combination of flow and non-flow related impacts. Flow related impacts include altered flow regime due to Balfour and Harhoff Dams and non-flow related impacts include deteriorated water quality due to WWTW and agriculture, erosion and alien species (fish and vegetation).</p> <p>REC: B/C Improvement of the PES due to HIGH EIS rating. An improvement is based on increased base flows (released from upstream dams) as well as erosion control measures in the tributaries to address erosion and increased sediment loads in the reach and alien woody vegetation control.</p> <p>AEC Down: D This scenario was not developed as the macroinvertebrates and fish are already in a D EC. A D AEC would involve the maintenance of the current ECs of fish and macroinvertebrates and a deterioration of the riparian vegetation EC. Any flow related changes will however cause deterioration in the riparian vegetation EC and would result in the instream and biota ECs to drop to an E.</p>	<table border="1"> <thead> <tr> <th>Driver Components</th> <th>PES Category</th> <th>Trend</th> <th>REC</th> </tr> </thead> <tbody> <tr> <td>HYDROLOGY</td> <td>E</td> <td></td> <td></td> </tr> <tr> <td>WATER QUALITY</td> <td>C/D</td> <td>Negative D</td> <td>C</td> </tr> <tr> <td>GEOMORPHOLOGY</td> <td>B/C</td> <td>Negative C</td> <td>B</td> </tr> </tbody> </table>	Driver Components	PES Category	Trend	REC	HYDROLOGY	E			WATER QUALITY	C/D	Negative D	C	GEOMORPHOLOGY	B/C	Negative C	B											
	Driver Components	PES Category	Trend	REC																								
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		<table border="1"> <thead> <tr> <th>Response Components</th> <th>PES Category</th> <th>Trend</th> <th>REC</th> </tr> </thead> <tbody> <tr> <td>FISH</td> <td>D</td> <td>Stable</td> <td>C</td> </tr> <tr> <td>MACRO INVERTEBRATES</td> <td>D</td> <td>Stable</td> <td>C</td> </tr> <tr> <td>INSTREAM</td> <td>D</td> <td></td> <td>C</td> </tr> <tr> <td>RIPARIAN VEGETATION</td> <td>B/C</td> <td>Negative C/D</td> <td>B</td> </tr> <tr> <td>ECOSTATUS</td> <td>C</td> <td></td> <td>B/C</td> </tr> </tbody> </table>	Response Components	PES Category	Trend	REC	FISH	D	Stable	C	MACRO INVERTEBRATES	D	Stable	C	INSTREAM	D		C	RIPARIAN VEGETATION	B/C	Negative C/D	B	ECOSTATUS	C		B/C		
	Response Components	PES Category	Trend	REC																								
	FISH	D	Stable	C																								
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RIPARIAN VEGETATION	B/C	Negative C/D	B																									
ECOSTATUS	C		B/C																									

13.2 HYDROLOGY

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

- 95%: Representing droughts for both wet and dry months. This would represent 5% on the stress duration graphs.
- 45%: Representing maintenance flows for both wet and dry months. This would represent 55% on the stress duration graphs.

13.3 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 G, Section G1 – 2.2.

The fish and macroinvertebrate flow requirements for different Ecological Categories (ECs) are provided in Table 13.1 and Figure 13.1 and 13.2. 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 13.1 and 13.2.

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

PES: **Green**

REC: **Purple**

Summarised motivations for the final requirements are provided in Table 13.2.

Table 13.1 Species and integrates stress requirements as well as the final integrated stress and flow requirements

Duration	LSR stress	Integ stress	SSR stress	Integ stress	FDI stress	Integ. stress	FINAL* (Integrated stress)*	FLOW (m ³ /s)
PES: C EcoStatus			FISH: D			MACROINVERTEBRATES: D		
DRY SEASON								
5%	9	9	10	10	7	9.8	9	0.04
55%	7	7	7	7	5	7	7	0.08
WET SEASON								
5%	7	7	7	7	5	7	7	0.08
55%	0.8	3.5	2	3	3	3	3	0.28
REC: B/C EcoStatus			FISH: C			MACROINVERTEBRATES: C		
DRY SEASON								
55%	5	5	Improvements based on non-flow related changes.		4	6.5	5	0.125
WET SEASON								
55%	0.4	1.9	Improvements based on non-flow related changes.		2.5	2.5	1.9	0.55

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

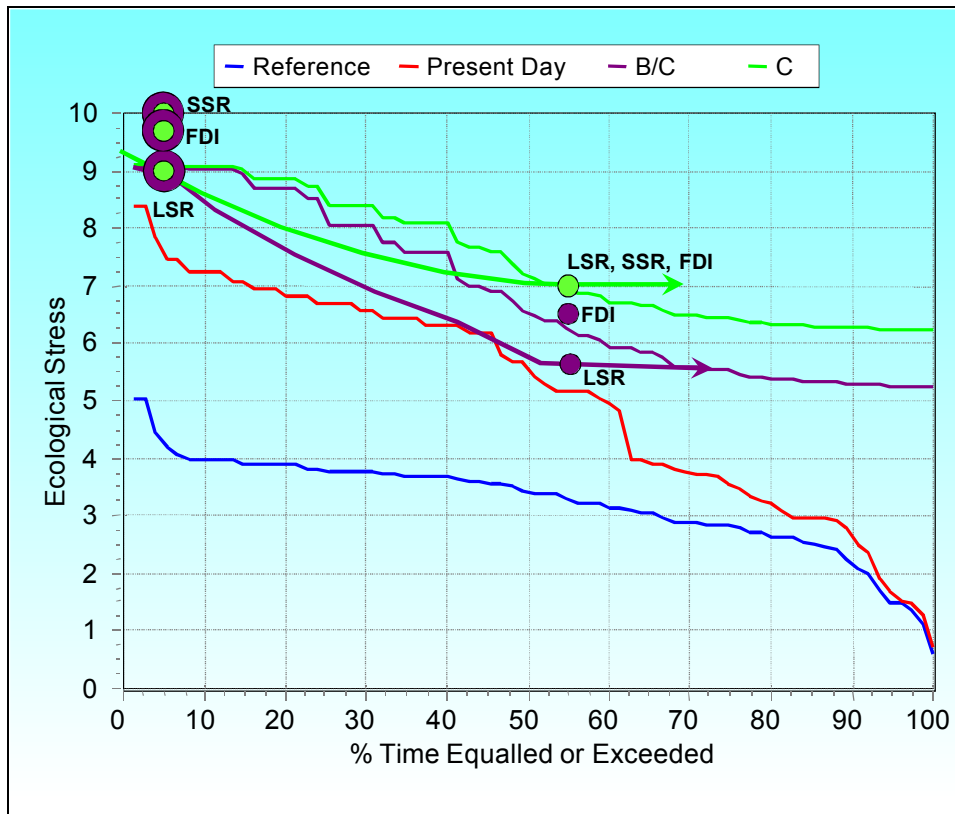


Figure 13.1 EWR 9: Stress Duration Curve for a C PES and B/C REC - DRY season

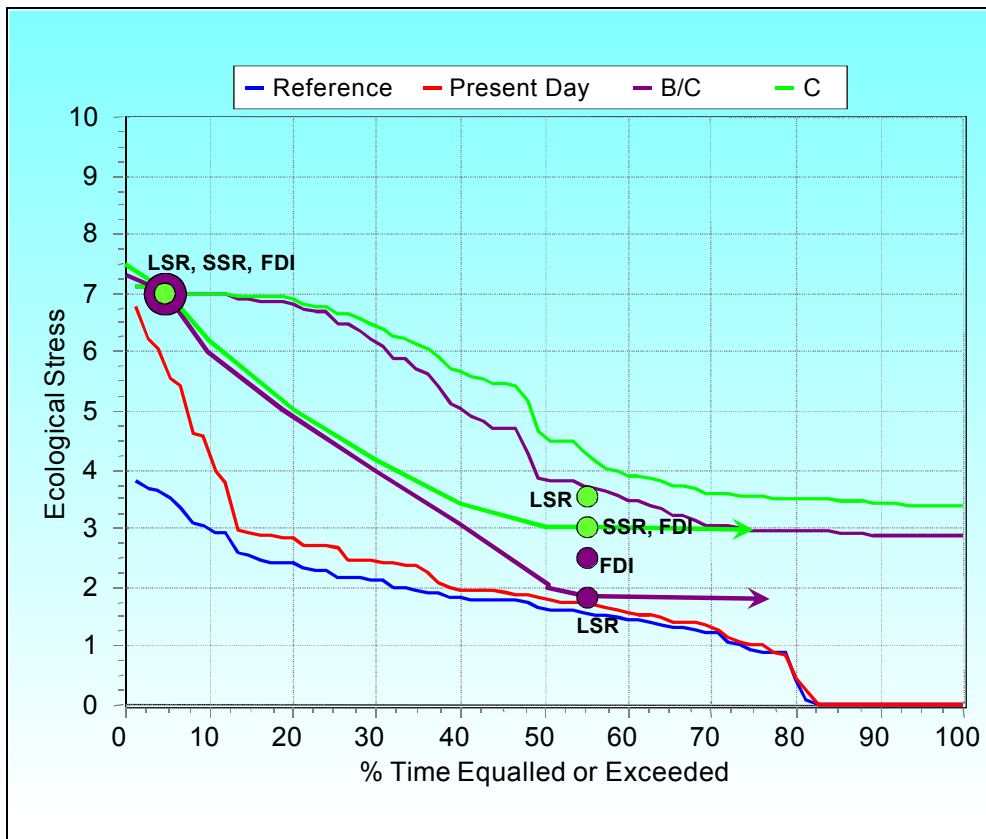


Figure 13.2 EWR 9: Stress Duration Curve for a C PES and B/C REC - WET season

Table 13.2 Summary of EWR 9 motivations

Month	% Stress duration	Component stress	Integrated stress	Flow m ³ /s	Comment
PES: C EcoStatus		FISH: D		MACROINVERTEBRATES: D	
Aug	5% drought	9 LSR	9	0.04	Adequate depths in pools (both SD and SS) are maintained to ensure survival. Very limited FS habitats (no FD and FI) for especially juvenile survival and the maintenance of adequate oxygen levels in the pools will be available to maintain the LSR in the PES during drought conditions in the dry season.
	55% maintenance	7 LSR	7	0.08	Very limited fast habitat will be maintained (some FS, FI and no FD) to provide adequate survival habitat for especially the juveniles, and feeding habitat for adults. Maintenance of some SD as refuge areas (especially at night by adults and juveniles to escape from extreme temperature fluctuations in shallow waters).
Feb	5% drought	7 LSR	7	0.08	Very limited FD habitat will still be available, but at least adequate FS and FI will be maintained. This is critical habitat to enable spawning, egg and larvae development. Limited FS and adequate SD habitats should be maintained under these conditions for the survival of juveniles and adults during this period.
	55% maintenance	2 SSR	3	0.28	At this stress level flow should be adequate to ensure some inundation of macrophytes (especially in SD) and thereby creating some preferred habitat in the form of overhanging vegetation and aquatic vegetation. The provision of adequate cover is especially important at the site due to the presence of alien predator MSAL.
REC: B/C EcoStatus		FISH: C		MACROINVERTEBRATES: C	
Aug	5% drought	9 LSR	9	0.04	See PES.
	55% maintenance	5 LSR	5	0.125	At this stress level, the abundance and availability of FS and FI habitat will be improved although FD habitats will still not be

Month	% Stress duration	Component stress	Integrated stress	Flow m ³ /s	Comment
					available during the dry season. The improvement in the FS and FI should however result in the habitat suitability for the guild, which should be reflected by improved FROC and abundance of this species, with a resultant improvement of the EC.
Feb	5% drought	7 LSR	7	0.08	See PES.
	55% maintenance	0.4 LSR	1.9	0.55	Improvement in habitat availability for guild. This can be expected to result in improved spawning success, increased survival of fry and juveniles and increased abundance and FROC of all live stages of BAEN. This will result in improved EC for BAEN and contribute to an overall improvement of the fish EC towards a C.

The above flows were checked by the riparian vegetation specialist to ensure that these requirements are adequate to achieve the EC in which the marginal vegetation should be, as well as any other flow dependant vegetation that could occur.

The vegetation indicators used were *Cyperus*, *Gomphostigma*, *Persecaria* and *Salix* species. The resulting conditions of the vegetation indicators to the required low flows are described below. In conclusion, the low flows would maintain the PES and REC of the riparian vegetation (Table 13.3).

Table 13.3 Verification of low flow requirements to maintain the vegetation EC

PES: RIPARIAN VEGETATION EC B/C (ECOSTATUS C)	
Dry Season maintenance	Riparian vegetation requires dry and wet base flows to vary between 0.15 and 0.35 m ³ /s for activation and inundation respectively, of the lower limits of <i>Cyperus</i> , <i>Gomphostigma</i> , <i>Persecaria</i> and <i>Salix</i> species. These are attained in all cases for the PES and REC
Dry Season drought	Lower limit roots and rhizomes remain sufficiently activated to facilitate survival.
Wet Season maintenance	<i>Cyperus marginatus</i> and <i>Gomphostigma virgatum</i> are inundated at the lower limit of their distributions only. Survival and reproductive output is sufficient to maintain the PES.
Wet Season drought	Drought stress is evident. No inundation of riparian vegetation occurs. Survival will be sufficient, but reproductive output will be severely reduced.
REC: RIPARIAN VEGETATION EC: B (ECOSTATUS B/C)	
Dry Season maintenance	Not significantly different from PES.
Wet Season maintenance	On average 20% more inundation occurs than with PES flows. Survival and reproductive output is sufficient to maintain REC.

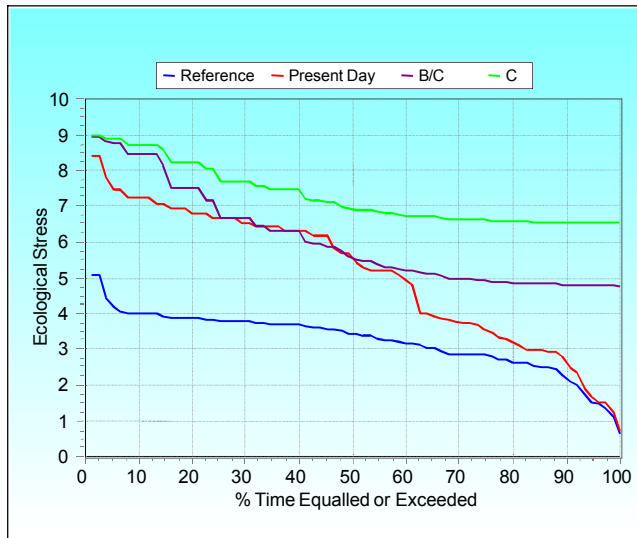
13.3.1 Final low flow requirements

To produce the final results (Figure 13.3), the DRM results for the specific category are modified according to specialists’ requirements (Figure 13.1 and 13.2). 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 changes for C, B and C/D EC.

- 0 Upper shift values: Set at 100% for all months.
- 0 Shape factor values: Set to 6 for Jul, Aug and Sep.
- B/C EC
 - 0 Distribution factors: 2.4 for maintenance.
- C EC
 - 0 Distribution factors: 1.0 for maintenance and 0.3 for drought

Dry Season (August)



Wet Season (February)

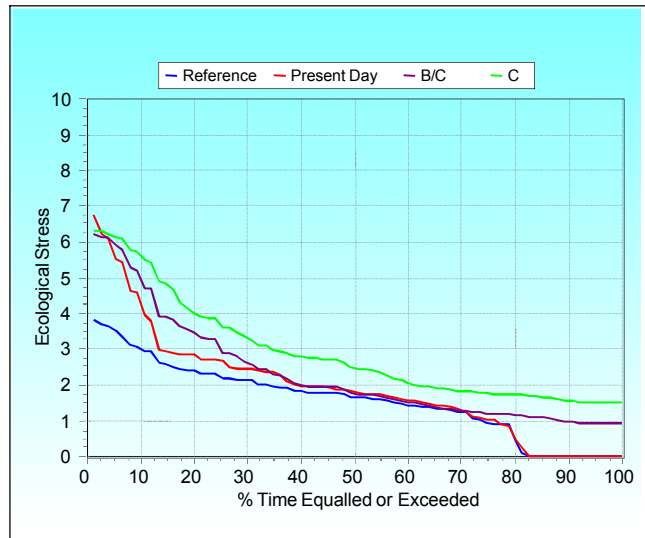


Figure 13.3 EWR 9: Final stress requirements for low flows

13.4 HIGH FLOW REQUIREMENTS

The high flow classes are identified as follows:

- The geomorphologist and riparian vegetation specialist identify the range of flood classes required and list the functions of each flood.
- The instream specialists then indicate which of the instream flooding functions are addressed by the floods identified for geomorphology and riparian vegetation (indicated by a ✓ in Table 13.4).
- Any of the floods required by the instream biota and not addressed by the floods already identified, must then be described (in terms of ranges and functions) for the instream biota.

Results are provided in Table 13.4 and detailed motivations provided in Table 13.5.

Table 13.4 Checklist of Geomorphology and Riparian vegetation floods and which cater for instream biota flood requirements

FLOOD CLASS	FLOOD RANGE (m ³ /s)	GEOMORPHOLOGY AND RIPARIAN VEGETATION MOTIVATION	Fish flood functions						Macroinvertebrate flood functions			
			Migration cues and spawning	Migration habitat (depth etc.)	Clean spawning substrate	Create nursery areas	Resetting water quality	Inundate vegetation for spawning	Breeding and hatching cues	Clear fines	Scour substrate	Reach or inundate specific areas
I	1 - 2	Vegetation: Activation of <i>Miscanthus</i> lower limits. Geomorphology: Scouring of fines from the bed of the active channel.	✓	✓	✓	✓	✓	✓		✓		
II	3 - 6	Geomorphology: Activates sedges in the backchannel of the bench; inundates and activates the active channel bench. Vegetation: Inundation of <i>Miscanthus</i> and about 50% of the <i>Cyperus</i> .	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
III	8 - 20	Geomorphology: Inundation and activation of the paired terraces (which are extensive upstream of the site). Vegetation: Inundation to the upper limits of the <i>Cyperus</i> , <i>Gomphostigma</i> and <i>Persecaria</i> .	✓	✓	✓	✓	✓	✓				
IV	> 40	Geomorphology: Activates the ephemeral terrace (floodplain). Vegetation: Activates the woody zone (<i>Leucosidea</i> and <i>Rhus</i> spp.).	✓	✓	✓	✓	✓	✓				

Further information is provided in Appendix G, Table G8.

The number of high flow events required for each EC is provided in Table 13.5. No observed daily data was available to check flood requirements against.

Table 13.5 EWR 9: The recommended number of high flow events required

FLOOD CLASS	FLOOD RANGE (m ³ /s)	INVERTEBRATES	FISH	VEGETATION	GEOMORPHOLOGY	FINAL (Frequency)	MONTHS	DAILY AVERAGE	DURATION
PES SCENARIO: C									
I	1 - 2	2	5	4	4	5	Oct, Nov, Dec, Jan, Feb (2)	1.5	3
II	3 - 6	1	4	1	1	1	Jan	5	4
III	8 - 20			1:2	1:2	1:2			
IV	> 40			1:3	1:5	1:5			
REC SCENARIO: B/C									
I	1 - 2	4	6	6	5 - 6	6	Oct, Nov, Dec (2), Feb (2)	1.5	3
II	3 - 6	2	5	1:1	1:1	1	Jan	5	4
III	8 - 20		1	1:2	1:2	1:2			
IV	> 40		1:2	1:3	1:5	1:5			

13.5 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 13.6 – 13.7). Floods with a frequency higher than 1:1 is not included.
- The EWR rule table, which provides the EWR recommended flows as a duration table, showing flows that should be provided when linked to a natural trigger (natural hydrology). An EWR rule table is supplied for the low flows only, and for low and high flows combined (Appendix G, Section G2.4).

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

Table 13.6 EWR table for PES: C

Desktop version:		2	Virgin MAR (MCM)	31.313
BFI	0.383	Distribution type		Vaal
MONTH	LOW FLOWS		HIGH FLOWS	
	Maintenance (m ³ /s)	Drought (m ³ /s)	Daily average (m ³ /s) on top of base flow	Duration (days)
OCTOBER	0.120	0.050	1.5	3
NOVEMBER	0.177	0.066	1.5	3
DECEMBER	0.147	0.060	1.5	3
JANUARY	0.182	0.066	5	4
FEBRUARY	0.231	0.079	1.5	3
			1.5	3
MARCH	0.180	0.066		
APRIL	0.160	0.064		
MAY	0.143	0.059		
JUNE	0.123	0.057		
JULY	0.080	0.050		
AUGUST	0.065	0.040		
SEPTEMBER	0.075	0.040		
TOTAL MCM	6.475	4.402		2.074
% OF VIRGIN	20.68	14.06		6.62
Total IFR			6.64	
% of MAR			21.22	

Table 13.7 EWR table for REC: B/C

Desktop version:		2	Virgin MAR (MCM)	31.313
BFI	0.383	Distribution type		Vaal
MONTH	LOW FLOWS		HIGH FLOWS	
	Maintenance (m ³ /s)	Drought (m ³ /s)	Daily average (m ³ /s) on top of base flow	Duration (days)
OCTOBER	0.220	0.050	1.5	3
NOVEMBER	0.358	0.066	1.5	3
DECEMBER	0.280	0.060	1.5	3
JANUARY	0.377	0.066	5	4
FEBRUARY	0.500	0.079	1.5	3
MARCH	0.373	0.066	1.5	3
APRIL	0.312	0.064		
MAY	0.268	0.059		
JUNE	0.207	0.057		
JULY	0.150	0.050		
AUGUST	0.110	0.040		
SEPTEMBER	0.099	0.040		
TOTAL MCM	10.808	8.502		2.307
% OF VIRGIN	34.52	27.15		7.37
Total IFR	10.85			
% of MAR	34.65			

A comparison between the differences in terms of percentages of the various types of flow blocks are provided in Table 13.8.

Table 13.8 Modifications made to the DRM for EWR 9

Changes	PES C		REC B/C	
	DRM	EWR	DRM	EWR
MLIFR - Maintenance low flow	11.1%	14.1%	15.4%	27.1%
DLIFR - Drought low flow	5.3%	5.8%	5.3%	5.8%
MHIFR - Maintenance high flow	10.0%	6.6%	11.1%	7.3%
Long-term % of virgin MAR	19.3%	21.1%	22.4%	31.4%

14 APPLICATION OF HFSR: PRESENT FLOWS MORE THAN NATURAL

Author: MD Louw (Rivers for Africa)

14.1 BACKGROUND

During the EWR scenario assessment of the Upper Vaal, 5 EWR sites were identified as having more flows than natural with:

- EWR 10 and EWR 11 having more flows than natural during all seasons.
- EWR 4 and EWR 5 having more flows than natural during the dry season with seasonal reversal (i.e. present flows are much lower than natural during the wet season).
- EWR 1 having more flows than natural during the dry season only – the present flows in the wet season are similar than natural.

Therefore the standard HFSR approach could not be applied to these sites to determine low flow requirements for the EWR scenarios. The HFSR method was refined to cater for these situations by Ms Delana Louw with input from all the specialists and the general approach is provided below.

14.2 ECOCLASSIFICATION

In rivers where the present flow is less than natural, the ecological state normally becomes worse as the flow decreases further (from natural) and improves toward natural as flow increases. Once the increasing flows become higher than natural, the ecological state starts decreasing again. Therefore in a situation with more present flow than natural, the ecological state becomes worse with more flow and improves with less flow. The approach to this situation in terms of the EcoClassification approach is described in Figure 14.1 which represents a stress duration graph for one month.

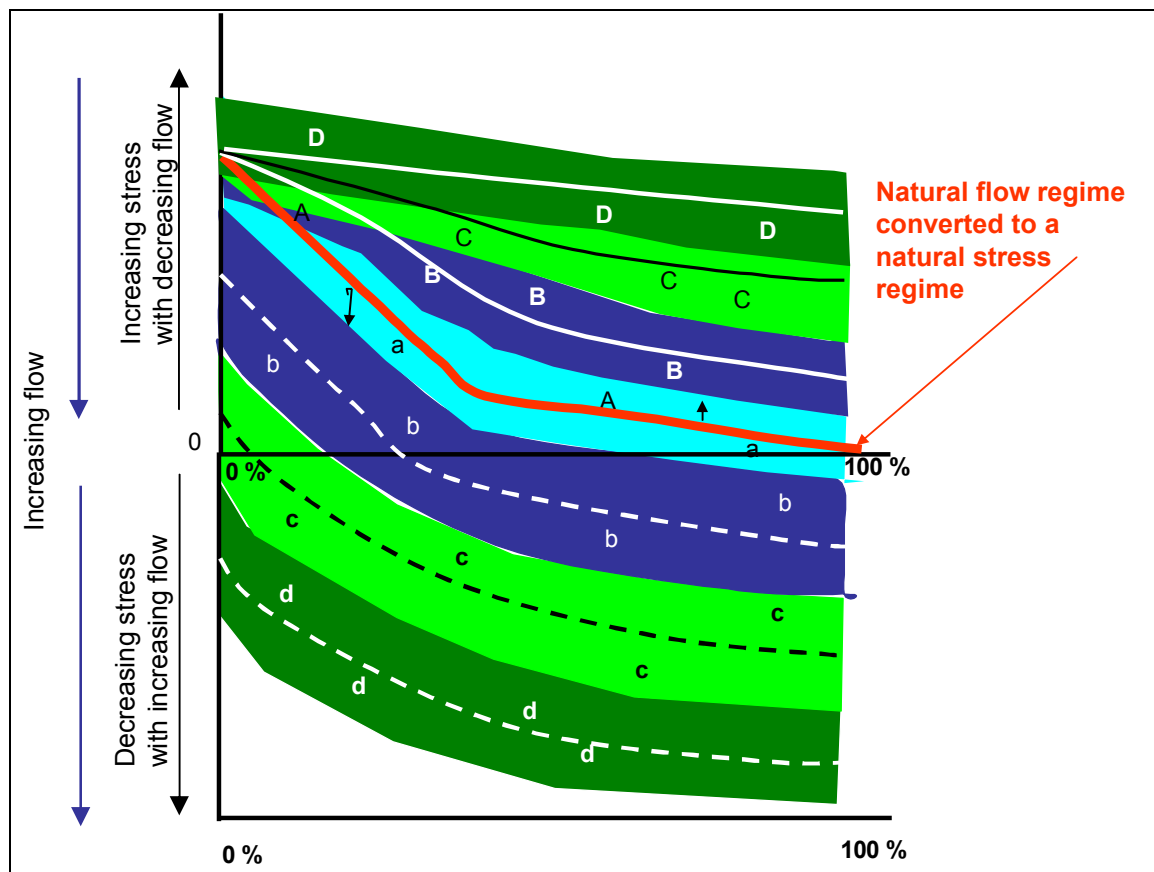


Figure 14.1 Conceptual understanding of the relationship between change in flow/stress and the change in EC

Each Ecological Category (EC) is represented by a band (e.g. the A EC band is represented by light blue). The EC with capital letters (A, B etc.) illustrate higher stress and lower flows than natural, whereas the small letters (a, b, etc.) illustrate the reversal. Therefore, as flow increases above natural, the ecological state decreases to a d and further on to an f. The bands on both sides of natural (e.g. a 'B' band and a 'b' band) are not necessarily the same width.

During the EcoClassification assessment, ecological objectives were set in terms of the above for the relevant EWR sites where present day flows were higher than natural flows. This would mean e.g. that if the most likely future development is an increase in flow, then the AEC down was described in terms of increased flow.

14.3 DETERMINATION OF STRESS FLOW INDICES

The stress flow index was generated in terms of habitat and biotic response according to the standard process. As some of the EWR scenarios required an assessment of flows that were higher than reference hydrology, the 0 – 10 stress index had to be extended to accommodate flows (and stress) that were higher than the flows that the zero stress represented. The process followed to describe this is set out below and illustrated in Figure 14.2:

- The first stress index was set for flows which ranged from zero flows to the maximum natural base flow according to the standard HFSR process (i.e. zero flow = +10 stress; 0 stress = maximum natural base flow). The habitat and biota response values were given a '+' value, i.e. **the plus value refers to an increase in stress from the zero value.**
- An additional stress flow index was populated which continues from the zero stress and identifies stress at various flows. It was not necessary to set a whole range of stresses.

The range of stresses more than zero stress would therefore consist of higher flows than the zero stress. These habitat and biota response values were given a ‘-’ value, i.e. **the minus value refers to more flows and more stress than the zero value.**

- The integrated stress curve for the “plus” flow stress relationship represents the **lowest stress** for fish, macroinvertebrates or riparian vegetation at a specific flow while integrated stress curve for the “minus” flow stress relationship represents the **highest stress** for fish, macroinvertebrates or riparian vegetation at a specific flow.

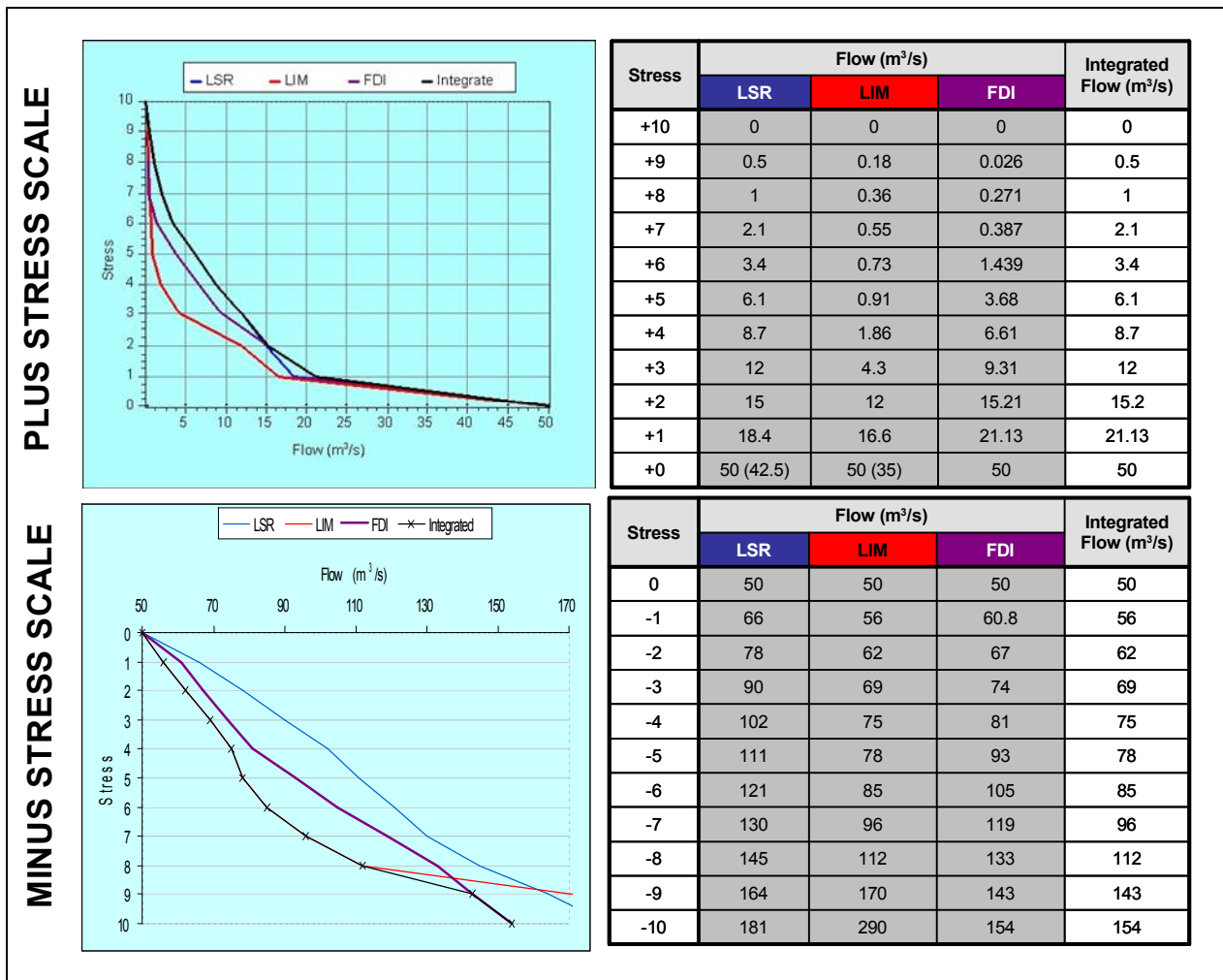


Figure 14.2 Extended stress-flow matrix to address flows (and stress) that is higher than the flows represented by zero stress

14.4 DETERMINING STRESS REQUIREMENTS

The following steps were followed to set the stress requirements and produce the results:

- As part of the EcoClassification process, objectives were set for maintaining, improving, or degrading the Ecological Category. These objectives were investigated further to determine exactly how the EWR scenarios would be met.
- Specialists indicated that it was easier to identify the EC bands rather than just a single requirement. This is provided (Figure 14.3) in the relevant stress duration curves to illustrate what the requirements were. Therefore the band around the present hydrology is provided and indicates where (either by increased flows or decreased flows, i.e. increased or decreased stress) the EC will change.

- The relationship between stress, flow/discharge and EC as it increases and decreases is illustrated in Figure 14.3.

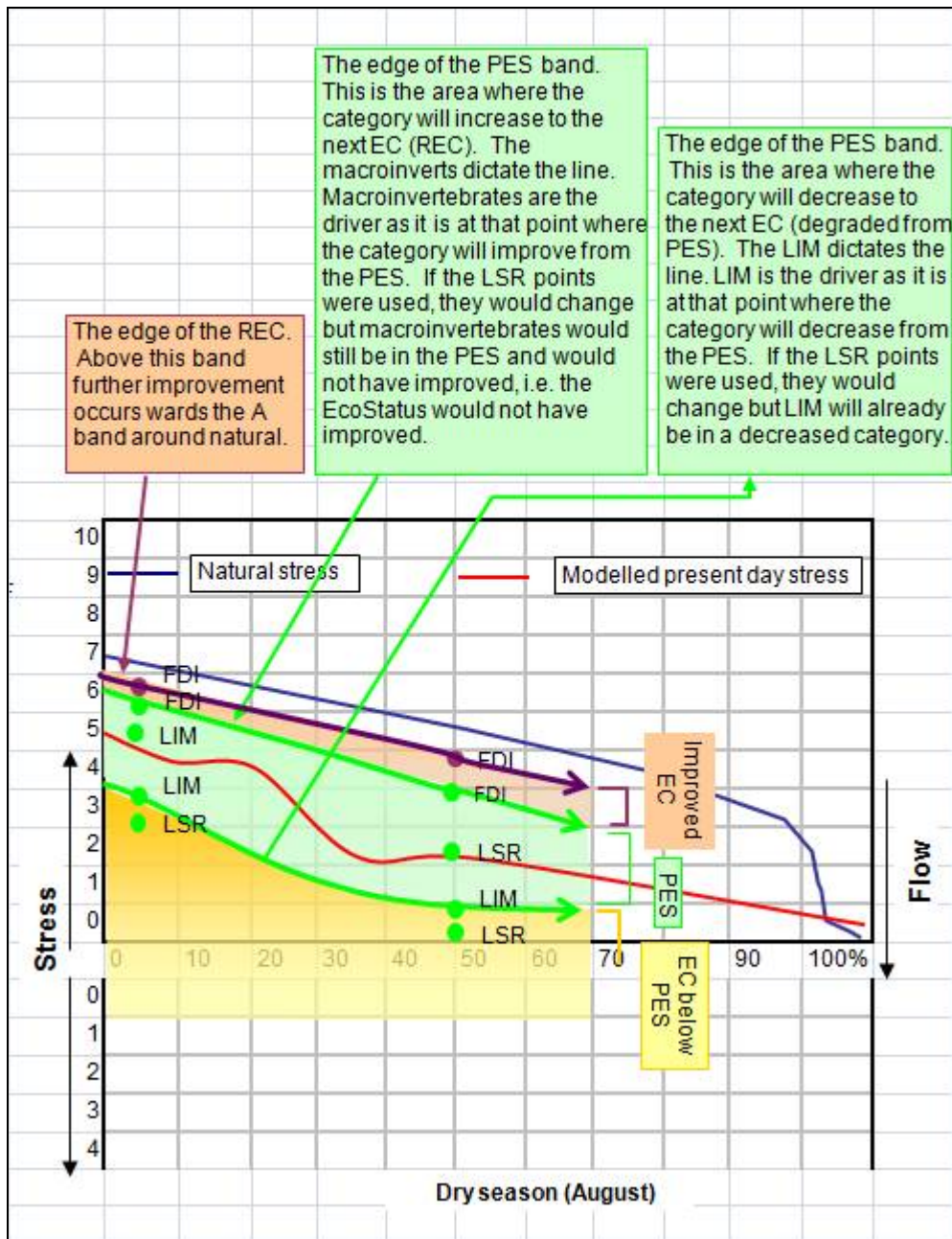


Figure 14.3 Stress duration graph illustrating the relationship between the change in stress and flow, and EC

14.5 PRODUCING EWR RULE AND EWR TABLES

In cases with more flows than natural, the present hydrology is used within the Desktop Reserve Model (DRM) and the HFSR hydrology model as the reference flow (rather than natural). This is required as the DRM does not cater for flows set higher than the reference hydrology. The EWR rule tables are provided where ALL the flow requirements are lower than the reference hydrology.

Where a scenario was set for higher flows than the reference hydrology, the EWR rule tables could not be generated. The Fish Flow Habitat Assessment (FFHA) model was used to provide a flow duration graph, but due to an artefact of the model, not all the high flows could be provided. It is

strongly recommended that the DRM and the HFSR model be adjusted to cater for these situations.

14.6 MORE FLOWS THAN NATURAL IN ALL SEASONS

EWR 10 and 11 are examples of the situation where the flows are higher than natural in all seasons. This would mean that to improve the situation, one would have to decrease flows in all the months. An AEC down could imply increased flows. When describing this AEC, one would highly likely state that flows will be increased in all seasons. In reality, flows could be increased in only one season, but this sort of scenario will have to be assessed during the evaluation of ecological consequences of operational scenarios. Figure 14.4 illustrates the trend for setting of stress requirements for both an improved and a decreased scenario and shows theoretically how the EC changes from the present day flows for an improved scenario where flows are decreased.

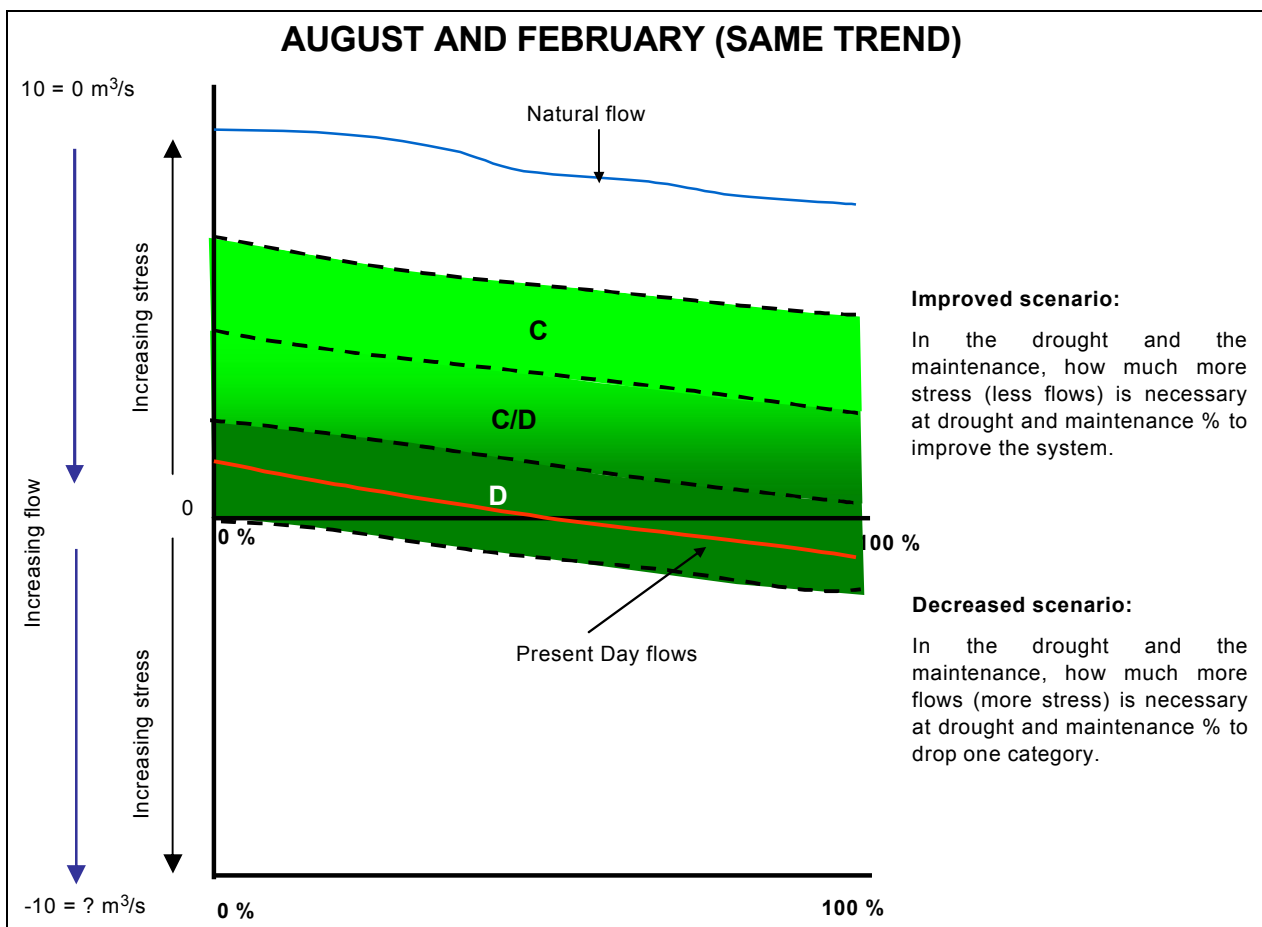


Figure 14.4 AEC_↑ and AEC_↓ trend where the flows are more than natural during all the seasons

14.7 MORE FLOWS THAN NATURAL IN ONLY SOME SEASONS WITH SEASONAL REVERSAL IN SOME CASES

This approach is relevant for EWR 4 (De Neys) and EWR 5 (Scandinavia) in the Vaal River. The summarised problems at these sites are:

- Flows are higher than natural during the dry season.
- Flows are lower than natural during the wet season, AND significantly lower than the flows in the dry season.
- This has resulted in a complete seasonal reversal.

With a seasonal reversal, as is the case here, one has to regain some of the seasonality and improving the system will only be achieved with more flows in the wet season and less flows in the dry season. This creates a very complex set of circumstances.

Figure 14.5 illustrates this conceptually where flows are decreased during the dry season and increased during the wet season. When setting the requirements for the two seasons, both seasons must be considered at the same time. This would also be the case for evaluating operational scenarios, as an improvement in the one season, will only result in an overall improvement if this is the case in both seasons. Figure 14.6 illustrates this showing more detail.

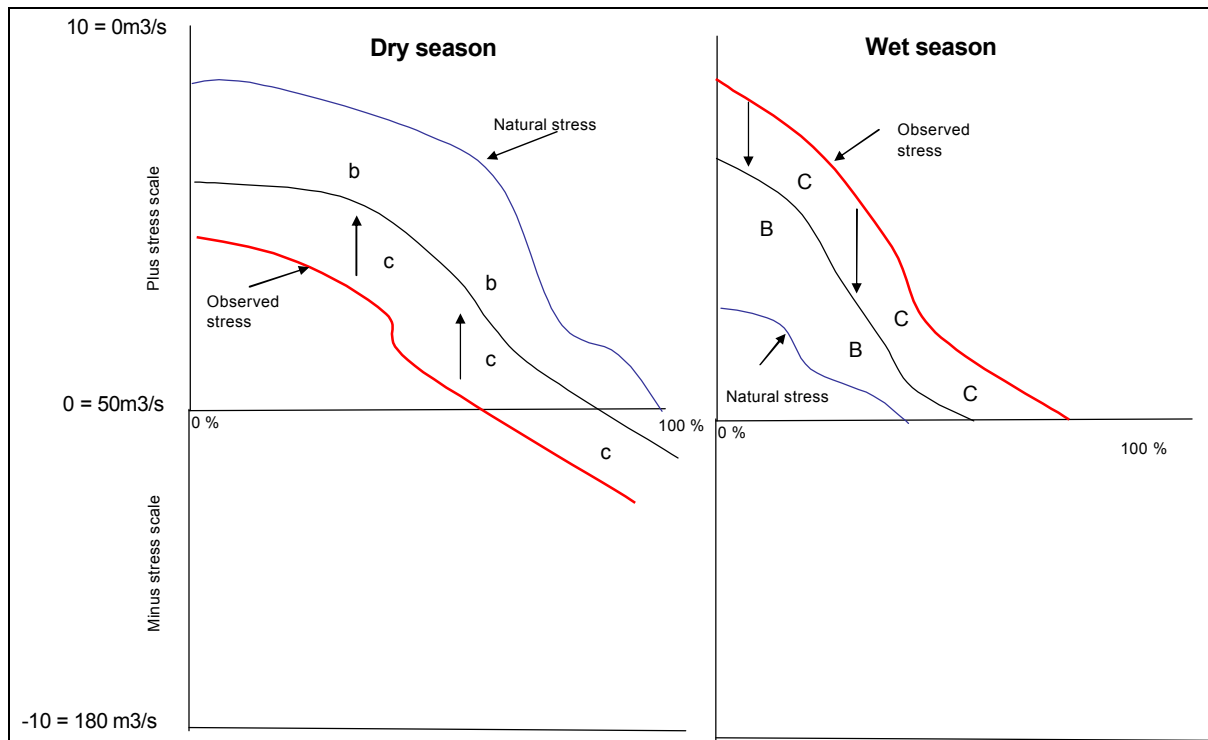


Figure 14.5 Approach for determining requirements when improving the EC where seasonal reversal is applicable

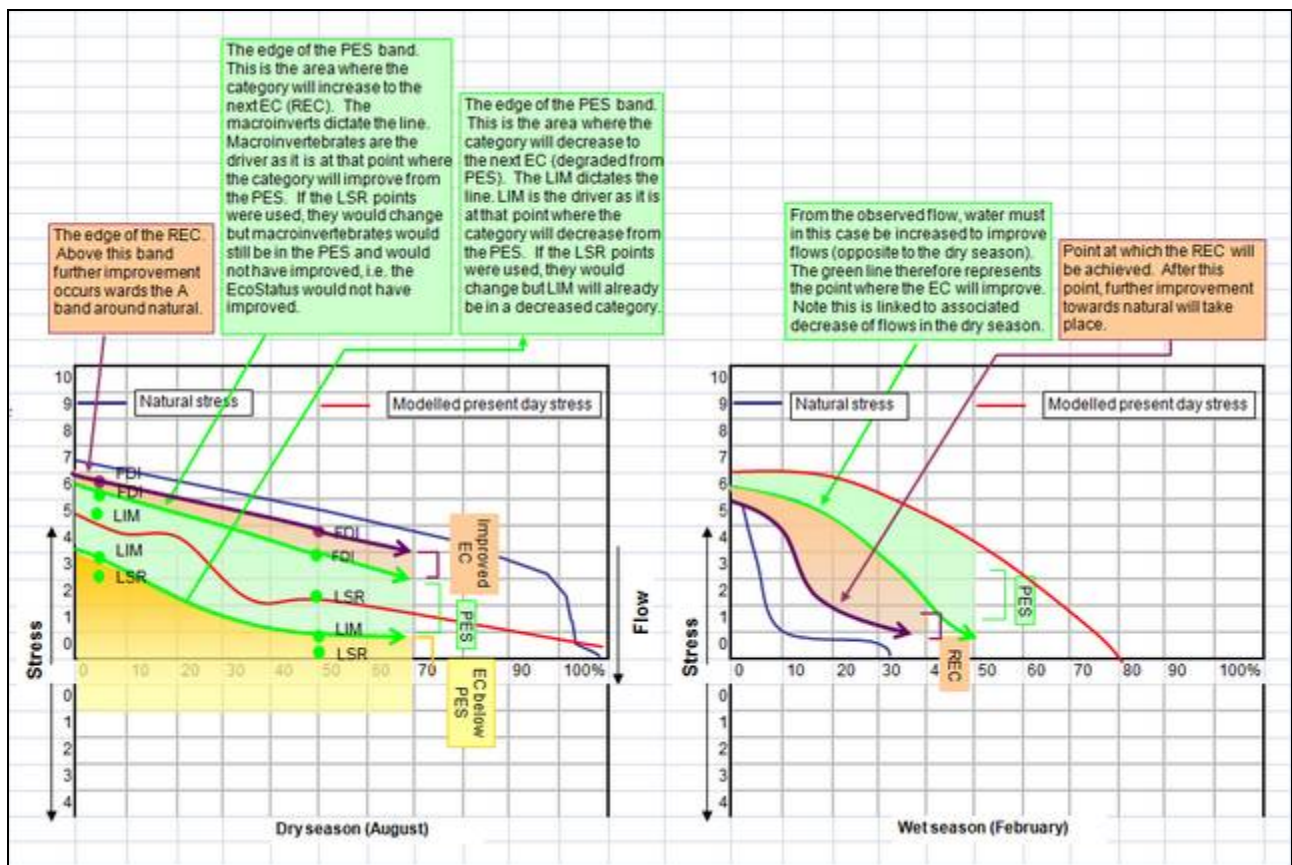


Figure 14.6 Approach for determining requirements when improving the EC where seasonal reversal is applicable - selection of final requirements considering all the biological responses

This situation is also partially relevant for EWR 1 in the Vaal River. The seasonal reversal is not as significant as in these examples. Significantly more flows in the dry season occur. Flows in the wet season are similar to natural. The same principles as above prevail.

15 EWR 10: SUIKERBOS DS (SUIKERBOSRAND RIVER) – DETERMINATION OF STRESS INDICES

NOTE: All supporting specialist information for EWR 10 is summarized in Volume 2, Appendix H.

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

15.1 INDICATOR SPECIES OR GROUP

15.1.1 Fish indicator group 1: Large semi-rheophilic species (BAEN, BKIM)

Indicator species: *Labeobarbus aeneus* (BAEN) and *Labeobarbus kimberleyensis* (BKIM). Refer to Section 2.1.1 and Appendix B, Table B1.

15.1.2 Fish indicator group 2: Small limnophilic species (PPHI, TSPA)

The small limnophilic (LIM) species, *Pseudocrenilabrus philander* (PPHI) and *Tilapia sparrmanii* (TSPA) were considered as potential valuable indicators at this site as a result of too much water, and therefore too high flows for species with a preference for slow habitats. Additional information is provided in Appendix H, Table H1. Its optimal preferred general habitat is Slow Deep (SD) and Slow Shallow (SS) preferably with overhanging vegetation, undercut banks or aquatic vegetation as cover, although they also make use of large substrates (cobbles, boulders and bedrock) as general habitat. Breeding takes place during the spring and summer, with males constructing nests in soft substrates. Optimal habitats for egg and larvae development, nursery areas and in general for juveniles and adults are SD and SS habitats.

This guild was used only for the AEC down (increased flows in dry and wet season).

15.1.3 Macroinvertebrate indicator taxa

Indicator taxa: Hydropsychid caddisflies and Simuliidae. Refer to Section 2.1.3.

15.1.4 Riparian vegetation indicator species

Indicator species included:

- *Cyperus marginatus*: Refer to Section 2.1.4.
- *Miscanthus junceus*: Refer to Section 2.1.4.

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

Habitat response is used to derive the biota's response to provide a biota stress index and represents the instantaneous response of habitat to flow changes, based on a site specific (+10) – 0 – (-10) scale for instream biota where:

- +10: No flow (i.e., there can still be surface water in pools).
- 0: Optimum habitat (fixed at the natural maximum baseflow – calculated using the wettest flow month discharge at the maintenance % of 50 – 60% for the Vaal River at the EWR site).
- -10: Habitat at flows above natural maximum baseflow.

The abundance of fish velocity-depth classes are provided in Appendix H, Table H2 and Table H3.

The instantaneous response of flow dependent invertebrate (FDI) taxa provides the % occurrence of various velocity-substrate classes under different flow conditions are provided in Appendix H, Table H6).

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 10 – (-10) where:

- +10 = No flow (i.e., there can still be surface water in pools). The biota response will depend on the indicator groups present, i.e. rheophilics will be gone whereas semi-rheophilics will still be present and survive.
- 0 = Optimum habitat with least amount of stress possible for the indicator groups AT THE SITE (fixed at the natural maximum baseflow in the same way as for the habitat response).
- -1 – (-10) = habitat changes resulting in a major change from the natural composition of the assemblage.

The fish species response index is calculated using the fish habitat rating (cf Section 2.2.1) (Appendix H, Table H4 and Table H5) 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 H, Table H7).

15.2.3 Integrated stress curve

The integrated stress curve is designed as described in Chapter 2, Section 4.2.3. Figure 15.1 and Figure 15.2 illustrates this graphically.

In this specific case, the LSR fish stress index represents the integrated stress index (these values are the highest flow for a stress) for the plus stress 2 - 10, therefore the blue curve (representing the LSR stress index) is lying 'beneath' the integrated stress line (black) (Figure 15.1). On the minus stress scale, the FDIs (Purple line) forms the majority of the integrated stress line (Figure 15.2).

Table 15.1 Species stress discharges used to determine biotic stress – Decreased flows

Stress	Flow (m ³ /s)			Integrated Flow (m ³ /s)
	LSR	LIM	FDI	
+10	0	0	0	0
+9	0.24	0.03	0.002	0.24
+8	0.48	0.06	0.009	0.48
+7	0.64	0.1	0.04	0.64
+6	0.85	0.13	0.169	0.85
+5	0.98	0.16	0.517	0.98
+4	1.21	0.19	0.876	1.21
+3	1.47	0.55	1.207	1.47
+2	1.73	0.81	1.6	1.73
+1	2	1.15	2.2	2.2
0	2.5	2.2	2.5	2.5

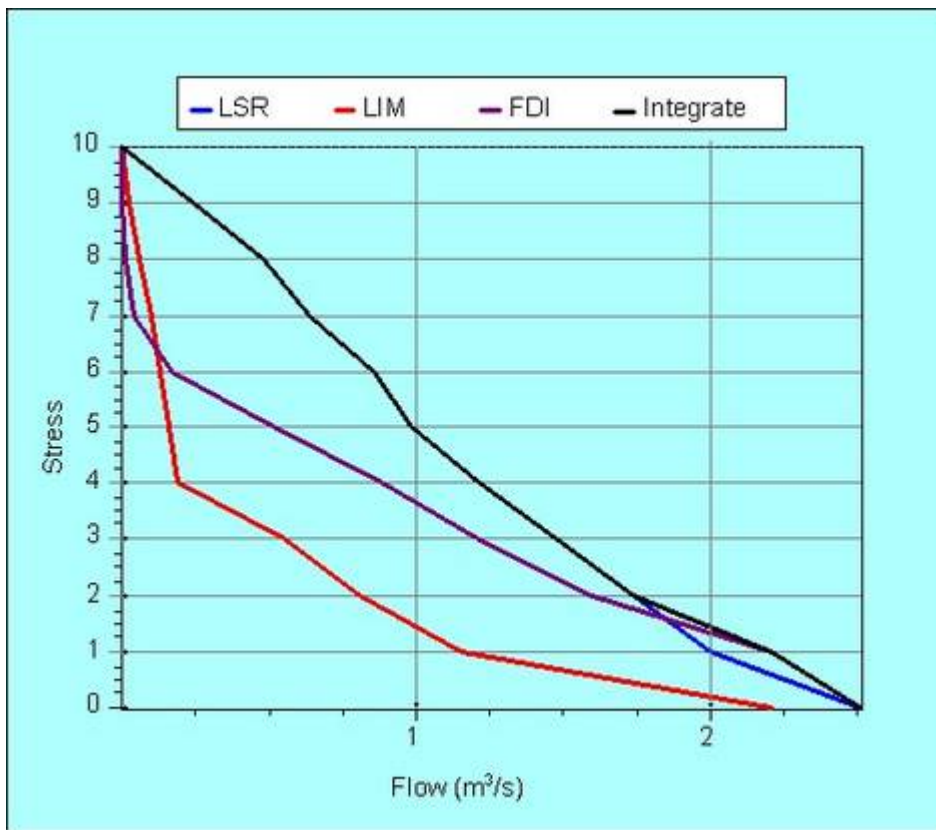


Figure 15.1 Component and integrated stress curves for EWR 10 – Decreased flows

Table 15.2 Species stress discharges used to determine biotic stress – Increased flows

Stress	Stress Flow (m ³ /s)			Integrated Flow (m ³ /s)
	LSR	LIM	FDI	
0	2.5	2.5	2.527	2.5
-1	5	5	2.895	2.9
-2	6.75	5.9	3.747	3.7
-3	8.25	7.3	4.775	4.8
-4	13.7	8.3	8.328	8.3
-5	21.8	9.5	10.965	9.5
-6	30	11	12.428	11
-7	55.7	22.4	13.989	14
-8	81.4	42	15.649	15.65
-9	107	78	17.407	17
-10	132.9	114	20.232	20

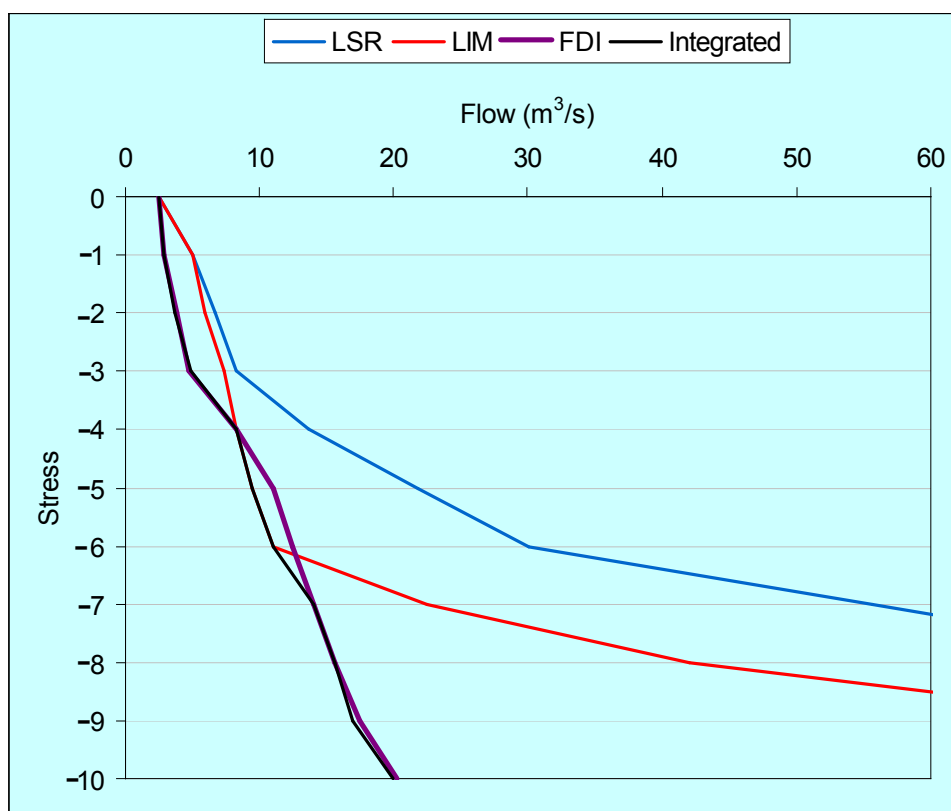


Figure 15.2 Component and integrated stress curves for EWR 10 – Increased flows

Table 15.3 provides the summarised biotic response for the integrated stresses.

Table 15.3 Integrated stress and summarised habitat/biotic responses

Integrated stress	m ³ /s	Habitat and/or Biotic responses
+10	0	Only pool dwelling species present. Only hyporheic refugia, no surface water for FDIs. Indicator taxa no longer present. Standing water habitats only.
+9 (LSR)	0.24	LIM guild: Nursery habitat is good (4*) while abundance and cover is low (2.5) and spawning, water quality and connectivity is moderate (3 – 3.5). LSR guild: All habitats are very rare (0.5) and spawning habitat is absent (0).

Integrated stress	m ³ /s	Habitat and/or Biotic responses
+8 (LSR)	0.48	LIM guild: Nursery habitat is good and the rest of the habitats are moderate. LSR guild: Spawning habitat is very rare and the rest of the habitats are very low (1).
+7 (LSR)	0.64	LIM guild: Spawning, nursery and connectivity is good while rest of habitats are moderate. LSR guild: Connectivity is low (2) and rest of habitats are very low.
+6 (LSR)	0.85	LIM guild: All habitats are good. LSR guild: All habitats are low. Critical FDI habitats limited. All life stages viable in limited areas, critical life stages of some sensitive rheophilic species at risk.
+5 (LSR)	0.98	LIM guild: As above. LSR guild: Spawning and water quality habitats are moderate and the rest of the habitats are moderate (2.5).
+4 (LSR)	1.21	Reduced FDI critical habitat. Most rheophilic species persist, but abundances reduced.
+3 (LSR)	1.47	
+2 (FDI)	1.73	
+1 (FDI)	2.2	LIM guild: All habitats are optimal (5). LSR guild: Cover and abundance is good and the rest of the habitats optimal. All FDI habitats plentiful. 90 % rheophilic species persist.
0	2.5	Fish guild: All habitats are optimal. Zero stress pegged. All FDI very abundant and healthy.
-1 (LIM)	2.9	All FDI habitats plentiful.
-2 (LIM)	3.7	Fish guild: Spawning habitats is good while rest of habitats is optimal. Critical FDI habitats sufficient.
-3 (LIM)	4.8	Fish guild: Water quality and connectivity is optimal, spawning habitat is moderate and the rest of the habitats are good. Reduced critical FDI habitat.
-4 (LIM)	8.3	LIM guild: Water quality is good, spawning and nursery habitat is low and rest of habitats is moderate. LSR guild: Spawning habitat is very low, nursery habitat is moderate and the rest of the habitats are good. Maximum current speeds stabilize. Average current speeds exceed 0.6 m/s. 40 % loss of <i>Cyperus</i> .
-5 (LIM)	9.5	LIM guild: Spawning habitat is very low, nursery habitat is low water quality is good and the rest of the habitats are moderate. LSR guild: Spawning habitat is very low, water quality and connectivity is moderate and the rest of habitats is moderate.
-6 (LIM)	11	LIM guild: Spawning habitat very rare (0.5), nursery habitat is very low and the rest of the habitats is low with good water quality. LSR guild: Spawning habitat is very rare, connectivity and water quality is good and the rest of the habitats are moderate. Critical FDI habitats reduced.
-7 (LIM)	14	Critical FDI habitats very reduced.
-8 (LIM)	15.65	Mostly fast flowing FDI habitats.
-9 (FDI)	17	Fast-flowing FDI habitats only.
-10 (FDI)	20	Bank full discharge. Habitats suitable for fast flowing taxa only. Critical habitats limited, high potential for erosion. Residual habitat for slow flowing taxa.

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

16 EWR 10: SUIKERBOS DS (SUIKERBOSRAND RIVER) – DETERMINATION OF EWR SCENARIOS

16.1 ECOCLASSIFICATION SUMMARY OF EWR 10

The aims at EWR 10 were to maintain the PES as the REC. Two EWR scenarios were investigated, i.e. an improved (from PES) AEC and an AEC lower than the PES.

EWR 10 Suikerbos DS (Suikerbosrand River)				
<p>EIS: MODERATE PES: C/D Combination of flow and non-flow related impacts. Flow related impacts include elevated base flow and increased floods due to mining, SAPPI, urban runoff and Blesbokspruit input. Non-flow related impacts include deteriorated water quality due to industries, agriculture and urban activities; erosion, and exotic alien invasion (fish and vegetation).</p> <p>REC: C/D Maintain the PES due to the MODERATE EIS rating.</p> <p>AEC up: C Improved water quality management in the Blesbokspruit catchment. The biotic condition of the biota will improve under this scenario although no improvement will be evident in the riparian vegetation component. The riparian vegetation EC is associated with increased flows rather than water quality. NOTE: The recommendations at EWR 9 are to improve the low flows in the dry season. This could increase flows to the level that is problematic at EWR 10. This will have to be treated as a scenario in a systems context and evaluated.</p> <p>AEC down: D The scenario is increased base flows.</p>				
Driver Components	PES and REC Category	Trend	AEC ↑	AEC ↓
HYDROLOGY	D			
WATER QUALITY	D/E	Negative	D	D/E
GEOMORPHOLOGY	C	Negative C	C	-C
Response Components	PES Category	Trend	REC	AEC ↓
FISH	C/D	Stable	C	D
MACRO INVERTEBRATES	C/D	Stable	C	D
INSTREAM	C/D		C	D
RIPARIAN VEGETATION	C	Negative D	C	D
ECOSTATUS	C/D		C	D

These ECs was achieved as follows:

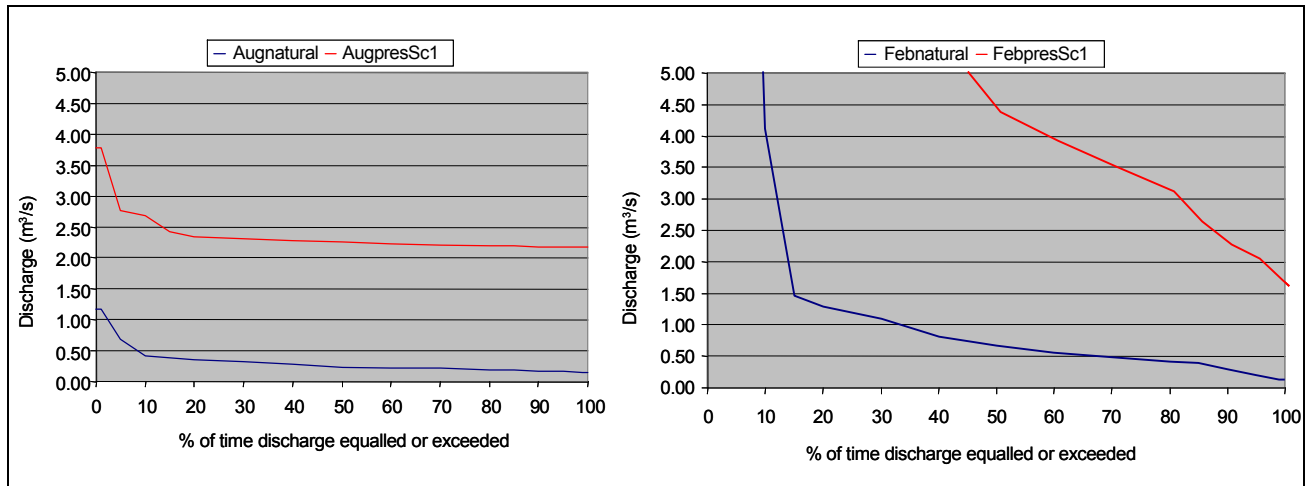
- PES: The present hydrology has resulted in the PES of a C/D. The borders of this PES band, representing more and less flow than the present hydrology, were identified. This band therefore consisted of a scenario where flows could be increased and decreased.
- AEC up (Improved PES): Improvement was only possible by REMOVING water (i.e. increasing the stress towards natural). Improvement was also only possible if water quality problems did not deteriorate when water was removed. If the water quality was not addressed in conjunction with the removal of flow, then a decreased flow would not achieve an improvement. Stress values provided for the AEC of a C represents the border between the C and the B EC.
- AEC down (EC lower than the PES): This would be achieved by INCREASING the flows. Based on the assumption that the increase would be constant during the year, stress values were provided for increased flows where the PES changes from a C/D to a D.

16.2 HYDROLOGY

Both the Suikerbosrand River (EWR 10) and the Blesbokspruit River (EWR 11) had significantly MORE flow under present conditions than under natural conditions (Figure 16.1). From the information known of these systems, this aspect of the modelled hydrology is correct. No gauges with any reliable data exist. The modelled present hydrology is used as the reference hydrology.

Dry Season (August)

Wet Season (February)



Augnatural: Modelled natural hydrology in m³/s

AugpresSc1: Modelled present hydrology (Scenario 1) in m³/s

Figure 16.1 Flow duration graphs for Aug and Feb for the Suikerbosrand River at EWR 10

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

- 95%: Representing droughts for both wet and dry months. This would represent 5% on the stress duration graphs.
- 50%: Representing maintenance flows for both wet and dry months. This would represent 50% on the stress duration graphs.
- Any additional points which had specific significance in terms of flow or stress requirements.

16.3 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 H, Section H2.1 – 2.2.

The fish and macroinvertebrate flow requirements for different Ecological Categories (ECs) are provided in Table 16.1 and Figure 16.2 and 16.3. 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 16.2 and 16.3.

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 requirements

Duration	LSR stress	Integ stress	LIM stress	Integ stress	FDI stress	Integ stress	FINAL* (Integrated stress)*	FLOW (m ³ /s)
PES and REC:C/D EcoStatus			FISH: C/D			MACROINVERTEBRATES: C/D		
DRY SEASON								
5%	+6.3	+6.3	+0.6	+2.2	+2	+2.5	+6.3	0.78
30%	+5.2	+5.2	+0.5	+2			+5.2	0.95
50%	+4.5	+4.5	+0.5	+1.9	+1.5	+1.5	+4.5	1.095
WET SEASON								
5%	+2.5	+2.5	+1	+4	+3.2	+4.2	+4.2	1.146
10%	+2.1	+2.1	+0.6	+2.1			+2	1.73
50%					-2	-2	-2	3.7
AEC up: C EcoStatus			FISH: C			MACROINVERTEBRATES: C		
DRY SEASON								
5%	+6.8	+6.8	+1.48	+4.9	+4.5	+6.5	6.8	0.68
30%	+5.6	+5.6	+1.49	+4.9			5.6	0.92
50%	+4.8	+4.8	+1.43	+4.8	+4	+5.5	5.5	0.91
WET SEASON								
5%	+6.1	+6.1	+2.2	+7	+4	+5.5	7	0.64
10%	+2.5	+2.5	+1.3	+4.8			4.8	1.026
50%					0	0	0	2.5
AEC down: D EcoStatus			FISH: D			MACROINVERTEBRATES: D		
DRY SEASON								
5%	-2	-3.5	-2.1	-3.2	0	0	0	2.5
50%	-3.5	-6	-2.2	-3.3	-1	-1	-1	2.9
WET SEASON								
5%	-3	-4	-2	-3.25	1	1	1	2.2
10%	-3.6	-6.1	-2.1	-3.2			-3.2	5.5
50%					-4	-4	-4	8.3

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

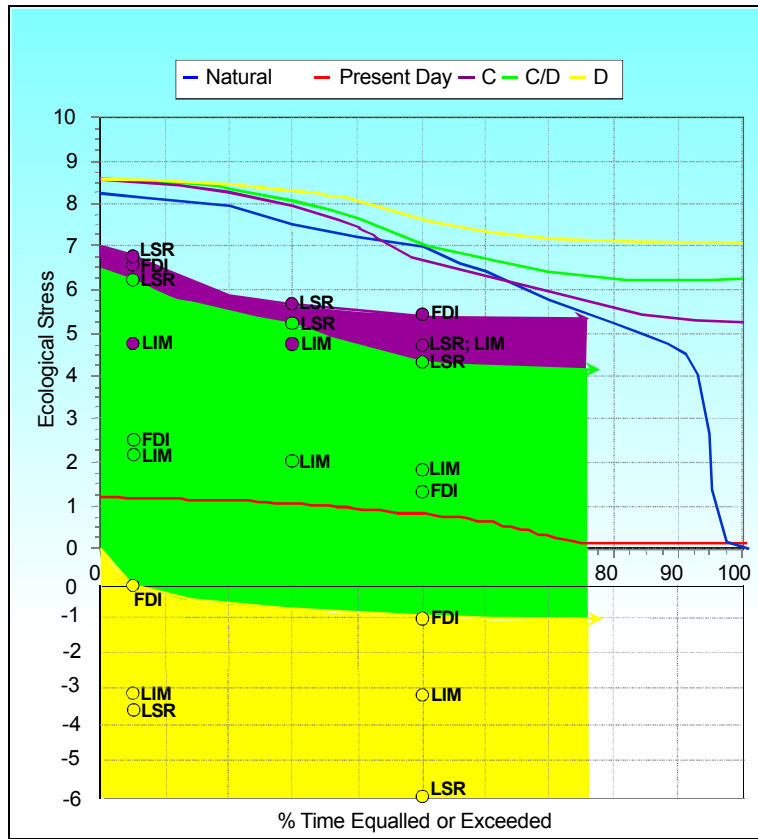


Figure 16.2 EWR 10: Stress Duration Curve for a C/D PES and REC, C AEC up and D AEC down - DRY season

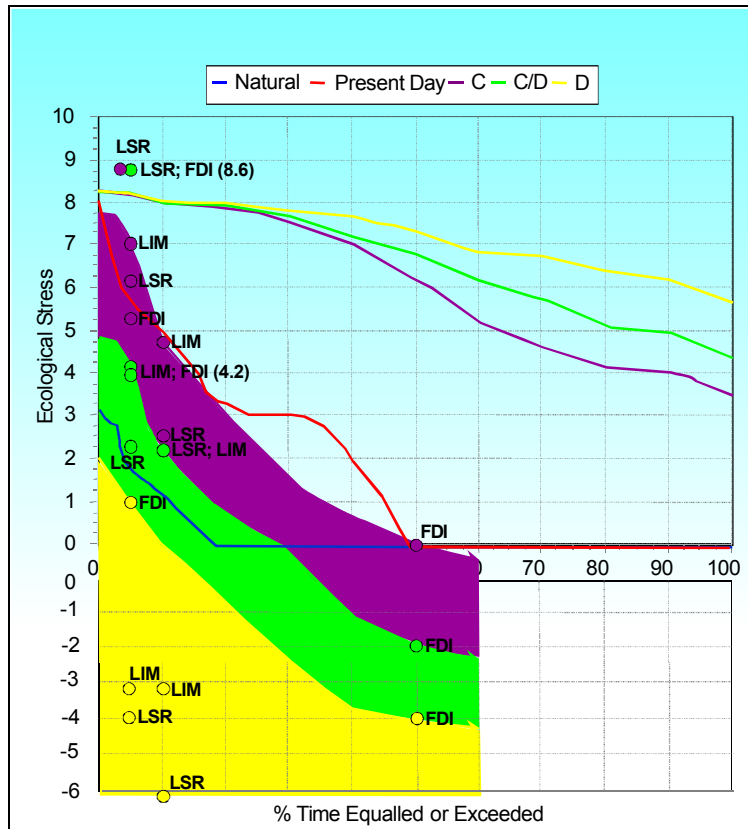


Figure 16.3 EWR 10: Stress Duration Curve for a C/D PES and REC, C AEC up and D AEC down - WET season

Table 16.2 Summary of EWR 10 motivations

Month	% Stress duration	Component stress	Integrated stress	Flow m ³ /s	Comment ¹
PES and REC:C/D EcoStatus		FISH: C/D		MACROINVERTEBRATES: C/D	
Aug	5% drought	+6.3 LSR	+6.3	0.78	182% of the habitats that can be expected under natural conditions, and it is estimated that it would maintain this guild in its PES during drought periods
	50% maintenance	+4.5 LSR	+4.5	1.095	It is estimated that the total habitat suitability would be 186% of what can be expected under natural conditions, as a result of flows still being higher than expected under natural conditions (under present flows during the dry season, the habitat suitability percentage is 293% of natural condition).
Feb	5% drought	+3.2 FDI	+4.2	1.146	Average depth needed for wet season drought is between 0.25 and 0.31 m, and average current velocity is between 0.25 and 0.34 m/s. Critical habitats (FCS) comprise between 21 and 29% of habitats available.
	50% maintenance	-2 FDI	-2	3.7	Average depth needed for wet season maintenance is between 0.37 and 0.48 m, and average current velocity is 0.46 to 0.7 m/s. Critical habitats (FCS) comprise between 20 and 30% of habitats available.
AEC up: C EcoStatus		FISH: C		MACROINVERTEBRATES: C	
Aug	5% drought	+6.8 LSR	+6.8	0.682	See PES.
	50% maintenance	+4 FDI	+5.5	0.91	Average depth needed for dry season maintenance is between 0.25 and 0.29 m, and average current velocity is between 0.25 and 0.31 m/s (Spp Stress between +3 and +1.5). Critical habitats (FCS) comprise between 21 and 28 % of habitats available.
Feb	5% drought	+2.2 LIM	+7	0.64	Flows will ensure enough habitat that it would maintain this guild in its PES during drought periods.
	50% maintenance	0 FDI	0	2.5	Average depth needed is between 0.32 and 0.37 m, and average current velocity is 0.37 and 0.46 m/s. Critical habitats (FCS) comprise between 30 and 31% of habitats available.
AEC down: D EcoStatus		FISH: D		MACROINVERTEBRATES: C/D	
Aug	5% drought	0 FDI	0	2.5	Average depth needed for dry season drought is between 0.32 and 0.34 m, and average current velocity is between 0.37 and 0.39 m/s.
	50% maintenance	-1 FDI	-1	2.9	Average depth needed for dry season maintenance is between 0.31 and 0.37 m, and average current velocity is between 0.34 and 0.46 m/s.
Feb	5% drought	1 FDI	1	2.2	Average depth needed for wet season drought is between 0.3 and 0.32 m, and average current velocity is 0.34 and 0.37 m/s.
	50% maintenance	-4 FDI	-4	8.3	Average depth needed for wet season maintenance is 0.48 and 0.55 m, and average current velocity is between 0.70 and 0.78 m/s.

¹ See Chapter 3, Table 3.2.

The above flows were checked by the riparian vegetation specialist to ensure that these requirements are adequate to achieve the EC in which the marginal vegetation should be, as well as any other flow dependant vegetation that could occur.

The vegetation indicators used were *C. marginatus* and *M. junceus* species. The resulting conditions of the vegetation indicators to the required low flows are described below. In conclusion, the low flows would maintain the PES and REC of the riparian vegetation (Table 16.3).

Table 16.3 Verification of the low flow requirement to maintain the vegetation EC

PES and REC: RIPARIAN VEGETATION EC C (ECOSTATUS C/D)
<p>Dry Season maintenance Dry season base flow is sufficient for the maintenance of marginal zone <i>Cyperus</i>. Flows will inundate lower limit of <i>Cyperus</i> population on Left Hand Bank (LHB). <i>Cyperus</i> population on Right Hand Bank (RHB) will be 4 cm from the water level. Upper limit of <i>Cyperus</i> on both banks is approx 73 cm from the inundation level, although the population will be under stress, die-off of <i>Cyperus</i> is not expected.</p> <p>Dry Season drought Drought flow for 5% of the time is sufficient for maintenance of marginal zone <i>Cyperus</i>. Flows will inundate lower limit of <i>Cyperus</i> population on Left hand Bank. <i>Cyperus</i> population on RNB will be 10 cm from the inundation level. Upper limit of <i>Cyperus</i> on both banks is approx 80 cm from the inundation level, although the population will be under stress, die-off of <i>Cyperus</i> is not expected.</p> <p>Wet Season maintenance Wet season base flow is sufficient for maintenance of marginal zone <i>Cyperus</i>. Flows will inundate lower limit of <i>Cyperus</i> population on both banks (by 12 – 30 cm). The lower limit of <i>Miscanthus junceus</i> (in the marginal zone) will be approx 6 -30 cm from the water level and upper limit (in the lower zone) will be approx 0.9 – 1.2 m from the average wet season base flow. The upper limit of the <i>Cyperus</i> population (which occurs in the Lower Zone) will be just over 50 cm from the water level.</p> <p>Wet Season drought Wet season flow for 5% of the time is sufficient for maintenance of marginal zone <i>Cyperus</i>. Flows will inundate lower limit of <i>Cyperus</i> population on LHB. <i>Cyperus</i> population on RHB will be 3 cm from the water level. Upper limit of <i>Cyperus</i> on both banks is approx 72 cm from the inundation level, although the population will be under stress, die-off of <i>Cyperus</i> is not expected.</p>
AEC up: RIPARIAN VEGETATION EC: C (ECOSTATUS C)
<p>Dry Season maintenance Dry season base flow is sufficient for maintenance of marginal zone <i>Cyperus</i>. Flows will inundate lower limit of <i>Cyperus</i> population on Left hand Bank by 17 cm. <i>Cyperus</i> population on RHB will be 6 cm from the water level. Upper limit of <i>Cyperus</i> on both banks is approx 54 – 74 cm from the inundation level. Although the population will be under stress, die-off of <i>Cyperus</i> is not expected. The lower limit of <i>M. junceus</i> is similarly 20 – 60 cm from the average dry season base flow water level.</p> <p>Dry Season drought Drought flow of 0.68 m³/s is sufficient for maintenance of C category for the Riparian Vegetation. Flows will inundate lower limit of <i>Cyperus</i> population on LHB by 11 cm. <i>Cyperus</i> population on RHB will be 12 cm from the water level. The upper limit of <i>Cyperus</i> on both banks is approx 60 – 80 cm from the inundation level. Although the population will be under stress, die-off of <i>Cyperus</i> is not expected.</p> <p>Wet Season maintenance Wet season base flows are sufficient for the maintenance of a C riparian vegetation Category. These flows will inundate lower limit of <i>Cyperus</i> population on both banks (by 6 – 29 cm). The upper limit of <i>Cyperus</i> (in the Lower Zone) on both banks is approx 40 – 60 cm from the inundation level. The lower limit of <i>M. junceus</i> is similarly 12 – 52 cm from the average wet season base flow water level.</p> <p>Wet Season drought A wet season flow of 0.64 m³/s for 5% of the time is sufficient for maintenance of marginal zone <i>Cyperus</i>. Flows will inundate lower limit of <i>Cyperus</i> population on LHB by 11 cm. <i>Cyperus</i> population on RHB will be 12 cm from the inundation level. Upper limit of <i>Cyperus</i> on both banks is approx 60 – 80 cm from the inundation level, although the population will be under stress, die-off of <i>Cyperus</i> is not expected.</p>
AEC down: RIPARIAN VEGETATION EC: D (ECOSTATUS D)
<p>Dry Season drought Dry season base flow of 2.9 m³/s will inundate the lower limit of <i>Cyperus</i> (in the marginal zone) on both banks by 8 – 31 cm. Continuous inundation during low flow season will result in die-off of marginal zone <i>Cyperus</i>. This inundation stress will cause the marginal zone to shrink resulting in a drop from the PES of a C to a D category.</p> <p>Dry Season maintenance Drought flow of 2.5 m³/s is sufficient for maintenance of D category for the Riparian Vegetation. Flows will inundate lower limit of <i>Cyperus</i> population on both banks (by 6 – 30 cm).</p> <p>Wet Season maintenance Wet season base flow of 8.3 m³/s will be sufficient for maintaining a D riparian vegetation category. These flows will result in the inundation of the marginal zone up to the marginal/lower zone interface, this translates into the inundation of the lower limit of <i>Cyperus</i> by 28 – 50 cm and the lower limit of <i>M. junceus</i> on the RHB by 9 cm. The upper limit of the <i>Cyperus</i> population (in the Lower Zone) at this site will be approx 20 - 40 cm from the average water level whereas the</p>

upper limit of *Miscanthus* will be 0.7 - 1.1 m from the water level.

Wet Season drought

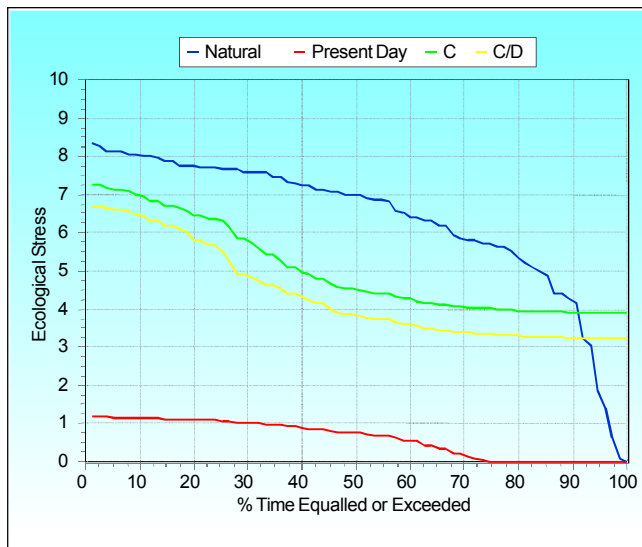
A flow of 2.2 m³/s for 5% of the time during an average wet season is sufficient for the maintenance of D category for Riparian Vegetation. Flows will inundate lower limit of *Cyperus* population on both banks by 4 - 7 cm.

16.3.1 Final low flow requirements

To produce the final results (Figure 16.4), the DRM results for the specific category are modified according to specialists' requirements (Figure 16.1 and 16.2). 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 changes for C and C/D EC.
 - 0 Shape values: 5 for Jan, Feb and Mar. Other months were set at 6.
 - 0 All upper shift values were set at 98% for all months.
 - 0 Maximum value was set at 100% for Jan, Feb and Mar.
- D EC
 - 0 Could not provide results as the flows represent higher flows than the reference hydrology.
- Manual editing had to be used to achieve a result.

Dry Season (August)



Wet Season (February)

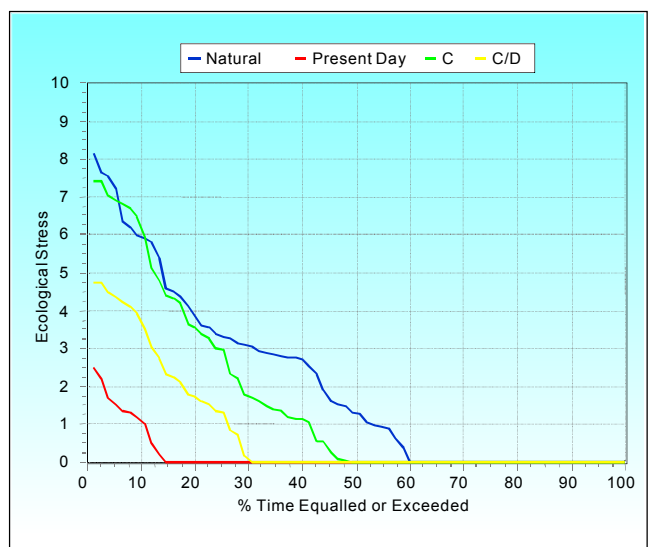


Figure 16.4 EWR 10: Final stress requirements for low flows

16.4 HIGH FLOW REQUIREMENTS

The high flow classes are identified as follows:

- The geomorphologist and riparian vegetation specialist identify the range of flood classes required and list the functions of each flood.
- The instream specialists then indicate which of the instream flooding functions are addressed by the floods identified for geomorphology and riparian vegetation (indicated by a ✓ in Table 16.4).

- Any of the floods required by the instream biota and not addressed by the floods already identified, must then be described (in terms of ranges and functions) for the instream biota.

Results are provided in Table 16.4 and detailed motivations provided in Table 16.5.

Table 16.4 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 and spawning	Migration habitat (depth etc.)	Clean spawning substrate	Create nursery areas	Resetting water quality	Inundate vegetation for spawning	Breeding and hatching cues	Clear fines	Scour substrate	Reach or inundate specific areas
I	5 - 6 (3.5 ave)	Geomorphology: This flow class would scour fines and inundate the lower bench. Vegetation: Inundates 50% of the marginal zone and 40 - 50% of the <i>Cyperus</i> population. Activates the lower limit of <i>Miscanthus</i> population.	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
II	8 - 12 (6 ave)	Geomorphology: This flow class would scour fines, inundate and activate the lower bench, and is responsible for more than 10% of the transport of fines and gravels. Vegetation: Inundates the marginal zone and majority of the <i>Cyperus</i> population as well as lower limits of <i>Miscanthus</i> .	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
III	20 - 40 (10 - 12 ave)	Geomorphology: This flow class would inundate the lower terrace on the left bank, and is responsible for more than 20% of the transport of fines and gravels. Vegetation: Inundates the majority of the lower zone and <i>Miscanthus</i> population.	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
IV	70 + (75 ave)	Geomorphology: This flow class would inundate the upper terrace on the left bank, and is the effective discharge for the small cobbles at the site (activation and transport of cobbles). Vegetation: Floods the lower zone and activates the woody zone. Helps prevent terrestrialization by woody vegetation.	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

Further information is provided in Appendix H, Table H11.

The number of high flow events required for each EC is provided in Table 16.5. No observed daily data was available to check flood requirements against.

Table 16.5 EWR 10: The recommended number of high flow events required

FLOOD CLASS	FLOOD RANGE (m ³ /s)	INVERTEBRATES	FISH	VEGETATION	GEOMORPHOLOGY	FINAL (Frequency)	MONTHS	DAILY AVERAGE	DURATION
PES and REC SCENARIO: C/D									
I	5 - 6 (3.5 ave)			3	4	4	Nov, Dec, Jan and Feb	3.5	3
II	8 - 12 (6 avg)			1	2	2	Jan, Mar	6	4
III	20 - 40 (10 - 12 ave)			1:2	1	1	Feb	11	4
IV	70 + (75 ave)			1:3	1:2	1:2			
AEC up SCENARIO: C									
I	5 - 6 (3.5 ave)			3	4	4	Nov, Dec, Jan and Feb	3.5	3
II	8 - 12 (6 avg)			1	2	2	Jan, Mar	6	4
III	20 - 40 (10 - 12 ave)			1:2	1	1:2	Feb	11	4
IV	70 + (75 ave)			1:3	1:2	1:2			
AEC down SCENARIO: D*									
I	5 - 6 (3.5 ave)			5+	5	5	Nov, Dec, Jan, Feb, Mar	3.5	3
II	8 - 12 (6 avg)			2	3	3	Dec, Jan, Mar	6	4
III	20 - 40 (10 - 12 ave)			1	1	1	Feb	11	4
IV	70 + (75 ave)			1:3	1:2	1:2			

* This scenario includes increased base flows from mine dewatering and increased urbanization. Increased urbanisation will also result in increased storm runoff, i.e. the Class I and II floods. This will contribute to the resulting AEC of a D. The number of floods described for the D EC does therefore NOT represent flood requirements, but the resulting floods expected under this scenario.

16.5 FINAL FLOW REQUIREMENTS

The low and high flows were combined to produce the final flow requirements for the C/D and the C ECs as:

- An EWR table, which shows the results of high flows and low flows for each month separately (Table 16.6 – 16.7). Floods with a frequency higher than 1:1 is not included.
- The EWR rule table, which provides the EWR recommended flows as a duration table, showing flows that should be provided when linked to a natural trigger (natural hydrology). An EWR rule table is supplied for the low flows only, and for low and high flows combined (Appendix H, Section H2.4).

No EWR rule or EWR table were provided for the D EC as the DRM could not be used due to the flows being higher than the reference hydrology. The low flows EWR rule is useful for operating the system, whereas the EWR table must be used for operation of high flows.

Table 16.6 EWR table for PES and REC: C/D

Desktop version:		2	Present Day MAR (MCM)	149.271
			Virgin MAR (MAR)	86.976
BFI	0.568	Distribution type		Vaal
MONTH	LOW FLOWS		HIGH FLOWS	
	Maintenance (m ³ /s)	Drought (m ³ /s)	Daily average (m ³ /s) on top of base flow	Duration (days)
OCTOBER	1	0.7		
NOVEMBER	1.4	0.814	3.5	3
DECEMBER	1.5	0.807	3.5	3
JANUARY	1.8	0.892	3.5 6	3 4
FEBRUARY	2.5	1.018	3.5 11	3 4
MARCH	2	0.887	6	4
APRIL	1.8	0.864		
MAY	1.4	0.806		
JUNE	1.15	0.782		
JULY	0.9	0.74		
AUGUST	0.85	0.701		
SEPTEMBER	0.9	0.697		
TOTAL MCM	44.967	25.465	6.369	
% OF PD	30.12	17.06	4.27	
% OF VIRGIN	51.7	29.28	7.32	

Table 16.7 EWR table for AEC up: C

Desktop version:		2	Present Day MAR (MCM)	149.271
			Virgin MAR (MAR)	86.976
BFI	0.568	Distribution type		Vaal
MONTH	LOW FLOWS		HIGH FLOWS	
	Maintenance (m ³ /s)	Drought (m ³ /s)	Daily average (m ³ /s) on top of base flow	Duration (days)
OCTOBER	0.85	0.55		
NOVEMBER	1.4	0.55	3.5	3
DECEMBER	1.45	0.55	3.5	3
JANUARY	1.85	0.53	3.5 6	3 4
FEBRUARY	2.4	0.56	3.5 11	3 4
MARCH	1.9	0.53	6	4
APRIL	1.6	0.55		
MAY	1.4	0.55		
JUNE	1.2	0.55		
JULY	1	0.55		
AUGUST	0.85	0.6		
SEPTEMBER	0.8	0.55		
TOTAL MCM	43.675	17.396	6.21	
% OF PD	29.26	11.65	4.16	
% OF VIRGIN	50.22	20	7.14	

A comparison between the differences in terms of percentages of the various types of flow blocks are provided in Table 16.8.

Table 16.8 Modifications made to the DRM for EWR 10

Changes	PES and REC C/D		AEC up C	
	DRM	EWR	DRM	EWR
MLIFR - Maintenance low flow	12.4%	30.1%	16.0%	29.3%
DLIFR - Drought low flow	8.6%	17.1%	8.6%	11.6%
MHIFR - Maintenance high flow	7.1%	4.3%	7.8%	4.1%
Long-term % of PD MAR	20.4%	41.1%	22.6%	33.6%

17 EWR 11: BLESBOKSPRUIT (BLESBOKSPRUIT RIVER) – DETERMINATION OF STRESS INDICES

NOTE: All supporting specialist information for EWR 11 is summarized in Volume 2, Appendix I.

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

17.1 INDICATOR SPECIES OR GROUP

17.1.1 Fish indicator group 1: Large semi-rheophilic species (BAEN, BKIM)

Indicator species: *Labeobarbus aeneus* (BAEN) and *Labeobarbus kimberleyensis* (BKIM). Refer to Section 2.1.1 and Appendix B, Table B1.

17.1.2 Fish indicator group 2: Small limnophilic species (PPHI, TSPA)

Indicator species: *Pseudocrenilabrus philander* (PPHI) and *Tilapia sparrmanii* (TSPA) Refer to Section 15.1.1 and Appendix H, Table H1. This guild was used only for the AEC down (increased flows in dry and wet season).

17.1.3 Macroinvertebrate indicator taxa

Indicator taxa: Hydropsychid caddisflies and Simuliidae. Refer to Section 2.1.3.

17.1.4 Riparian vegetation indicator species

Indicator species included:

- *Persecaria* spp.: Refer to section 6.1.4.
- *Phragmites australis*: Refer to Section 8.1.3.
- *C. bulbispermum*: Refer to section 10.1.4.
- *Typha capensis*: Perennial riparian obligate, reaching up to 2.5 m. Occurs in large communities. Widespread along water courses and in marshy areas. Does not like fast flowing water. Flowers from Dec - Mar.

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

Habitat response is used to derive the biota's response to provide a biota stress index and represents the instantaneous response of habitat to flow changes, based on a site specific (+10) – 0 – (-10) scale for instream biota where:

- +10: No flow (i.e., there can still be surface water in pools).

- 0: Optimum habitat (fixed at the natural maximum baseflow – calculated using the wettest flow month discharge at the maintenance % of 50 – 60% for the Vaal River at the EWR site).
- -10: Habitat at flows above natural maximum baseflow.

The abundance of fish velocity-depth classes are provided in Appendix I, Table I1 and I2.

The instantaneous response of flow dependent invertebrate (FDI) taxa provides the % occurrence of various velocity-substrate classes under different flow conditions are provided in Appendix K, Table I5).

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 10 – (-10) where:

- +10 = No flow (i.e., there can still be surface water in pools). The biota response will depend on the indicator groups present, i.e. rheophilics will be gone whereas semi-rheophilics will still be present and survive.
- 0 = Optimum habitat with least amount of stress possible for the indicator groups AT THE SITE (fixed at the natural maximum baseflow in the same way as for the habitat response).
- -1 – (-10) = habitat changes resulting in a major change from the natural composition of the assemblage.

The fish species response index is calculated using the fish habitat rating (cf Section 2.2.1) (Appendix I, Table I3 and I4) 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 I, Table I6).

17.2.3 Integrated stress curve

The integrated stress curve is designed as described in Chapter 2, Section 4.2.3. Figure 17.1 and Figure 17.2 illustrates this graphically.

In this specific case, the LSR fish stress index represents the integrated stress index (these values are the highest flow for a stress) for the plus stress 6 – 10. Therefore the blue curve (representing the LSR stress index) is lying 'beneath' the integrated stress line (black) (Figure 17.1). On the minus stress scale, the FDI (green line) forms the majority of the integrated stress line.

Table 17.1 Species stress discharges used to determine biotic stress – Decreased flows

Stress	Flow (m ³ /s)			Integrated Flow (m ³ /s)
	LSR	LIM	FDI	
+10	0	0	0	0
+9	0.06	0.03	0.003	0.06
+8	0.13	0.06	0.008	0.13
+7	0.18	0.1	0.02	0.18
+6	0.22	0.14	0.111	0.22
+5	0.25	0.18	0.172	0.27

Stress	Flow (m ³ /s)			Integrated Flow (m ³ /s)
	LSR	LIM	FDI	
+4	0.32	0.22	0.25	0.33
+3	0.28	0.28	0.345	0.4
+2	0.45	0.37	0.461	0.46
+1	0.54	0.5	0.611	0.611
0	0.7	0.7	0.796	0.7

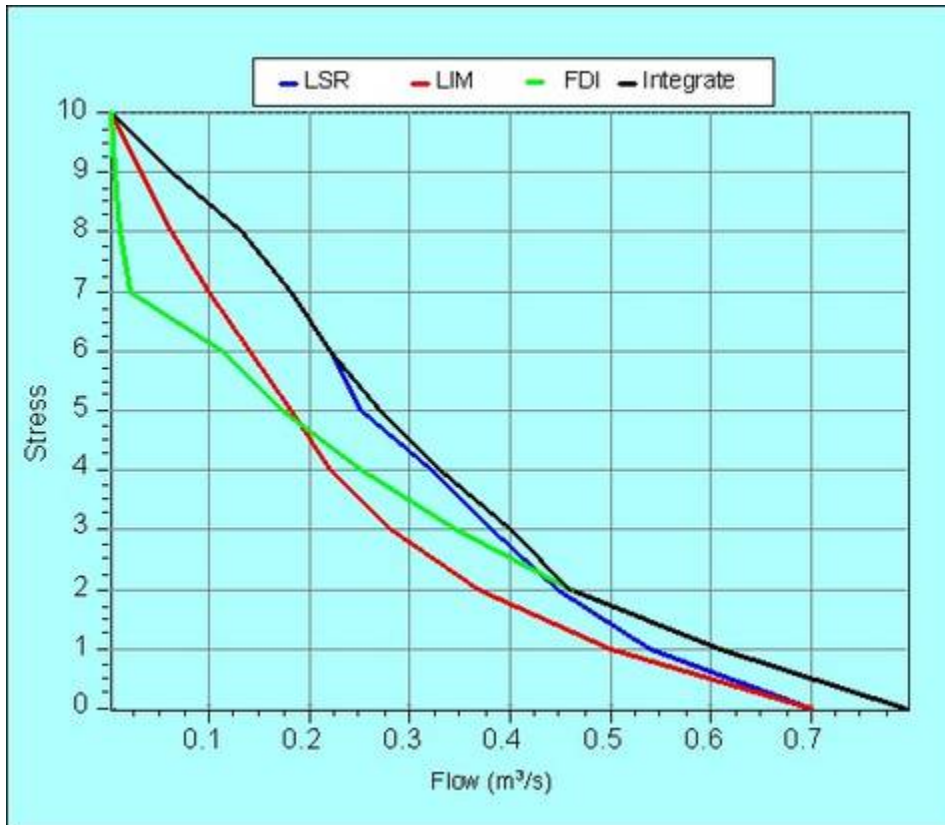


Figure 17.1 Component and integrated stress curves for EWR 11 – Increased flows

Table 17.2 Species stress discharges used to determine biotic stress – Increased flows

Stress	Flow (m ³ /s)			Integrated Flow (m ³ /s)
	LSR	LIM	FDI	
0	0.7	0.7	0.7	0.7
-1	2.21	1.5	1.268	1.268
-2	3.48	1.9	2.025	1.9
-3	6.2	2.2	2.441	2.2
-4	10.4	3.4	3.129	3.129
-5	15	4.4	4.438	4.4
6	22.6	7.1	5.942	5.942
-7			11.992	11.3
-8			13.327	13.3
-9			15.202	15.2
-10			22.595	22.595

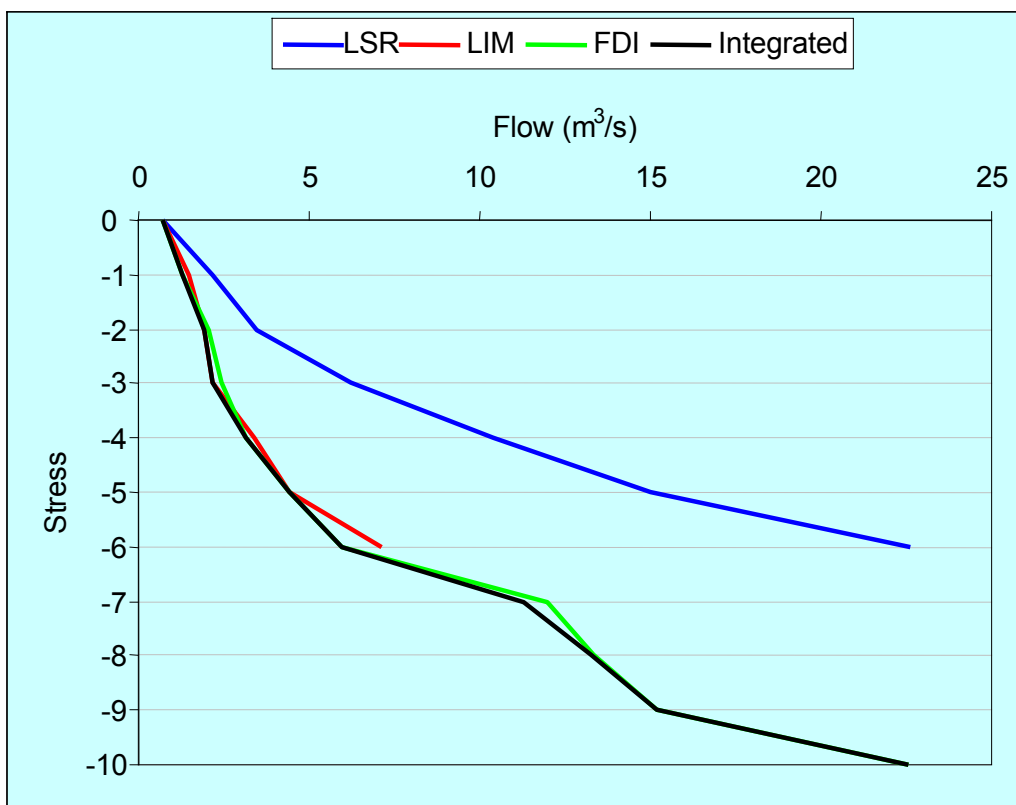


Figure 17.2 Component and integrated stress curves for EWR 11 – Increased flows

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

Table 17.3 Integrated stress and summarised habitat/biotic responses

Integrated stress	m ³ /s	Habitat and/or Biotic responses
+10	0	Only pool dwelling species present. Only hyporheic refugia, no surface water for FDI. Indicator taxa no longer present. Standing water habitats only.
+9 (LSR)	0.06	LIM guild: Spawning habitat absent (0*), connectivity and water quality is very rare (0.5) while nursery, abundance and cover is very low (1 – 1.5). LSR guild: All habitats are very rare.
+8 (LSR)	0.13	LIM guild: Spawning habitat is very low while rest of habitats is low (2 – 2.5). LSR guild: Spawning and connectivity is very rare, water quality is low and the rest of the habitats are very low. Critical FDI habitat residual. Low quality, moderate/slow velocity. Sensitive rheophilic species rare, critical stages of sensitive rheophilic species non-viable and at risk for some less sensitive species.
+7 (LSR)	0.18	Critical FDI habitat very reduced, moderate/low quality. Moderate/slow velocity, few deep areas WP moderately/very reduced. Critical life-stages of sensitive rheophilic species at risk or non-viable.
+6 (LSR)	0.22	LIM guild: Spawning and nursery habitat is low while rest of habitats are moderate (3). LSR guild: Spawning and connectivity is very low while rest of habitats is low.
+5 (LIM)	0.27	LIM guild: Spawning habitat is low and rest of habitats is moderate. LSR guild: Water quality is moderate while rest of habitats is low. Critical FDI habitats limited and of moderate quality. Moderate velocity, some deep areas. Wide WP moderately reduced. All life stages viable in limited areas, critical life stages of some sensitive rheophilic species at risk.
+4 (LIM)	0.33	LIM guild: Spawning and nursery habitats is moderate and rest of habitats are good (4). LSR guild: Spawning, cover and abundance is low. Other habitats are moderate. Reduced critical FDI habitat and critical quality. Moderate velocity, fairly deep. Most rheophilic species persist, but abundances reduced.
+3	0.4	LIM guild: Habitat occurrence is similar to above, just slightly better.

Integrated stress	m ³ /s	Habitat and/or Biotic responses
(LIM)		LSR guild: Nursery and water quality habitats are good. The rest of the habitats are moderate.
+2 (LIM)	0.46	Critical FDI habitats sufficient. Quality slightly reduced, fast, WP slightly reduced. . Most rheophilic species persist, but slight (80 %) reduction.
+1 (FDI)	0.611	LIM guild: Spawning and nursery habitat is good, rest of habitats is optimal (5). LSR guild: All habitats is good. All FDI habitats plentiful, high quality. Fast, wide WP. 90% rheophilic species persist.
0	0.7	Fish guild: Habitats are optimal. Zero stress pegged at naturalized hydrology wet season maintenance base flow. All FDI very abundant and healthy.
-1 (FDI)	1.268	All FDI habitats plentiful, high quality. Fast, WP slightly increased.
-2 (LIM)	1.9	LIM guild: Spawning and nursery habitats are moderate and rest of habitats are good with optimal water quality. LSR guild: All habitats are good with optimal water quality.
-3 (LIM)	2.2	LIM guild: All habitats are moderate with good water quality. LSR guild: As above. Reduced FDI critical habitat reduced critical quality
-4 (FDI)	3.129	Maximum current speeds stabilize. Average current speeds exceed 0.6 m/s for FDI.
-5 (LIM)	4.4	LIM guild: All habitats moderate with good water quality. LSR guild: Good water quality and connectivity with other habitats moderate. Critical FDI habitat reduced. Entire marginal zone inundated.
-6 (FDI)	5.942	Average depths exceed 0.5 m leading to potential light limitation. Marginal zone inundated and reduced by about 50% for FDI.
-7 (LIM)	11.3	LIM guild: Good water quality with very rare nursery habitats. Other habitats are very low. LSR guild: Good water quality and moderate connectivity. Other habitats are low. Critical FDI habitats very reduced.
-8 (FDI)	13.3	Mostly fast flowing FDI habitats. Critical habitats limited.
-9 (FDI)	15.2	Fast flowing FDI habitats only. 75% loss of marginal vegetation.
-10 (FDI)	22.595	Bank full discharge. FDI habitats suitable for fast flowing taxa only. Critical habitats limited, high potential for erosion. Residual habitat for slow flowing taxa.

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

18 EWR 11: BLESBOKSPRUIT (BLESBOKSPRUIT RIVER) – DETERMINATION OF EWR SCENARIOS

18.1 ECOCLASSIFICATION SUMMARY OF EWR 11

The aims at EWR 11 are to improve the PES to the REC. The Instream EcoStatus is presently in a D/E which is unacceptable. This is due largely to both the water quality problems, and the increased flows. This was the only scenario investigated.

EWR 11 Blesbokspruit (Blesbokspruit River)																																											
<p>EIS: LOW Site is characterised by water quality problems and elevated flows.</p> <p>PES: D Mainly flow related impacts that include increased base flows and floods due to mine water decants, urban runoff, agriculture and return flows from WWTW. Water quality is also heavily impacted due to these activities and erosion has increased. Alien fish species occur.</p> <p>REC: D Maintain the PES due to the LOW EIS rating, with macroinvertebrates improving to D.</p> <p>An improved EcoStatus based on a hypothetical flow regime is not feasible at this site. Decreased flows as a scenario is possible and will result in deteriorated water quality.</p> <p>The improvement of the macroinvertebrate EC is only possible with improved water quality. Improved water quality is only possible with better water quality management, which is unlikely, but feasible at a cost. Due to the huge amount of salts in the system, this improvement will only be a long term option.</p> <p>The implications for setting flows are the following: Flow requirements to maintain the present state would be based on present flows. Only increased flows can be evaluated as a scenario to determine whether increased flows (with either improved or the same water quality) will maintain the EcoStatus.</p>	<table border="1"> <thead> <tr> <th>Driver Components</th> <th>PES Category</th> <th>Trend</th> <th>REC</th> </tr> </thead> <tbody> <tr> <td>HYDROLOGY</td> <td>D/E</td> <td></td> <td></td> </tr> <tr> <td>WATER QUALITY</td> <td>D/E</td> <td>Negative D/E</td> <td>D</td> </tr> <tr> <td>GEOMORPHOLOGY</td> <td>C</td> <td>Negative C/D</td> <td>C</td> </tr> <tr> <th>Response Components</th> <th>PES Category</th> <th>Trend</th> <th>REC</th> </tr> <tr> <td>FISH</td> <td>D</td> <td>Stable</td> <td>C</td> </tr> <tr> <td>MACRO INVERTEBRATES</td> <td>D/E</td> <td>Stable</td> <td>D</td> </tr> <tr> <td>INSTREAM</td> <td>D/E</td> <td></td> <td>C/D</td> </tr> <tr> <td>RIPARIAN VEGETATION</td> <td>D</td> <td>Negative D/E</td> <td>D</td> </tr> <tr> <td>ECOSTATUS</td> <td>D</td> <td></td> <td>D</td> </tr> </tbody> </table>			Driver Components	PES Category	Trend	REC	HYDROLOGY	D/E			WATER QUALITY	D/E	Negative D/E	D	GEOMORPHOLOGY	C	Negative C/D	C	Response Components	PES Category	Trend	REC	FISH	D	Stable	C	MACRO INVERTEBRATES	D/E	Stable	D	INSTREAM	D/E		C/D	RIPARIAN VEGETATION	D	Negative D/E	D	ECOSTATUS	D		D
Driver Components	PES Category	Trend	REC																																								
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INSTREAM	D/E		C/D																																								
RIPARIAN VEGETATION	D	Negative D/E	D																																								
ECOSTATUS	D		D																																								

These ECs was achieved as follows:

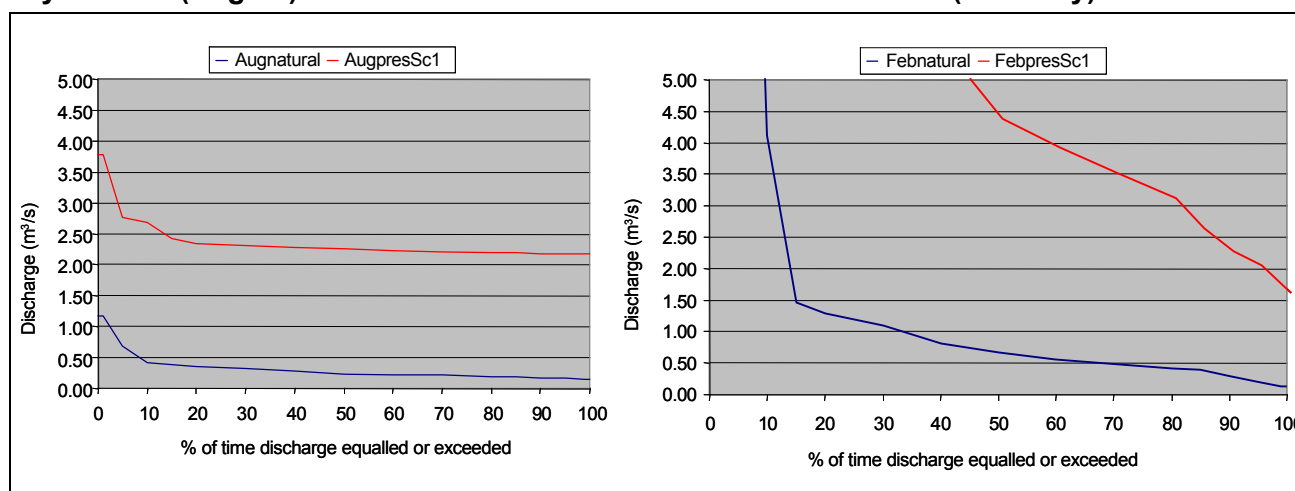
- PES: Identification of the band around the present hydrology which would maintain the PES. This band therefore consisted of a scenario where flows could be increased or decreased. As only an improvement of the PES was considered as the Instream PES was already in a D/E EC, only the band between the PES and the improved category (REC) was described. Note, that if there is only an increase in one season, and the distribution between seasons change – these assumptions will not necessarily be valid anymore.
- Improved PES (the REC): Improvement was only possible by REMOVING water (i.e. increasing the stress towards natural). Improvement was also only possible if water quality problems did not deteriorate when water was removed. If the water quality was not addressed in conjunction with the decrease in flow, then an improvement in the EcoStatus would not be achieved.
- Under the REC scenario the instream condition is a C/D and to determine the flow requirements for an improved instream condition a C DRM was run.

18.2 HYDROLOGY

The Blesbokspruit River has significantly MORE flow during the present season than natural (more than at EWR 10) (see Figure 16.2). From the information known of these systems, this aspect of the modelled hydrology is correct. No gauges with any reliable data exist apart from the gauge in the Blesbokspruit at Heidelberg. The gauge has however only 4 years of data with lots of missing data. In this case, it was recommended that the modelled present hydrology was used as the reference hydrology.

Dry Season (August)

Wet Season (February)



Augnatural: Modelled natural hydrology in m³/s

AugpresSc1: Modelled present hydrology (Scenario 1) in m³/s

Figure 18.1 Flow duration graphs for Aug and Feb for the Blesbokspruit at EWR 11

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

- 95%: Representing droughts for both wet and dry months. This would represent 5% on the stress duration graphs.
- 50%: Representing maintenance flows for both wet and dry months. This would represent 50% on the stress duration graphs.
- Any additional points which had specific significance in terms of flow or stress requirements.

18.3 LOW FLOW REQUIREMENTS (IN TERMS OF STRESS)

The integrated stress index is used to identify required stress levels at specific durations for the wet and dry month/season. Specialist motivations for the stresses are provided in Appendix I, Section I2.1 – 2.2.

The fish and macroinvertebrate flow requirements for different Ecological Categories (ECs) are provided in Table 18.1 and Figure 18-2 and 18-3. 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 18-2 and 18-3.

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

PES: Green

REC: Purple

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 requirements

Duration	LSR stress	Integ stress	LIM stress	Integ stress	FDI stress	Integ stress	FINAL* (Integrate d stress)*	FLOW (m ³ /s)
PES: D EcoStatus		FISH: D			MACROINVERTEBRATES: D/E			
DRY SEASON								
5%	4.5	4.5	-2.4	-2.4	0	0	4.5	0.3
50%	3.2	3.2	-2.6	-2.6	-1.5	-1.5	3.2	0.38
70%	0.1	0.2	-2.9	-2.9			0.2	0.759
WET SEASON								
5%	3	3.3	0.46	0.8	-0.5	-0.5	3.3	0.37
20%	0.76	1.4	-0.17	-0.1			1.4	0.5513
50%	-1.3	-3.3	-0.65	-1	-1	-1	-1	1.268
REC: D EcoStatus		FISH: C			MACROINVERTEBRATES: D			
DRY SEASON								
5%	5.8	5.8	-0.3	-0.3	1.5	1.5	5.8	0.23
50%	4.5	4.5	-1.3	-1.5	0	0	4.5	0.3
70%	3.6	3.6	-2.7	-2.7			3.6	0.358
WET SEASON								
5%	3.89	3.89	2.17	3.7	0.5	0.5	3.89	0.338
20%	1.47	1.47	0.77	1.5			1.5	0.51
50%					+1.1	+1.1	+1.1	0.47
70%	-0.5	-0.5	-0.38	-0.3			-0.5	0.95

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

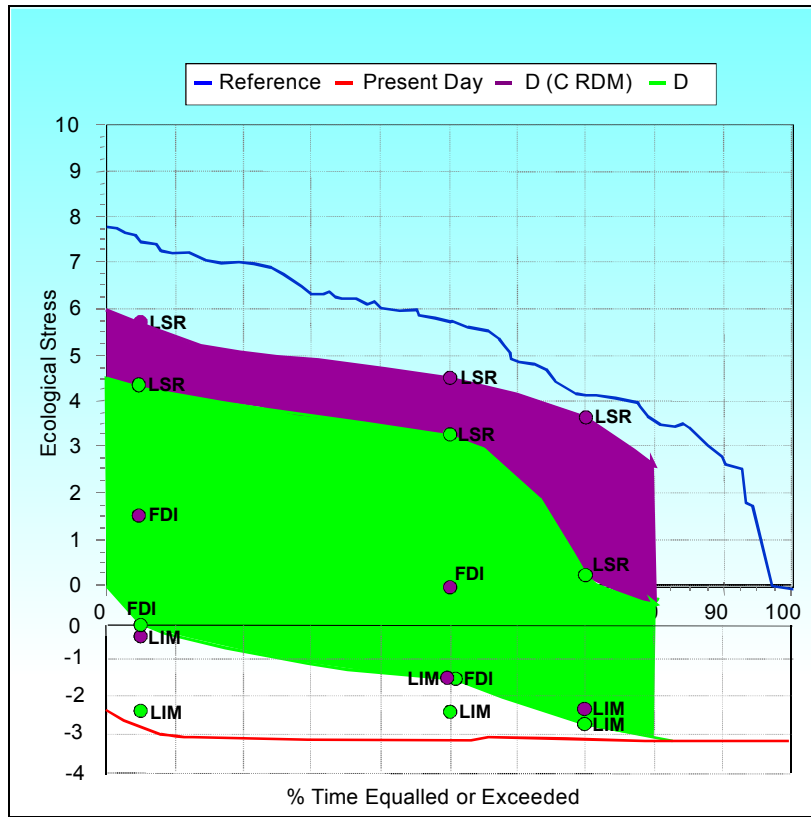


Figure 18.2 EWR 11: Stress Duration Curve for a D PES and REC, D - DRY season

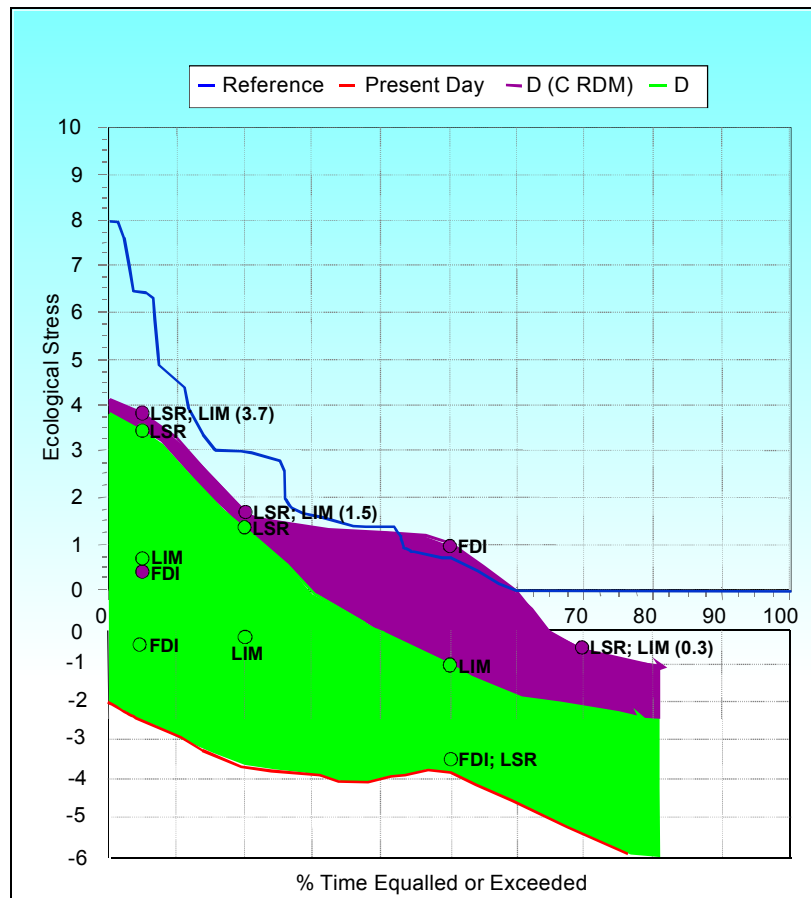


Figure 18.3 EWR 11: Stress Duration Curve for a D PES and REC, D - WET season

Table 18.2 Summary of EWR 11 motivations

Month	% Stress duration	Component stress	Integrated stress	Flow m ³ /s	Comment
PES: D EcoStatus		FISH: D		MACROINVERTEBRATES: D/E	
Aug	5% drought	4.5 LSR	4.5	0.3	Presence of 204% of the habitats that can be expected under natural conditions. It is estimated that it would maintain this guild in its PES during drought periods.
	50% maintenance	3.2 LSR	3.2	0.38	The total habitat suitability would be 129% of what can be expected under natural conditions. The habitat composition at the site is higher than expected during natural conditions as a result of flows still being higher than under natural conditions. It is estimated that fish would remain in the PES at this fish stress level. Although more suitable habitats will therefore be available, any shift from natural conditions will result in a negative impact on the ecological integrity of the system. This will be the result of habitat deterioration through scouring and flooding, change in natural habitat composition at the site, altered food webs and population structures, etc.
Feb	5% drought	3 LSR	3.3	0.379	Presence of 162% of the habitats that can be expected under natural conditions, and it is estimated that it would maintain this guild in its PES during drought periods.
	50% maintenance	-1 FDI	-1.1	1.268	Average depth needed for wet season maintenance is between 0.19 m, and average current velocity is 0.37 m/s. Critical habitat (FCS) comprises 19% of habitats available.
REC: D EcoStatus		FISH: C		MACROINVERTEBRATES: D	
Aug	5% drought	5.8 LSR	5.8	0.23	Flows will ensure enough habitat that it would maintain this guild in its PES during drought periods.
	50% maintenance	4.5 LSR	4.5	0.3	The total habitat suitability would be 126% of what can be expected under natural conditions. Although more suitable habitats will therefore be available, any shift from natural conditions will result in a negative impact on the ecological integrity. This will be the result of habitat deterioration, change in food webs and population structures, etc.
Feb	5% drought	3.89 LSR	3.89	0.31	Flows will ensure enough habitat that it would maintain this guild in its PES during drought periods.
	50% maintenance	1.1 FDI	1.1	0.47	Average depth needed for wet season maintenance is between 0.19 and 0.25 m, and average current velocity is 0.37 and 0.5 m/s. Critical habitats (FCS) comprise between 16 and 19% of habitats available.

1 See Chapter 3, Table 3.2.

The above flows were checked by the riparian vegetation specialist to ensure that these requirements are adequate to achieve the EC in which the marginal vegetation should be, as well as any other flow dependant vegetation that could occur.

The vegetation indicators used were *Persecaria* spp. and *T. capensis*. The resulting conditions of the vegetation indicators to the required low flows are described below. In conclusion, the low flows would maintain the PES and REC of the riparian vegetation (Table 18.3).

Table 18.3 Verification of the low flow requirements to maintain the vegetation EC

PES: RIPARIAN VEGETATION EC D (ECOSTATUS D)
<p>Dry Season drought Similar to dry season base flow, and vegetation should survive these periods.</p> <p>Dry Season maintenance Similar flows to wet season drought. Large scale survival of marginal and lower zone vegetation ensured.</p> <p>Wet Season drought No inundation of any marginal zone vegetation, but flow is sufficient to ensure the survival of most individuals (upper limit of <i>T. capensis</i> and <i>Persecaria</i> spp. at 30 and 55 cm above water level respectively). Flower and fruit abortion will occur.</p> <p>Wet Season maintenance Marginal zone about 50% inundated, with lower limits of <i>Typha capensis</i> and <i>Persecaria</i> spp. inundated to about 20 cm. This is sufficient as a base flow to maintain marginal and lower zone riparian obligates.</p>
REC: RIPARIAN VEGETATION EC: D (ECOSTATUS D)
<p>Dry Season maintenance No inundation of any marginal zone vegetation, but flow is sufficient to ensure the survival of most individuals (upper limit of <i>T. capensis</i> and <i>Persecaria</i> spp. at 35 and 57 cm above water level respectively).</p> <p>Wet Season maintenance Reduced flow not sufficient to inundate marginal zone, but will ensure survival of riparian obligates. Lower zone likely to expand and marginal zone shrink.</p>

18.3.1 Final low flow requirements

To produce the final results, the DRM results for the specific category are modified according to specialists' requirements (Figure 18.3 and 18.4). 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 changes for PES D (DRM D) and REC D (DRM C):
 - o Shape values: 5 for Jan, Feb and Mar. Other months were set at 6.
 - o All upper shift values were set at 98% for all months.
- Manual editing had to be used to achieve a result.

18.4 HIGH FLOW REQUIREMENTS

The high flow classes are identified as follows:

- The geomorphologist and riparian vegetation specialist identify the range of flood classes required and list the functions of each flood.
- The instream specialists then indicate which of the instream flooding functions are addressed by the floods identified for geomorphology and riparian vegetation (indicated by a ✓ in Table 18.4).
- Any of the floods required by the instream biota and not addressed by the floods already identified, must then be described (in terms of ranges and functions) for the instream biota.

No floods could be motivated for the maintenance of the geomorphological condition at EWR 11. Due to increased flows (increased baseflows due to mine dewatering and increased floods due to the urbanizing catchment), the river is eroding and the channel is now wider and deeper than the reference condition. The incision and widening of the channel has eroded any morphological cues

from the site and the reach. To maintain or improve the geomorphological condition at this site will require better management of the baseflows – i.e. reduced baseflows if possible.

Results are provided in Table 18.4 and detailed motivations provided in Table 18.5.

Table 18.4 Identification of instream functions addressed by the identified floods for riparian vegetation

FLOOD CLASS	FLOOD RANGE (m ³ /s)	RIPARIAN VEGETATION MOTIVATION	Fish flood functions					Macroinvertebrate flood functions			
			Migration cues and spawning	Migration habitat (depth etc.)	Clean spawning substrate	Create nursery areas	Resetting water quality	Inundate vegetation for spawning	Breeding and hatching cues	Clear fines	Scour substrate
I	4 - 6	Inundates marginal zone and <i>Persecaria</i> population. Inundates <i>P. australis</i> and <i>T. capensis</i> lower limits to 50 cm at least, which will prevent in-channel migration.	√	√	√	√	√	√	√	√	√
II	8 - 10	Inundates the lower zone and <i>T. capensis</i> and <i>P. australis</i> populations completely.	√	√	√	√	√	√	√	√	√
III	17 - 25	Inundates the lower zone and lower portions of the upper zone. Activates <i>Cyperus hexamita</i> and <i>M. junceus</i> populations and floods <i>C. bulbisperrum</i> (triggers flowering).	√	√	√	√	√				

Further information is provided in Appendix I, Table I11.

The number of high flow events required for each EC is provided in Table 18.5. Limited (4 year record) of observed daily data was available to check flood requirements against.

Table 18.5 EWR 10: The recommended number of high flow events required

FLOOD CLASS	FLOOD RANGE (m ³ /s)	INVERTEBRATES	FISH	VEGETATION	GEOMORPHOLOGY	FINAL (Frequency)	MONTHS	DAILY AVERAGE	DURATION
PES and REC SCENARIO: D									
I	4 - 6			3:1		3	Dec, Jan, Feb	3	3
II	8 - 10			2:1		2	Jan, Mar	6	4
III	17 - 25			1		1	Feb	12	4

18.5 FINAL FLOW REQUIREMENTS

The low and high flows were combined to produce the final flow requirements for the D and the C ECs as:

- An EWR table, which shows the results of high flows and low flows for each month separately (Table 18.6 – 18.7). Floods with a frequency higher than 1:1 is not included.

- The EWR rule table, which provides the EWR recommended flows as a duration table, showing flows that should be provided when linked to a natural trigger (natural hydrology). An EWR rule table is supplied for the low flows only, and for low and high flows combined (Appendix I, Section I2.4).

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

Table 18.6 EWR table for PES: D

Desktop version:		2	Present Day MAR (MCM)	100.691
			Virgin MAR (MAR)	29.136
BFI	0.706	Distribution type		Vaal
MONTH	LOW FLOWS		HIGH FLOWS	
	Maintenance (m ³ /s)	Drought (m ³ /s)	Daily average (m ³ /s) on top of base flow	Duration (days)
OCTOBER	0.210	0.034		
NOVEMBER	0.310	0.300		
DECEMBER	0.400	0.300	3	3
JANUARY	0.540	0.340	3 6	3 4
FEBRUARY	0.600	0.370	3 12	3 4
MARCH	0.550	0.340	6	4
APRIL	0.540	0.340		
MAY	0.490	0.320		
JUNE	0.400	0.300		
JULY	0.310	0.300		
AUGUST	0.210	0.300		
SEPTEMBER	0.210	0.300		
TOTAL MCM	12.494	9.289	5.77	
% OF PD	12.41	9.23	5.73	
% OF VIRGIN	42.88	31.88	19.80	

Table 18.7 EWR table for REC: D (C DRM)

Desktop version:		2	Present Day MAR (MCM)	100.691
			Virgin MAR (MAR)	29.136
BFI	0.706	Distribution type		Vaal
MONTH	LOW FLOWS		HIGH FLOWS	
	Maintenance (m ³ /s)	Drought (m ³ /s)	Daily average (m ³ /s) on top of base flow	Duration (days)
OCTOBER	0.25	0.026		
NOVEMBER	0.35	0.224		
DECEMBER	0.45	0.236	3	3
JANUARY	0.61	0.267	3 6	3 4
FEBRUARY	0.69	0.299	3 12	3 4
MARCH	0.62	0.267	6	4
APRIL	0.6	0.264		
MAY	0.55	0.25		
JUNE	0.45	0.237		
JULY	0.35	0.227		
AUGUST	0.25	0.22		
SEPTEMBER	0.25	0.216		
TOTAL MCM	14.196	7.161	5.77	
% OF PD	14.10	7.11	5.73	
% OF VIRGIN	48.72	24.58	19.80	

A comparison between the differences in terms of percentages of PD of the various types of flow blocks are provided in Table 18.8.

Table 18.8 Modifications made to the DRM for EWR 11

Changes	PES D (DRM D)		REC D (DRM C)	
	DRM	EWR	DRM	EWR
MLIFR - Maintenance low flow	11.7%	12.4%	20.9%	14.1%
DLIFR - Drought low flow	10.8%	9.2%	10.8%	7.1%
MHIFR - Maintenance high flow	5.3%	5.7%	6.2%	5.7%
Long-term % of PD MAR	20.6%	25.9%	22.6%	21.2%

19 EWR 1: UITKOMS (VAAL RIVER) - DETERMINATION OF STRESS INDICES

NOTE: All supporting specialist information for EWR 1 is summarized in Volume 2, Appendix J.

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

19.1 INDICATOR SPECIES OR GROUP

19.1.1 Fish indicator group 1: Large semi-rheophilic species (BAEN, BKIM)

Indicator species: *Labeobarbus aeneus* (BAEN) and *Labeobarbus kimberleyensis* (BKIM). Refer to Section 2.1.1 and Appendix B, Table B1.

19.1.2 Fish indicator group 2: Small semi-rheophilic species (BANO)

Indicator species: *Barbus anoplus* (BANO). Refer to Section 2.1.1 and Appendix B, Table B2.

19.1.3 Macroinvertebrate indicator taxa

Indicator taxa: Hydropsychid caddisflies and Simuliidae. Refer to Section 2.1.3.

19.1.4 Riparian vegetation indicator species

Indicator species included:

- *C. marginatus*, *G. virgatum* and *M. junceus*: Refer to section 2.1.4.
- *C. bulbispermum*: Refer to section 10.1.4.

19.2 STRESS FLOW INDEX

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

19.2.1 Habitat response

Habitat response is used to derive the biota's response to provide a biota stress index and represents the instantaneous response of habitat to flow changes, based on a site specific 0 – 10 scale for instream biota where:

- 0 – Optimum habitat (fixed at the natural maximum baseflow – calculated using the wettest flow month discharge at the maintenance % of 50 – 60% for the Vaal River at the EWR site).
- 10 - No flow (i.e., there can still be surface water in pools).

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

- 0 = Velocity - depth class is absent under the specific flow condition.
- 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 and FDI in Appendix J, Table J5.

19.2.2 Biota response

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

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

The fish species response index is calculated using the fish habitat rating (cf Section 2.2.1) (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).

19.2.3 Integrated stress curve

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

The shaded species stress discharges in Table 19.1 indicate the discharges 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 19.1 illustrates this graphically.

In this specific case, the SSR fish stress index represents the integrated stress index (these values are the highest flow for a stress) for stress 0 - 6, therefore the red curve (representing the SSR stress index) is lying 'beneath' the integrated stress line (black) (Figure 19.1).

Table 19.1 Species stress discharges used to determine biotic stress

Stress	Flow (m ³ /s)			Integrated Flow (m ³ /s)
	SSR	LSR	FDI	
0	10	7	5.5	10
1	8	6.5	3.16	8
2	5.5	5.5	2.13	5.5
3	4.8	4.25	1.87	4.8
4	3	3	1.61	3
5	2.2	2.2	1.02	2.2
6	0.98	0.98	0.832	0.98
7	0.6	0.79	0.645	0.79
8	0.4	0.6	0.457	0.6
9	0.1	0.25	0.27	0.27
10	0	0	0	0

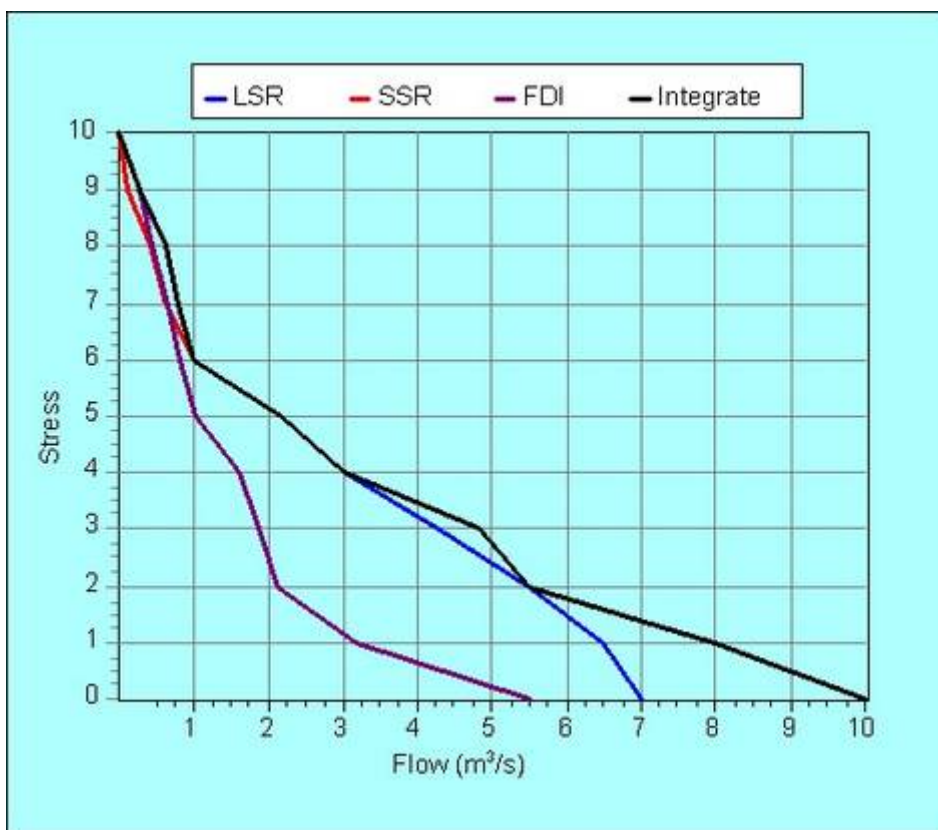


Figure 19.1 Component and integrated stress curves for EWR 1

Table 19.2 provides the summarised biotic response for the integrated stresses.

Table 19.2 Integrated stress and summarised habitat/biotic responses

Integrated stress	Flow m ³ /s	Habitat and/or Biotic responses
0 (SSR)	10	Fish guild: All habitats optimal (5 ⁺). All FDI habitats in excess and macroinvertebrates very abundant and healthy.
1 (SSR)	8	As above with minor decrease in habitat availability

Integrated stress	Flow m ³ /s	Habitat and/or Biotic responses
2 (SSR)	5.5	SSR guild: Spawning and nursery habitats are very rare (0.5) while rest of habitats is optimal. LSR guild: All habitats are good (4) with optimal water quality. Critical FDI habitat sufficient. All flow dependent macroinvertebrates very abundant and healthy.
3 (SSR)	4.8	SSR guild: Good cover and abundance, very rare spawning and nursery habitats while abundance and water quality is still optimal. LSR guild: Spawning and nursery habitat is moderate (3), while other habitats are good with optimal water quality.
4 (SSR)	3	SSR guild: As above although cover and abundance is moderate. LSR guild: All habitats are moderate with good water quality. Reduced FDI critical habitat. 90 % rheophilic species persist.
5 (SSR)	2.2	SSR guild: Spawning and nursery habitat is very rare, while cover and abundance is low (2). Abundance and water quality is good – optimal. LSR guild: All habitat occurrences are low with good water quality. Critical FDI habitat limited. Most rheophilic species persist, but slight (80 %) reduction.
6 (SSR)	0.98	SSR guild: Cover and connectivity is very low (1). Abundance is moderate and water quality is good. LSR guild: Abundance and connectivity is low, while spawning, nursery and cover is very low. Critical FDI habitat residual. Critical life-stages of sensitive rheophilic species at risk or non-viable.
7 (LSR)	0.79	
8 (LSR)	0.6	SSR guild: Spawning, nursery and cover is very rare, abundance moderate and the rest of the habitats are low – very low. LSR guild: Spawning and nursery habitats are very rare while rest of habitats is very low.
9 (FDI)	0.27	SSR guild: Cover is absent and spawning, nursery and connectivity is very rare. Abundance and water quality is low – very low. LSR guild: Most habitats are very rare and spawning and nursery habitats are absent. FDI: No critical habitat. Mostly pool dwellers; all life stages of most rheophilic species non-viable.
10	0	Only pool dwelling species present. Only hyporheic refugia, no surface water for FDIs. Indicator taxa no longer present.

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

20 EWR 1: UITKOMS (VAAL RIVER) - DETERMINATION OF EWR SCENARIOS

20.1 ECOCLASSIFICATION SUMMARY OF EWR 1

EWR 1 Uitkoms (Vaal River)																																																						
<p>EIS: HIGH Presence of rare and endangered <i>Labeobarbus kimberleyensis</i> and diversity of habitat.</p> <p>PES: B/C Combination of flow and non-flow related impacts. Flow related impacts are mainly due to interbasin transfers (Heysope and Zaaihoek). Mining and agricultural activities in area has caused water quality deterioration and erosion.</p> <p>REC: B/C The EIS at EWR 1 is HIGH and the PES warrants an improvement. An improvement in the PES EcoStatus would mean that fish and macroinvertebrates must improve from a C to a B EC. No improvement in riparian vegetation is needed as the current EC is an A/B. An improvement in the biotic component EC is dependent on water quality changes and not flow related issues. It seems that the water quality at this site is problematic as the fish show signs of serious bacterial infection and quality sensitive macroinvertebrates are absent. Diatoms also indicate that water quality is impaired; however, it is not certain what the water quality problems are. To improve the EC therefore, the water quality problems must be identified to determine how it can be addressed. As no improvement in flow is required, no EWR for the REC will be undertaken.</p> <p>AEC down 1: C A hydrological regime with increased base flows for longer periods of time in the winter (longer than present transfer) as well as fluctuations in temperature.</p> <p>AEC down 2: C A hydrological regime with decreased base flows below natural (no transfers) with potential for some low flows. Decreased moderate floods. Deteriorated water quality due to increased impacts of mining.</p>	<table border="1"> <thead> <tr> <th>Driver Components</th> <th>PES and REC Category</th> <th>Trend</th> <th>AEC₁</th> <th>AEC₂</th> </tr> </thead> <tbody> <tr> <td>HYDROLOGY</td> <td>C</td> <td></td> <td></td> <td></td> </tr> <tr> <td>WATER QUALITY</td> <td>C</td> <td>Stable</td> <td>C</td> <td>C</td> </tr> <tr> <td>GEOMORPHOLOGY</td> <td>B/C</td> <td>Negative</td> <td>C</td> <td>C</td> </tr> <tr> <th>Response Components</th> <th>PES Category</th> <th>Trend</th> <th>AEC₁</th> <th>AEC₂</th> </tr> <tr> <td>FISH</td> <td>C (B)</td> <td>Negative</td> <td>D</td> <td>D</td> </tr> <tr> <td>MACRO INVERTEBRATES</td> <td>C (B)</td> <td>Stable</td> <td>C</td> <td>D</td> </tr> <tr> <td>INSTREAM</td> <td>C</td> <td></td> <td>C</td> <td>D</td> </tr> <tr> <td>RIPARIAN VEGETATION</td> <td>A/B</td> <td>Stable</td> <td>B/C</td> <td>B/C</td> </tr> <tr> <td>ECOSTATUS</td> <td>B/C (B)</td> <td></td> <td>C</td> <td>C</td> </tr> </tbody> </table>	Driver Components	PES and REC Category	Trend	AEC ₁	AEC ₂	HYDROLOGY	C				WATER QUALITY	C	Stable	C	C	GEOMORPHOLOGY	B/C	Negative	C	C	Response Components	PES Category	Trend	AEC ₁	AEC ₂	FISH	C (B)	Negative	D	D	MACRO INVERTEBRATES	C (B)	Stable	C	D	INSTREAM	C		C	D	RIPARIAN VEGETATION	A/B	Stable	B/C	B/C	ECOSTATUS	B/C (B)		C	C	<p>Note: Categories in red relates to a REC based on water quality improvements.</p>		
	Driver Components	PES and REC Category	Trend	AEC ₁	AEC ₂																																																	
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	INSTREAM	C		C	D																																																	
	RIPARIAN VEGETATION	A/B	Stable	B/C	B/C																																																	
ECOSTATUS	B/C (B)		C	C																																																		

The present day flows are representative of a PES of a B/C EC. Due to the negative trend, the PES could degrade to a C EC. To address the negative trajectory and maintain the PES and REC, the flows that are presently higher than natural must decrease. The B/C requirements are representative of this scenario. It must be noted that the assumption is that water quality will not degrade with decreased flows.

Flows were not recommended for the AEC down 2 as the decreased low flows below natural is an extremely unlikely scenario as it would require a large volume to be removed from present day. AEC down 1 (increased flows above present day during the dry season) was also not evaluated as a EWR rule cannot be generated due to the flows being higher than the reference hydrology. If an operational scenario is provided that reflects flows more than the present day flow, the ecological consequences and resulting EC can be determined using the existing hydraulic and stress information.

20.2 HYDROLOGY

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

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

- 45%: Representing maintenance flows for both wet and dry months. This would represent 55% on the stress duration graphs.
- Any additional points which had specific significance in terms of flow or stress requirements.

20.3 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.

The fish and macroinvertebrate flow requirements for different Ecological Categories (ECs) are provided in Table 20.1 and Figure 20.1 and 20.2. 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 20.1 and 20.2.

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

PES and REC: **Purple**

Summarised motivations for the final requirements are provided in Table 20.2.

Table 20.1 Species and integrates stress requirements as well as the final integrated stress and flow requirements

Duration	LSR stress	Integ stress	SSR stress	Integ stress	FDI stress	Integ. stress	FINAL* (Integrated stress)*	FLOW (m ³ /s)
PES and REC: B/C EcoStatus			FISH: C			MACROINVERTEBRATES: C		
DRY SEASON								
5%	9.1	9.1	10	10	8	8.8	8.8	0.336
20%	8.2	8.2					8.2	0.534
55%	4.5	4.5	6.2	6.5	6	7	4.5	2.6
WET SEASON								
5%	5.2	5.2	7	8.2	7	8	5.2	1.956
55%	2	2	3.5	3.5	2	5.1	2	5.5

* Final refers to the final stress selected as the EWR requirement, i.e. the lowest integrated stress.

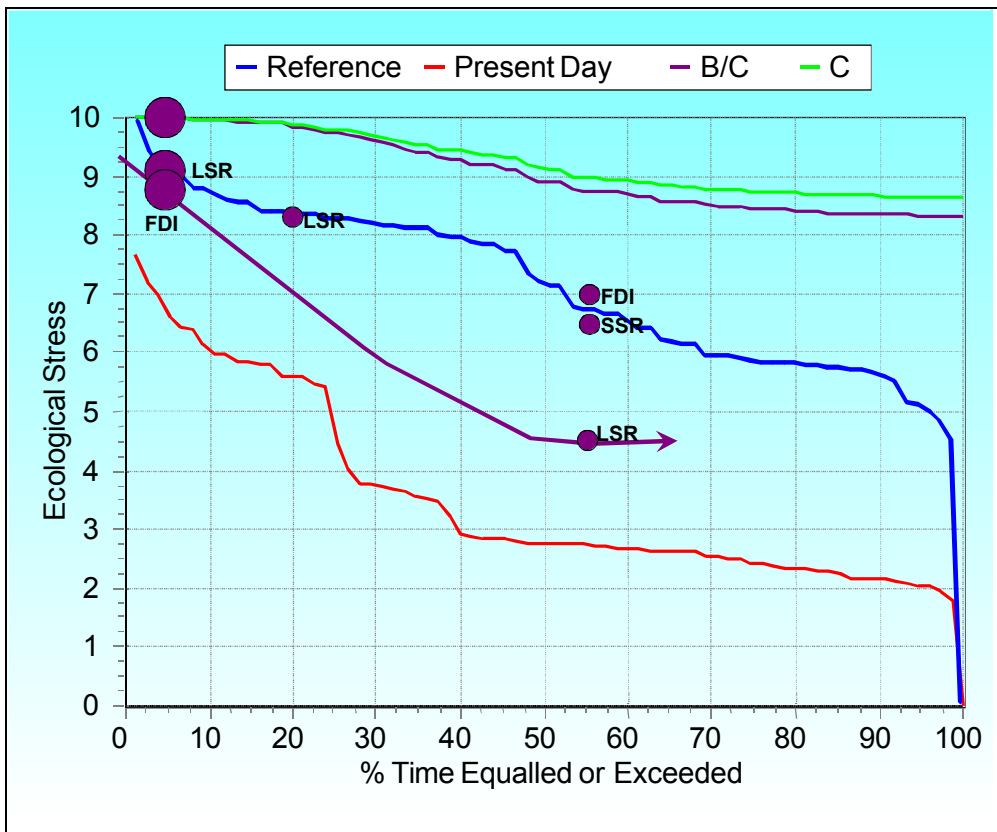


Figure 20.1 EWR 1: Stress Duration Curve for a B/C PES and REC, and C AEC - DRY season

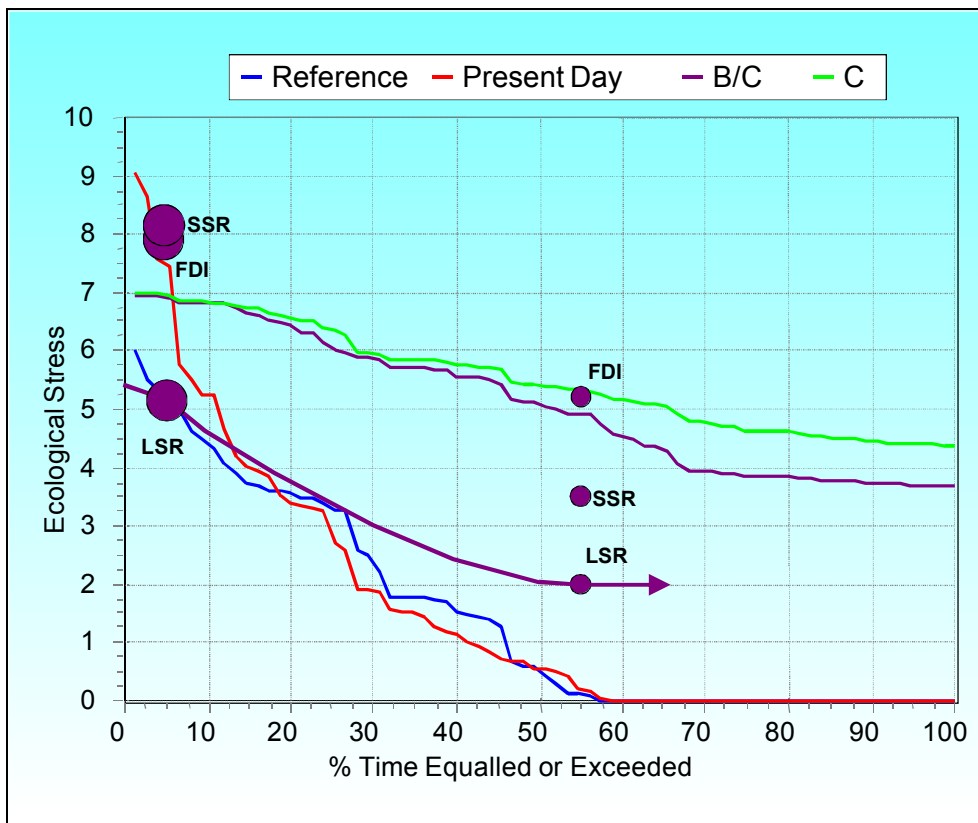


Figure 20.2 EWR 1: Stress Duration Curve for a B/C PES and REC, and C AEC - WET season

Table 20.2 Summary of EWR 1 motivations

Month	% Stress duration	Component stress	Integrated stress	Flow m ³ /s	Comment*
PES and REC: B/C EcoStatus		FISH: C		MACROINVERTEBRATES: C	
Aug	5% drought	8.8 FDI	8.8	0.336	Flows will provide an average depth of 0.16 m and flow of 0.10 m/s to ensure the survival of FDI taxa.
	35% maintenance	4.5 LSR	4.5	2.6	Adequate FS habitat for juveniles and SD habitat for adults to ensure survival during winter.
Feb	5% drought	5.2 LSR	5.2	1.956	Some critical FS habitats should be available for a period to enable spawning, egg and larvae development. Some FS and adequate SD habitats should then be maintained for the survival of juveniles and adults during this period.
	35% maintenance	2 LSR	2	5.5	Suitable FS and FD habitat to ensure spawning and development of all life stages. Adequate SD habitat for refuge of juveniles.

* See Chapter 3, Table 3.2.

The above flows were checked by the riparian vegetation specialist to ensure that these requirements are adequate to achieve the EC in which the marginal vegetation should be, as well as any other flow dependant vegetation that could occur.

The vegetation indicators used were *C. marginatus* and *Gomphostigma* species. The resulting conditions of the vegetation indicators to the required low flows are described below. In conclusion, the low flows would maintain the PES and REC of the riparian vegetation.

PES and REC: RIPARIAN VEGETATION EC A/B (ECOSTATUS B/C)
<p>Dry Season maintenance <i>C. marginatus</i> rhizome level remains activated for survival. The water level of 0.34 m is below <i>Gomphostigma</i> rooting level.</p> <p>Dry Season drought Flows are sufficient to inundate the lower limits of <i>C. marginatus</i> rhizomes on the marginal zone, and to facilitate the survival of <i>Gomphostigma</i>.</p> <p>Wet Season maintenance Inundates about 50% marginal zone and activates <i>Gomphostigma</i>.</p> <p>Wet Season drought Flows are sufficient to inundate the lower limits of <i>C. marginatus</i> rhizomes on the marginal zone, and facilitate the survival of <i>Gomphostigma</i> (0.13 m below root level).</p>

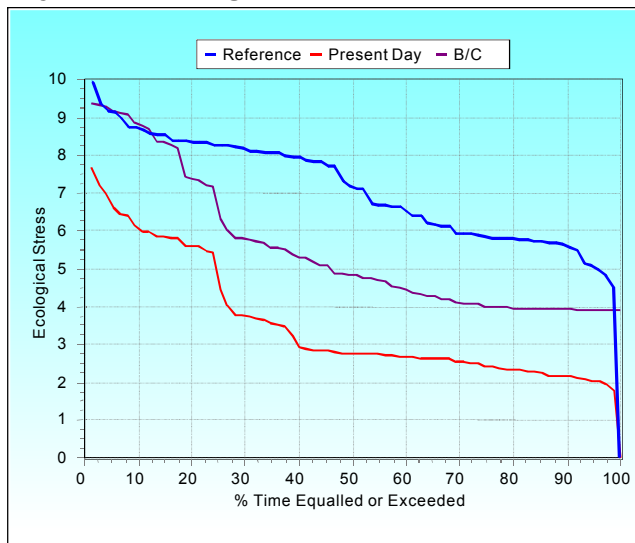
20.3.1 Final low flow requirements

To produce the final results (Figure 20.3), the DRM results for the specific category are modified according to specialists’ requirements (Figure 20.1 and 20.2). 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 rules for B/C
 - 0 Assurance rules: Shape parameters: Feb - Changed from a 9 to 6; Aug – Changed from 8 to 7.
 - 0 Assurance rules: Upper shift values were changed to 100% for all months.

- B/C EC – Present day was used as reference.
 - 0 Distribution factors: 0.3 for maintenance; 0.75 for drought.
 - 0 Other flows were edited to match.

Dry Season (August)



Wet Season (February)

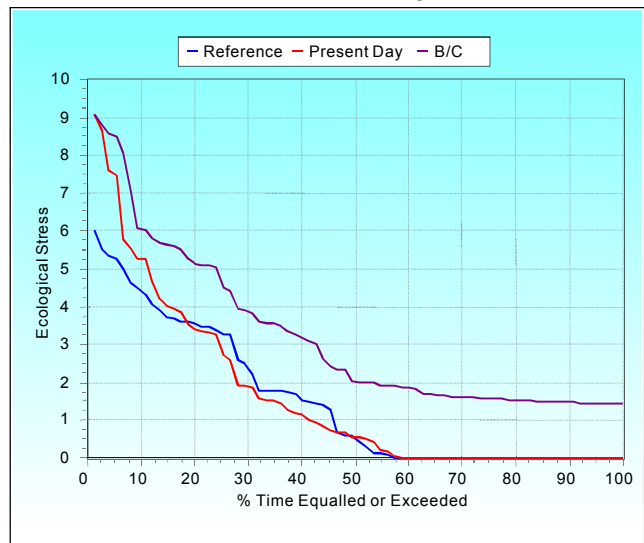


Figure 20.3 EWR 1: Final stress requirements for low flows

20.4 HIGH FLOW REQUIREMENTS

The high flow classes are identified as follows:

- The geomorphologist and riparian vegetation specialist identify the range of flood classes required and list the functions of each flood.
- The instream specialists then indicate which of the instream flooding functions are addressed by the floods identified for geomorphology and riparian vegetation (indicated by a ✓ in Table 20.3).
- Any of the floods required by the instream biota and not addressed by the floods already identified, must then be described (in terms of ranges and functions) for the instream biota.

Results are provided in Table 20.3 and detailed motivations provided in Table 20.4.

Table 20.3 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 cues	Spawning substrate	Create nursery areas	Resetting water quality	Inundate vegetation for spawning	Breeding and hatching cues	Clear fines	Scour substrate	Reach or inundate specific areas	Reset water quality
I	8 - 10	Vegetation: Maintains sedges.		✓	✓	✓	✓	✓	✓		✓			
II	15 - 35	Geomorphology: Activates gravels, moves fines. Vegetation: Activates lower portion of grassland.	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
III	50 - 120	Geomorphology: Critical to move fines, activates gravels. Vegetation: Activates lower portion of grassland.	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
IV	200 - 340	Geomorphology: Moves > 50% gravels. Vegetation: Activates upper portion of grassland.	✓	✓		✓		✓	✓					
V	420	Geomorphology: Moves > 10 cm cobbles. Vegetation: Activates macro channel bank shrub layer.	✓			✓		✓	✓					

Further information is provided in Appendix J, Table J11.

The number of high flow events required for each EC is provided in Table 20.4. No observed daily data was available to check flood requirements against.

Table 20.4 EWR 1: The recommended number of high flow events required

FLOOD CLASS	FLOOD RANGE (m ³ /s)	INVERTEBRATES ¹	FISH	VEGETATION	GEOMORPHOLOGY	FINAL (Frequency)	MONTHS	DAILY AVERAGE	DURATION
PES and REC SCENARIO: B/C									
I	8 - 10	5		4		5	Nov, Dec, Jan, Feb, Mar	6	3
II	15 - 35	3	3	2	2	3	Nov, Dec, Feb	18	5
III	50 - 120			1 - 1:2	1 - 1:2	1 - 1:2	Jan	60	5
IV	200 - 340			1:3 - 1:4	1:3 - 1:4	1:3 - 1:4	Wet Season		
V	420			1:5	1:5	1:5	Wet Season		

¹ Macroinvertebrates

How the reduced floods would impact on the system is unsure. This reach already experiences very high base flows, but the largely natural floods ameliorate the impacts of the high base flows. Under the AEC, with reduced base flows and reduced floods, it is likely that the geomorphology may change quite quickly.

20.5 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 20.5). Floods with a frequency higher than 1:1 is not included;
- the EWR rule table, which provides the EWR recommended flows as a duration table, showing flows that should be provided when linked to a natural trigger (natural hydrology). An EWR rule table is supplied for the low flows only, and for low and high flows combined (Appendix J, Section J2.4).

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

Table 20.5 EWR table for PES and REC: B/C

Desktop version:		2	Virgin MAR (MCM)	332.3
BFI	0.316	Distribution type		Vaal
MONTH	LOW FLOWS		HIGH FLOWS	
	Maintenance (m ³ /s)	Drought (m ³ /s)	Daily average (m ³ /s) on top of base flow	Duration (days)
OCTOBER	2.900	0.200		
NOVEMBER	3.700	0.220	6 18	3 5
DECEMBER	4.000	0.250	6 18	3 5
JANUARY	4.300	0.260	6 60	3 5
FEBRUARY	5.200	0.265	6 18	3 5
MARCH	3.700	0.040	6	3
APRIL	3.000	0.080		
MAY	2.600	0.030		
JUNE	2.500	0.150		
JULY	2.400	0.150		
AUGUST	2.400	0.150		
SEPTEMBER	2.600	0.160		
TOTAL MCM	102.894	5.115	28.030	
% OF VIRGIN	30.97	1.54	8.44	
Total IFR	130.92			
% of MAR	39.4			

A comparison between the differences in terms of percentages of the various types of flow blocks are provided in Table 20.6.

Table 20.6 Modifications made to the DRM for EWR 1

Changes	PES and REC B/C	
	DRM	EWR
MLIFR - Maintenance low flow	12.8%	35.7%
DLIFR - Drought low flow	2.9%	1.8%
MHIFR - Maintenance high flow	12.2%	9.7%
Long-term % of virgin MAR	20.8%	40.5%

21 EWR 4: DE NEYS (VAAL RIVER) – DETERMINATION OF STRESS INDICES

NOTE: All supporting specialist information for EWR 4 is summarized in Volume 2, Appendix K.

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

21.1 INDICATOR SPECIES OR GROUP

21.1.1 Fish indicator group 1: Large semi-rheophilic species (BAEN, BKIM)

Indicator species: *Labeobarbus aeneus* (BAEN) and *Labeobarbus kimberleyensis* (BKIM). Refer to Section 2.1.1 and Appendix B, Table B1.

21.1.2 Fish indicator group 2: Small limnophilic species (PPHI, TSPA)

Indicator species: *Pseudocrenilabrus philander* (PPHI) and *Tilapia sparrmanii* (TSPA). Refer to Section 15.1.2 and Appendix H, Table H1.

21.1.3 Macroinvertebrate indicator taxa

Indicator taxa: Hydropsychid caddisflies and Simuliidae. Refer to Section 2.1.3.

21.1.4 Riparian vegetation indicator species

Indicator species included:

- *C. marginatus*: Refer to Section 2.1.4.
- *G. virgatum*: Refer to Section 2.1.4.
- *Persecaria* spp.: Refer to section 6.1.4.
- *Salix mucronata*: Refer to section 12.1.4.

21.2 STRESS FLOW INDEX

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

21.2.1 Habitat response

Habitat response is used to derive the biota's response to provide a biota stress index and represents the instantaneous response of habitat to flow changes, based on a site specific (+10) – 0 – (-10) scale for instream biota where:

- +10: No flow (i.e., there can still be surface water in pools).
- 0: Optimum habitat (fixed at the natural maximum baseflow – calculated using the wettest flow month discharge at the maintenance % of 50 – 60% for the Vaal River at the EWR site).

- -10: Habitat at flows above natural maximum baseflow.

The abundance of fish velocity-depth classes are provided in Appendix K, Table K1 and K2.

The instantaneous response of flow dependent invertebrate (FDI) taxa provides the % occurrence of various velocity-substrate classes under different flow conditions are provided in Appendix K, Table K5).

21.2.2 Biota response

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

- +10 = No flow (i.e., there can still be surface water in pools). The biota response will depend on the indicator groups present, i.e. rheophilics will be gone whereas semi-rheophilics will still be present and survive.
- 0 = Optimum habitat with least amount of stress possible for the indicator groups AT THE SITE (fixed at the natural maximum baseflow in the same way as for the habitat response).
- -1 – (-10) = habitat changes resulting in a major change from the natural composition of the assemblage.

The fish species response index is calculated using the fish habitat rating (cf Section 2.2.1) (Appendix K, Table K3 and K4) 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 K, Table K6).

21.2.3 Integrated stress curve

The integrated stress curve is designed as described in Chapter 2, Section 4.2.3. Figure 21.1 and Figure 21.2 illustrates this graphically.

In this specific case, the LSR fish stress index represents the integrated stress index (these values are the highest flow for a stress) for the plus stress 0 – 1 AND 2 - 10, therefore the blue curve (representing the LSR stress index) is lying 'beneath' the integrated stress line (black) (Figure 21.1). On the minus stress scale, the limnophilics (red line) forms the majority of the integrated stress line (Figure 21.2).

Table 21.1 Species stress discharges used to determine biotic stress – Decreased flows

Stress	Flow (m ³ /s)			Integrated Flow (m ³ /s)
	LSR	LIM	FDI	
+10	0	0	0	0
+9	0.5	0.18	0.026	0.5
+8	1	0.36	0.271	1
+7	2.1	0.55	0.387	2.1
+6	3.4	0.73	1.439	3.4
+5	6.1	0.91	3.68	6.1
+4	8.7	1.86	6.61	8.7
+3	12	4.3	9.31	12
+2	15	12	15.21	15.2
+1	18.4	16.6	21.13	21.13
+0	50 (42.5)	50 (35)	50	50

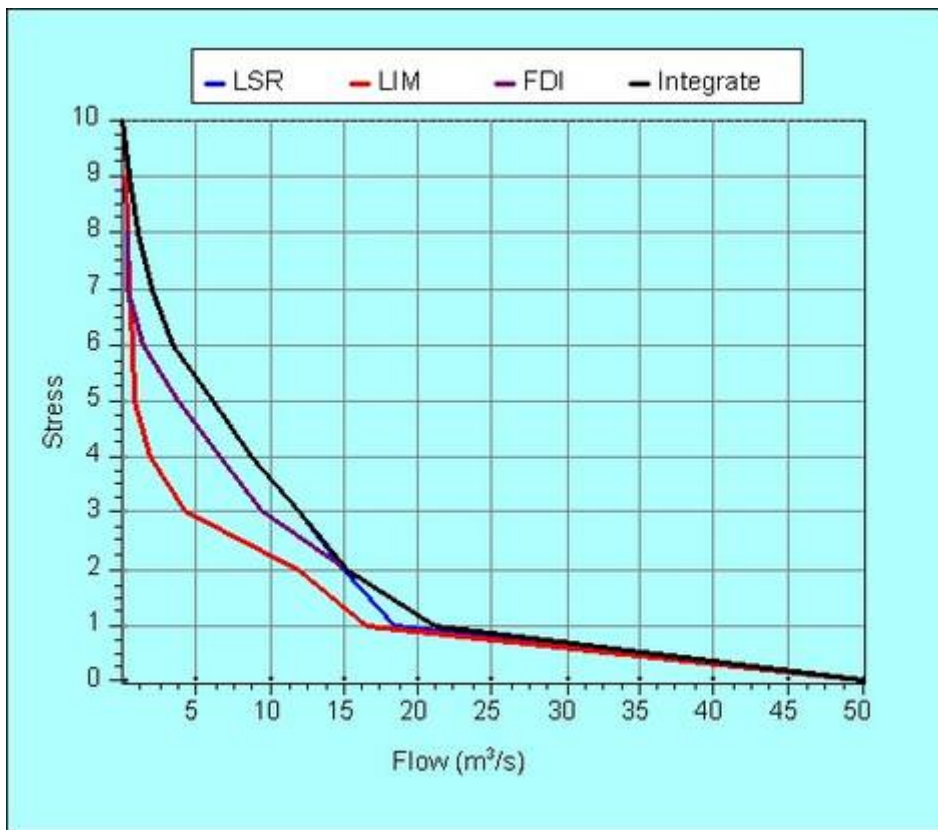


Figure 21.1 Component and integrated stress curves for EWR 4 – Decreased flows

Table 21.2 Species stress discharges used to determine biotic stress – Increased flows

Stress	Flow (m ³ /s)			Integrated Flow (m ³ /s)
	LSR	LIM	FDI	
0	50	50	50	50
-1	66	56	60.8	56
-2	78	62	67	62
-3	90	69	74	69
-4	102	75	81	75
-5	111	78	93	78
-6	121	85	105	85
-7	130	96	119	96
-8	145	112	133	112
-9	164	170	143	143
-10	181	290	154	154

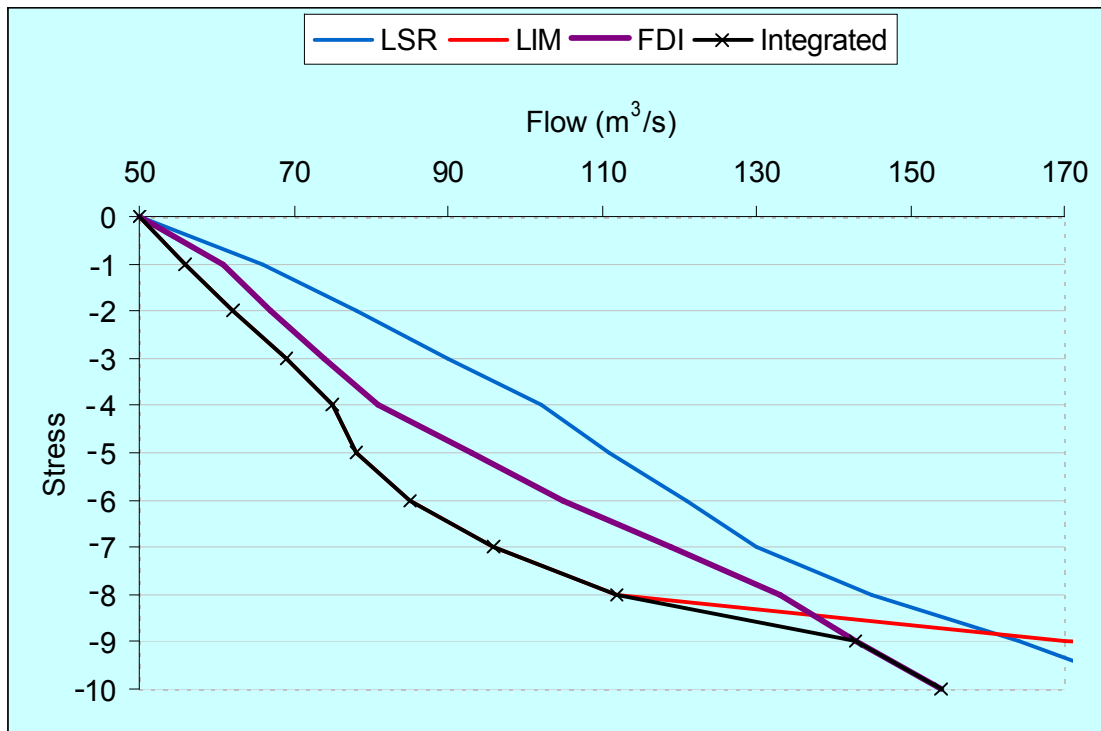


Figure 21.2 Component and integrated stress curves for EWR 4 – Increased flows

Table 21.2 provides the summarised biotic response for the integrated stresses.

Table 21.3 Integrated stress and summarised habitat/biotic responses

Integrated stress	m ³ /s	Habitat and/or Biotic responses
+10	0	Only pool dwelling species present. Only hyporheic refugia, no surface water for FDIs. Indicator taxa no longer present.
+9 (LSR)	0.5	No critical FDI habitat. Some rheophilic species persist, but most disappear. All life stages of sensitive rheophilic species at risk or non-viable.
+8 (LSR)	1	LIM guild: Spawning habitat is very low (1 ⁺) and nursery habitat is low (2.5). The rest of the habitats are moderate (3 – 3.5). LSR guild: Connectivity is very rare (0.5), while the rest of the habitats are very low.
+7 (LSR)	2.1	
+6 (LSR)	3.4	LIM guild: Abundance and cover is good, while spawning habitat is low. Rest of habitats is moderate. LSR guild: Connectivity and water quality is very low while rest of habitats is low. Critical habitat very reduced. Critical life stages of sensitive rheophilic species at risk or non-viable.
+5 (LSR)	6.1	Critical habitats limited. All life stages viable in limited areas, critical life stages of some sensitive rheophilic species at risk.
+4 (LSR)	8.7	Reduced critical FDI habitat. Most rheophilic species persist, but abundances reduced.
+3 (LSR)	12	LIM guild: Spawning habitat is moderate while rest of habitats is good. LSR guild: Nursery habitat is good while rest of habitats is moderate.
+2 (FDI)	15.2	LIM guild: As above, but water quality is optimal. LSR guild: As above but connectivity and water quality is good. Critical FDI habitat sufficient. Most rheophilic species persist, but slight (80 %) reduction.
+1 (FDI)	21.13	LIM guild: All habitats are optimal. LSR guild: Water quality and connectivity is optimal while rest of habitats are good (4.5) All FDI habitat plentiful, high quality. 90 % rheophilic species persist.
0	50	All FDI habitat in excess. All flow dependent macroinvertebrates very abundant and healthy.
-1 (LIM)	56	
-2 (LIM)	62	Fish guild: All habitats are good to optimal (4.5 – 5). All FDI habitats plentiful, high quality.
-3 (LIM)	69	Critical FDI habitats sufficient.
-4 (LIM)	75	LIM guild: Connectivity and water quality is good (4) while rest of habitats are low (2.5). LSR guild: All habitats are good with optimal water quality. Reduced critical FDI habitat.
-5 (LIM)	78	
-6 (LIM)	85	Maximum current speeds stabilize. Average current speeds exceed 0.6 m/s for FDI taxa.
-7 (LIM)	96	LIM guild: Connectivity is moderate and water quality is good. The rest of the habitats are very rare. LSR guild: Connectivity and water quality is good. Cover, abundance and nursery habitat is moderate and nursery habitat is low. Critical FDI habitat reduced.
-8 (LIM)	112	Critical FDI habitat very reduced.
-9 (FDI)	143	Fish guild: Water quality is moderate and connectivity is very low. Rest of the habitats is very rare (0.5). Fast flowing habitats only.
-10 (FDI)	154	Fish guild: Water quality is moderate but all other habitats are very rare. Bank full discharge. Habitats suitable for fast flowing taxa only. Critical habitats limited and high potential for erosion. Residual habitat for slow flowing taxa.

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

22 EWR 4: DE NEYS (VAAL RIVER) – DETERMINATION OF EWR SCENARIOS

22.1 ECOCLASSIFICATION SUMMARY OF EWR 4

The aims at EWR 4 are to improve the PES to an EC that represents the REC. Two scenarios were investigated, i.e. an improved (from PES) EC (i.e. the REC) and an EC lower than the PES.

EWR 4 De Neys (Vaal River)				
<p>EIS: HIGH The presence of the rare and endangered <i>Labeobarbus kimberleyensis</i>. The Vaal River being a large river, which is rare in South Africa. The diversity of riparian and instream habitats which include runs, rocky outcrops and rapids as well as pools. Important refugia such as pools. Being the only area between the Vaal Dam and barrage where yellowfish can breed.</p> <p>PES: C Impacts are mostly due to flow related problems, especially the presence of Vaal Dam and lack of flow variability. Increased base flows (dry season) occur as well as reduced frequencies of moderate floods due to releases from the Vaal Dam to maintain a target TDS concentration of 600 mg/l downstream of Vaal Barrage.</p> <p>REC: B/C Improvement of PES due to HIGH EIS rating. A B EcoStatus could not be attained due to the limited operational possibilities from the Vaal Dam. Scenario includes improvement of seasonal variability (decreased base flows during the dry season and increased wet season flows above the current base flows).</p> <p>AEC Down: D Increased constant base flows if salinity problems are exacerbated leading to a loss of variability. Decreased frequency of floods.</p>				
Driver Components	PES Category	Trend	REC	AEC↓
HYDROLOGY	D/E			
WATER QUALITY	C	Stable	C	C/D
GEOMORPHOLOGY	D	Stable	D	D
Response Components	PES Category	Trend	REC	REC
FISH	C	Stable	B	D
MACRO INVERTEBRATES	C/D	Stable	C	C/D
INSTREAM	C		B/C	D
RIPARIAN VEGETATION	C	Negative	B/C	D
ECOSTATUS	C		B/C	D

These ECs will be achieved as follows:

- PES and REC: The original aim during the EcoClassification process identified that increased variability between seasons and an attempt to modify the seasonal reversal would be required to improve the situation. This implies that the dry season should become dryer (i.e. removing water) and the wet season wetter (increased flows).
- EC lower than the PES: This will be achieved by INCREASING the flows and is scenario-based. Based on the assumption that the increase will be constant during the year, a scenario was assessed where the category will be lower than the PES. Only the dry season was assessed as increased flows in the wet season forms part of the improved scenario. The assumption is that the impact of increased flows during the dry season, which will exacerbate the seasonality problem, will be sufficient to assess the decreased flows.

NOTE: The seasons cannot be evaluated in isolation from each other as seasonality changes are largely responsible for the change in EC.

22.2 HYDROLOGY

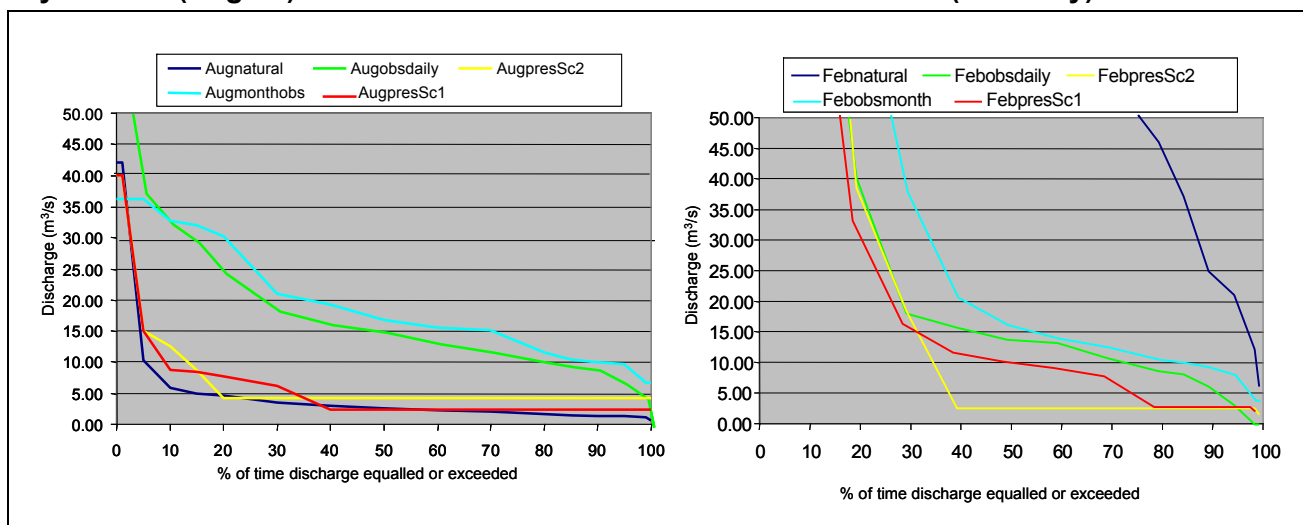
Gauge C2H122 is the nearest gauge to EWR 4 and has a 26 year flow record dating from 1980. The observed data is very good and reflects the actual releases from Vaal Dam. Low flows and zero flows are measured accurately by this gauge.

Simulated present day flows reflect the required releases from Vaal Dam to maintain a target TDS concentration of 600 mg/l downstream of Vaal Barrage. Releases are also made for Sasol’s Sasolburg Complex and Eskom. Under severe drought conditions releases are also made in support of downstream users (e.g. Midvaal and Sedibeng Water) and Bloemhof Dam. In recent analysis, large discrepancies were identified in actual releases made from the dam for dilution purposes.

At the time of the specialist workshop, the simulated present day flows still represented releases from Vaal Dam to maintain target TDS which in reality were not happening. Two versions of present day flows were provided, reflecting different scenarios of maintaining target TDS. The observed hydrology therefore bears no resemblance to both scenarios of present hydrology (especially in the dry season) (Figure 22.1) as both versions (Sc1 and Sc2) of present hydrology are based on preferred system operation. The modelled present day hydrology record is only available up to 1994 with limited overlap with the gauge record.

Dry Season (August)

Wet Season (February)



Augnatural: Modelled natural hydrology in m³/s

AugpresSc2: Modelled present hydrology (Scenario 2) in m³/s

AugpresSc1: Modelled present hydrology (Scenario 1) in m³/s

Augobsdaily: Daily observed flow in m³/s

Augmonthobs: Monthly observed hydrology in m³/s

Figure 22.1 Flow duration graphs showing the various hydrologies for the wet and dry season

The hydrological issues at this site are the following:

- Seasonal reversal has taken place.
- The present day flows are higher than natural during the dry season and vice versa for the wet season.
- No moderate floods occur, only large artificial floods from spills.

Therefore the following conclusions regarding the hydrology at EWR 4 were made:

- Natural hydrology could not be used as reference as the flows set would be more than natural in the dry season.
- Present hydrology could not be used as flows did not represent reality.
- As the observed hydrology represents the only real indication of the flow regime, this hydrology was used as the reference hydrology even though the record was short. As the biota has adapted to the observed hydrology, missing hydrological cycle data was not an issue.
- Both versions of modelled present day hydrology could be assessed as scenarios during the next phase of the project.

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

- 95%: Representing droughts for both wet and dry months. This would represent 5% on the stress duration graphs.
- 50%: Representing maintenance flows for both wet and dry months. This would represent 50% on the stress duration graphs.
- Any additional points which had specific significance in terms of flow or stress requirements.

22.3 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 – 2.2.

The fish and macroinvertebrate flow requirements for different Ecological Categories (ECs) are provided in Table 22.1 and Figure 22.2 and 22.3. The results are plotted for the wet and dry season on stress duration graphs. The stress requirements (as a 'hand drawn line'²) are illustrated in Figures 22.2 and 22.3.

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

PES: Green REC: Purple AEC down: Yellow

Summarised motivations for the final requirements are provided in Table 22.2.

² Note that the hand drawn line represents the fuzzy border (as it is a continuum) between different ECs.

Table 22.1 Species and integrates stress requirements as well as the final integrated stress and flow requirements

Duration	LSR stress	Integ stress	LIM stress	Integ stress	FDI stress	Integ stress	FINAL* (Integrated stress)*	FLOW (m ³ /s)
PES: C EcoStatus FISH: C MACROINVERTEBRATES: C/D								
DRY SEASON								
5%	+4.4	+4	+2.66	+4.8	+4.3	+5.2	+5.2	5.56
50%	+1.9	+1.9	+1.1	+1.9	+2.5	+3	+3	12
90%	+0.6	+0.6	+0.5	+0.6			+0.6	32.66
WET SEASON								
5%	+3.18	+3.18	+2.4	+4.2	+3.5	+4.3	+3.18	11.406
10%	+2.5	+2.5	+2.3	+4.1			+2.5	13.6
20%	+2.14	+2.14	+1.8	+2.5			+2.14	14.76
30%					+0.8	+0.8	+0.8	26.904
REC: B/C EcoStatus FISH: B MACROINVERTEBRATES: C								
DRY SEASON								
5%	+5.31	+5.31	+3	+5.8	+5	+5.8	+5.8	3.93
50%	+2.7	+2.7	+1.8	+2.5	+3	+3.8	+3.8	9.36
90%	+1.3	+1.7	+0.8	+0.9			+0.9	24
WET SEASON								
5%	+2.56	+2.56	+2.3	+4.1	+4	+4.8	+4.8	6.6
10%	+2.0	+2	+2	+3			+2	15.2
20%	+1.3	+1.7	+1.3	+2			+1.7	16.986
50%					+1.3	+1.3	+1.3	19.35
AEC down: D EcoStatus FISH: D MACROINVERTEBRATES: C/D								
DRY SEASON								
5%	+2.42	+2.42	+1.7	+2.6	Increased flows will not change the EC, therefore the same as PES.		+2.6	13.284
50%	+0.5	+0.5	+0.7	+0.8		+0.8	26.904	
90%	+0.06	+0.06	+0.35	+0.3		+0.3	41.33	
WET SEASON								
Although there are more flows than present in the dry season, the wet season remains the same as present and was therefore not assessed.								

* Final refers to the final stress selected as the EWR requirement, i.e. the lowest integrated stress.

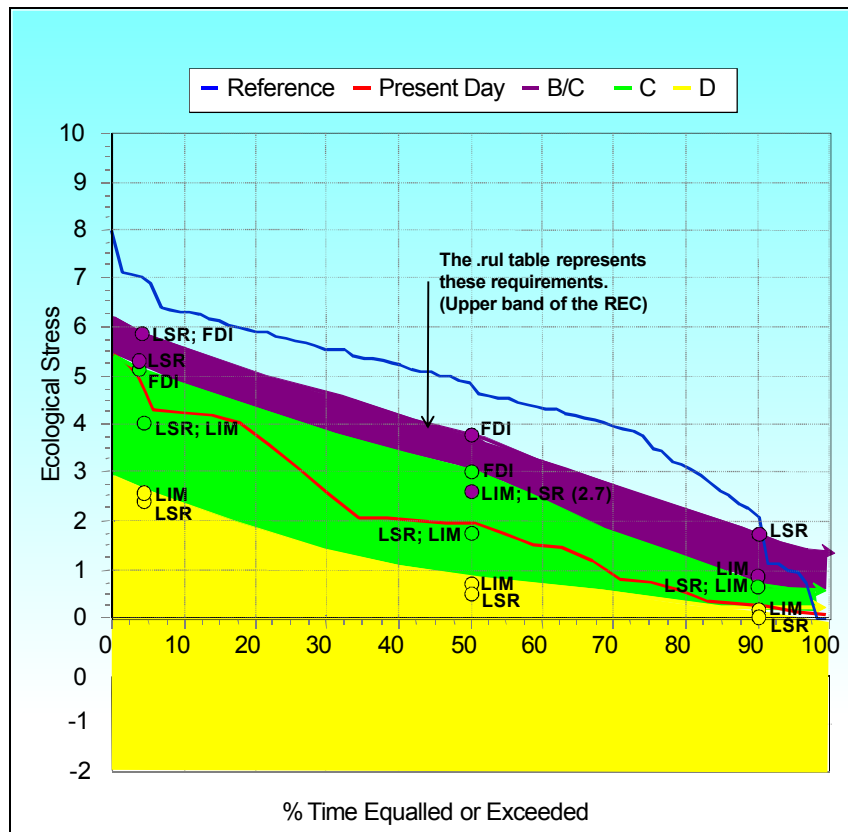


Figure 22.2 EWR 4: Stress Duration Curve for a C PES, B/C REC, and D AEC down - DRY season

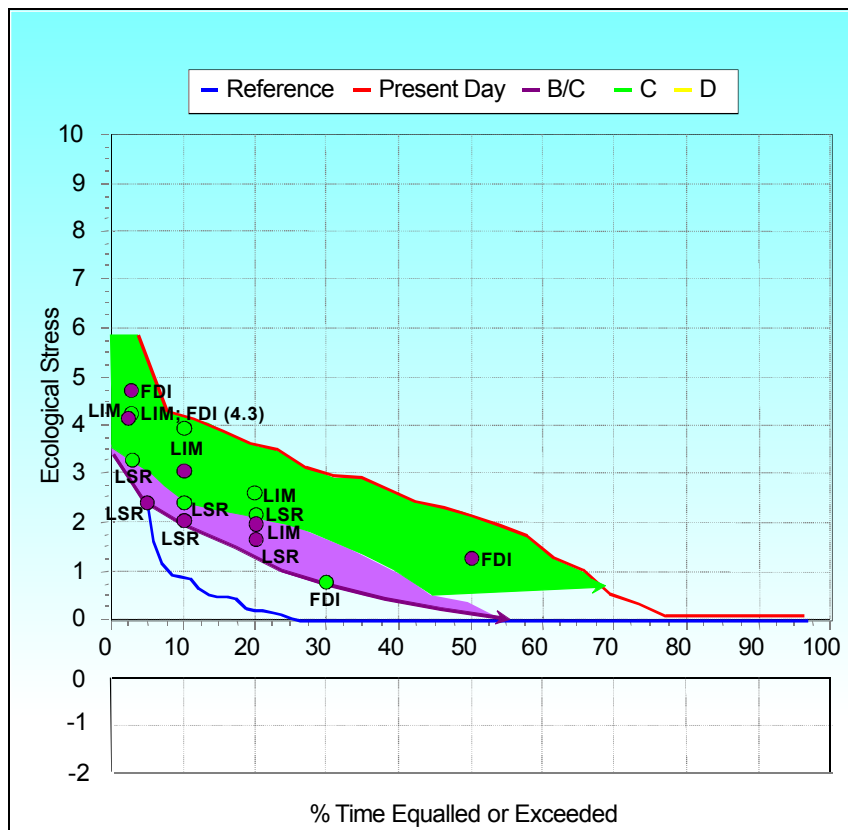


Figure 22.3 Stress Duration Curve for a C PES, B/C REC, and D AEC down - WET season

Table 22.2 Summary of EWR 4 motivations

Month	% Stress duration	Component stress	Integrated stress	Flow m ³ /s	Comment ¹
PES: C EcoStatus		FISH: C		MACROINVERTEBRATES: C/D	
Aug	5% drought	+4.3 FDI	+5.2	5.56	Average depth needed for dry season maintenance is 0.21 m, and average current velocity is 0.3 m/s. At these flows there is very limited very fast flow.
	50% maintenance	+2.5 FDI	+3	12	Average depth needed for dry season maintenance is 0.29 m, and average current velocity is 0.45 m/s.
Feb	5% drought	+3.18 LSR	+3.18	11.406	These flows would enable the maintenance of this fish guild at this site in a category C during the wet season.
	20%	+2.14 LSR	+2.14	14.76	the habitat suitability will be 78% of the expected optimal wet season habitat suitability under natural conditions.
REC: B/C EcoStatus		FISH: B		MACROINVERTEBRATES: C	
Aug	5% drought	+3 FDI	+5.8	3.93	Average depth needed for dry season maintenance is 0.18 m, and average current velocity is 0.26 m/s. At these flows there is very limited very fast flow.
	50% maintenance	+3 FDI	+3.8	9.36	Average depth needed for dry season maintenance is 0.26 m, and average current velocity is 0.42 m/s
Feb	5% drought	+4 FDI	+4.8	6.6	Average depth needed for wet season drought is 0.23 m, and average current velocity is 0.35 m/s.
	50% maintenance	1.3 FDI	1.3	19.35	Average depth needed for wet season maintenance is between 0.37 m, and the average current velocity is 0.52 m/s. A wide range of current speeds and substrate types is available.
AEC down: D EcoStatus		FISH: D		MACROINVERTEBRATES: C/D	
Aug	5% drought	+1.7 LIM	+2.6	13.284	Although more suitable habitats are available, any shift from natural conditions will result in a negative impact on the ecological integrity. This will be the result of habitat deterioration, change in food webs and population structures, etc.
	50% maintenance	+0.7 LIM	+0.8	26.904	

¹ See Chapter 3, Table 3.2.

The above flows were checked by the riparian vegetation specialist to ensure that these requirements are adequate to achieve the EC in which the marginal vegetation should be, as well as any other flow dependant vegetation that could occur.

The vegetation indicator used was *S. mucronata* species. The resulting conditions of the vegetation indicators to the required low flows are described below. In conclusion, the low flows would maintain the PES and REC of the riparian vegetation (Table 22.3).

Table 22.3 Verification of the low flow requirements to maintain the vegetation EC

PES: RIPARIAN VEGETATION EC C (ECOSTATUS C)
<p>Dry Season maintenance Lower limit of sedges up to 30 cm in undated (50% of population). Slight die off may occur at the lower limits because inundation stress during the dry season is more threatening than in the wet season.</p> <p>Dry Season drought Lower limit of sedges up to 16 cm inundated (25% of population). Current status will remain.</p> <p>Wet Season maintenance Lower limit sedges up to 45 cm in undated (75% of population). Current status will remain. <i>S. mucronata</i> requires 10 – 80 cm rooting depth to inundation level.</p> <p>Wet Season drought Lower limit sedges up to 30 cm in undated (50% of population). Current status will remain.</p>
REC: RIPARIAN VEGETATION EC: B/C (ECOSTATUS B/C)
<p>Dry Season maintenance Lower limit of sedges up to 20 cm in undated (40% of population). Reduced low flows in dry season not likely to cause changes to PES for riparian vegetation.</p> <p>Dry Season drought Lower limit of sedges up to 12 cm inundated (20% of population).</p> <p>Wet Season maintenance Lower limit sedges up to 37 cm in undated (60% of population). Reduced low flows in wt season not likely to cause changes to PES for riparian vegetation. Overall, flows set for B/C will not change vegetation status, but this scenario included non-flow related mitigation to improve the vegetation status i.e. physical removal of alien vegetation.</p> <p>Wet Season drought Lower limit of sedges up to 17 cm in undated (40% of population).</p>
AEC down : RIPARIAN VEGETATION EC: D (ECOSTATUS D)
<p>Dry Season drought Lower limit of sedges up to 45 cm in undated (75% of population). <i>S. mucronata</i> requires 10 – 80 cm rooting depth to inundation level. Due to the relatively high level of sedge inundation in the dry season, it is expected that sedges will die off and the marginal zone will shrink. The EC is likely to reduce to D for riparian vegetation.</p> <p>Dry Season maintenance Lower limit of sedges up to 35 cm inundated (60% of population). <i>S. mucronata</i> requires 20 – 90 cm rooting depth to inundation level.</p>

22.4 HIGH FLOW REQUIREMENTS

The high flow classes are identified as follows:

- The geomorphologist and riparian vegetation specialist identify the range of flood classes required and list the functions of each flood.
- The instream specialists then indicate which of the instream flooding functions are addressed by the floods identified for geomorphology and riparian vegetation (indicated by a ✓ in Table 22.4).
- Any of the floods required by the instream biota and not addressed by the floods already identified, must then be described (in terms of ranges and functions) for the instream biota.

Results are provided in Table 22.4 and detailed motivations provided in Table 22.5.

Table 22.4 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 and spawning	Migration habitat (depth etc.)	Clean spawning substrate	Create nursery areas	Resetting water quality	Inundate vegetation for spawning	Breeding and hatching cues	Clear fines	Scour substrate	Reach or inundate specific areas
I	15 - 25	Vegetation: Inundates the marginal zone, <i>Gomphostigma</i> , <i>Persecaria</i> and 50 - 60% of the <i>C. marginatus</i> population.	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
II	40 - 96	Vegetation: Inundates <i>C. marginatus</i> completely and 50% of the <i>S. mucronata</i> population. Also floods mid-channel features which will help prevent terrestrialization.	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
III	120 – 200 (80 ave)	Geomorphology: This near bankfull flood would scour the bed of the active channel, removing fines and cleaning the cobbles and boulders. Vegetation: Inundates the lower zone completely, as well as <i>S. mucronata</i> population.	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

Further information is provided in Appendix K, Table K10.

The number of high flow events required for each EC is provided in Table 22.5. No observed daily data was available to check flood requirements against.

Table 22.5 EWR 4: The recommended number of high flow events required

FLOOD CLASS	FLOOD RANGE (m ³ /s)	INVERTEBRATES	FISH	VEGETATION	GEOMORPHOLOGY	FINAL (Frequency)	MONTHS	DAILY AVERAGE*	DURATION
PES SCENARIO: C									
I	15 - 25			4		4	Early summer/summer		3 - 5 days
II	40 - 96			1		1	Early to late summer		5 days
III	120 – 200 (80 ave)			1:2	1:2	1:2	Wet season		
REC SCENARIO: B/C									
I	15 - 25			6:1		6:1	Early summer/summer		3 - 5 days
II	40 - 96			2:1		2:1	Early to late summer		5 days
III	120 – 200 (80 ave)			1:2	1	1	Wet season		
AEC down SCENARIO: D									
I	20 (ave)			4		4	Early summer/summer		>5 days
II	(40 - 80) 60 (ave)			1		1	Early to late summer		>5 days

FLOOD CLASS	FLOOD RANGE (m ³ /s)	INVERTEBRATES	FISH	VEGETATION	GEOMORPHOLOGY	FINAL (Frequency)	MONTHS	DAILY AVERAGE*	DURATION
III	100 - 130			1:2	1:2	1:2	Wet season		

* For the floods included in the table, the daily average and total volume of each flood were not available and the ranges were provided.

The bed is highly mobile, so Potential Bed Model Transport (PBMT) would be appropriate. However, the site is immediately below the very large Vaal Dam and thus all sediment (except suspended load) has been cut off by the upstream dam. There is thus very limited sediment supply in this reach (between the Vaal Dam and Vaal Barrage), and setting any flood flows would remove sediment but there will be little opportunity for sediment replenishment within the reach.

A single flood flow has been requested (Class III) near bankfull flow that will be sufficient to scour the bed, cleaning the cobble/boulder habitats. Smaller floods for sediment transport functions have not been requested since almost all the sediment inputs have been cut off due to the Vaal Dam.

22.5 FINAL FLOW REQUIREMENTS

The present day flows (presented by observed hydrology) represents the C PES. No EWR rule and EWR table was provided for this EcoStatus. The values set for the C PES represents the border of the C and B bands. This information is therefore available to evaluate operational flow scenarios and provided in Table 22.6. For the floods included in the table, the daily average and total volume of each flood were not available and the ranges were provided.

The values provided for the REC of a B/C represents the change from the B to the A band. The DRM could not be used to provide these EWR rule and EWR tables. To provide the EWR table for the REC, the low flow values generated through the FFHA were used to populate the table. Floods were then included. The daily average and total volume of each flood were not available and the ranges were provided (Table 22.7).

No table could be provided for the AEC down as only low flow values for one month was provided. The wet season remained unchanged from the observed flows.

This information can be used to evaluate operational scenarios.

For the EWR rule table, the table generated in the FFHA model was used as the DRM could not be applied. The EWR rule table includes low flows only (Appendix K, Section K4).

Table 22.6 EWR table for PES: C

		Observed MAR (MCM)		1977.26
		Distribution type		Vaal
MONTH	LOW FLOWS		HIGH FLOWS	
	Maintenance (m ³ /s)	Drought (m ³ /s)	Daily average (m ³ /s) on top of base flow	Duration (days)
OCTOBER	13.05	3.44		
NOVEMBER	16.02	5.04	15 - 25	3 - 5
DECEMBER	17.65	5.58	15 - 25	3 - 5
JANUARY	18.23	5.98	15 - 25	3 - 5
FEBRUARY	17.38	6.63	40 - 96	5
MARCH	16.60	5.58	15 - 25	3 - 5
APRIL	13.95	4.72		
MAY	11.01	4.14		
JUNE	10.03	4.14		
JULY	9.540	3.98		
AUGUST	9.370	3.98		
SEPTEMBER	9.370	3.98		
TOTAL MCM	426.06	150.06		

Table 22.7 EWR table for REC: B/C

		Observed MAR (MCM)		1977.26
		Distribution type		Vaal
MONTH	LOW FLOWS		HIGH FLOWS	
	Maintenance (m ³ /s)	Drought (m ³ /s)	Daily average (m ³ /s) on top of base flow	Duration (days)
OCTOBER	13.05	3.44		
NOVEMBER	16.02	5.04	15 - 25	3 - 5
DECEMBER	17.65	5.58	15 - 25	3 - 5
JANUARY	18.23	5.98	15 - 25	3 - 5
FEBRUARY	17.38	6.63	80	
MARCH	16.60	5.58	15 - 25 40 - 96	3 - 5 5
APRIL	13.95	4.72		
MAY	11.01	4.14		
JUNE	10.03	4.14		
JULY	9.540	3.98		
AUGUST	9.370	3.98		
SEPTEMBER	9.370	3.98		
TOTAL MCM	426.06	150.06		

23 EWR 5: SCANDINAVIA (VAAL RIVER) – DETERMINATION OF STRESS INDICES

NOTE: All supporting specialist information for EWR 5 is summarized in Volume 2, Appendix L.

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

23.1 INDICATOR SPECIES OR GROUP

23.2 Fish indicator group 1: Large semi-rheophilic species (BAEN, BKIM)

Indicator species: *L. aeneus* (BAEN) and *L. kimberleyensis* (BKIM). Refer to Section 2.1.1 and Appendix B, Table B1.

23.2.1 Fish indicator group 2: Small limnophilic species (PPHI, TSPA)

Indicator species: *P. philander* (PPHI) and *T. sparrmanii* (TSPA Refer to Section 21.1.2 and Appendix K, Table K1. This guild was used only for the AEC down (increased flows in dry and wet season).

23.2.2 Macroinvertebrate indicator taxa

Indicator taxa: Hydropsychid caddisflies and Simuliidae. Refer to Section 2.1.3.

23.2.3 Riparian vegetation indicator species

Indicator species included:

- *C. marginatus*: Refer to Section 2.1.4.
- *M. junceus*: Refer to Section 2.1.4.
- *Persecaria* spp.: Refer to section 6.1.4.
- *C. bulbispermum*: Refer to section 10.1.4.
- *P.s australis*: Refer to Section 8.1.3.
- *Setaria nigrirostris*: Perennial tufted grass which occurs on turf soil and damp places. Seasonal inundation is required to maintain clay.

23.3 STRESS FLOW INDEX

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

23.3.1 Habitat response

Habitat response is used to derive the biota's response to provide a biota stress index and represents the instantaneous response of habitat to flow changes, based on a site specific (+10) – 0 – (-10) scale for instream biota where:

- +10: No flow (i.e., there can still be surface water in pools).
- 0: Optimum habitat (fixed at the natural maximum baseflow – calculated using the wettest flow month discharge at the maintenance % of 50 – 60% for the Vaal River at the EWR site).
- -10: Habitat at flows above natural maximum baseflow.

The abundance of fish velocity-depth classes are provided in Appendix L, Table L1 and Table L2.

The instantaneous response of flow dependent invertebrate (FDI) taxa provides the % occurrence of various velocity-substrate classes under different flow conditions are provided in Appendix L, Table L5).

23.3.2 Biota response

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

- +10 = No flow (i.e., there can still be surface water in pools). The biota response will depend on the indicator groups present, i.e. rheophilics will be gone whereas semi-rheophilics will still be present and survive.
- 0 = Optimum habitat with least amount of stress possible for the indicator groups AT THE SITE (fixed at the natural maximum baseflow in the same way as for the habitat response).
- -1 – (-10) = habitat changes resulting in a major change from the natural composition of the assemblage.

The fish species response index is calculated using the fish habitat rating (cf Section 2.2.1) (Appendix L, Table L3 – L4) 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 L, Table L6).

23.3.3 Integrated stress curve

The integrated stress curve is designed as described in Chapter 2, Section 4.2.3. Figure 23.1 and Figure 23.2 illustrates this graphically.

In this specific case, the LSR fish stress index represents the integrated stress index (these values are the highest flow for a stress) for the plus stress. Therefore the blue curve (representing the LSR stress index) is lying 'beneath' the integrated stress line (black) (Figure 23.1). On the minus stress scale, the limnophilics (red line) forms the majority of the integrated stress line (Figure 23.2).

Table 23.1 Species stress discharges used to determine biotic stress – Decreased flows

Stress	Flow (m ³ /s)			Integrated Flow (m ³ /s)
	LSR	LIM	FDI	
+10	0	0	0	0
+9	3	0.71	0.2	3
+8	5.5	1.43	0.59	5.5
+7	7	2.14	1.31	7
+6	8.8	2.86	3.4	8.8

Stress	Flow (m ³ /s)			Integrated Flow (m ³ /s)
	LSR	LIM	FDI	
+5	11	3.57	6.4	11
+4	14	4.29	8.4	14
+3	20.9	5	12.2	20.9
+2	31.4	7	15.5	31.4
+1	52.5	10	27.8	52.5
0	90	90	90	90

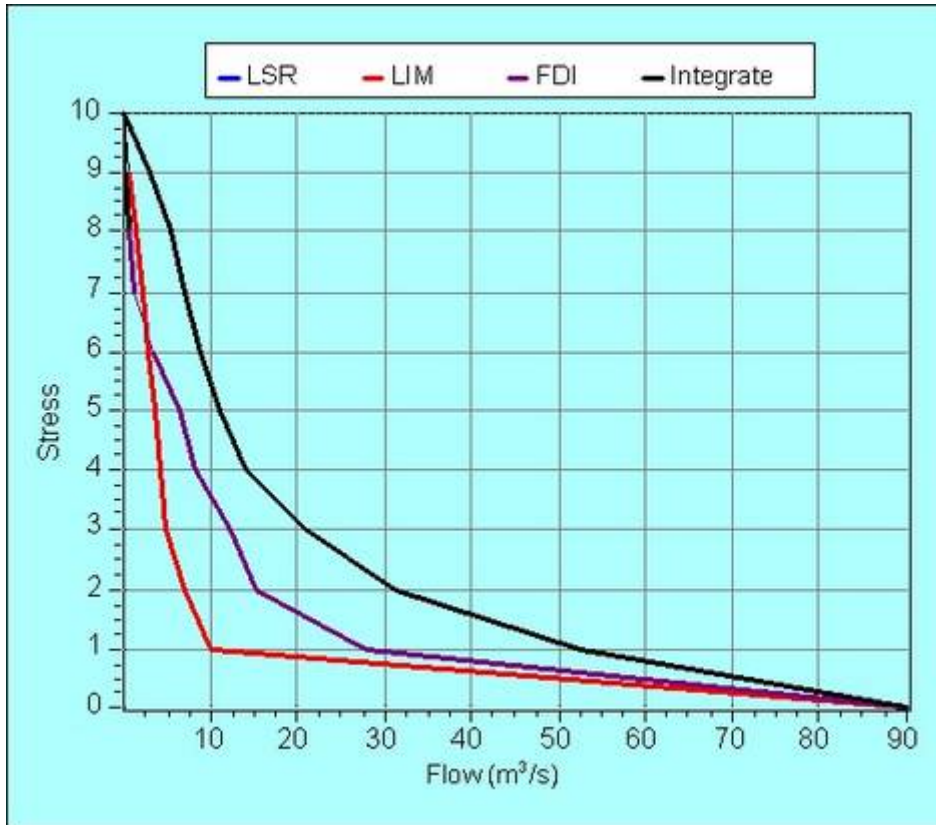


Figure 23.1 Component and integrated stress curves for EWR 5 – Decreased flows

Table 23.2 Component and integrated stress curves for EWR 5 – Increased flows

Stress	Flow (m ³ /s)			Integrated Flow (m ³ /s)
	LSR	LIM	FDI	
0	90	90	90	90
-1	101	91.3	95	91.3
-2	110	92.5	99	92.5
-3	117	93.7	103	93.7
-4	128	95	107	95
-5	146	100	112	100
-6	162	110	116	110
-7	184	120	120	120
-8	220	135	125	125
-9	280	150	130	130
-10	340	183	134	134

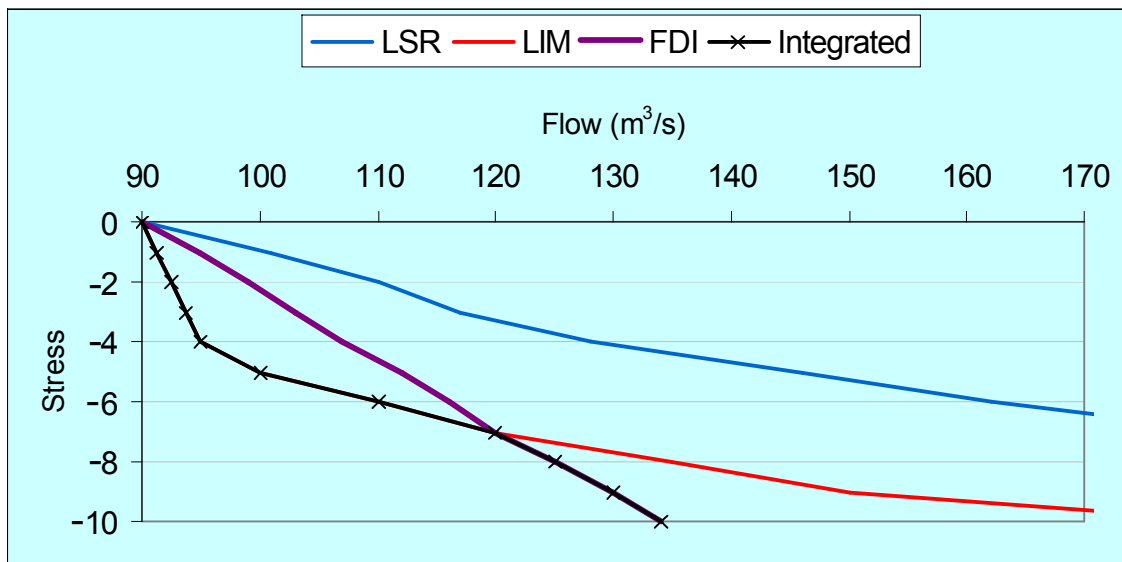


Figure 23.2 Component and integrated stress curves for EWR 5 – Increased flows

Table 23.3 provides the summarised biotic response for the integrated stresses.

Table 23.3 Integrated stress and summarised habitat/biotic responses

Integrated stress	m ³ /s	Habitat and/or Biotic responses
+10	0	Only pool dwelling species present. Only hyporheic refugia, no surface water for FDIs. Indicator taxa no longer present.
+9 (LSR)	3	Critical FDI habitat residual. Sensitive rheophilic species rare, critical stages of sensitive rheophilic species non-viable and at risk for some less sensitive species.
+8 (LSR)	5.5	LIM guild: All habitats are moderate (3*). LSR guild: Nursery, abundance and cover is very low (1), while rest of habitats is absent (0).
+7 (LSR)	7	LIM guild: All habitats are good (4). LSR guild: Nursery, Abundance and cover is low (2) while rest of habitats is very low (1). Critical FDI habitat very reduced. Critical life-stages of sensitive rheophilic species at risk or non-viable.
+6 (LSR)	8.8	Critical FDI habitats limited. All life stages viable in limited areas, critical life stages of some sensitive rheophilic species at risk.
+5 (LSR)	11	LIM guild: Habitats as above. LSR guild: All habitats are low (2).
+4 (LSR)	14	LIM guild: All habitats are optimal (5). LSR guild: Spawning habitat is low while rest of habitats are moderate.
+3 (LSR)	20.9	LIM guild: As above. LSR guild: Cover and abundance is good, while rest of habitats is moderate.
+2 (FDI)	31.4	LIM guild: As above. LSR guild: Spawning habitat is moderate while rest of habitat is good.
+1 (LSR)	52.5	
0	90	Fish guild: All habitats are optimal. Zero stress pegged. All FDI very abundant and healthy.
-1 (LIM)	91.3	
-2 (LIM)	92.5	
-3 (LIM)	93.7	
-4 (LIM)	95	LIM guild: All habitats are moderate (3). LSR guild: All habitats are optimal. All FDI habitat plentiful, high quality.

Integrated stress	m³/s	Habitat and/or Biotic responses
-5 (LIM)	100	LIM guild: All habitats are low (2). LSR guild: Connectivity and water quality is optimal while rest of habitats is good. Critical FDI habitats sufficient.
-6 (LIM)	110	LIM guild: As above. LSR guild: Water quality and connectivity is still optimal, abundance and cover is good and spawning and nursery is moderate. Critical FDI habitat reduced.
-7 (FDI)	120	LIM guild: All habitats are very low. LSR guild: Spawning and nursery habitat is low, abundance and cover is moderate and spawning and nursery habitat is low. Critical FDI habitats very reduced.
-8 (FDI)	125	Mostly fast flowing FDI habitats PRESENT. Critical FDI habitat limited.
-9 (FDI)	130	Fast flowing FDI habitats only. 75% loss of marginal vegetation.
-10 (FDI)	134	LIM guild: All habitats are very low. LSR guild: Water quality and connectivity is good, nursery habitat is very low and the rest of the habitats are low. Bank full discharge.

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

24 EWR 5: SCANDINAVIA (VAAL RIVER) – DETERMINATION OF EWR SCENARIOS

24.1 ECOCLASSIFICATION SUMMARY OF EWR 5

The aims at EWR 5 are to improve the PES to an EC that represents the REC. Two scenarios were investigated, i.e. an improved (from PES) EC (i.e. the REC) and an EC lower than the PES.

EWR 5 Scandinavia (Vaal River)																																																										
<p>EIS: HIGH Presence of rare and endangered <i>Labeobarbus kimberleyensis</i>, and Rand Highveld Grassveld vegetation type. Most importantly, this site falls within the Vredefort Dome World Heritage Site and the river is an important feature within this World Heritage Site.</p> <p>PES: C/D Combination of flow and non-flow related impacts. Flow related impacts include increased base flows and reduced frequency of moderate floods due to Vaal Dam and Barrage and releases to regulated TDS levels. Non-flow related impacts include agriculture, and urban sewage and industrial waste and the occurrence of gauges, weirs and dams in the system.</p> <p>REC: C Improvement of the PES due to HIGH EIS rating. A B/C EcoStatus could not be attained due to the limited operational possibilities from the Vaal Dam. Scenario includes decreased base flows for 3 days (during winter) (to improve macroinvertebrates EC) and increased moderate floods in the wet season.</p> <p>AEC down: D Increased base flows. Possibility of further decrease of floods due to the development in tributaries and increased return flows.</p>																																																										
<table border="1"> <thead> <tr> <th>IHI</th> <th>Driver Components</th> <th>PES Category</th> <th>Trend</th> <th>REC</th> <th>AEC↓</th> </tr> </thead> <tbody> <tr> <td rowspan="3">INSTREAM</td> <td>HYDROLOGY</td> <td>D</td> <td></td> <td>C/D</td> <td>D</td> </tr> <tr> <td>WATERQUALITY</td> <td>E</td> <td>Negative</td> <td>D/E</td> <td>E</td> </tr> <tr> <td>GEOMORPHOLOGY</td> <td>C</td> <td>Negative</td> <td>C</td> <td>C/D</td> </tr> <tr> <th colspan="2">Response Components</th> <th>PES Category</th> <th>Trend</th> <th>REC</th> <th>AEC↓</th> </tr> <tr> <td colspan="2">FISH</td> <td>C</td> <td>Stable</td> <td>B</td> <td>D</td> </tr> <tr> <td colspan="2">MACRO INVERTEBRATES</td> <td>C</td> <td>Stable</td> <td>C</td> <td>C/D</td> </tr> <tr> <td colspan="2">INSTREAM</td> <td>C</td> <td></td> <td>B/C</td> <td>D</td> </tr> <tr> <td colspan="2">RIPARIAN VEGETATION</td> <td>D</td> <td>Negative</td> <td>C</td> <td>-D</td> </tr> <tr> <td colspan="2">ECOSTATUS</td> <td>C/D</td> <td></td> <td>C</td> <td>D</td> </tr> </tbody> </table>	IHI	Driver Components	PES Category	Trend	REC	AEC↓	INSTREAM	HYDROLOGY	D		C/D	D	WATERQUALITY	E	Negative	D/E	E	GEOMORPHOLOGY	C	Negative	C	C/D	Response Components		PES Category	Trend	REC	AEC↓	FISH		C	Stable	B	D	MACRO INVERTEBRATES		C	Stable	C	C/D	INSTREAM		C		B/C	D	RIPARIAN VEGETATION		D	Negative	C	-D	ECOSTATUS		C/D		C	D
	IHI	Driver Components	PES Category	Trend	REC	AEC↓																																																				
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ECOSTATUS		C/D		C	D																																																					

These ECs will be achieved as follows:

- PES and REC: The original aim during the EcoClassification process identified that increased variability between seasons and an attempt to modify the seasonal reversal would be required to improve the situation. This implies that the dry season should become dryer (i.e. removing water) and the wet season wetter (increased flows).
- EC lower than the PES: This will be achieved by INCREASING the flows and is scenario-based. Based on the assumption that the increase will be constant during the year, a scenario was assessed where the category will be lower than the PES. Only the dry season was assessed as increased flows in the wet season forms part of the improved scenario. The assumption is that the impact of increased flows during the dry season, which will exacerbate the seasonality problem, will be sufficient to assess the decreased flows.

NOTE: The season cannot be evaluated in isolation from each other as seasonality changes are largely responsible for the change in EC.

24.2 HYDROLOGY

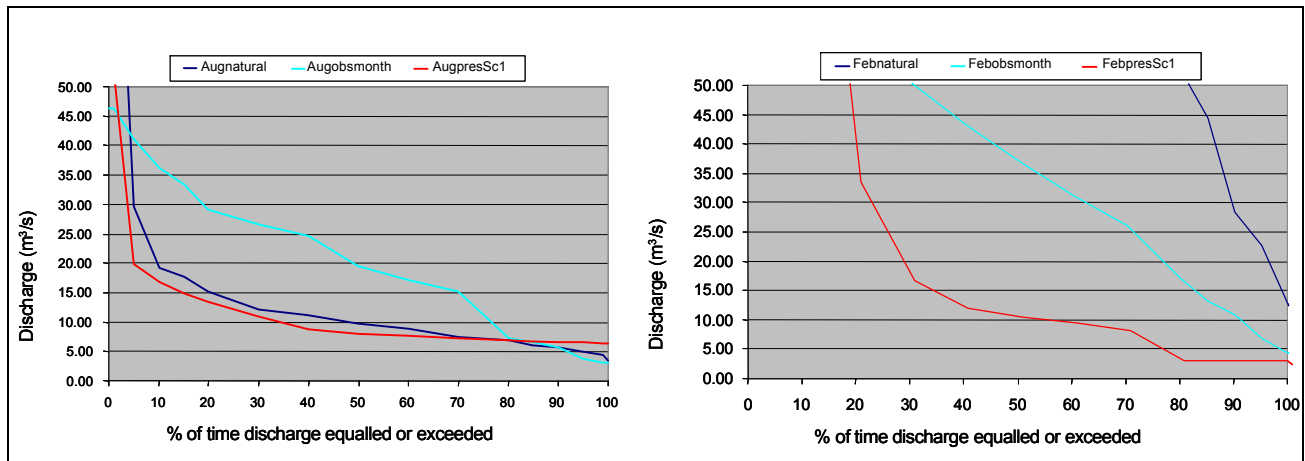
The situation regarding modelled present day scenarios, observed and natural is the same as for EWR 4. EWR 5 has a gauge which is some distance from the site (C2H018). Monthly observed

data from this gauge was used as even with missing data, the observed flows still provided a better indication of present flows than the modelled present flows. The gauge record provides flow for 70 years.

The hydrological situation is similar to that at EWR 4 with seasonal reversal being less prominent (Figure 24.1).

Dry Season (August)

Wet Season (February)



Augnatural: Modelled natural hydrology in m³/s
 AugpresSc1: Modelled present hydrology (Scenario 1) in m³/s

Augobsmonth: Monthly observed hydrology in m³/s

Figure 24.1 Flow duration graphs showing the various hydrologies for the wet and dry season

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

- 95%: Representing droughts for both wet and dry months. This would represent 5% on the stress duration graphs.
- 45%: Representing maintenance flows for both wet and dry months. This would represent 55% on the stress duration graphs.
- Any additional points which had specific significance in terms of flow or stress requirements.

24.3 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 – 2.2.

The fish and macroinvertebrate flow requirements for different Ecological Categories (ECs) are provided in Table 24.1 and Figure 24.2 and 24.3. The results are plotted for the wet and dry season on stress duration graphs. The stress requirements (as a ‘hand drawn line’³) are illustrated in Figures 24.2 and 24.3.

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

PES: **Green** REC: **Purple** AEC down: **Yellow**

³ Note that the hand drawn line represents the fuzzy border (as it is a continuum) between different ECs.

Summarised motivations for the final requirements are provided in Table 24.1.

Table 24.1 Species and integrates stress requirements as well as the final integrated stress and flow requirements

Duration	LSR stress	Integ stress	LIM stress	Integ stress	FDI stress	Integ stress	FINAL* (Integrated stress)*	FLO W (m ³ /s)
PES:C/D EcoStatus			FISH: C			MACROINVERTEBRATES: C		
DRY SEASON								
5%	+8.7	+8.7	Limnophilic species are expected to primarily react to a further increase in flows, and were therefore only considered for the AEC down scenario.		+6	+8.6	+8.7	3.75
50%	+4.5	+4.5			+3	+4.7	+4.5	12.5
90%	+1.9	+1.9					+1.9	33.51
WET SEASON								
5%	+7.3	+7.3	As above.		+4	+6	+7.3	6.55
20%	+3	+3			+0.9	+2	+3	20.9
50%	+1.4	+1.4					1.4	44
REC: C EcoStatus			FISH: B			MACROINVERTEBRATES: C		
DRY SEASON								
5%	+8.7	+8.7	As above.		Increasing flows in both the wet and dry season is not expected to improve the EC of macroinvertebrates.		+8.7	3.75
50%	+5	+5					+5	11
90%	+2.9	+2.9					+2.9	21.95
WET SEASON								
5%	+6.4	+6.4	As above.		As above.		+6.4	8.08
20%	+2	+2					+2	31.4
50%	+1.3	+1.3					+1.3	46.17
AEC down: D EcoStatus			FISH: D			MACROINVERTEBRATES: C/D		
DRY SEASON								
5%	+8.4	+8.4	0.2	0.4	6	6.5	8.4	4.5
50%	+1.7	+1.7	0.2	0.4	0.8	3.7	3.7	25.77
90%	+1.2	+1.2	0.2	0.4			1.2	48.28
WET SEASON								
Although there are more flows than present in the dry season, the wet season remains the same as present and was therefore not assessed.								

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

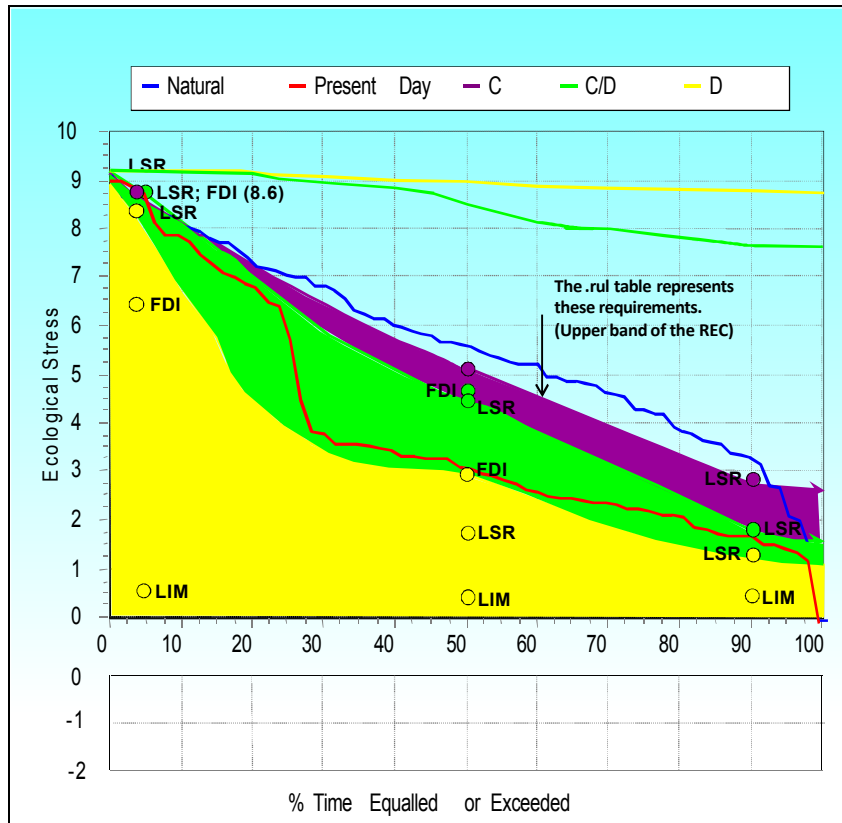


Figure 24.2 EWR 5: Stress Duration Curve for a C/D PES, C REC, and D AEC down - DRY season

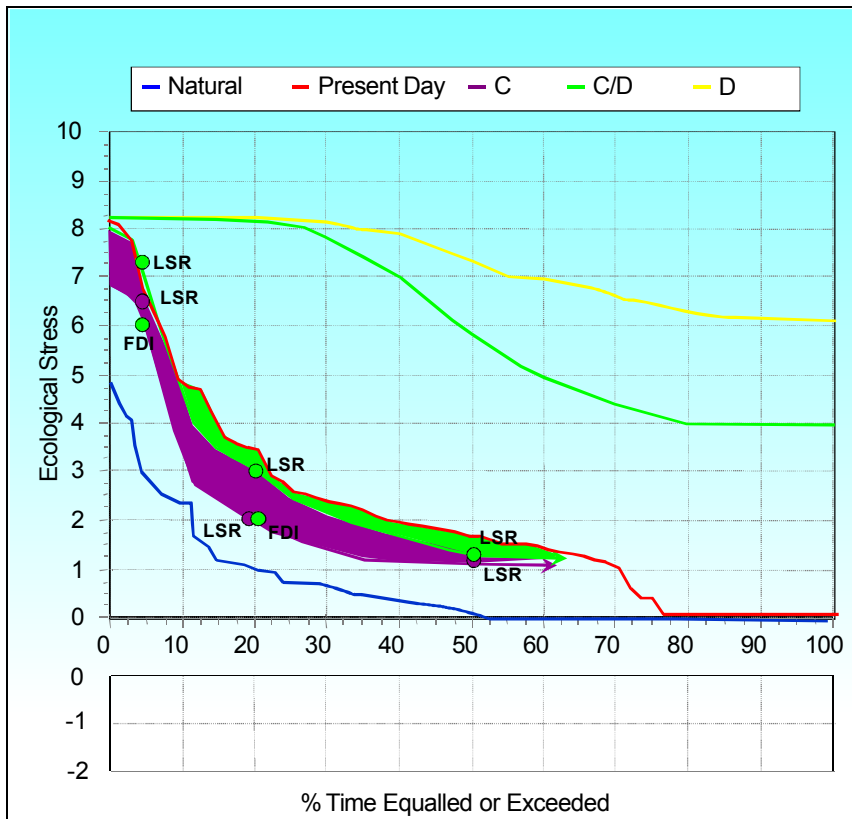


Figure 24.3 EWR 5: Stress Duration Curve for a C/D PES, C REC, and D AEC down - WET season

Table 24.2 Summary of EWR 5 motivations

Month	% Stress duration	Component stress	Integrated stress	Flow m ³ /s	Comment ¹
PES: C/D EcoStatus		FISH: C			MACROINVERTEBRATES: C/D
Aug	5% drought	8.7 LSR	8.7	3.75	Total habitat suitability is 70.9% of what can be expected under natural conditions, and it is estimated that it would maintain this guild in its present state during drought periods.
	50% maintenance	4.5 LSR	4.5	12.5	The total habitat suitability would be 135% of what can be expected under natural conditions, as a result of flows still being higher than expected under natural conditions. It is estimated that these habitat conditions should be adequate to maintain this guild within this reach in its present state. Although more suitable habitats will therefore be available, any shift from natural conditions will result in a negative impact on the ecological integrity. This will be the result of habitat deterioration, change in food webs and population structures, etc.
Feb	5% drought	7.3 LSR	7.3	6.55	This equates to a total habitat suitability score of 43% of optimal wet season habitat suitability expected during natural droughts. These flows would enable the maintenance of this fish guild at this site in its PES during the wet season droughts.
	20% assurance	3 LSR	3	20.9	The habitat suitability will be 68% of the expected optimal wet season habitat suitability under natural conditions. It is estimated that these habitat conditions should be adequate to maintain this guild within its present state.
REC: C EcoStatus		FISH: B			MACROINVERTEBRATES: C
Aug	5% drought	8.7 LSR	8.7	3.75	See PES.
	50% maintenance	5 LSR	5	11	The total habitat suitability would be 114% of what can be expected under natural conditions. This is a vast improvement of the present 142% habitat suitability.
Feb	5% drought	6.4 LSR	6.4	8.08	See PES.
	20% assurance	2 LSR	2	31.4	The total habitat suitability would be 89 % of what can be expected under natural conditions. It is estimated that these habitat conditions should be adequate to improve this guild with one ecological category.
AEC down: D EcoStatus		FISH: D			MACROINVERTEBRATES: C/D
Aug	5% drought	8.4 LSR	8.4	7.9	See PES.
	50% maintenance	1.7 LSR	1.7	37.73	The total habitat suitability would be 187% of what can be expected under natural conditions. Although more suitable habitats will therefore be available, any shift from natural conditions will result in a negative impact on the ecological integrity. This will be the result of habitat deterioration, change in food webs and population structures, etc.

¹ See Chapter 3, Table 3.2.

The above flows were checked by the riparian vegetation specialist to ensure that these requirements are adequate to achieve the EC in which the marginal vegetation should be, as well as any other flow dependant vegetation that could occur.

The vegetation indicators used were *Persecaria* spp. The resulting conditions of the vegetation indicators to the required low flows are described below. In conclusion, the low flows would maintain the PES and REC of the riparian vegetation (Table 22.3).

Table 24.3 Verification of the low flow requirements to maintain the vegetation EC

PES: RIPARIAN VEGETATION EC D (ECOSTATUS C/D)
<p>Dry Season maintenance Sedges are inundated between 12 and 30 cm (100% of population inundation). <i>Persecaria</i> spp. at water level to 20 cm above water level. Slight die off of sedges are likely to occur at the lower limits because inundation stress during the dry season is more threatening than in the wet season.</p> <p>Dry Season drought Lower limit of sedges are inundated up to 5 cm (about 10% of population). <i>Persecaria</i> spp. between 20 and 40 cm above water level and will survive:</p> <p>Wet Season maintenance 100% of sedge and <i>Persecaria</i> populations are inundated (45 – 60 cm and 14 - 32cm below water level respectively). Some senescence of both populations will occur at the lower levels due to extreme and extended inundation stress. Upper portions of these populations are likely to expand.</p> <p>Wet Season drought The majority of the sedge population remains inundated at these flows (15 cm inundation to 2 cm above water level) and therefore remains viable. <i>Persecaria</i> spp. between 15 and 30 cm above water level. Some die back may occur and flower or fruit abortion will occur. Population will remain viable however.</p>
REC: RIPARIAN VEGETATION EC: C (ECOSTATUS C)
<p>Dry Season maintenance Not significantly different from PES flows.</p> <p>Dry Season drought Same as PES.</p> <p>Wet Season maintenance 100% of sedge and <i>Persecaria</i> populations are inundated (46 - 63cm and 15 – 33 cm below water level respectively). Some senescence of both populations will occur at the lower levels due to extreme and extended inundation stress. Upper portions of these populations likely to expand and reproduce sufficiently.</p> <p>Wet Season drought 100% of sedge population is slightly inundated (3 – 20 cm). <i>Persecaria</i> spp. population not inundated at all (10 – 28 cm above water level). Flows are sufficient to ensure survival of both populations.</p>
AEC down : RIPARIAN VEGETATION EC: D (ECOSTATUS D)
<p>Dry Season drought Sedges inundated between 2 and 19 cm (100% of population inundation). <i>Persecaria</i> spp. 11 to 29 cm above water level. Flow is sufficient to ensure survival of both populations.</p> <p>Dry Season maintenance Sedges are inundated up to 57 cm. <i>Persecaria</i> spp. up to 27 cm inundation (100% of both populations). Both sedges and <i>Persecaria</i> are likely to die back in these depths of water (especially at the lower limits) because inundation occurs in the dry season.</p>

24.4 HIGH FLOW REQUIREMENTS

The high flow classes are identified as follows:

- The geomorphologist and riparian vegetation specialist identify the range of flood classes required and list the functions of each flood.
- The instream specialists then indicate which of the instream flooding functions are addressed by the floods identified for geomorphology and riparian vegetation (indicated by a ✓ in Table 24.4.
- Any of the floods required by the instream biota and not addressed by the floods already identified, must then be described (in terms of ranges and functions) for the instream biota.

Results are provided in Table 24.4 and detailed motivations provided in Table 24.5.

Table 24.4 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 and spawning	Migration habitat (depth etc.)	Clean spawning substrate	Create nursery areas	Resetting water quality	Inundate vegetation for spawning	Breeding and hatching cues	Clear fines	Scour substrate	Reach or inundate specific areas
I	40 - 100 (50 ave)	Geomorphology: This flow class represents the effective discharge for the (1 – 3 mm) fines in the system. These floods will also inundate and activate the low active bench at the site. Vegetation: Inundates the marginal zone and marginal zone vegetation (<i>Cyperus</i> , <i>Persecaria</i> , <i>Typha</i> , and <i>Phragmites</i>).	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
II	180 - 260	Vegetation: Activates hydrophilic terrestrial grasses (<i>S. nigrirostris</i>) and <i>Crinum</i> , inundates 40% of the lower zone and floods lateral bars/terraces on uncut banks.	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
III	400 - 570	Vegetation: Inundates 60% of the lower zone, inundates <i>Crinum</i> and <i>Setaria</i> (important for reproductive productivity).	✓	✓	✓	✓	✓	✓				
IV	800	Geomorphology: This large flood represents the effective discharge for (20 mm) gravels at the site, and this flood would also inundate the lower terrace at the site. Vegetation: Inundates 100% of the lower zone, activates the tree line (important to prevent terrestrialization).	✓	✓	✓	✓	✓	✓				

Further information is provided in Appendix L, Table L10.

The number of high flow events required for each EC is provided in Table 24.5. No observed daily data was available to check flood requirements against.

Table 24.5 EWR 5: The recommended number of high flow events required

FLOOD CLASS	FLOOD RANGE (m ³ /s)	INVERTEBRATES	FISH	VEGETATION	GEOMORPHOLOGY	FINAL (Frequency)	MONTHS	DAILY AVERAGE*	DURATION
PES SCENARIO: C/D									
I	40 - 100 (50 ave)			3:1	4	3:1	Early summer/summer		3 days
II	180 - 260			1		1	Early to late summer		3 - 5 days
III	400 - 570			1:2		1:2	Summer		
IV	800			1:3	1:3	1:3	Wet season		
REC SCENARIO: C									

FLOOD CLASS	FLOOD RANGE (m ³ /s)	INVERTEBRATES	FISH	VEGETATION	GEOMORPHOLOGY	FINAL (Frequency)	MONTHS	DAILY AVERAGE*	DURATION
I	40 - 100 (50 ave)			4:1	4	4:1	Early summer/summer		3 days
II	180 - 260			2:1		2:1	Early to late summer		3 - 5 days
III	400 - 570			1:2		1:2	Summer		
IV	800			1:3	1:3	1:3	Wet season		
AEC SCENARIO: D									
I	40 - 100 (50 ave)			3:1	3	3:1	Early summer/summer		3 days
II	180 - 260			1		1	Early to late summer		3 - 5 days
III	400 - 570			1:2		1:2	Summer		
IV	800			1:3	1:5	1:3	Wet season		

* For the floods included in the table, the daily average and total volume of each flood were not available and the ranges were provided.

24.5 FINAL FLOW REQUIREMENTS

The present day flows (presented by observed hydrology) represents the C/D PES. No EWR rule and EWR table was provided for this EcoStatus. The values set for the C/D PES represents the border of the D and C bands. This information is therefore available to evaluate operational flow scenarios and provided in Table 24.6. For the floods included in the table, the daily average and total volume of each flood were not available and the ranges were provided.

The values provided for the REC of a C represents the change from the C to the B band. The DRM could not be used to provide these EWR rule and EWR tables. To provide the EWR table for the REC, the low flow values generated through the FFHA were used to populate the table. Floods were then included. The daily average and total volume of each flood were not available and the ranges were provided (Table 24.7).

No table could be provided for the AEC down as only low flow values for one month was provided. The wet season remained unchanged from the observed flows. This information can be used to evaluate operational scenarios.

This information can be used to evaluate operational scenarios.

For the EWR rule table the table generated in the FFHA model was used as the DRM could not be applied. The EWR rule table includes low flows only (Appendix L, Section L2.4).

Table 24.6 EWR table for PES: C/D

		Observed MAR (MCM)		457.683
		Distribution type		Vaal
MONTH	LOW FLOWS		HIGH FLOWS	
	Maintenance (m ³ /s)	Drought (m ³ /s)	Daily average (m ³ /s) on top of base flow	Duration (days)
OCTOBER	17.98	5		
NOVEMBER	25.92	5.95	50	3
DECEMBER	40.47	7	50	3
JANUARY	47.23	10.10	50	3
FEBRUARY	46.17	8.08	180 – 260	3 -5
MARCH	44.48	7.00	50 400 - 570	3
APRIL	20.10	5.50		
MAY	14.0	4.85		
JUNE	9.02	4.00		
JULY	10.10	4.00		
AUGUST	11	3.75		
SEPTEMBER	11	4.75		
TOTAL MCM	780.06	183.76		

Table 24.7 EWR table for REC: C

		Observed MAR (MCM)		457.683
		Distribution type		Vaal
MONTH	LOW FLOWS		HIGH FLOWS	
	Maintenance (m ³ /s)	Drought (m ³ /s)	Daily average (m ³ /s) on top of base flow	Duration (days)
OCTOBER	17.98	5		
NOVEMBER	25.92	5.95	50	3
DECEMBER	40.47	7	50	3
JANUARY	47.23	10.10	50	3
FEBRUARY	46.17	8.08	180 – 260	3 -5
MARCH	44.48	7.00	50 400 - 570	3
APRIL	20.10	5.50		
MAY	14.0	4.85		
JUNE	9.02	4.00		
JULY	10.10	4.00		
AUGUST	11	3.75		
SEPTEMBER	11	4.75		
TOTAL MCM	780.06	183.76		

25 RE-EWR 1: KLEIN VAAL (KLEIN VAAL) - (DETERMINATION OF EWR SCENARIOS

25.1 ECOCLASSIFICATION SUMMARY OF RE-EWR 1

RE-EWR 1: Klein Vaal (Klein Vaal River)																																
<p>EIS: MODERATE PES: C Flow related impacts include interbasin transfer and abstraction altering hydrological regime. Non-flow related impacts include deterioration in water quality, increased erosion due to cattle and agricultural activities. Loss of habitat due to farm dams.</p> <p>REC: C Maintain the PES due to the MODERATE EIS rating. The C EcoStatus is due to the riparian vegetation EC of a D as the instream EC is an A/B. The riparian vegetation PES is due to non-flow related impacts (grazing and trampling) and highly likely a very localised impact.</p> <p>AEC down: C/D A hydrological regime with decreased base flows. Increased periods of zero flows during dry season.</p>		<table border="1"> <thead> <tr> <th>Driver Components</th> <th>PES and REC Category</th> <th>AEC↓</th> </tr> </thead> <tbody> <tr> <td>HYDROLOGY</td> <td>A/B</td> <td></td> </tr> <tr> <td>WATER QUALITY</td> <td>B/C</td> <td>B/C</td> </tr> <tr> <td>GEOMORPHOLOGY</td> <td>B/C</td> <td>B/C</td> </tr> <tr> <th>Response Components</th> <th>PES Category</th> <th>REC</th> </tr> <tr> <td>FISH</td> <td>B</td> <td>C</td> </tr> <tr> <td>MACRO INVERTEBRATES</td> <td>A/B</td> <td>C</td> </tr> <tr> <td>INSTREAM</td> <td>A/B</td> <td>C</td> </tr> <tr> <td>RIPARIAN VEGETATION</td> <td>D</td> <td>D</td> </tr> <tr> <td>ECOSTATUS</td> <td>C</td> <td>C/D</td> </tr> </tbody> </table>	Driver Components	PES and REC Category	AEC↓	HYDROLOGY	A/B		WATER QUALITY	B/C	B/C	GEOMORPHOLOGY	B/C	B/C	Response Components	PES Category	REC	FISH	B	C	MACRO INVERTEBRATES	A/B	C	INSTREAM	A/B	C	RIPARIAN VEGETATION	D	D	ECOSTATUS	C	C/D
	Driver Components	PES and REC Category	AEC↓																													
	HYDROLOGY	A/B																														
	WATER QUALITY	B/C	B/C																													
	GEOMORPHOLOGY	B/C	B/C																													
	Response Components	PES Category	REC																													
	FISH	B	C																													
	MACRO INVERTEBRATES	A/B	C																													
	INSTREAM	A/B	C																													
	RIPARIAN VEGETATION	D	D																													
ECOSTATUS	C	C/D																														

RE-EWR 1 was assessed at a rapid level for low flows and therefore the HFSR method for setting low flows were not applied to this site. The Reserve was estimated using the Hughes Desktop Reserve Model (DRM) (DWAf, 1999) for the Ecological Category (EC) set. Therefore for the low flow requirements, the estimated Reserve was verified and the DRM was adjusted if needed. High flows were set using the standard Comprehensive approach.

25.2 HYDROLOGY

The highest and lowest low flow months selected as the key months are February (wet) and August (dry). The flows that were assessed by the specialists to verify the DRM are discussed in Section 25.3.

25.3 LOW FLOW REQUIREMENTS

The flow requirement results were largely based on the requirements of macroinvertebrates as the macroinvertebrates were already in an A/B category and the DRM was sufficient for the macroinvertebrate requirements. The low flow requirements of the REC and AEC down EcoStatus were evaluated by the fish specialist and motivations are provided in Table 25.1. The two unshaded cells represent the adjusted desktop reserve model values.

Table 25.1 Summary of RE-EWR 1 motivations

Season	Initial desktop flows		Adjusted desktop flows		Response
	Drought (m ³ /s)	Maintenance (m ³ /s)	Drought (m ³ /s)	Maintenance (m ³ /s)	
PES and REC: C EcoStatus			FISH: B		MACROINVERTEBRATES: A/B
Aug	0	0.025	0	0.033	<p>Dry Season drought There are no rheophilic species present in this reach, and the semi-rheophilic and limnophilic species will be able to survive short periods of no flow, especially if adequate depths are maintained in the SD habitats. These would become important refuge areas during the winter drought periods.</p> <p>Dry Season maintenance At this flow very limited FVS (4%) and FS (1%) will be available, which would be suitable for the survival of all semi-rheophilic species (BAEN, BANO, LCAP, BPAL and LUMB) during the dry season. These flows will not create optimal habitats, but should sustain at least the flow related water quality to ensure survival during the dry season. These flows should also maintain acceptable levels of SS and SD (with adequate depth) for maintenance of the expected species. Under severe conditions, this flow should allow the fish to undertake limited downstream avoidance migrations to seek adequate refuge habitats.</p>
Feb	0.073	0.174	No change		<p>Wet Season drought Under this condition, crucial FS and FVS will still be available, although the FI habitats will be lost. These habitats should however be adequate for the survival of most species under these drought conditions during the wet season.</p> <p>Wet Season maintenance At these flows, adequate FVS, FS and FI will be available. The maintenance of these flows will be important to meet the habitat requirements of especially the semi rheophilic species (BAEN, LCAP) that require these habitats for spawning and early life stage development. Juvenile BAEN also has a preference for these habitats (especially during the day), while SD areas would be used as refuge areas during the night.</p>
AEC down: C/D EcoStatus			FISH: C		MACROINVERTEBRATES: C
Aug	0	0.019	0	0.024	<p>Dry Season maintenance At this flow very limited Fast Very Shallow (FVS) will still be available but FS (and other fast habitats) will be lost. These flows would not be optimal for the survival of the fish species present, but due to the fact that they are all semi-rheophilic and limnophilic species, they should be able to survive the dry season at this flow rate. These flows should maintain acceptable levels of SS and SD (with adequate depth) for maintenance of the expected species. Although the fast habitats (riffle/rapids) will not be available for the fish species due to its relative shallowness, the flow will be important to maintain acceptable depth and water quality levels within the SS and SD habitats, which will be important refuge habitats. It is however estimated that under these flows the present status of the fish will deteriorate towards a lower category.</p>
Feb	0.073	0.125	No change		<p>Dry Season maintenance At these flows, adequate FVS and FS will be available, with limited FI habitat. The maintenance of these habitats will be important to meet the habitat requirements of especially the semi-rheophilic species (BAEN, and LCAP) that require these habitats for spawning and early life stage development. Juveniles BAEN also has a preference for</p>

Season	Initial desktop flows		Adjusted desktop flows		Response
	Drought (m ³ /s)	Maintenance (m ³ /s)	Drought (m ³ /s)	Maintenance (m ³ /s)	
					these habitats (especially during the day), while SD areas would be used as refuge areas during the night. Condition and availability of fast habitats at these flows will be less than that under present conditions, and it can be expected that the fish assemblage would deteriorate and result in a decrease in the category.

25.3.1 Final low flow requirements

The verification of the DRM indicated that maintenance flows for the dry season had to be increased. The increase in flows would cater for the fish requirements and provide adequate critical macroinvertebrate biotopes (fast flows over coarse substrates) and required maximum velocities that exceed 0.4 m/s.

To produce the final results, the DRM results for the specific category were adjusted. 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:

- C and C/D EC.
 - 0 Assurance rules: Shape factor set at 0.7.
 - 0 Assurance rules: Upper shift values were changed to 100% for all months.
 - 0 Distribution factors: 0.58 for maintenance

25.4 HIGH FLOW REQUIREMENTS

The same method for determining high flows for the Comprehensive sites was followed for RE-EWR1.

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 (Table 25.2).
- 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 25.2).

Results are provided in Table 25.2 and detailed motivations provided in Table 25.3.

Table 25.2 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 and spawning	Migration habitat (depth etc.)	Clean spawning substrate	Create nursery areas	Resetting water quality	Inundate vegetation for spawning	Breeding and hatching cues	Clear fines	Scour substrate	Reach or inundate specific areas
I	1-3	Geomorphology: Activates the fines and gravels of the active channel (removes the fines) and allows for some deposition and recreation of low bars. Vegetation: Inundation of the marginal zone (<i>Miscanthus</i> are in this zone downstream of the cross-section).	✓	✓	✓	✓	✓	✓		✓		
II	7-12	Geomorphology: Activates and inundates the lower terrace and scours the cobbles on the channel bed. Vegetation: Activates or inundates <i>Crinum</i> and <i>Miscanthus</i> .	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
III	>20	Vegetation: Activates the woody zone (<i>Leucosidea</i>) and the upper ephemeral terrace.	✓	✓	✓	✓	✓	✓				

The number of high flow events required for each EC is provided in Table 25.3. No observed daily data was available to check flood requirements against.

Table 25.3 RE-EWR 1: The recommended number of high flow events required

FLOOD CLASS	FLOOD RANGE (m ³ /s)	INVERTEBRATES	FISH	VEGETATION	GEOMORPHOLOGY	FINAL (Frequency)	MONTHS	DAILY AVERAGE	DURATION
PES and REC SCENARIO: C									
I	1-3	6		4	3	6	Oct, Nov, Dec, Jan, Feb, Mar	1.5	3
II	7-12	2		1:1	1	2?	Jan, Feb	8	3
III	>20			1:3	1:5	1:3			
AEC down: SCENARIO: C/D									
I	1-3	4		2	2	4	Oct, Nov, Dec, Feb	1.5	3
II	7-12	1		1	1	1	Jan	8	3
III	>20			1:3	1:5	1:3			

25.5 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 25.4 and Table 25.6). Floods with a frequency higher than 1:1 was not included;
- The EWR rule table, which provides the EWR recommended flows as a duration table, showing flows that should be provided when linked to a natural trigger (natural hydrology).

An EWR rule table is supplied for the low flows only, and for low and high flows combined (Table 25.5 and Table 25.7).

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

Table 25.4 EWR table for PES and REC: C

Desktop version:		2	Virgin MAR (MCM)	26.09
BFI	0.287	Distribution type		Vaal
MONTH	LOW FLOWS		HIGH FLOWS	
	Maintenance (m ³ /s)	Drought (m ³ /s)	Daily average (m ³ /s) on top of base flow	Duration (days)
OCTOBER	0.053	0.019	1.5	3
NOVEMBER	0.094	0.035	1.5	3
DECEMBER	0.119	0.049	1.5	3
JANUARY	0.13	0.053	1.5 8	3 3
FEBRUARY	0.175	0.073	1.5 8	3 3
MARCH	0.12	0.03		
APRIL	0.084	0.023		
MAY	0.055	0		
JUNE	0.043	0		
JULY	0.039	0		
AUGUST	0.033	0		
SEPTEMBER	0.036	0.012		
TOTAL MCM	2.560	0.762		3.888
% OF VIRGIN	9.81	2.92		14.90
Total IFR			6.45	
% of MAR			24.74	

Table 25.5 RE-EWR 1 assurance rules for PES and REC: C

Desktop Version 2, Printed on 2008/07/07
 Summary of IFR rule curves for: REv_EWR1 Natural Monthly Flows
 Determination based on defined BBM Table with site specific assurance rules.
 Regional Type: Vaal PES and REC = C

Data are given in m³/s mean monthly flow

Month	% Points									
	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	0.180	0.177	0.170	0.158	0.139	0.113	0.084	0.057	0.037	0.022
Nov	0.335	0.295	0.261	0.227	0.174	0.144	0.110	0.078	0.056	0.039
Dec	0.364	0.325	0.291	0.256	0.202	0.169	0.131	0.096	0.071	0.060
Jan	1.417	1.186	0.994	0.825	0.561	0.457	0.338	0.228	0.150	0.115
Feb	1.613	1.357	1.143	0.953	0.657	0.537	0.399	0.272	0.183	0.142
Mar	0.275	0.270	0.259	0.241	0.211	0.172	0.126	0.084	0.055	0.041
Apr	0.119	0.117	0.113	0.105	0.093	0.077	0.059	0.042	0.030	0.024
May	0.078	0.076	0.073	0.067	0.057	0.044	0.029	0.015	0.005	0.001
Jun	0.061	0.060	0.057	0.052	0.044	0.034	0.023	0.012	0.004	0.000
Jul	0.055	0.054	0.052	0.047	0.040	0.031	0.020	0.011	0.004	0.001
Aug	0.047	0.046	0.044	0.040	0.034	0.026	0.017	0.009	0.003	0.001
Sep	0.051	0.050	0.049	0.045	0.041	0.034	0.027	0.020	0.015	0.012

Reserve flows without High Flows

Oct	0.075	0.074	0.072	0.067	0.060	0.051	0.040	0.030	0.023	0.020
Nov	0.134	0.132	0.127	0.119	0.107	0.090	0.072	0.054	0.042	0.036
Dec	0.169	0.167	0.161	0.152	0.137	0.117	0.094	0.072	0.057	0.050
Jan	0.185	0.182	0.176	0.166	0.149	0.127	0.102	0.078	0.062	0.054
Feb	0.249	0.245	0.237	0.223	0.202	0.172	0.138	0.107	0.085	0.075
Mar	0.171	0.167	0.161	0.150	0.133	0.109	0.082	0.057	0.039	0.032

Apr	0.119	0.117	0.113	0.105	0.093	0.077	0.059	0.042	0.030	0.024
May	0.078	0.076	0.073	0.067	0.057	0.044	0.029	0.015	0.005	0.001
Jun	0.061	0.060	0.057	0.052	0.044	0.034	0.023	0.012	0.004	0.000
Jul	0.055	0.054	0.052	0.047	0.040	0.031	0.020	0.011	0.004	0.001
Aug	0.047	0.046	0.044	0.040	0.034	0.026	0.017	0.009	0.003	0.001
Sep	0.051	0.050	0.049	0.045	0.041	0.034	0.027	0.020	0.015	0.012
Natural Duration curves										
Oct	2.080	0.411	0.332	0.235	0.164	0.138	0.101	0.067	0.037	0.022
Nov	3.843	2.481	1.339	0.930	0.613	0.444	0.347	0.266	0.066	0.039
Dec	4.816	3.286	1.986	1.684	1.195	0.840	0.553	0.332	0.187	0.093
Jan	3.517	2.423	1.781	1.557	1.075	1.016	0.672	0.526	0.347	0.175
Feb	6.213	2.025	1.616	1.058	0.827	0.628	0.484	0.355	0.256	0.145
Mar	2.117	1.378	0.907	0.676	0.511	0.437	0.295	0.198	0.097	0.063
Apr	0.926	0.640	0.394	0.336	0.224	0.170	0.123	0.104	0.073	0.027
May	0.500	0.254	0.161	0.131	0.086	0.071	0.060	0.052	0.041	0.011
Jun	0.243	0.158	0.116	0.093	0.077	0.062	0.058	0.050	0.019	0.000
Jul	0.168	0.134	0.105	0.078	0.071	0.060	0.052	0.049	0.030	0.007
Aug	0.134	0.112	0.093	0.082	0.067	0.056	0.049	0.041	0.034	0.015
Sep	0.204	0.139	0.108	0.077	0.066	0.058	0.050	0.039	0.027	0.019

Table 25.6 EWR table for AEC down: C/D

Desktop version:		2	Virgin MAR (MCM)		26.09
BFI	0.287	Distribution type		Vaal	
MONTH	LOW FLOWS		HIGH FLOWS		
	Maintenance (m³/s)	Drought (m³/s)	Daily average (m³/s) on top of base flow	Duration (days)	
OCTOBER	0.038	0.019	1.5	3	
NOVEMBER	0.067	0.035	1.5	3	
DECEMBER	0.085	0.049	1.5	3	
JANUARY	0.093	0.053	8	3	
FEBRUARY	0.125	0.073	1.5	3	
MARCH	0.086	0.03			
APRIL	0.06	0.023			
MAY	0.039	0			
JUNE	0.03	0			
JULY	0.028	0			
AUGUST	0.024	0			
SEPTEMBER	0.026	0.012			
TOTAL MCM	1.829	0.762	2.177		
% OF VIRGIN	7.01	2.92	8.35		
Total IFR	4.01				
% of MAR	15.36				

Table 25.7 RE-EWR 1 assurance rules for AEC down: C/D

Summary of IFR rule curves for: REv_EWR1 Natural Monthly Flows
 Determination based on defined BBM Table with site specific assurance rules.
 Regional Type: Vaal AEC = C/D

Data are given in m³/s mean monthly flow

	% Points									
Month	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	0.173	0.170	0.164	0.152	0.134	0.109	0.082	0.056	0.037	0.022
Nov	0.308	0.270	0.236	0.204	0.155	0.129	0.100	0.073	0.054	0.039
Dec	0.331	0.293	0.260	0.228	0.178	0.150	0.119	0.089	0.069	0.059
Jan	1.186	0.992	0.831	0.690	0.470	0.385	0.287	0.197	0.134	0.105
Feb	0.416	0.373	0.335	0.297	0.238	0.202	0.161	0.124	0.097	0.085
Mar	0.138	0.135	0.130	0.122	0.109	0.090	0.070	0.051	0.037	0.031
Apr	0.096	0.094	0.091	0.085	0.076	0.064	0.050	0.037	0.028	0.024
May	0.062	0.061	0.058	0.053	0.045	0.035	0.023	0.012	0.004	0.001
Jun	0.048	0.047	0.045	0.041	0.035	0.027	0.018	0.009	0.003	0.000

Jul	0.045	0.044	0.042	0.038	0.033	0.025	0.017	0.009	0.003	0.000
Aug	0.038	0.037	0.036	0.033	0.028	0.021	0.014	0.007	0.003	0.000
Sep	0.042	0.041	0.040	0.037	0.034	0.029	0.023	0.018	0.014	0.012
Reserve flows without High Flows										
Oct	0.061	0.060	0.058	0.055	0.050	0.043	0.034	0.027	0.022	0.019
Nov	0.107	0.106	0.103	0.097	0.088	0.076	0.062	0.049	0.040	0.036
Dec	0.136	0.134	0.130	0.124	0.113	0.098	0.081	0.066	0.055	0.050
Jan	0.149	0.147	0.143	0.135	0.123	0.107	0.089	0.072	0.059	0.054
Feb	0.200	0.198	0.192	0.182	0.166	0.145	0.120	0.098	0.082	0.074
Mar	0.138	0.135	0.130	0.122	0.109	0.090	0.070	0.051	0.037	0.031
Apr	0.096	0.094	0.091	0.085	0.076	0.064	0.050	0.037	0.028	0.024
May	0.062	0.061	0.058	0.053	0.045	0.035	0.023	0.012	0.004	0.001
Jun	0.048	0.047	0.045	0.041	0.035	0.027	0.018	0.009	0.003	0.000
Jul	0.045	0.044	0.042	0.038	0.033	0.025	0.017	0.009	0.003	0.000
Aug	0.038	0.037	0.036	0.033	0.028	0.021	0.014	0.007	0.003	0.000
Sep	0.042	0.041	0.040	0.037	0.034	0.029	0.023	0.018	0.014	0.012
Natural Duration curves										
Oct	2.080	0.411	0.332	0.235	0.164	0.138	0.101	0.067	0.037	0.022
Nov	3.843	2.481	1.339	0.930	0.613	0.444	0.347	0.266	0.066	0.039
Dec	4.816	3.286	1.986	1.684	1.195	0.840	0.553	0.332	0.187	0.093
Jan	3.517	2.423	1.781	1.557	1.075	1.016	0.672	0.526	0.347	0.175
Feb	6.213	2.025	1.616	1.058	0.827	0.628	0.484	0.355	0.256	0.145
Mar	2.117	1.378	0.907	0.676	0.511	0.437	0.295	0.198	0.097	0.063
Apr	0.926	0.640	0.394	0.336	0.224	0.170	0.123	0.104	0.073	0.027
May	0.500	0.254	0.161	0.131	0.086	0.071	0.060	0.052	0.041	0.011
Jun	0.243	0.158	0.116	0.093	0.077	0.062	0.058	0.050	0.019	0.000
Jul	0.168	0.134	0.105	0.078	0.071	0.060	0.052	0.049	0.030	0.007
Aug	0.134	0.112	0.093	0.082	0.067	0.056	0.049	0.041	0.034	0.015
Sep	0.204	0.139	0.108	0.077	0.066	0.058	0.050	0.039	0.027	0.019

A comparison between the differences in terms of percentages of the various types of flow blocks are provided in Table 25.8.

Table 25.8 Modifications made to the DRM for RE-EWR 1

Changes	PES and REC C		AEC down C/D	
	DRM	EWR	DRM	EWR
MLIFR - Maintenance low flow	9.1%	9.8%	6.6%	7.0%
DLIFR - Drought low flow	2.9%	2.9%	2.9%	2.9%
MHIFR - Maintenance high flow	10.9%	14.9%	19.8%	8.4%
Long-term % of virgin MAR	19.5%	24.1%	17.7%	16.2%

26 RE-EWR 2: MOOI (MOOI RIVER) - (DETERMINATION OF EWR SCENARIOS

26.1 ECOCLASSIFICATION SUMMARY OF RE-EWR 2

RE-EWR 2: Mooi (Mooi River)																					
<p>EIS: LOW PES: D This naturally would have been a wetland with a badly defined channel. Wetland tools were used to represent the driver state and the river tools used to assess the responses.</p> <p>Some very rare constricted areas with small riffles occur. This site is downstream of the Klerkskraal Dam and about the only reach with remnants of wetland intact. This is a short section. The rest of the MRU is very badly degraded and would be in a lower category. Downstream of the Wonderfontein inflow, the bad water quality would be the overriding concern. The PES is in a D and the rest of the MRU would be in an E or even lower. It will not be possible to improve the category by improving flows as the fish is already in a C EC and the riparian vegetation EC is due to non-flow related impacts. However, the macroinvertebrate EC might improve to at least a D with some improved flow.</p>	<table border="1"> <thead> <tr> <th>Driver Components</th> <th>PES Category</th> </tr> </thead> <tbody> <tr> <td>HYDROLOGY</td> <td>E</td> </tr> <tr> <td>WATER QUALITY</td> <td>C</td> </tr> <tr> <td>WETLAND HABITAT INTEGRITY</td> <td>E</td> </tr> <tr> <th>Response Components</th> <th>PES Category</th> </tr> <tr> <td>FISH</td> <td>C</td> </tr> <tr> <td>AQUATIC INVERTEBRATES</td> <td>E</td> </tr> <tr> <td>INSTREAM</td> <td>D</td> </tr> <tr> <td>RIPARIAN VEGETATION</td> <td>D</td> </tr> <tr> <td>ECOSTATUS</td> <td>D</td> </tr> </tbody> </table>	Driver Components	PES Category	HYDROLOGY	E	WATER QUALITY	C	WETLAND HABITAT INTEGRITY	E	Response Components	PES Category	FISH	C	AQUATIC INVERTEBRATES	E	INSTREAM	D	RIPARIAN VEGETATION	D	ECOSTATUS	D
Driver Components	PES Category																				
HYDROLOGY	E																				
WATER QUALITY	C																				
WETLAND HABITAT INTEGRITY	E																				
Response Components	PES Category																				
FISH	C																				
AQUATIC INVERTEBRATES	E																				
INSTREAM	D																				
RIPARIAN VEGETATION	D																				
ECOSTATUS	D																				

RE-EWR 2 was assessed at a Rapid level for low flows and therefore the HFSR method for setting low flows were not applied to this site. The Reserve was estimated using the Hughes Desktop Reserve Model (DRM) (DWA, 1999) for the Ecological Category (EC) set. Therefore for the low flow requirements, the estimated Reserve was verified and the DRM was adjusted if needed. High flows were set using the standard Comprehensive approach.

26.2 HYDROLOGY

The highest and lowest low flow months selected as the key months are February (wet) and August (dry). The flows that were assessed by the specialists to verify the DRM are discussed in Section 26.3.

26.3 LOW FLOW REQUIREMENTS

The flow requirement results were largely based on the requirements of macroinvertebrates as the fish species present are wetland type species. The DRM is adequate to maintain the population as adequate depth in pools are present and vegetation is inundated for larger species e.g. CGAR. It is important to maintain adequate water quality for especially species such as AJOH and BPAL. The low flow requirements of the PES EcoStatus were evaluated by the macroinvertebrate specialist and motivations are provided in Table 26.1.

Table 26.1 Summary of RE-EWR 2 motivations

Season	Initial desktop flows	Adjusted Desktop flows	Response
	Maintenance (m ³ /s)	Maintenance (m ³ /s)	
PES: D EcoStatus			FISH: C
			MACROINVERTEBRATES: E
Aug	0.11	0.12	Dry Season maintenance Discharge of 0.12 m ³ /s is recommended for the PES. The average depth needed for indicator taxa during dry season maintenance is 0.13 m, and average current velocity is 0.11 m/s. At the recommended flows in the dry season sufficient hydraulic habitat is present to maintain a few flow-

Season	Initial desktop flows	Adjusted Desktop flows	Response
	Maintenance (m ³ /s)	Maintenance (m ³ /s)	
			dependent macroinvertebrates, such as Simuliidae and Baetidae and improve the EC to a D.
Feb	0.12	0.16	Wet Season maintenance Discharge of 0.16 m ³ /s is recommended for the PES. Average depth for these taxa during wet season maintenance is 5 cm higher than dry season maintenance in order to provide seasonal variation in conditions and improve the presence of flow dependant taxa. Average current speeds remain unchanged at 0.11 m/s. Only 9 taxa were collected at this site.

26.3.1 Final low flow requirements

The verification of the DRM indicated that maintenance flows for the dry and wet season of the PES had to be increased to cater for the macroinvertebrate requirements.

To produce the final results, the DRM results for the specific category were adjusted. 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.

26.4 HIGH FLOW REQUIREMENTS

The same method for determining high flows of the Comprehensive sites was followed for RE-EWR 2.

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 (Table 26.2).

Results are provided in Table 26.2 and detailed motivations provided in Table 26.3.

Table 26.2 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
I	1 - 2	Geomorphology: Several small floods throughout the wet season to recharge the floodplain (which has peat wetlands) and provide for evapotranspiration of reeds. Vegetation: Maintain the floodplain vegetation and bank vegetation (<i>T. capensis</i> mainly).
II	>8	Geomorphology: Annual flood to spread across the floodplain, recharging the peats, activating cut off channels, inundating the floodplain vegetation and reedbeds

The Mooi is an extensive floodplain system which is highly altered due to extensive peat mining in this reach. Floods required to recharge the floodplain and maintain floodplain vegetation have been estimated and recommended above. The confidence is however low due to site unsuitability (non-representative).

The number of high flow events required for each EC is provided in Table 26.3. No observed daily data was available to check flood requirements against.

Table 26.3 RE-EWR 2: The recommended number of high flow events required

FLOOD CLASS	FLOOD RANGE (m ³ /s)	INVERTEBRATES	FISH	VEGETATION	GEOMORPHOLOGY	FINAL (Frequency)	MONTHS	DAILY AVERAGE	DURATION
PES D									
I	1 - 2			6					
II	>8			1					

26.5 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 26.4). Floods with a frequency higher than 1:1 was not included;
- The EWR rule table, which provides the EWR recommended flows as a duration table, showing flows that should be provided when linked to a natural trigger (natural hydrology). An EWR rule table is supplied for the low flows only, and for low and high flows combined (Table 26.5).

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

Table 26.4 EWR table for PES: D

		Virgin MAR (MCM)		37.695	
		Distribution type		Vaal	
MONTH	LOW FLOWS		HIGH FLOWS		
	Maintenance (m ³ /s)	Drought (m ³ /s)	Daily average (m ³ /s) on top of base flow	Duration (days)	
OCTOBER	0.12	0.106			
NOVEMBER	0.12	0.109			
DECEMBER	0.12	0.106			
JANUARY	0.128	0.108			
FEBRUARY	0.155	0.124			
MARCH	0.153	0.115			
APRIL	0.16	0.12			
MAY	0.154	0.116			
JUNE	0.154	0.118			
JULY	0.146	0.113			
AUGUST	0.143	0.112			
SEPTEMBER	0.137	0.113			
TOTAL MCM	4.44	3.571		2.744	
% OF VIRGIN	11.77	9.47		7.28	
Total IFR			7.18		
% of MAR			19.05		

Table 26.5 RE-EWR 2 assurance rules for PES: D

Desktop Version 2, Printed on 2008/09/12
 Summary of IFR rule curves for: REv_EWR2 Natural Monthly Flows
 Determination based on site specific parameters from SPATSIM database.
 Regional Type: Vaal PES: D

Data are given in m³/s mean monthly flow

Month	% Points									
	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	0.222	0.218	0.210	0.196	0.176	0.153	0.132	0.118	0.110	0.109
Nov	0.430	0.370	0.318	0.267	0.202	0.168	0.142	0.127	0.120	0.119
Dec	0.300	0.270	0.240	0.209	0.168	0.144	0.126	0.116	0.112	0.112
Jan	0.304	0.273	0.243	0.211	0.170	0.145	0.127	0.117	0.114	0.114
Feb	1.233	0.992	0.792	0.613	0.383	0.290	0.220	0.183	0.168	0.167
Mar	0.416	0.404	0.378	0.334	0.277	0.218	0.173	0.146	0.135	0.133
Apr	0.385	0.377	0.359	0.329	0.284	0.232	0.185	0.153	0.137	0.134
May	0.206	0.203	0.197	0.186	0.171	0.153	0.136	0.124	0.118	0.116
Jun	0.210	0.208	0.202	0.191	0.176	0.158	0.141	0.128	0.121	0.118
Jul	0.202	0.200	0.194	0.185	0.170	0.153	0.136	0.124	0.116	0.114
Aug	0.201	0.198	0.192	0.182	0.168	0.151	0.134	0.122	0.115	0.113
Sep	0.230	0.227	0.219	0.205	0.186	0.162	0.141	0.125	0.118	0.116
Reserve flows without High Flows										
Oct	0.189	0.187	0.181	0.171	0.156	0.139	0.124	0.113	0.108	0.107
Nov	0.187	0.184	0.176	0.164	0.149	0.132	0.120	0.112	0.109	0.109
Dec	0.183	0.180	0.172	0.160	0.144	0.128	0.116	0.109	0.107	0.107
Jan	0.187	0.183	0.175	0.162	0.145	0.129	0.117	0.111	0.109	0.109
Feb	0.213	0.209	0.200	0.186	0.167	0.148	0.135	0.127	0.124	0.124
Mar	0.199	0.195	0.188	0.175	0.158	0.141	0.127	0.120	0.116	0.116
Apr	0.213	0.210	0.204	0.192	0.176	0.157	0.139	0.127	0.121	0.120
May	0.206	0.203	0.197	0.186	0.171	0.153	0.136	0.124	0.118	0.116
Jun	0.210	0.208	0.202	0.191	0.176	0.158	0.141	0.128	0.121	0.118
Jul	0.202	0.200	0.194	0.185	0.170	0.153	0.136	0.124	0.116	0.114
Aug	0.201	0.198	0.192	0.182	0.168	0.151	0.134	0.122	0.115	0.113
Sep	0.202	0.199	0.193	0.182	0.167	0.149	0.133	0.121	0.115	0.114
Natural Duration curves										
Oct	1.770	1.131	0.881	0.758	0.676	0.605	0.549	0.526	0.482	0.392
Nov	1.736	1.296	0.976	0.934	0.768	0.691	0.625	0.575	0.486	0.386
Dec	1.990	1.430	1.086	0.963	0.866	0.721	0.635	0.560	0.459	0.370
Jan	2.289	1.542	1.314	1.086	0.960	0.810	0.717	0.635	0.504	0.306
Feb	2.956	1.951	1.459	1.257	1.058	0.909	0.773	0.678	0.562	0.417
Mar	2.759	1.882	1.572	1.284	1.049	0.896	0.792	0.698	0.609	0.437
Apr	2.789	2.157	1.674	1.354	1.076	0.957	0.860	0.760	0.679	0.529
May	2.042	1.688	1.370	1.146	0.963	0.885	0.821	0.706	0.657	0.541
Jun	2.253	1.574	1.188	1.046	0.899	0.802	0.741	0.683	0.640	0.556
Jul	1.945	1.381	1.030	0.960	0.892	0.788	0.698	0.650	0.616	0.571
Aug	1.949	1.232	1.012	0.874	0.803	0.736	0.665	0.620	0.586	0.534
Sep	1.952	1.088	0.961	0.810	0.756	0.702	0.617	0.590	0.559	0.494

27 CONCLUSIONS AND RECOMMENDATIONS

The process followed to identify realistic recommendations is to:

- Identify the confidences associated with the low and high flow results; and
- based on this to make realistic recommendations on any work that can be undertaken to improve the confidences.

An evaluation is then made whether these recommendations can be accommodated in a monitoring programme that should follow EWR assessments or whether specific work is required.

27.1 SUMMARY OF FINAL RESULTS

The natural and present day MARs as provided by WRP are given in Table 27.1. The final flow requirements are expressed as a percentage of either the natural or present day MAR in Table 27.2.

Table 27.1 Natural and PD MARs of the EWR sites

Site	Virgin MAR	Present MAR
EWR 1	288.8 MCM	332.72
EWR 2	457.7 MCM	267.12
EWR 3	858.1 MCM	603.09
EWR 4	1977.3 MCM	1130.72
EWR 5	2288 MCM	1364.54
EWR 6	95.3 MCM	84.53
EWR 7	23.5 MCM	23.5
EWR 8	474.3 MCM	425.39
EWR 9	31.3 MCM	29.47
EWR 10	86.98 MCM	134.84
EWR 11	29.14 MCM	80.64

Table 27.2 Summary of results as a percentage of the natural MAR

EWR site	EC	Maintenance low flows (%nMAR)	Drought low flows (%nMAR)	High flows (%nMAR)	Long term mean (% nMAR)
Virgin MARs					
EWR 2	C PES, REC	6.6	1.1	7	12.7
	B AEC up	11.3	1.1	7.6	16.2
	C/D AEC down	3.1	1.1	6.2	9.5
EWR 3	C PES, REC	10.6	0.9	3.7	14.6
	B AEC up	20.4	1.8	4.3	22.7
	C/D AEC down	4.5	0.9	3.2	8.8
EWR 6	B/C PES, REC	18.4	18.4	8.1	23.4
	C AEC down	8.8	1.7	6.5	14.9
EWR 7	B/C PES, REC	34.8	2.8	13.2	24
	C AEC down	19.6	2.8	5.1	25.8
EWR 8	C PES, REC	5.1	1.2	6.6	11.5
	B/C AEC up	6.6	1.2	7	12.6
	D AEC down	3.1	1.2	5.7	9.7
EWR 9	C PES	14.1	5.8	6.6	21.1
	B/C REC	27.1	5.8	7.3	31.4
EWR 1	B/C PES, REC	35.7	1.8	9.7	40.5

EWR site	EC	Maintenance low flows (%nMAR)	Drought low flows (%nMAR)	High flows (%nMAR)	Long term mean (% nMAR)
Present Day (PD) MAR					
EWR 10	C/D PES, REC	30.1	17.1	4.3	41.1
	C AEC down	29.3	11.6	4.1	33.6
EWR 11	D PES (DRM D)	12.4	9.2	5.7	25.9
	D REC (DRM C)	14.1	7.1	5.7	21.2
EWR 4	Could not be generated.				
EWR 5	Could not be generated.				

27.2 CONFIDENCES

27.2.1 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, so even if the fish data availability and understanding of habitat requirements are of low confidence, the confidence in the much higher recommended requirement, which is based on macroinvertebrates, will cater for fish requirements and therefore 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 27.3 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.

Confidence is defined below and applicable to all confidence ratings:

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

Table 27.3 Confidence in low flows for biotic responses

EWR SITE	FISH	MACROINVERTS	RIP VEG	COMMENT	OVERALL CONFIDENCE
EWR 2	4	3	4	<p>Fish: The recommendations for the most important indicator species BAEN were met and exceeded where the macroinvertebrate stress level drives the flow requirements, especially during the wet season, the most important time for BAEN. At the recommended stress level/flows adequate habitat will be provided to sustain all the important habitat requirements of all life stages of the indicator species. The requirements and habitat preferences of this species had been well documented. The data and information gathered regarding this species specifically sampled at this EWR site has also been high.</p> <p>Macroinvertebrates: The flow requirements are mostly driven by the macroinvertebrate requirements..</p> <p>Riparian vegetation: Low flow requirements of fish and macroinvertebrates are sufficient to facilitate riparian vegetation survival and functionality. Accurate vegetation survey points facilitated easy assessment, and main riparian obligates were well understood.</p>	3.5
EWR 3	4	4	4	<p>Fish: The low flows for this site was predominantly driven by the requirements of LSR guild. It is estimated that at the recommended stress level/flows adequate habitat will be provided to sustain all the important habitat requirements of all life stages of the indicator species within the categories of concern. The requirements and habitat preferences of the indicator species had been well documented. The data and information gathered regarding this species specifically sampled at this EWR site has also been high.</p> <p>Macroinvertebrates: The flow requirements set by the LSR guild were sufficient for the macroinvertebrates. Reference data for the determination of the PES was partly based on data collected by Dr Mark Chutter from this site (Chutter, 1967).</p> <p>Riparian vegetation: See EWR 2.</p>	4
EWR 6	4	4	4	<p>Fish: The wet season flows are driven by the macroinvertebrate requirements, which are of less stress, and thus higher flows, than those required for the fish. Dry season flows/stress levels are guided by the semi-rheophilic indicator BAEN, and it is estimated that the requested flows are adequate to sustain their required refuge habitats for this periods. The requirements and habitat preferences of this species had been well documented, and the requirements of spawning and early life stages are very valuable for setting flow conditions for especially the wet season. The requirement for inundated vegetation during the wet season for the purpose of vegetation breeders is also met with the recommended stress level/flows for the wet season.</p> <p>Macroinvertebrates: More flow is available than required during the dry season. Flow recommendations in the wet season are driven by macroinvertebrates. Confidence is high as flow requirements were based on two indicator taxa with well defined flow requirements (Hydropsychidae 2 spp+ and Simuliidae) Reference data for the determination of the PES was partly based on data collected by Dr Mark Chutter from this site (Chutter, 1967).</p> <p>Riparian vegetation: Low flow requirements of fish and macroinvertebrates are sufficient to facilitate riparian vegetation survival and functionality. Low flow requirements for the AEC will elicit a vegetation response in keeping with anticipated changes. Accurate vegetation survey points facilitate assessment, and main riparian obligates present were well understood.</p>	4
EWR 7	4	2	3.5	<p>Fish: The recommended flows are primarily driven by the requirements of macroinvertebrates. The stress levels/recommended flows are adequate to provide the required refuge areas in dry period, and more importantly the habitats for different life stages (including spawning, egg development, larvae) in the wet season. The requirements and habitat preferences of the indicator group is well documented and valuable information were gathered regarding these species at the site during the present study.</p> <p>Macroinvertebrates: The requirements were mostly driven by macroinvertebrates. As the requirements were based on depth of vegetation inundation only, the confidence in setting flows was lower than for a stream with flow dependent taxa.</p> <p>Riparian vegetation: See EWR 2, although confidence is slightly lower due to only one survey that was undertaken.</p>	2
EWR 8	4	4	3	<p>Fish: Both the recommended wet and dry season flows are driven by the requirements of the LSR guild. The requirements are adequate for the provision of the refuge areas in dry period, and more importantly the habitats for different life stages (including spawning, egg development, larvae) in the wet season. The requirements and habitat preferences of this species had been well documented, and the requirements of spawning and early life stages are very valuable for setting flow conditions for especially the wet season. No requirements have been set for species with requirements for inundated vegetation for spawning, as flow changes would not make significant differences to this habitat component.</p> <p>Macroinvertebrates: The macroinvertebrate requirements are more than met by the fish requirements. In addition flow requirements were based on two indicator taxa with well defined flow-requirements (Hydropsychidae and Simuliidae). Reference data for the determination of the macroinvertebrate PES was partly based on data collected by Dr Mark Chutter from this site (Chutter, 1967)..</p>	4

EWR SITE	FISH	MACROINVERTS	RIP VEG	COMMENT	OVERALL CONFIDENCE
				Riparian vegetation: Low flow requirements of fish and macroinvertebrates are sufficient to facilitate riparian vegetation survival and functionality. Accurate vegetation survey points facilitated assessment, but low flows will cause water stress and confidence is lower as to when/if fatalities will occur.	
EWR 9	4	4	3	<p>Fish: The recommended PES dry season flows are driven by the requirements of the LSR guild while the wet season PES is driven by the macroinvertebrates and SSR guild. The stress levels/recommended flows are adequate to provide the required refuge areas in dry period, and more importantly the habitats for different life stages (including spawning, egg development, larvae) in the wet season. The requirements and habitat preferences of this species had been well documented, and the requirements of spawning and early life stages are very valuable for setting flow conditions for especially the wet season. Adequate inundated vegetation will also be available in the wet season for species with a requirement for this cover feature. The recommended stress level/flows should furthermore be adequate to sustain the requirements of most of the other fish species at the site.</p> <p>Macroinvertebrates: There is more maintenance flow available than required to sustain the PES during both the wet and dry flow periods, as the flow requirements are mostly driven by the requirements for fish. The indicators used were Hydropsychidae and Simuliidae with well defined flow requirements.</p> <p>Riparian vegetation: Low flow requirements of fish and macroinvertebrates are sufficient to facilitate riparian vegetation survival and functionality. Vegetation survey points facilitated assessment.</p>	4
EWR 10	4	1.5	3	<p>Fish: The recommended flows are mostly driven by macroinvertebrates, while some flows are driven by the LSR guild and the wet improved flows by the LIM guild. The flows driven by the macroinvertebrates exceed the requirements set for fish and should therefore be more than adequate for fish. The requirements of these species are relatively well documented and valuable information was also gained for these species during the current project.</p> <p>Macroinvertebrates: The confidence in the recommended flows meeting the requirements for macroinvertebrates is low as the PES is driven mainly by water quality, and not flow. The situation with higher flows than natural is complex to interpret in terms of biota responses. The water quality problems add to the complexity.</p> <p>Riparian vegetation: See EWR 9.</p>	2.75
EWR 11	4	3	3	<p>Fish: All the flows at this site are driven by the requirements of the LSR guild. The requirements are adequate to provide the required refuge areas in dry period, and more importantly the habitats for different life stages (including spawning, egg development, larvae) in the wet season. The requirements and habitat preferences of this species have been well documented, and the requirements of spawning and early life stages are very valuable for setting flow conditions for especially the wet season. Adequate inundated vegetation will also be available in the wet season for species with a requirement for this cover feature. The recommended stress level/flows should furthermore be adequate to sustain the requirements of most of the other fish species at the site.</p> <p>Macroinvertebrates: The flow requirements set by the LSR guild were sufficient for the macroinvertebrates. Therefore, even if the situation with higher flows than natural is complex to interpret in terms of biota responses, the confidence is higher than at site 10 as the macroinvertebrates are not the driver.</p> <p>Riparian vegetation: See EWR 9.</p>	4
EWR 1	4	4	4	<p>Fish: BAEN's requirements were met and drive the recommended stress level/flows to maintain the current PES. At these flows adequate habitat will be provided to sustain all the important habitat requirements of all life stages (indicator). The requirements and habitat preferences of this species had been well documented. The data and information gathered regarding this species specifically sampled at this EWR site has also been high.</p> <p>Macroinvertebrates: Data availability fairly good, but limited topographical cues.</p> <p>Riparian vegetation: More flow than would be required to maintain the marginal zone is provided. Riparian obligates (species dependant on flows) were well represented.</p>	4
EWR 4	4	1	3.5	<p>Fish: Most of the requirements were driven by the macroinvertebrate requirements and therefore exceeded the requirements for fish.</p> <p>Macroinvertebrates: The confidence in the recommended flows is very low as the PES is potentially driven mainly by water quality, and not flow. This, combined with the seasonality change, results in a low confidence in the determination of macroinvertebrate response to changed flows.</p> <p>Riparian vegetation: Low flow requirements of fish and macroinvertebrates are sufficient to facilitate riparian vegetation survival.</p>	1
EWR 5	3	2	3.5	<p>Fish: The requirements were predominantly driven by the requirements of the LSR guild. The requirements provide adequate habitat will to sustain all the important habitat requirements of all life stages of the indicator species within the categories of concern. The requirements and habitat preferences of the indicator species had been well documented. The data and information gathered regarding this species specifically sampled at this EWR site has also been high.</p>	3

EWR SITE	FISH	MACROINVERTS	RIP VEG	COMMENT	OVERALL CONFIDENCE
				<p>Macroinvertebrates: The confidence in the recommended flows is very low as the PES is potentially driven mainly by water quality, and not flow. This, combined with the seasonality change, results in a low confidence in the determination of macroinvertebrate response to changed flows. However, as the requirements are driven by the fish, the confidence is higher than at EWR 4.</p> <p>Riparian vegetation: Low flow requirements of fish and macroinvertebrates are sufficient to facilitate riparian vegetation survival.</p>	

27.2.2 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 27.4) represents an average of the riparian vegetation and geomorphology confidence as these two components determine the flood requirements.

Table 27.4 Confidence in high flows

EWR SITE	FISH	MACROINVERTS	RIPARIAN VEGETATION	GEOMORPHOLOGY	COMMENT	OVERALL CONFIDENCE
EWR 2	3	3	4	2	<p>Fish: The recommended floods are adequate in terms of frequency, size and duration to provide various functions regarding fish migration, creation of spawning habitats and nursery areas.</p> <p>Macroinvertebrates: Floods recommended are adequate in terms of macroinvertebrates..</p> <p>Riparian vegetation: Flows are only required for marginal and lower zones since the upper zone comprised of terrestrial grassland. The vegetation survey points were adequate. The channel shape is simple so increased the confidence in estimation.</p> <p>Geomorphology: Available data is poor (the available hydrology is very far removed from a natural pattern) and this has reduced the confidence of the PBMT. In addition, PBMT has limited suitability for this site (immediately below a large dam which cuts off most sediment), and is confounded by the bottom releases from the dam (which are laden with fines). No morphological cues because the site is heavily altered/engineered from the natural condition. The reach is between two large dams, so the floods are more applicable for the downstream reach than the actual site.</p>	3
EWR 3	3	3	4	3	<p>Fish: See EWR 2.</p> <p>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.</p> <p>Riparian vegetation: Vegetation survey points were adequate. Riparian obligates were sufficiently common to facilitate high confidence flow estimation and well understood.</p> <p>Geomorphology: There are no morphological cues at this site- both banks are cut or eroding. Additionally, much of the bed sediment at the site is highly angular and probably locally derived.</p>	3.5

EWR SITE	FISH	MACROINVERTEBRATES	RIPARIAN VEGETATION	GEOMORPHOLOGY	COMMENT	OVERALL CONFIDENCE
EWR 6	3.5	3	4	3	Fish: See EWR 2.	3.5
					Macroinvertebrates: See EWR 3.	
					Riparian vegetation: Vegetation survey points were adequate. Riparian obligates were sufficiently common to facilitate high confidence flow estimation.	
					Geomorphology: <ul style="list-style-type: none"> The nearest gauge (with observed flows to undertake PBMT modelling) is very far downstream, and then includes the contributions of two major tributaries. The flows for the EWR site have had to be scaled (by catchment area) back from this gauge, so confidence that these realistically represent flows at the site is moderate, and low for large floods (because the downstream gauge is drowned out during big floods). However, the catchment has few impacts in terms of intensive water use, and there are no major dams upstream of the site (but many farm dams and some limited irrigation), so moderate and large floods are not likely to be highly impacted. Determination of flows is further confounded by the bedrock nature of the site – there are no alluvial morphological cues to use to set flows. Flow determination for geomorphology has had to rely on the low confidence PBMT modelling results. 	
EWR 7	4	4	4	3.5	Fish: See EWR 2.	3.8
					Macroinvertebrates: See EWR 2.	
					Riparian vegetation: There were sufficient riparian obligate species to use as indicators of flow requirements.	
					Geomorphology: Confidence in the actual floodplain driving mechanisms is high, but the frequency of flooding is less well understood at this stage. Vegetation (riparian) indicators should be able to compensate for this shortfall.	
EWR 8	3.5	4	4	3.5	Fish: See EWR 2.	3.8
					Macroinvertebrates: See EWR 2.	
					Riparian vegetation: Confidence in hydraulic and hydrological data high. Riparian obligates were sufficiently common to facilitate high confidence flow estimation.	
					Geomorphology: <ul style="list-style-type: none"> The nearest gauge (with observed flows to undertake PBMT modelling) is very close the site, therefore a high confidence in the observed hydrology, although the record is less than 20 years long. Determination of flows were confounded by the bedrock nature of the site – there were very limited alluvial morphological cues to set flows, and much of the apparent bed sediment (boulders/cobbles) were derived locally from the bedrock slopes and cliffs, therefore they do not represent the reach sediments. The transport of finer sands and gravels has thus been focused on for the sediment modelling.. 	
EWR 9	3.5	4	4	2	Fish: See EWR 2.	3
					Macroinvertebrates: See EWR 2.	
					Riparian vegetation: Sufficient riparian obligate species were present to use as indicators of flow requirements.	
					Geomorphology: <ul style="list-style-type: none"> There was no available observed hydrology for the reach. PBMT modelling could therefore not be undertaken for this site. Some morphological cues were present in the upstream pool area (upstream of the cross-section). The upper terrace is paired on the LHB and the lower bench is an annually flooded feature. Without the PBMT modelling it was difficult to accurately determine the frequencies/return intervals of the floods which were identified. Determination of flows at the cross-section was confounded by the bedrock nature of the riffle – there were very limited alluvial morphological cues to set flows, and much of the apparent bed sediment (boulders/cobbles) was derived locally from the underlying resistant dyke. The cues were inferred from the upstream alluvial features. Flow determination for geomorphology has therefore been based on low confidence morphological cues. 	
EWR 10	3.5	4	4	4	Fish: See EWR 3.	4
					Macroinvertebrates: See EWR 2.	

EWR SITE	FISH	MACROINVERTEBRATES	RIPARIAN VEGETATION	GEOMORPHOLOGY	COMMENT	OVERALL CONFIDENCE
					<p>Riparian vegetation: Sufficient riparian obligate species were present to use as indicators of flow requirements.</p> <p>Geomorphology: The significant discharge classes identified through the PBMT results were confirmed by the presence of a number of geomorphological cues at this alluvial site (i.e. the flow classes and morphological cues coincided very well). Confidence in the results was thus high.</p>	
EWR 11	3.5	4	4		<p>Fish: See EWR 2.</p> <p>Macroinvertebrates: See EWR 2.</p> <p>Riparian vegetation: See EWR 10.</p> <p>Geomorphology: No floods could be motivated for the maintenance of the geomorphological condition at EWR 11. Refer to Section 18.4.</p>	4
EWR 1	3	4	4	4	<p>Fish: Breeding requirements well known for BANO and other vegetation breeders. These recommended floods furthermore closely resemble those that can be expected under natural conditions. Other floods also adequately provide other important functions regarding fish biology.</p> <p>Macroinvertebrates: See EWR 2.</p> <p>Riparian vegetation: See EWR 10.</p> <p>Geomorphology: Available data was fairly good, and observed flows relevant for the site, results from the PBMT and identification of effective flows, correlated very closely with the vegetation indicators for high flows.</p> <p>How the reduced floods would impact on the system is unsure. This reach already experiences very high base flows, but the largely natural floods ameliorate the impacts of the high base flows.</p>	4
EWR 4	3	3	3	1.5	<p>Fish: See EWR 2.</p> <p>Macroinvertebrates: See EWR 2.</p> <p>Riparian vegetation: Few riparian obligate species were present to use as indicators of flow requirements.</p> <p>Geomorphology: The bed is highly mobile, so PBMT would be appropriate. However, the site is immediately below the very large Vaal Dam and thus all sediment (except suspended load) has been cut off by the upstream dam. A single flood was recommended and confidence is low as it is uncertain what the response in terms of habitat will be.</p>	2.25
EWR 5	3	3	4	4	<p>Fish: See EWR 2.</p> <p>Macroinvertebrates: See EWR 2.</p> <p>Riparian vegetation: See EWR 4</p> <p>Geomorphology: The stage of the significant discharge classes (effective discharges) identified through the PBMT results coincided with the presence of geomorphological cues (benches and terraces) at this alluvial site - i.e. the flow classes and morphological cues correspond very well. Confidence in the results is thus high.</p>	4

27.2.3 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 assessment. This will be different than the confidence in the hydrology for water resources management and planning. The scale of requirements is very different, and that is why high confidence hydrology for water resource management purposes often does not provide sufficient confidence for EWR assessment. The confidence in hydrology is provided in Table 27.5.

Table 27.5 Confidence in hydrology

EWR site	Natural hydrology	Present hydrology	Observed hydrology	Local knowledge/information	Comment	Confidence: Median	Confidence: Average
2	4	2	4	2	Hydrology was simulated at the site. Historical release record was used to simulate the releases for Standerton and downstream farmers. The observed data available and of good quality. Complete observed record influenced by Grootdraai Dam. Modelled present day hydrology is low at all sites due to the out of date nature of the hydrology available.	3	3
3	3	2	4	3	Some scaling of the natural record took place which may have caused inaccuracies. PD flows are affected by Grootdraai Dam and assumptions were made in terms of the disaggregation of unlawful irrigation water use both in the Klip River catchment and along the main stem of the Vaal River.	3	3
6	3	1	1.5	2	Some scaling of the natural and present day record took place, which may have caused inaccuracies in the present day record due to the large number of farms dams upstream from site. Additionally some unlawful use was not taken into account with the present day simulation. Observed data good after 1960, although far away from site.	1.8	1.9
7	4	4	1	2	Natural hydrology was scaled to EWR site. No land use upstream from site. Site is thus considered to be pristine.	3	2.8
8	3	1.5	2	3	Some scaling of the natural and present day records took place. Upstream use is mainly by farm dams, irrigation and small urban demands. Relatively large unlawful use was not taken into account in the present day simulation. Observed data at the site is of poor quality and does not measure low flows accurately.	2.5	2.4
9	3	0.5	1	2.5	Some scaling of the natural record took place. The present day record did not include an upstream dam built by the Balfour Municipality which was constructed in 1998, and is therefore not representative of current hydrology. No observed records could be sourced from Rand Water.	1.8	1.8
10	3	3	1	3	Observed flows from both stations indicated far lower flows than simulated present day flows. Observed record relatively short. Disaggregation of land use information decreased accuracy of naturalised flows. Several land uses are present upstream from the EWR site, including mining consumptive use and dewatering, paved urban runoff enhancements (i.e. runoff from impervious portions of urbanised areas) and urban consumptive use and return flows. The most recent information on actual water use and mine discharges were obtained and used for the simulation of the present day flows.	3	2.5
11	3	2	1	3	Disaggregation of land use decreased accuracy of naturalised flows. Several land uses are present upstream from the EWR site, including mining consumptive use and dewatering, paved urban runoff enhancements and urban consumptive use and return flows. There is also a wetland upstream of this EWR site. Observed data not sufficient for comparison purposes.	2.5	2.3
1	3	3	3	2.5	Some area scaling and disaggregation use were done which might slightly influence the natural flows and present day simulations. A moderate amount of unlawful use was not included in the present day flows. The observed data available was of poor quality and incomplete and the catchment is influenced by development. Not daily data was available for natural conditions only modelled data was available.	3	2.9
4	4	1	4	2	Natural hydrology was simulated at this point as part of the Vaal River System Analysis Update Study. Observed low flows were higher than both the natural and present day data, except for low flows lower than 95% exceedance. The observed station is a very good station and reflect the actual releases from Vaal Dam since 1980	3	2.8
5	4	1.5	2.5	3	Natural hydrology was scaled to EWR sites which may have cause a reduction in accuracy. Present day simulation was affected by Vaal Dam releases and issues in Blesbokspruit and Suikerbosrand River, i.e. mining and urban return flows as well as urban runoff enhancements. The most recent information in terms of mine discharges were obtained from surveys done for the area and was included in the simulation of present day flows. The present day and the observed record correlated well, except for the low flows, where the present day flows were higher than the	2.8	2.8

EWR site	Natural hydrology	Present hydrology	Observed hydrology	Local knowledge/information	Comment	Confidence: Median	Confidence: Average
					observed or natural flows.		

27.2.4 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 27.6 – 27.6 are as follows:

Green: 4 - 5

Yellow: 2.5 - 3.9

Red: 1 - 2.4

where:

1 (very low confidence)

2 (low confidence)

3 (medium confidence)

4 (high confidence)

5 (very high confidence)

Table 27.6 Overall Confidence in EWR results

Site	Hydrology	Biological responses Low flows	Hydraulic: Low Flows	OVERALL: LOW FLOWS	COMMENT	Biophysical responses: High flows	Hydraulics: High Flows	OVERALL: HIGH FLOWS	COMMENT
EWR 2	3	3.5	4	3.5	Macroinvertebrate requirements result in a slightly lower confidence than the fish due to uncertainties on the influence of water quality on the biota response.	3	4	3.5	High flow medium confidence due to the upstream dam and impact on sediment as well as the lack of morphological cues.
EWR 3	3	4	4	4	Biological responses medium due. Two-dimensional hydraulic modelling was undertaken. The hydraulic requirements for low flows largely within the range of measured flows.	3.5	5	3.5	Medium to high confidence due to bedrock nature of the site and lack of geomorphological cues.
EWR 6	1.9	4	3	3	Hydraulics: No measured flows between 0.003 and 1.0 m ³ /s. As many of the low flow requirements are within this range, the confidence is medium.	3.5	3	3	Hydraulics a medium confidence due to the lack of measured flows in the range of high flow recommendations.

Site	Hydrology	Biological responses Low flows	Hydraulic: Low Flows	OVERALL: LOW FLOWS	COMMENT	Biophysical responses: High flows	Hydraulics: High Flows	OVERALL: HIGH FLOWS	COMMENT
EWR 7	2.8	2	2.5	2	Hydraulics is low confidence as there is uncertainty whether zero flows equate to zero depth. Only one low flow measurement was available. The biota confidence is also low due to the fact that macroinvertebrate requirements are based on depth – however, no flow dependant macroinvertebrates are present.	3.8	3	3	Complex site with floodplain and wetland components.
EWR 8	2.4	4	3	3	Hydraulics: Complex site. Non-horizontal water surfaces. No measurements in the range of most low flow requirements.	3.8	5	4	Hydraulics of very high confidence as a suitable range of measured flows exists.
EWR 9	1.8	4	4	4	Hydraulically this is a complex site with non-horizontal water surfaces. As a suitable range of flows were measured in the high flow range, the confidence is high. The biota confidence medium to high due to	3	3	3	Hydraulically this is a complex site with only a single high flow measurement. The bedrock nature of the site and lack of geomorphological cues resulted in a moderate confidence for the biophysical responses.
EWR 10	2.5	2.8	3	3	Low flows set are below measurements for hydraulic calibrations. There is also uncertainty for flow class modelling. The medium confidence for the biota is due to the complexity of the water quality issues and the higher flows than natural.	4	4	4	Suitable range of measured flows for high flows resulting in high confidence for the hydraulics.
EWR 11	2.3	4	2.5	2.5	The low flows fall below the recommendations and the hydraulic confidence is therefore medium to high.	4	5	4	Suitable range of measured high flows result in very high confidence for the hydraulics.
EWR 1	2.9	4	2.5	2.5	The site is hydraulically complex. Most requirements fall below the measured minimum flow. There are also non-uniform flow conditions and uncertainty regarding the flow class modelling.	4	4	4	Hydraulics: Two of the three high flows fall within the range of measured flows.
EWR 4	2.8	1	3.5	1	Hydraulics: Recommendations are below measured minimum flows. There are non-uniform flow conditions and non-horizontal water surfaces and therefore uncertainty in the flow class modelling. The very low confidence of the biota is due to the macroinvertebrate uncertainty in their recommendations. The change in seasonality, water quality issues and increased flows in some seasons are difficult to interpret.	2.3	3	2.3	Low to Medium confidence due to the uncertainty in the geomorphological requirements due to the nature of the site, the effect of the Vaal Dam and the response in terms of habitat to the flood recommendations made.
EWR 5	2.8	3	3.5	3	Hydraulics: The recommendations are below the measured minimum. Non-uniform flow conditions exist. There is uncertainty for flow class modelling. See above for confidence motivation for biota.	4	3.5	3.5	The flood requirements are above the measured maximum resulting in a medium to high confidence only.

27.3 RECOMMENDATIONS

The low flow confidences range from MODERATE-HIGH to HIGH apart from EWR 7, 11, 1 and 4. Problems regarding EWR 7 are because the river is within a wetland and there was uncertainty regarding the macroinvertebrate requirements. EWR 4 is situated just below Vaal Dam and the site is complex to interpret due to water quality issues, the seasonality change and the increased flows above natural in the dry season. These issues can be addressed through Ecological Water Resources Monitoring (EWRM). EWR 11 and 1 are LOW to MEDIUM confidence due to the hydraulics confidence. The hydraulics confidence evaluation is based on the REC flows and whether they fall within the measured range of flows. The REC flows mostly require less flow than

present as these sites have higher flows than natural. As it is unlikely that decisions will be made to decrease flows from the present higher flows than natural, it is doubtful whether it is required to improve these flows.

The confidences in the high flows range from MEDIUM to HIGH at all sites apart from EWR 4. The low confidence at EWR 4 is due to uncertainty regarding flooding requirements recommended for geomorphology. No additional surveys or collation of information will address this uncertainty.

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

Table 27.7 provides a summary of the recommendations.

Table 27.7 Summary of recommendations required to improve confidences

EWR sites	Low flow confidence	High flow confidence	Recommendations
2	3.5	3.5	EWRM.
3	4	3.5	EWRM.
6	3	3	EWRM. If any improvement is required at this site, it is firstly recommended that a better idea of the present hydrological regime is obtained.
7	2	3	The wetland as a whole must be addressed and this would require the floodplain to be surveyed and hydraulics to be supplied for the whole floodplain.
8	3	4	EWRM.
9	4	3	EWRM.
10	3	4	EWRM.
11	2.5	4	EWRM.
1	2.5	4	EWRM.
4	1	2.3	EWRM.
5	3	3.5	EWRM.

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