

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

PROJECT NO: WP 9133

EWR Scenario Assessment for the Crocodile and Sabie-Sand Systems: VOLUME 3: SPECIALIST APPENDICES



JANUARY 2010

REPORT NO.: 26/8/3/10/12/010



water affairs

Department:
Water Affairs
REPUBLIC OF SOUTH AFRICA

**DEPARTMENT OF WATER AFFAIRS
CHIEF DIRECTORATE: RESOURCE DIRECTED MEASURES**

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

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

Approved for WFA by:



.....
Delana Louw
Technical Project Manager



.....
Adhishri Singh
Administrative Project Manager

Approved for the Chief Directorate: Resource Directed Measures by:



.....
Barbara Weston
Study Manager

Department of Water Affairs
Chief Directorate: Resource Directed Measures

COMPREHENSIVE RESERVE DETERMINATION STUDY FOR SELECTED WATER RESOURCES (RIVERS, GROUNDWATER AND WETLANDS) IN THE INKOMATI WATER MANAGEMENT AREA, MPUMALANGA

SABIE AND CROCODILE RIVER SYSTEMS: EWR SCENARIO REPORT: VOLUME 3 – SPECIALIST APPENDICES

JANUARY 2010

PREPARED BY: Rivers for Africa eFlows Consulting
PO Box 1684
Derdepark
Pretoria
0053

DWA Project No: WP 9133
Report No: 26/8/3/10/12/010



Reports as part of this project:

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

Bold indicates this report

REFERENCES

This report is to be referred in bibliographies as:

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

AKNOWLEDGEMENTS

Dr Neels Kleynhans, DWAF: RQS, for providing methods and approaches, review, and guidance.

Contributors to the report and specialist meeting:

Dr Birkhead, Drew (Hydraulics)
Dr Deacon, Andrew (Fish)
Mr Hoffman, Andre (Fish)
Prof Hughes, Denis (Hydrology)
Ms Koekemoer, Shael (Editing)
Dr Kleynhans, Neels (Fish and EcoClassification specialist)
Dr Kotze, Piet (Fish)
Ms Louw, Delana (Process facilitator)
Mr Mackenzie, James (Riparian vegetation)
Mr Mallory, Stephen (System Hydrology)
Mr Rountree, Mark (Fluvial Geomorphology)
Ms Singh, Adhishri (Report review)
Ms Thirion, Christa (Macroinvertebrates)
Dr Uys, Mandy (Macroinvertebrates)

Trainees:

The following trainees participated in the workshop:

Mr Desai, Ahmed (Hydraulics)
Mr Hlongwane, Lindo (Geomorphology)
Mr Senoge, Ntaki (Macroinvertebrates)
Ms Vos, Petro (Macroinvertebrates)

LIST OF APPENDICES

CROCODILE RIVER SYSTEM

APPENDIX A	Ecohydraulics of the Crocodile River system (AL Birkhead)
APPENDIX B	Supporting information for the determination of stress indices and EWR scenarios of EWR 1: Valeyspruit
APPENDIX C	Supporting information for the determination of stress indices and EWR scenarios of EWR 2: Goedehoop
APPENDIX D	Supporting information for the determination of stress indices and EWR scenarios of EWR 3: Poplar Creek
APPENDIX E	Supporting information for the determination of stress indices and EWR scenarios of EWR 4: Kanyamazane
APPENDIX F	Supporting information for the determination of stress indices and EWR scenarios of EWR 5: Malelane
APPENDIX G	Supporting information for the determination of stress indices and EWR scenarios of EWR 6: Nkongoma
APPENDIX H	Supporting information for the determination of stress indices and EWR scenarios of EWR 7: Honeybird

SABIE-SAND RIVER SYSTEM

APPENDIX I	Ecohydraulics of the Sabie-Sand River system (AL Birkhead)
APPENDIX J	Supporting information for the determination of stress indices and EWR scenarios of EWR 1: Upper Sabie
APPENDIX K	Supporting information for the determination of stress indices and EWR scenarios of EWR 2: Aan de Vliet
APPENDIX L	Supporting information for the determination of stress indices and EWR scenarios of EWR 3: Kidney
APPENDIX M	Supporting information for the determination of stress indices and EWR scenarios of EWR 4: Mac Mac
APPENDIX N	Supporting information for the determination of stress indices and EWR scenarios of EWR 5: Marite
APPENDIX O	Supporting information for the determination of stress indices and EWR scenarios of EWR 6: Mutlumuvi
APPENDIX P	Supporting information for the determination of stress indices and EWR scenarios of EWR 7: Thulandziteka
APPENDIX Q	Supporting information for the determination of stress indices and EWR scenarios of EWR 8: Sand

ABBREVIATIONS AND ACRONYMS

1/2/3/-D	One/Two/Three/-Dimensional
A/MSL	Above/Mean Sea Level
AEC	Alternative Ecological Category
Ave	Average
BBM	Building Block Methodology
CD: RDM	Chief Directorate: Resource Directed Measures
CSIR	Centre for Scientific and Industrial Research
D:RQS	Directorate: Resource Quality Services
DLIFR	Drought low flow
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
FBR	Fast over Bedrock
FCS	Fast over Coarse Sediment
FD	Fast (velocity > 0.3 m/s) and Deep (depth > 0.3 m)
FDC	Flow Duration Curves
FDI	Flow dependent macroinvertebrate
FFS	Fast over Fine Sediment
FI	Fast (velocity > 0.3 m/s) and Intermediate depth (0.2 m < depth < 0.3 m)
FROC	Frequency of Occurrence
FS	Fast shallow fish habitat
Geom.	Geomorphology/ical
GPS	Global Positioning System
HFSR	Habitat Flow Stressor Response
Integ	Integrated
Invert's	Macroinvertebrates
LIDAR	Light Detection And Ranging
LR	Large rheophilic fish
LSR	Large semi-rheophilic fish
MAR	Mean Annual Runoff
Marg.	Marginal
Max.	Maximum
MCM	Million Cubic Meters
Meas.	Measured
MHIFR	Maintenance high flow
Min.	Minimum
MLIFR	Maintenance low flow
MS	Microsoft
MV	Marginal vegetation
MVI	Marginal vegetation macroinvertebrate
OWS	Observed water surface

PD	Present Day
PES	Present Ecological State
prep.	preparation
Quat	Quaternary catchment
REC	Recommended Ecological Category
RHAM	Rapid Habitat Assessment Method
RU	Resource Unit
SBR	Slow over Bedrock
SCS	Slow over Coarse Sediment
SD	Slow deep fish habitat
SFS	Slow over Fine Sediment
SPATSIM	Spatial and Time Series Information Modelling
SR	Small rheophilic fish
SSR	Small semi-rheophilic fish species
SS	Slow shallow fish habitat
VEG	Fringing vegetation
Veg	Vegetation
VFBR	Very Fast over Bedrock
VFCS	Very fast over coarse substrate habitat
VFFS	Very Fast over Fine Sediment
VSBR	Very Slow over Bedrock
VSCS	Very Slow over Coarse Sediment
VSFS	Very Slow over Fine Sediment
WL	Water level
WMA	Water Management Area
WRC	Water Research Commission
WS	Water surface

CROCODILE RIVER SYSTEM**TABLE OF CONTENTS**

REFERENCES	i
AKNOWLEDGEMENTS	ii
LIST OF APPENDICES	iii
ABBREVIATIONS AND ACRONYMS	iv
ACKNOWLEDGEMENTS.....	2
OBJECTIVES	3
A1 ECOHYDRAULIC INFORMATION FOR ENVIRONMENTAL WATER ASSESSMENT ALONG THE CROCODILE RIVER SYSTEM.....	4
A1.1 DATA COLLECTION.....	4
A1.2 MODELLING.....	5
A2 RESULTS	6
A2.1 CROSS-SECTIONAL PROFILES	6
A2.2 LOOKUP TABLES	10
A3 CONFIDENCE IN THE HYDRAULIC CHARACTERISATIONS	11
A4 REFERENCES.....	12
B1 EWR 1: VALEYSPRUIT (CROCODILE RIVER) - DETERMINATION OF STRESS INDICES.....	15
B1.1 FISH INDICATOR SPECIES.....	15
B1.2 FISH STRESS INDEX.....	15
B1.3 MACROINVERTEBRATE STRESS INDEX.....	16
B1.4 RIPARIAN VEGETATION STRESS INDEX	17
B2 EWR 1: VALEYSPRUIT (CROCODILE RIVER) - DETERMINATION OF EWR SCENARIOS	19
B2.1 LOW FLOW REQUIREMENTS IN TERMS OF STRESS FOR FISH.....	19
B2.2 LOW FLOW REQUIREMENTS IN TERMS OF STRESS FOR MACROINVERTEBRATES	20
B2.3 LOW FLOW REQUIREMENTS IN TERMS OF RIPARIAN VEGETATION	21
B2.4 INSTREAM FLOOD FUNCTIONS.....	22
B2.5 EWR RULE TABLES	23
C1 EWR 2: GOEDEHOOP (CROCODILE RIVER) - DETERMINATION OF STRESS INDICES.....	26
C1.1 FISH INDICATOR SPECIES.....	26
C1.2 FISH STRESS INDEX.....	27
C1.3 MACROINVERTEBRATE STRESS INDEX.....	27
C1.4 RIPARIAN VEGETATION STRESS INDEX	29
C2 EWR 2: GOEDEHOOP (CROCODILE RIVER) - DETERMINATION OF EWR SCENARIOS	30
C2.1 LOW FLOW REQUIREMENTS IN TERMS OF STRESS FOR FISH.....	30
C2.2 LOW FLOW REQUIREMENTS IN TERMS OF STRESS FOR MACROINVERTEBRATES	31
C2.3 LOW FLOW REQUIREMENTS IN TERMS OF RIPARIAN VEGETATION	32
C2.4 INSTREAM FLOOD FUNCTIONS.....	32
C2.5 EWR RULE TABLES	34
D1 EWR 3: POPLAR CREEK (CROCODILE RIVER) - DETERMINATION OF STRESS INDICES.....	37
D1.1 FISH INDICATOR SPECIES.....	37
D1.2 FISH STRESS INDEX.....	37
D1.3 MACROINVERTEBRATE STRESS INDEX.....	38
D1.4 RIPARIAN VEGETATION STRESS INDEX	39

D2	EWR 3: POPLAR CREEK (CROCODILE RIVER) - DETERMINATION OF EWR SCENARIOS	40
D2.1	LOW FLOW REQUIREMENTS IN TERMS OF STRESS FOR FISH	40
D2.2	LOW FLOW REQUIREMENTS IN TERMS OF STRESS FOR MACROINVERTEBRATES	41
D2.3	LOW FLOW REQUIREMENTS IN TERMS OF RIPARIAN VEGETATION	42
D2.4	INSTREAM FLOOD FUNCTIONS	42
D2.5	EWR RULE TABLE	44
E1	EWR 4: KANYAMAZANE (CROCODILE RIVER) - DETERMINATION OF STRESS INDICES	46
E1.1	FISH INDICATOR SPECIES	46
E1.2	FISH STRESS INDEX	47
E1.3	MACROINVERTEBRATE STRESS INDEX	48
E1.4	RIPARIAN VEGETATION STRESS INDEX	49
E2	EWR 4: KANYAMAZANE (CROCODILE RIVER) - DETERMINATION OF EWR SCENARIOS	50
E2.1	LOW FLOW REQUIREMENTS IN TERMS OF STRESS FOR FISH	50
E2.2	LOW FLOW REQUIREMENTS IN TERMS OF STRESS FOR MACROINVERTEBRATES	52
E2.3	LOW FLOW REQUIREMENTS IN TERMS OF RIPARIAN VEGETATION	53
E2.4	INSTREAM FLOOD FUNCTIONS	53
E2.5	EWR RULE TABLES	54
F1	EWR 5: MALALANE (CROCODILE RIVER) - DETERMINATION OF STRESS INDICES	57
F1.1	FISH INDICATOR SPECIES	57
F1.2	FISH STRESS INDEX	58
F1.3	MACROINVERTEBRATE STRESS INDEX	59
F1.4	RIPARIAN VEGETATION STRESS INDEX	61
F2	EWR 5: MALALANE (CROCODILE RIVER) - DETERMINATION OF EWR SCENARIOS	62
F2.1	LOW FLOW REQUIREMENTS IN TERMS OF STRESS FOR FISH	62
F2.2	LOW FLOW REQUIREMENTS IN TERMS OF STRESS FOR MACROINVERTEBRATES	64
F2.3	INSTREAM FLOOD FUNCTIONS	67
F2.4	EWR RULE TABLES	68
G1	EWR 6: NKONGOMA (CROCODILE RIVER) - DETERMINATION OF STRESS INDICES	72
G1.1	FISH INDICATOR SPECIES	72
G1.2	FISH STRESS INDEX	72
G1.3	MACROINVERTEBRATE STRESS INDEX	73
G1.4	RIPARIAN VEGETATION STRESS INDEX	74
G2	EWR 6: NKONGOMA (CROCODILE RIVER) - DETERMINATION OF EWR SCENARIOS	76
G2.1	LOW FLOW REQUIREMENTS IN TERMS OF STRESS FOR FISH	76
G2.2	LOW FLOW REQUIREMENTS IN TERMS OF STRESS FOR MACROINVERTEBRATES	78
G2.3	LOW FLOW REQUIREMENTS IN TERMS OF RIPARIAN VEGETATION	80
G2.4	INSTREAM FLOOD FUNCTIONS	81
G2.5	EWR RULE TABLES	82
H1	EWR 7: HONEYBIRD (KAAP RIVER) - DETERMINATION OF STRESS INDICES	86
H1.1	FISH INDICATOR SPECIES	86
H1.2	FISH STRESS INDEX	86
H1.3	MACROINVERTEBRATE STRESS INDEX	87
H1.4	RIPARIAN VEGETATION STRESS INDEX	88

H2	EWR 7: HONEYBIRD (KAAP RIVER) - DETERMINATION OF EWR SCENARIOS.....	90
H2.1	LOW FLOW REQUIREMENTS IN TERMS OF STRESS FOR FISH.....	90
H2.2	LOW FLOW REQUIREMENTS IN TERMS OF STRESS FOR MACROINVERTEBRATES	92
H2.3	LOW FLOW REQUIREMENTS IN TERMS OF RIPARIAN VEGETATION	93
H2.4	INSTREAM FLOOD FUNCTIONS.....	94
H2.5	EWR RULE TABLES	95

LIST OF TABLES

APPENDIX A ECOHYDRAULICS OF THE SABIE RIVER SYSTEM

Table A1	Hydraulic data collected at EWR sites on the Crocodile River system	4
Table A2	Confidence ratings for the hydraulic characterisations for sites on the Crocodile River system.....	11

APPENDIX B SUPPORTING INFORMATION FOR THE DETERMINATION OF STRESS INDICES AND EWR SCENARIOS OF EWR 1: VALEYSRUIT

Table B1	Habitat requirements for different life stages of indicators species included in the SR guild	15
Table B2	EWR 1: Habitat suitability for the SR guild	15
Table B3	Fish stress index.....	16
Table B4	Habitat suitability for FDI taxa	16
Table B5	Macroinvertebrate (FDI) stress index.....	17
Table B6	Riparian vegetation stress index for indicator species.....	17
Table B7	Low flow requirements: SR guild.....	19
Table B8	Low flow requirements: FDI taxa.....	20
Table B9	Low flow requirements: Riparian vegetation species.....	21
Table B10	Functions for each Flood Class.....	22
Table B11	EWR 1 assurance rules for PES and REC: A/B	23

APPENDIX C SUPPORTING INFORMATION FOR THE DETERMINATION OF STRESS INDICES AND EWR SCENARIOS OF EWR 2: GOEDEHOOP

Table C1	Habitat requirements for different life stages of indicators species included in the SR guild	26
Table C2	EWR 2: Habitat suitability for the SR guild	27
Table C3	Fish stress index.....	27
Table C4	Habitat suitability for FDI taxa	28
Table C5	Macroinvertebrate (FDI) stress index.....	28
Table C6	Riparian vegetation stress index for indicator species.....	29
Table C7	Low flow requirements: SR guild.....	30
Table C8	Low flow requirements: FDI taxa.....	31
Table C9	Low flow requirements: Riparian vegetation species.....	32
Table C10	Functions for each Flood Class.....	33
Table C11	EWR 2 assurance rules for PES and REC: B	34
Table C12	EWR 2 assurance rules for AEC: C	35

APPENDIX D SUPPORTING INFORMATION FOR THE DETERMINATION OF STRESS INDICES AND EWR SCENARIOS OF EWR 3: POPLAR CREEK

Table D1	EWR 3: Habitat suitability for the SR guild	37
Table D2	Fish stress index.....	37
Table D3	Habitat suitability for FDI taxa	38
Table D4	Macroinvertebrate (FDI) stress index.....	39
Table D5	Riparian vegetation stress index for indicator species.....	39
Table D6	Low flow requirements: SR guild.....	40
Table D7	Low flow requirements: FDI taxa.....	41
Table D8	Low flow requirements: Riparian vegetation species.....	42
Table D9	Functions for each Flood Class.....	42
Table D10	EWR 3 assurance rules for PES: B/C	44

APPENDIX E SUPPORTING INFORMATION FOR THE DETERMINATION OF STRESS INDICES AND EWR SCENARIOS OF EWR 4: KANYAMAZANE

Table E1	Habitat requirements for different life stages of indicator species included in SR guild.....	46
Table E2	Habitat requirements for different life stages of indicator species included in LSR guild	46
Table E3	EWR 4: Habitat suitability for the SR and LSR guild	47
Table E4	Fish stress index.....	47
Table E5	Habitat suitability for FDI taxa	48
Table E6	Macroinvertebrate (FDI) stress index.....	48
Table E7	Riparian vegetation stress index for indicator species.....	49
Table E8	Low flow requirements: SR guild.....	50
Table E9	Low flow requirements: LSR guild.....	51
Table E10	Low flow requirements: FDI taxa.....	52
Table E11	Functions for each Flood Class.....	53
Table E12	EWR 4 assurance rules for PES and REC B:.....	54
Table E13	EWR 4 assurance rules for AEC: C/D.....	55

APPENDIX F SUPPORTING INFORMATION FOR THE DETERMINATION OF STRESS INDICES AND EWR SCENARIOS OF EWR 5: MALELANE

Table F1	Habitat requirements for different life stages of indicator species included in SR guild.....	57
Table F2	Habitat requirements for different life stages of indicator species included in LSR guild	57
Table F3	EWR 5: Habitat suitability for the SR and LSR guild	58
Table F4	Fish stress index.....	58
Table F5	Habitat suitability for FDI taxa	59
Table F6	Habitat suitability for MVI taxa.....	59
Table F7	Macroinvertebrate (FDI) stress index.....	60
Table F8	Macroinvertebrate (MVI) stress index	60
Table F9	Riparian vegetation stress index for indicator species.....	61
Table F10	Low flow requirements: SR guild.....	62

Table F11	Low flow requirements: LSR guild.....	63
Table F12	Low flow requirements: FDI taxa.....	64
Table F13	Low flow requirements: MVI taxa.....	65
Table F14	Functions for each Flood Class.....	67
Table F15	EWR 5 assurance rules for PES: C	68
Table F16	EWR 5 assurance rules for REC: B	69
Table F17	EWR 5 assurance rules for AEC: D	70

APPENDIX G SUPPORTING INFORMATION FOR THE DETERMINATION OF STRESS INDICES AND EWR SCENARIOS OF EWR 6: NKONGOMA

Table G1	EWR 6: Habitat suitability for the SR and LSR guild	72
Table G2	Fish stress index.....	73
Table G3	Habitat suitability for FDI taxa	73
Table G4	Macroinvertebrate (FDI) stress index.....	74
Table G5	Riparian vegetation stress index for indicator species.....	74
Table G6	Low flow requirements: SR guild.....	76
Table G7	Low flow requirements: LSR guild.....	77
Table G8	Low flow requirements: FDI taxa.....	79
Table G9	Low flow requirements: Riparian vegetation species.....	80
Table G10	Functions for each Flood Class.....	81
Table G11	EWR 6 assurance rules for PES: C	82
Table G12	EWR 6 assurance rules for REC: B	83
Table G13	EWR 6 assurance rules for AEC:D	84

APPENDIX H SUPPORTING INFORMATION FOR THE DETERMINATION OF STRESS INDICES AND EWR SCENARIOS OF EWR 7: HONEYBIRD

Table H1	EWR 7: Habitat suitability for the SR and LSR guild	86
Table H2	Fish stress index.....	87
Table H3	Habitat suitability for FDI taxa	87
Table H4	Macroinvertebrate (FDI) stress index.....	88
Table H5	Riparian vegetation stress index for indicator species.....	88
Table H6	Low flow requirements: SR guild.....	90
Table H7	Low flow requirements: LSR guild.....	91
Table H8	Low flow requirements: FDI taxa.....	92
Table H9	Low flow requirements: Riparian vegetation species.....	93
Table H10	Functions for each Flood Class.....	94
Table H11	EWR 7 assurance rules for PES: C	96
Table H12	EWR 7 assurance rules for REC: B	97
Table H13	EWR 7 assurance rules for AEC: D	98

LIST OF FIGURES

APPENDIX A ECOHYDRAULICS OF THE SABIE RIVER SYSTEM

Figure A1	Cross-sectional profile for EWR 1A (Crocodile River), showing the water level (WL) surveyed on 5 Oct. '07 and the position of vegetation (Veg.) markers	6
-----------	---	---

Figure A2	Cross-sectional profile for EWR 1B (Crocodile River), showing the water level (WL) surveyed on 5 Oct. '07 and the position of vegetation (Veg.) markers	6
Figure A3	Cross-sectional profile for EWR 2A (Crocodile River), showing the water level (WL) surveyed on 4 Oct. '07 and the position of vegetation (Veg.) markers	7
Figure A4	Cross-sectional profile for EWR 2B (Crocodile River), showing the water level (WL) surveyed on 4 Oct. '07 and the position of vegetation (Veg.) markers	7
Figure A5	Cross-sectional profile for EWR 3 (Crocodile River), showing the water level (WL) surveyed on 4 Oct. '07 and the position of vegetation (Veg.) and geomorphological (Geom.) markers	8
Figure A6	Cross-sectional profile for EWR 4A (Crocodile River), showing the water level (WL) surveyed on 3 Oct. '07 and the position of vegetation (Veg.) markers	8
Figure A7	Cross-sectional profile for EWR 4B (Crocodile River), showing the water level (WL) surveyed on 13 July '08.....	9
Figure A8	Cross-sectional profile for EWR 5 (Crocodile River), showing the water level (WL) surveyed on 1 Oct. '07 and the position of vegetation (Veg.) markers	9
Figure A9	Cross-sectional profile for EWR 6 (Crocodile River), showing the water level (WL) surveyed on 2 Oct. '07 and the position of vegetation (Veg.) markers	10
Figure A10	Cross-sectional profile for EWR 7 (Kaap River), showing the water level (WL) surveyed on 3 Oct. '07 and the position of vegetation (Veg.) markers.....	10

APPENDIX A: ECOHYDRAULICS OF THE SABIE RIVER

Dr AL Birkhead, Streamflow Solutions

ACKNOWLEDGEMENTS

The contributions to site selection and data collection by Delana Louw (Rivers for Africa), Mark Rountree (Fluvius Environmental Consultants), James Mackenzie (BioRiver Solutions), Mandy Uys (Laughing Waters), Shael Koekemoer (Koekemoer Aquatic Services) and Piet Kotze (Clean Stream Biological Services) is gratefully acknowledged. The Crocodile EWR Sites were selected in 2001 for a flow assessment study conducted by the CSIR.

OBJECTIVES

The objectives of the ecohydraulic component of this study are to provide geomorphologically and ecologically relevant hydraulic information (data collection, analysis and results) for assessing the Environmental Water Requirements (EWRs) at seven sites along the Crocodile River system and seven sites along the Sabie River system.

A1 ECOHYDRAULICS INFORMATION FOR ENVIRONMENTAL WATER ASSESSMENT ALONG THE CROCODILE RIVER SYSTEM

The application of holistic methods for ecological flow determination (refer to Tharme, 1996) requires environmental flow requirements to be expressed as discharge rates (including its temporal characteristics) through assessments of the presence of suitable habitat for certain biota at different flows. The interface between the way in which flow requirements are assessed and expressed is through the results of hydraulic measurements, analyses and modelling at sites along rivers. The primary product of these hydraulic analyses are relationships between discharge and the following determinants, which have been found over the course of numerous flow assessments, to be the most useful: depth (maximum and average), velocity (average), wetted perimeter, and width of the water surface. The discharge-depth (or rating) relationship is fundamental to hydraulic analysis, and is generally derived from a combination of measured and synthesized data (refer to Rowlston *et al.*, 2000; Birkhead, 1999; Jordanova *et al.*, 2004; Hirschowitz *et al.*, 2007 and Birkhead (in press) for descriptions of procedures for deriving hydraulic information for use in EWRs in South Africa). Once the rating relationship for a river section has been developed, the relationships between discharge and the other hydraulic parameters (listed above) may readily be computed using the cross-sectional geometry, and are generally provided in tabular format using look-up tables (refer to Section A2).

The cross-sectional profile plots and look-up tables comprise the “standard hydraulic data” used in EWR determinations in South Africa. Ecologists use these standard hydraulic data with the aid of site assessments and photographs to determine the quantity and quality of hydraulic habitat at different flows. Substantial experience and interpretation are required to provide assessments of site-based and reach-based biological habitats using cross-sectional surveys and the results of one-dimensional hydraulic analyses (biological habitat refers to the integration of the different components defining habitat (e.g. hydraulic, substrate and cover attributes for fish). Procedures have therefore been developed for using standard hydraulic information as the basis for quantifying hydraulic habitat for fish (refer to Hirschowitz *et al.*, 2007 and Birkhead (in press) for an explanation of the method). The method allows the assessment of abundance of different flow classes to be applied more consistently in EWRs, and has been used in this study.

A1.1 DATA COLLECTION

The measured discharge and flow depth data are provided in Tables A1 for the Crocodile River sites, together with the dates when the data were collected.

Table A1 Hydraulic data collected at EWR sites on the Crocodile River system

River	Site no.	Date	Discharge Q (m ³ /s)	Max. flow depth y (m)	Stage AMSL z (m)
Crocodile	1	05/10/07	0.05	0.58/0.15	NA
		25/08/01	0.10	0.61/0.19	
		19/11/01	2.7	1.15/0.69	
Crocodile	2	04/10/07	0.10	0.18/0.47	NA
		26/08/01	0.30	0.25/0.56	
		19/11/01	6.0	0.53/1.13	

River	Site no.	Date	Discharge Q (m ³ /s)	Max. flow depth y (m)	Stage AMSL z (m)
Crocodile	3	25/10/98 ¹	1.0	0.50	NA
		04/10/07	2.7	0.66	
		31/08/01	3.2	0.67	
		01/10/98 ¹	5.4	0.79	
		20/11/01	8.5	0.86	
Crocodile	4A	29/08/01	7.50	1.77	NA
		03/10/07	10.1	1.9	
		09/05/01	18.0	2.12	
		21/11/01	73	2.89	
	4B ²	13/07/08	5.0	0.57	NA
Crocodile	5	01/10/07	7.0	0.44	NA
		28/08/01	12.1	0.60	
		20/11/01	143	2.19	
Crocodile	6	02/10/07	3.3	0.85	NA
		27/08/01	3.3	0.85	
		21/11/01	136	1.93	
		02/02	7000	12.0	
Kaa	7	03/10/07	0.43	0.38	NA
		30/08/01	5.0	0.68	
		21/11/01	14.1	0.95	

¹ Data originally collected in 1998 as part of DWAF pilot study

² Rapid sites used to augment data from Site 4A (run/pool)

A/B - Cross-section A/B

NA - Not Applicable (local datum used)

A1.2 MODELLING

Predicted resistance coefficients, energy slopes and modelled rating relationships are archived electronically in Corel Quattro Pro and MS Excel, and included in the EWR ecohydraulics database (Birkhead *et al*, in prep.).

A2 RESULTS

A2.1 CROSS-SECTIONAL PROFILES

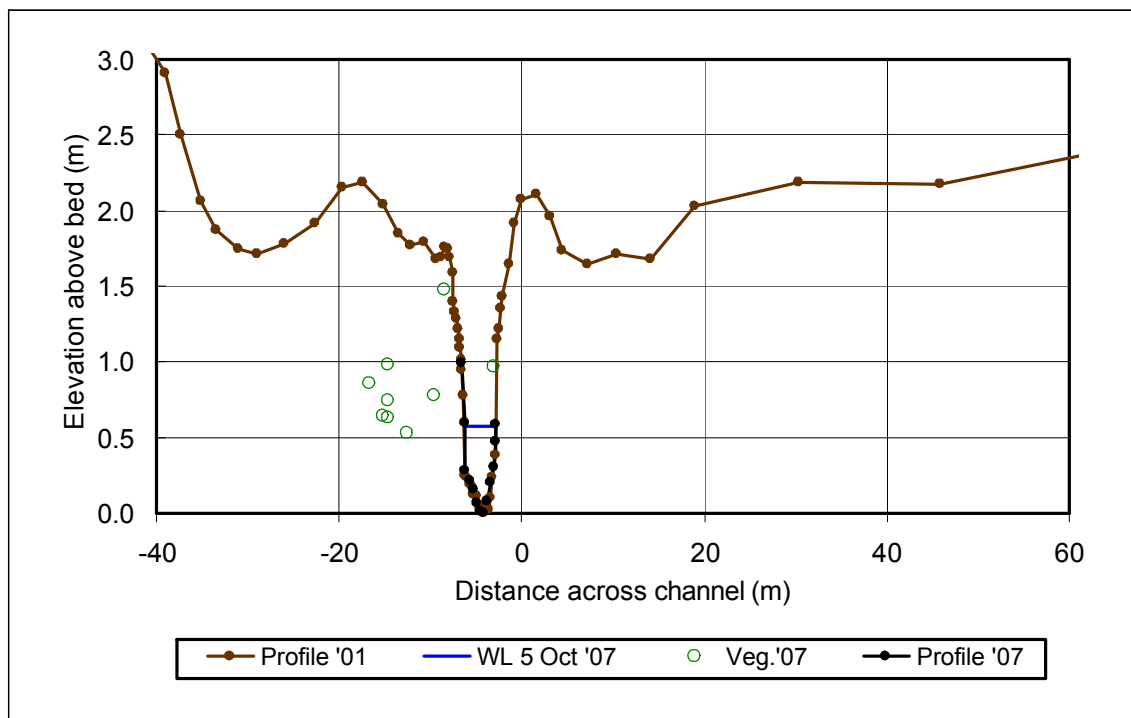


Figure A1 Cross-sectional profile for EWR 1A (Crocodile River), showing the water level (WL) surveyed on 5 Oct 2007 and the position of vegetation (Veg.) markers

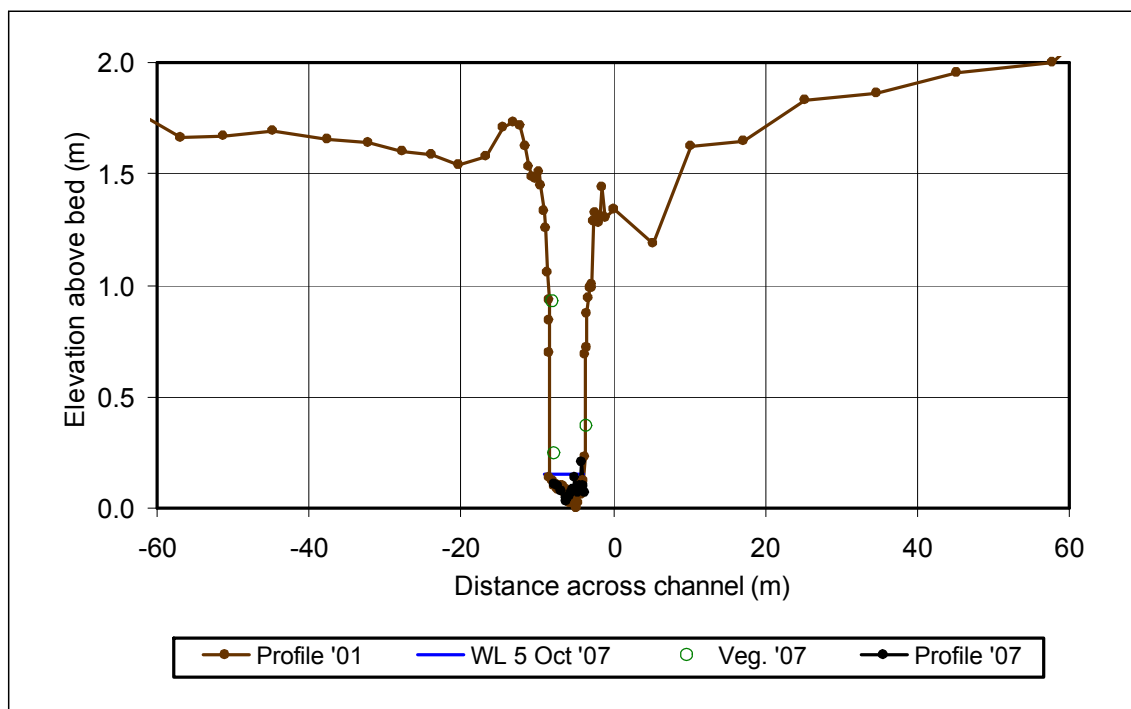


Figure A2 Cross-sectional profile for EWR 1B (Crocodile River), showing the water level (WL) surveyed on 5 Oct 2007 and the position of vegetation (Veg.) markers

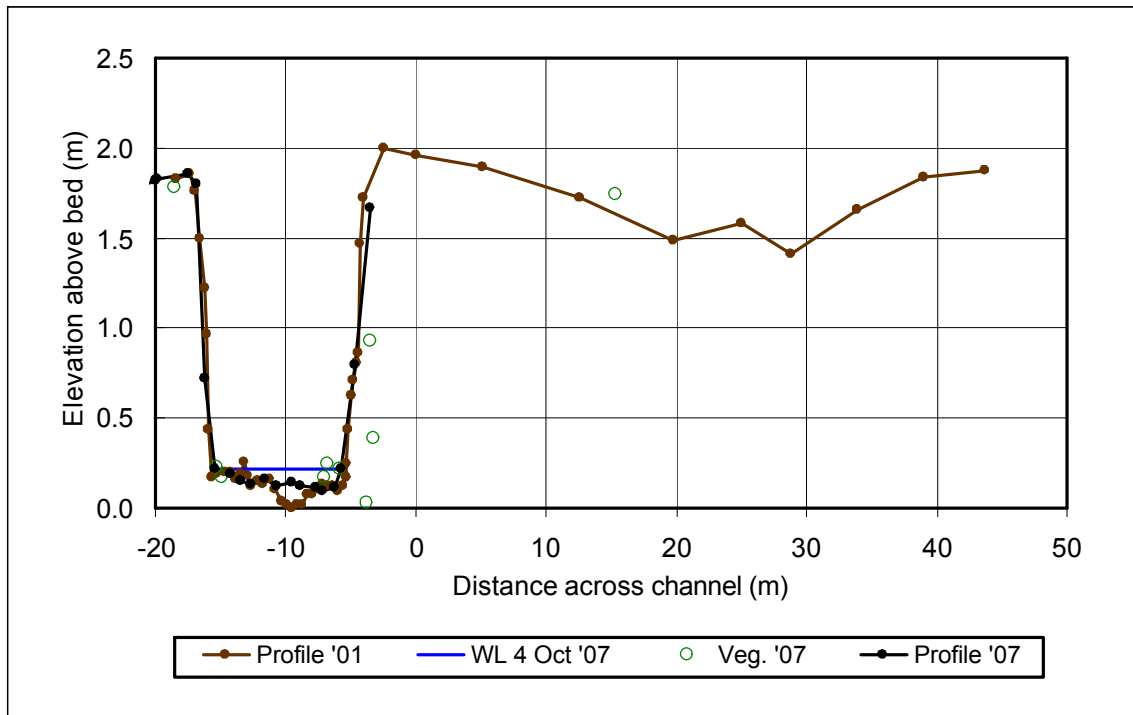


Figure A3 Cross-sectional profile for EWR 2A (Crocodile River), showing the water level (WL) surveyed on 4 Oct 2007 and the position of vegetation (Veg.) markers

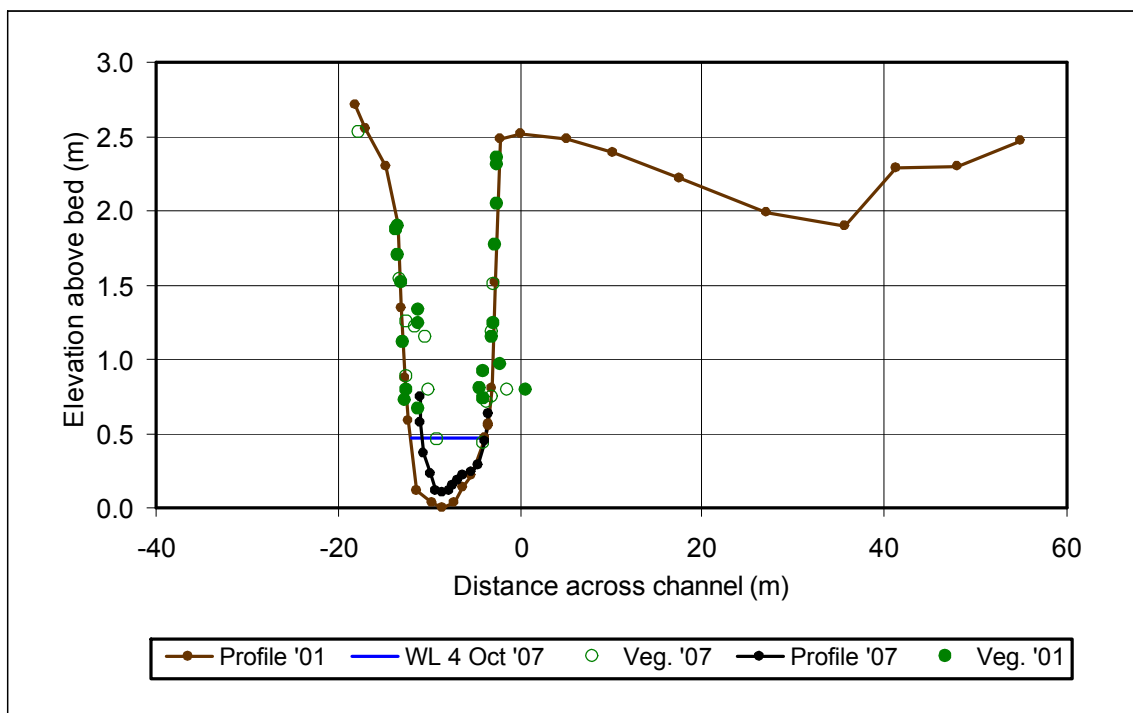


Figure A4 Cross-sectional profile for EWR 2B (Crocodile River), showing the water level (WL) surveyed on 4 Oct 2007 and the position of vegetation (Veg.) markers

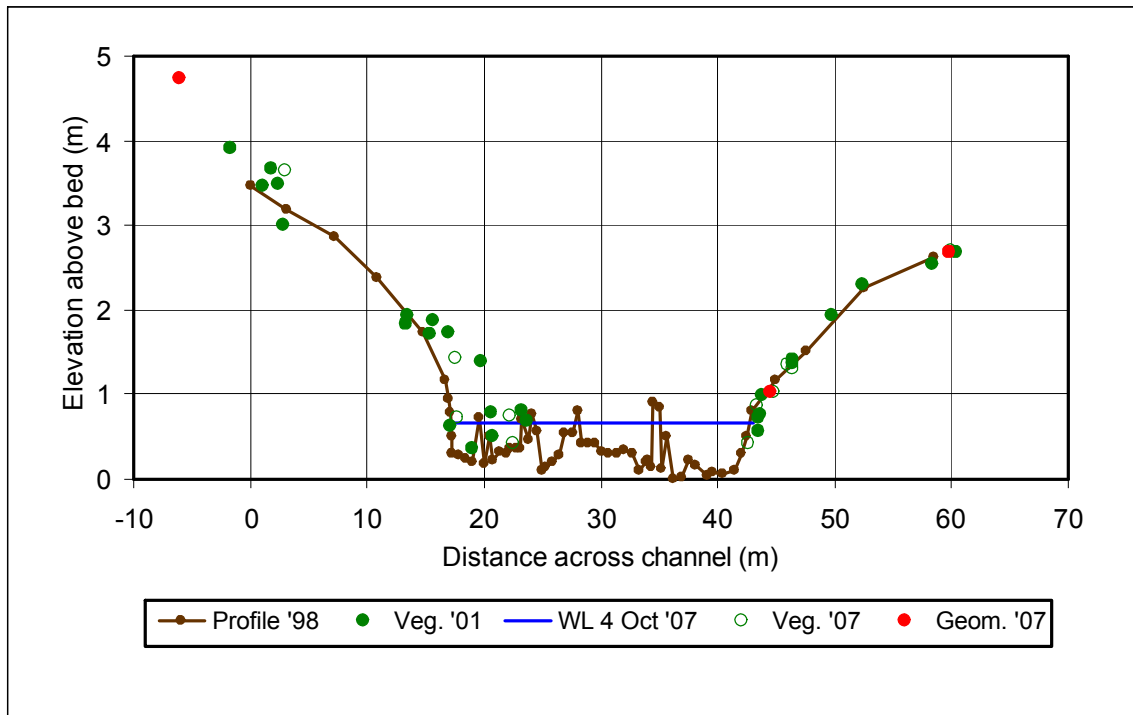


Figure A5 Cross-sectional profile for EWR 3 (Crocodile River), showing the water level (WL) surveyed on 4 Oct 2007 and the position of vegetation (Veg.) and geomorphological (Geom.) markers

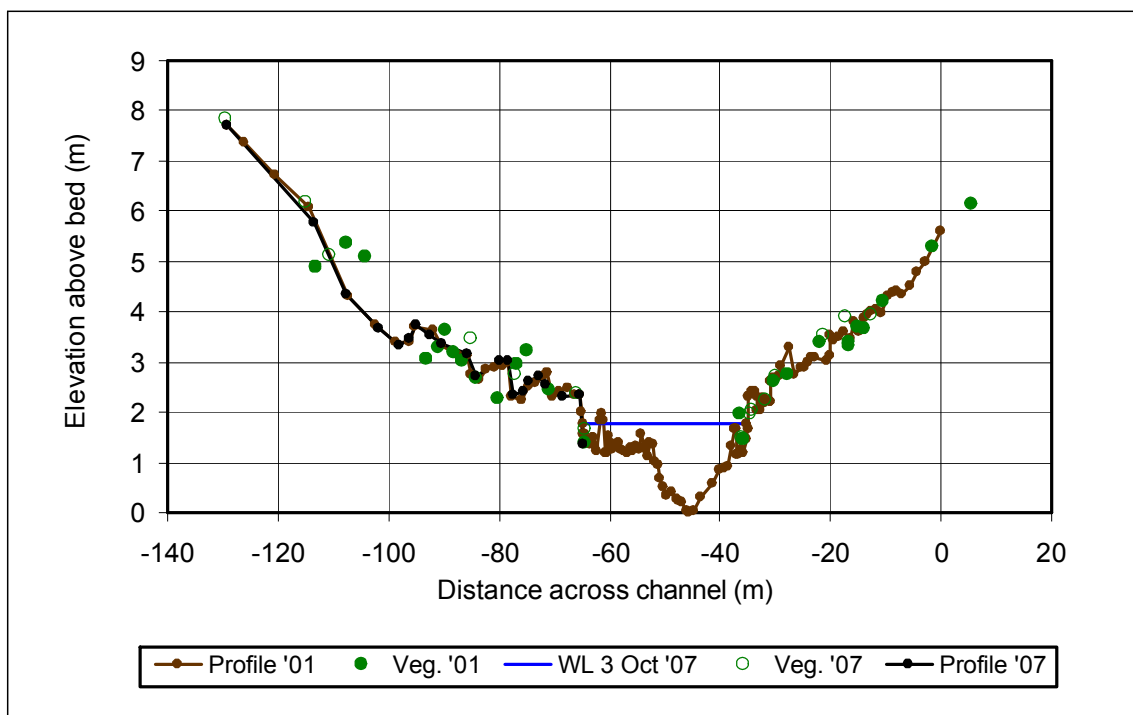


Figure A6 Cross-sectional profile for EWR 4A (Crocodile River), showing the water level (WL) surveyed on 3 Oct 2007 and the position of vegetation (Veg.) markers

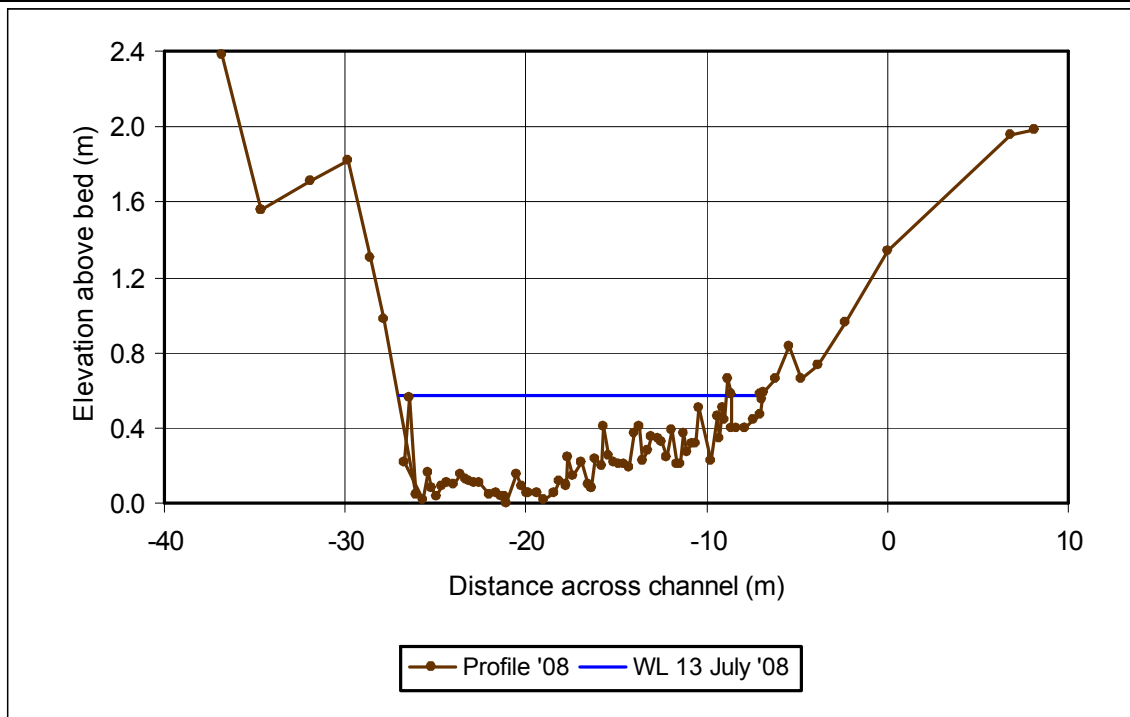


Figure A7 Cross-sectional profile for EWR 4B (Crocodile River), showing the water level (WL) surveyed on 13 July 2008

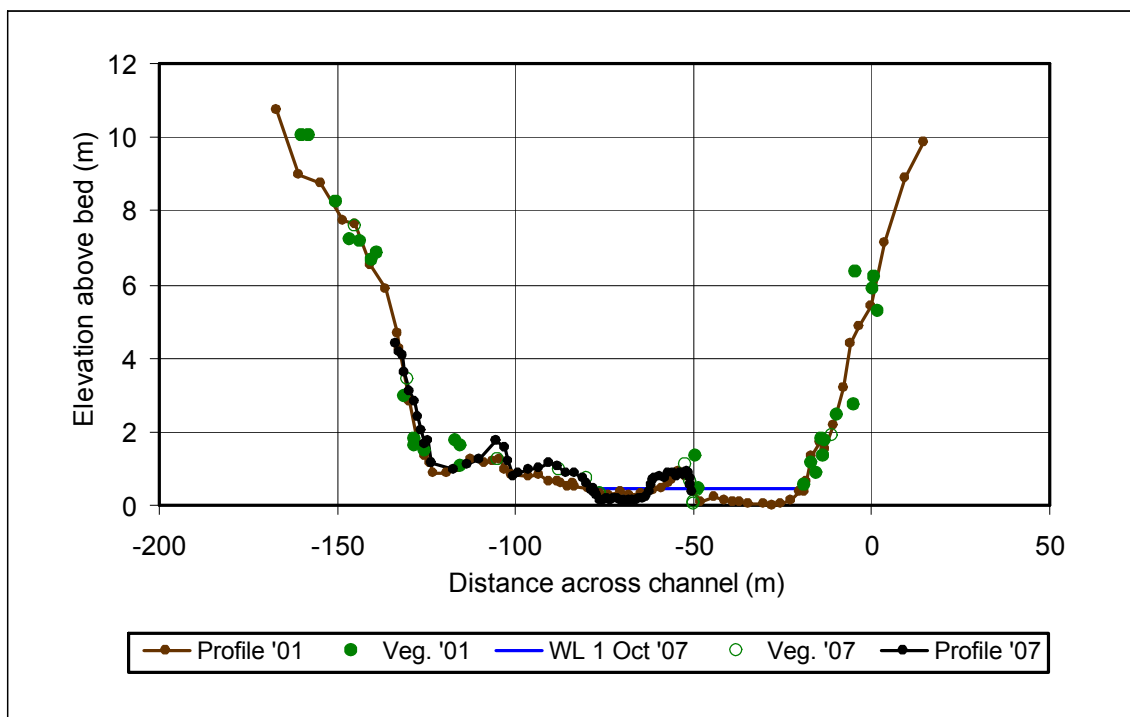


Figure A8 Cross-sectional profile for EWR 5 (Crocodile River), showing the water level (WL) surveyed on 1 Oct 2007 and the position of vegetation (Veg.) markers

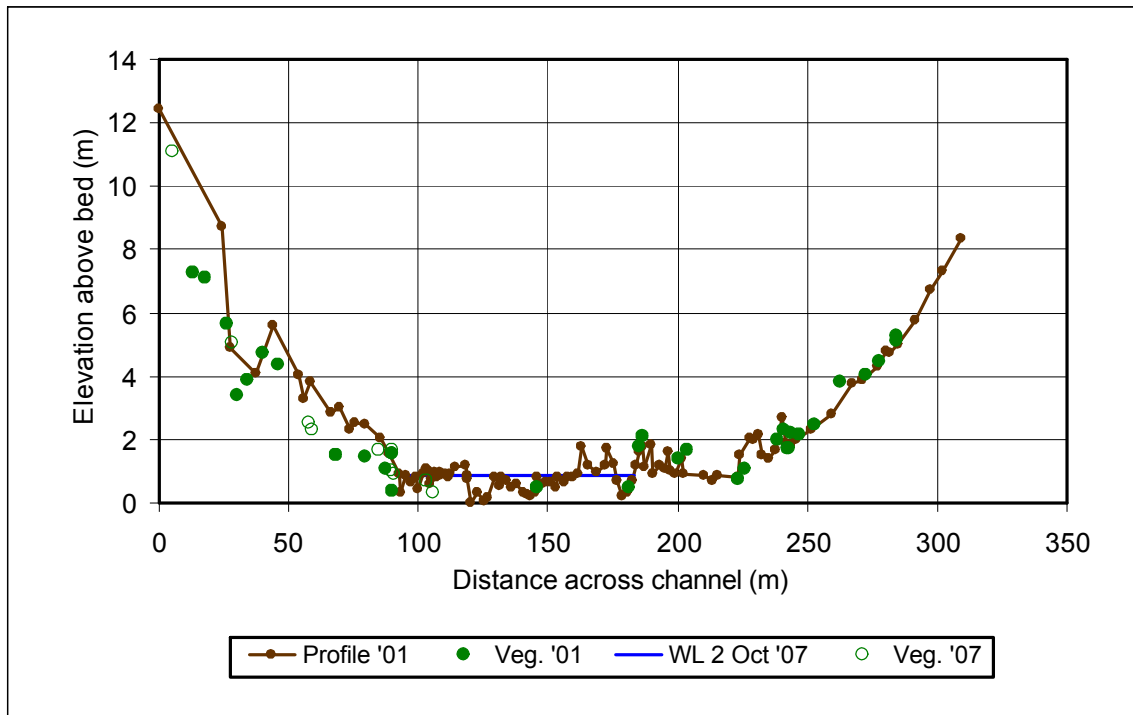


Figure A9 Cross-sectional profile for EWR 6 (Crocodile River), showing the water level (WL) surveyed on 2 Oct 2007 and the position of vegetation (Veg.) markers

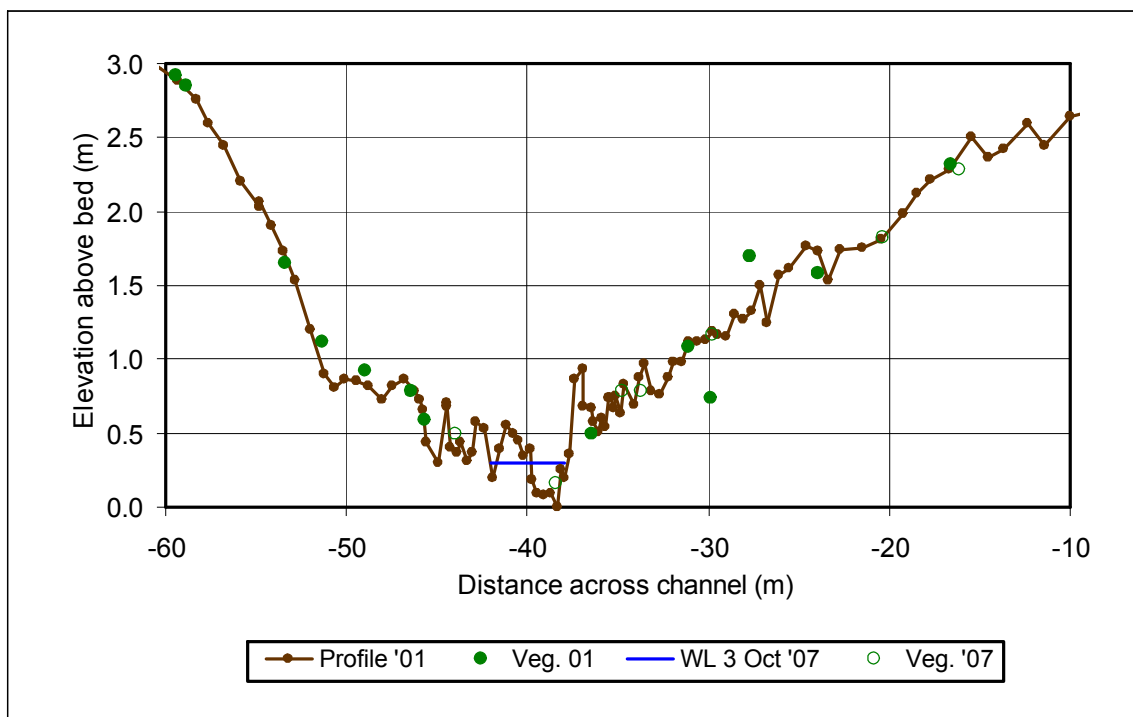


Figure A10 Cross-sectional profile for EWR 7 (Kaap River), showing the water level (WL) surveyed on 3 Oct 2007 and the position of vegetation (Veg.) markers

A2.2 LOOKUP TABLES

Lookup tables (hydraulic variables and flow-classes) are archived electronically in MS Excel.

A3 CONFIDENCE IN THE HYDRAULIC CHARACTERISATIONS

The confidence in hydraulic calibrations is provided in Table A2.

Table A2 Confidence ratings for the hydraulic characterisations for sites on the Crocodile River system

Site	REC	Season (dry/wet low & high flows)		Discharge, Q (m ³ /s)		Meas. range	Rating	Comments
				Exceedance (%)				
				95 ¹	65 ²			
1	A/B	Low	Dry	0.019	0.06	0.05 - 2.7	3	Below meas. min. Q.
			Wet	0.09	0.20		4	Within range meas. Q.
		High	1, 3, >10 ⁴		3		Above meas. max. Q.	
2	B	Low	Dry	0.17	0.32	0.10 - 6.0	4	Within meas. range Qs. Change bed profile 2001 - 2007.
			Wet	0.46	1.3		4	
		High	3, 9, 13 - 25 ^{3,5} , 30 - 35 ^{4,5}		3		Above meas. max. Q.	
3	B	Low	Dry	1.1	2.0	1.0 - 8.5	5	Within meas. range Qs.
			Wet	1.6	4.1		5	
		High	8, 15, 30, >90 ^{3-4, 5}		3		Above meas. max. Q.	
4	B	Low	Dry	1.3	4.1	7.5 - 73	2	Site 4A poor for low Qs. Augmented Rapid Site 4B (meas. Q = 5.0 m ³ /s).
			Wet	4.1	7.9		3	
		High	25, 40, 70, 170 - 220 ^{3,5}		4		Above meas. max. Q.	
5	B	Low	Dry	4.2	8.0	7.0 - 143	3	Below meas. min. Q. Possible change bed profile 2001 - 2007.
			Wet	5.4	16		4	
		High	8, 30, 50, 90, 340 ⁴		4		Mostly within meas. range Q.	
6	B	Low	Dry	1.7	7.3	1.4 - 136, 7000	4	Within meas. range Qs. Uncertainty flow class modelling: bedrock dominated site.
			Wet	7.3	15		4	
		High	10, 50, 100, 180 ³⁻⁴		4		Complex site. Limited meas. Qs.	
7	B	Low	Dry	0.086	0.80	0.43 - 14.1	3	Complex site. Below meas. min. Q. Uncertainty flow class modelling.
			Wet	0.71	2.2		3	
		High	5, 8, 15, 25, >130 ^{4,5}		3		Complex site. Above max. meas. Q.	

Rating: 0 - none, 1 - Low, 2 - Low/Medium, 3 - Medium, 4 - Medium/High, 5 - High

1 Drought conditions, 2 Maintenance conditions (refer to main report)

3 1:2 4 1:3 5 Peak

REC-Recommended Ecological Category

High flows are daily averages unless otherwise noted

Low - 'base' flows

A4 REFERENCES

- Birkhead, A.L. 1999. The procedure for generating hydraulic data for the Intermediate and Comprehensive Ecological Reserve (Quantity), Appendix R17. Water Resource Protection Policy Implementation, Resource Directed Measures for protection of Water Resources, Volume 3: River Ecosystems (Version 1.0). <http://www.dwaf.gov.za/documents.asp>
- Birkhead, A.L. (in press). The role of Ecohydraulics in the South African Ecological Reserve. In: Ecohydraulics for South African Rivers, James, C.S. and King, J.M. (eds), Water Research Commission report no. TT K5/1767/1, Pretoria, South Africa.
- Birkhead, A.L., Desai, A. and Louw, M.D. (in prep). Synthesis of hydraulic information collected over the past decade in Southern Africa to inform Environmental Flow Requirements. WRC Project K8/795/2.
- Hirschowitz, P.M., Birkhead, A.L. and James, C.S. 2007. Hydraulic modelling for ecological studies for South African Rivers. WRC Report No. 1508/1/07, Water Research Commission, Pretoria. 250pp. <http://www.wrc.org.za/publications/reports.htm>
- Jordanova, A.A., Birkhead, A.L., James, C.S. and Kleynhans, C.L. 2004. Hydraulics for determination of the ecological Reserve for rivers. Report to the Water Research Commission on the project "Hydraulic analyses for the determination of the ecological Reserve for rivers". WRC Report no. 1174/0/1.
- Kondolf, GM, Larsen, E.W. and Williams, J.G. 2000. Measuring and modelling the hydraulic environment for assessing instream flow. North American Journal of Fisheries Management, **20**, 1016-1028.
- Panfil, S. and Jacobson, R.B. 1999. Hydraulic modelling of in-channel habitats in the Ozark Highlands of Missouri: Assessment of the physical habitat sensitivity to environmental change. River studies station publications of the USGS CERC (Colombia Environmental Research Centre) river corridor habitat dynamics project. <http://www.cerc.usgs.gov/rss/rfmodel/>
- Quecedo, M. and Pastor, M. 2002. A reappraisal of the Taylor-Galerkin algorithm for drying-wetting areas in shallow water computations. International Journal for Numerical Methods in Fluids **38**, 515-531.
- Rowlston, B., Jordanova, A.A. and Birkhead A.L. 2000. Hydraulics In: Environmental flow assessment for rivers: Manual for the Building Block Methodology, King, J.M., Tharme, R.E. and de Villiers, M.S., (eds), Water Research Commission report No.TT 131/00, Pretoria, South Africa.
- Steffler, P. and Blackburn, J. 2006. River2D: Two-dimensional depth averaged model of river hydrodynamics and fish habitat. Introduction to depth-averaged modelling and user's manual. University of Alberta, Edmonton Alberta, Canada. <http://www.river2d.ualberta.ca>
- Tharme, R.E. 1996. Review of international methodologies for the quantification of the instream flow requirements of rivers. Water law review. Final report for policy development. Commissioned

by the Department of Water Affairs and Forestry, Pretoria. Freshwater Research Unit, University of Cape Town, Cape Town. 116pp.

Wright, N.G. 2001. Conveyance Implications for 2-D and 3-D Modelling. Part of scoping study for reducing uncertainty in river flood conveyance. Prepared for HR Wallingford and the Environment Agency (refer to Wallingford software, 2004).

**APPENDIX B: SUPPORTING INFORMATION FOR THE DETERMINATION OF STRESS
INDICES AND EWR SCENARIOS OF EWR 1: VALEYSPRUIT**

B1 EWR 1: VALEYSRUIT (CROCODILE RIVER) - DETERMINATION OF STRESS INDICES

Appendix B provides supporting information for the determination of stress indices of EWR 1 Valeyspruit (Chapter 3 and 4 of the Crocodile River System EWR Scenario Report: Volume 2).

B1.1 FISH INDICATOR SPECIES

Small semi-rheophilic (SSR) guild: The small semi-rheophilic species *Barbus anoplus* (BANO) was selected as indicator species. Its optimal preferred general habitat is Slow Deep (SD) and Slow Shallow (SS) preferably with overhanging vegetation or aquatic vegetation as cover, although they also make use of large substrates (cobbles, boulders and bedrock and even undercut banks) as general habitat.

The habitat requirements for the different life stages of the SR indicator fish species is summarised in Table B1 for the SR guild. Information in Bold type face indicates crucial habitat during the given life stage.

Table B1 Habitat requirements for different life stages of indicators species included in the SR guild

Species	Spawning	Egg and embryo development	Larvae	Juveniles	Adults
BANO	Flow habitat: SD, and SS (> 0.1 m) and marginal vegetation . Spawning season: Oct - Jan. Cue: Increased flow, temp., and water quality. Spawning takes place during the summer among flooded vegetation where adhesive eggs are.	Flow habitat: SD, and SS (> 0.1 m) and marginal vegetation . Months: Oct - Jan. > 16°C. Incubation: 4 – 5 days. Flows to last long enough for the egg to hatch out and embryos to develop.	Nursery areas (> 0.1 m) and margins of SS, SD . Backwaters formed by increased flow. Cover: Overhanging vegetation. Duration larval period: 2 months.	Flow habitat: Mostly SD and SS (> 0.1 m). Cover: Overhanging vegetation and undercut banks. Duration 3 – 6 months. Low flow refuge (June - Sep) SS (> 0.1 m) and SD . Cover: Cobbles, rocks and overhanging vegetation.	Flow habitat: SS, and SD . Cover: Cobbles and rocks, overhanging vegetation, and undercut banks. Duration: 3 – 6 months. Low flow refuge (Jun – Sep)r: SS (> 0.1 m) and SD . Cover: Cobbles, rocks overhanging vegetation.

B1.2 FISH STRESS INDEX

The abundance of fish velocity-depth classes are provided in Table B2.

Table B2 EWR 1: Habitat suitability for the SSR guild

SSR GUILD									
Depth classes	Discharges (m ³ /s)								
	0.025	0.04	0.05	0.06	0.08	0.10	0.21	0.32	0.39
Slow (<0.3 m/s) Very Shallow (<0.1 m) (SVS)	8	8	10	10	8	8	8	10	8
Slow (<0.3 m/s) Shallow (0.1 – 0.3 m) (SS)	4	4	4	4	4	4	4	4	6
Slow (<0.3 m/s) Deep (> 0.5 m) (SD)	4	4	4	4	4	4	4	4	4
Slow Shallow and Slow Deep	0	0	0	0	0	0	0	2	2
Fast (>0.3 m/s) Very Shallow (<0.1 m) (FVS)	10	10	10	10	10	10	10	10	10
Fast (>0.3 m/s) Shallow (0.1 – 0.3 m) (FS)	10	10	10	10	10	10	10	10	10
Fast (>0.3 m/s) Intermediate (0.2 – 0.3) (FI)	10	10	10	10	10	10	10	10	10
Fast (>0.3 m/s) Deep (> 0.3 m) (FD)	10	10	10	10	10	10	6	6	6
FAST TOTAL >0.1 m DEEP	10	10	10	10	10	10	6	6	6

The fish stress index is provided in Table B3

Table B3 Fish stress index

Habitat	Discharges (m ³ /s)								
	0.025	0.04	0.05	0.06	0.08	0.10	0.21	0.32	0.39
SMALL SEMI-RHEOPHILIC (SSR) GUILD									
Spawning habitat	1	2	3	3	3	3	3	3	3
Abundance	2.5	4	5	5	5	5	5	5	5
Cover	1	2.5	3	3	4	4	5	5	5
Connectivity (lateral & longitudinal)	2	4	5	5	5	5	5	5	5
Water Quality (esp. oxygen and temperature)	2.5	3.5	4	4	5	5	5	5	5
Species stress: BANO	6	4	3	3	2	2	0	0	0

B1.3 MACROINVERTEBRATE STRESS INDEX

The habitat flow index for flow dependent macroinvertebrate (FDI) taxa is provided in Table B4 and provides the % occurrence of various velocity and substrate classes under different flow conditions.

Table B4 Habitat suitability for FDI taxa

Habitat Flow Response Index	Habitat Response	Habitat Abundance and suitability													Flow (m ³ /s)
		VSCS ¹	SCS ²	FCS ³	VFCS ⁴	VFS ⁵	SFS ⁶	FFS ⁷	VFFS ⁸	VSB ⁹	SBR ¹⁰	FBR ¹¹	VFB ¹²	Veg ¹³	
0	All habitats in excess, very high quality. Very fast, very deep, very wide Wetted Perimeter (WP).	13	23	32	12	3	6	8	3	0	0	0	0	0	0.41
1	All plentiful, high quality. Fast, wide WP.	14	26	31	9	4	6	8	2	0	0	0	0	0	0.34
2	Critical habitats sufficient. Quality slightly reduced, fast, WP slightly reduced.	17	27	29	7	4	7	7	2	0	0	0	0	0	0.29
3	Reduced critical habitat and critical quality. Moderate velocity, fairly deep.	22	31	22	6	5	8	6	0	0	0	0	0	0	0.19
4	Critical habitats limited and of moderate quality. Moderate velocity, some deep areas. Wide WP moderately reduced.	24	33	18	4	6	8	4	1	1	1	0	0	0	0.15
5	Critical habitat very reduced, moderate/low quality. Moderate/slow velocity, few deep areas WP moderately/very reduced.	29	37	12	2	7	9	3	1	0	0	0	0	0	0.09
6	Critical habitat residual. Low quality, moderate/slow velocity.	32	37	9	1	8	9	2	0	1	1	0	0	0	0.06
7	No critical habitat, other habitats moderate quality. Slow, narrow WP.	50	27	3	0	12	7	1	0	0	0	0	0	0	0.019
8	Flowing water habitats residual and of low quality. Slow trickle, very narrow WP.	70	10	0	0	18	2	0	0	0	0	0	0	0	0.002
9		78	2	0	0	19	1	0	0	0	0	0	0	0	0.001
10	Standing water habitats only, very low quality, no flow.	80	0	0	0	20	0	0	0	0	0	0	0	0	0.000

1 Very Slow over Coarse Sediment

4 Very Fast over Coarse Sediment

7 Fast over Fine Sediment

10 Slow over Bedrock

13 Fringing vegetation

2 Slow over Coarse Sediment

5 Very Slow over Fine Sediment

8 Very Fast over Fine Sediment

11 Fast over Bedrock

3 Fast over Coarse Sediment

6 Slow over Fine Sediment

9 Very Slow over Bedrock

12 Very Fast over Bedrock

The stress index for FDI taxa is provided in Table B5 which rates the response of the species according to various biotic response metrics.

Table B5 Macroinvertebrate (FDI) stress index

Habitat characteristics					Biotic Response	Flow	Species Stress
Max depth (m)	Ave depth (m)	Max vel (m/s)	Ave vel (m/s)	WP (m)			
0.32	0.24	1.07	0.36	5.0	All flow dependent macroinvertebrates very abundant and healthy.	0.34	0
0.3	0.22	1.01	0.33	4.9	90% rheophilic species persist.	0.29	1
0.28	0.2	0.95	0.31	4.9	Most rheophilic species persist, but slight (80%) reduction.	0.19	2
0.24	0.16	0.83	0.25	4.8	Most rheophilic species persist, but abundances reduced.	0.15	3
0.22	0.14	0.75	0.23	4.8	All life stages viable in limited areas, critical life stages of some sensitive rheophilic species at risk.	0.09	4
0.18	0.1	0.6	0.18	4.7	Critical life-stages of sensitive rheophilic species at risk or non-viable.		5
0.16	0.08	0.53	0.16	4.6	Sensitive rheophilic species rare, critical stages of sensitive rheophilic species non-viable and at risk for some less sensitive species.	0.06	6
0.12	0.05	0.32	0.09	4.0	Some rheophilic species persist, but most disappear. All life-stages of sensitive rheophilic species at risk or non-viable.	0.039	7
0.06	0.03	0.16	0.04	1.5	Some rheophilic species persist, but at very low numbers. All life stages of most rheophilic species at risk or non-viable.	0.019	8
0.04	0.02	0.100	0.03	1.10	Indicator taxa no longer present.	0.002	9
					Standing water only, no flow dependent macroinvertebrates present.	0.001	10

B1.4 RIPARIAN VEGETATION STRESS INDEX

A riparian vegetation stress index is provided in Table B6.

Table B6 Riparian vegetation stress index for indicator species

Biotic response				
Species Stress	Flow (m ³ /s)	<i>Juncus lomatophyllus</i>	Flow (m ³ /s)	<i>Miscanthus</i>
0	0.2	Adults with full vigour and at maximum reproductive capacity. 50% of population inundated, upper limit rooting depth at 13 cm.	0.2	Adults with full vigour and at maximum reproductive capacity. Inundated to rooting depth of 10 cm.
1				
2				
3	0.05	Leaf wilting/stress commences, but is slight. Up to 20 cm rooting depth for upper limit, lower limit at water level on average.	0.04	Leaf wilting/stress commences, but is slight. Rooting depth from 10 to 20 cm.
4		Flower/fruit abortion commences.		Flower/fruit abortion commences.
5	0	Leaf wilting obvious, or vegetative parts begin unseasonal discolouration. Flower/fruit abortion widespread. Up to 26 cm rooting depth for sufficient soil moisture, flow has stopped but water remains in pool.		Leaf wilting obvious, or vegetative parts begin unseasonal discolouration. Flower/fruit abortion widespread.
6		Unseasonal thinning or partial mortality of above-ground parts (majority of the plant/s remains viable, but water stressed).	0	Unseasonal thinning or partial mortality of above-ground parts (majority of the plant/s remains viable, but water stressed). Rooting depth of 23 to 34 cm.
7				
8		Unseasonal loss or mortality of above-ground		Unseasonal loss or mortality of above-ground parts

Biotic response				
Species Stress	Flow (m ³ /s)	<i>Juncus lomatophyllus</i>	Flow (m ³ /s)	<i>Miscanthus</i>
		parts (only minor portions of plants remain viable). Rootstocks/rhizomes of some species remain viable.		(only minor portions of plants remain viable). Rootstocks/rhizomes of some species remain viable.
9		Complete mortality of small proportion of the population.		Complete mortality of small proportion of the population.
10		Widespread and complete mortality of population.		Widespread and complete mortality of population.

B2 EWR 1: VALEYSPRUIT (CROCODILE RIVER) - DETERMINATION OF EWR SCENARIOS

B2.1 LOW FLOW REQUIREMENTS IN TERMS OF STRESS FOR FISH

The fish low flow requirements for the EWR scenarios are summarised in Table B7 for the SSR guild.

Table B7 Low flow requirements: SSR guild

GENERAL
INDICATOR: The small semi-rheophilic species BANO is the only indigenous fish species present at the site and had to serve as the indicator species for this EWR site. BANO only reaches a maximum size of approximately 12 cm. Its optimal preferred general habitat is Slow Deep (SD) and Slow Shallow (SS) preferably with overhanging vegetation or aquatic vegetation as cover, although they also make use of large substrates (cobbles, boulders and bedrock and even undercut banks) as general habitat. Spawning takes place during the summer when rivers are swollen after rains. It lays its adhesive eggs amidst vegetation. The larvae hatch within 3 days and begin to swim and feed after 6/7 days. Flows should remain adequate to allow migration between reaches, thus pools should remain connected during wet season. Water levels providing inundated vegetation should last long enough for spawning, egg hatching and larvae development. Larvae and juveniles require SS and SD with adequate cover to allow optimal development and survival.
PES and REC: FISH EC A (ECOSTATUS A/B)
Dry Season maintenance BANO, as a moderately tolerant small semi-rheophilic has a high preference for SD and SS with cover (especially overhanging and aquatic vegetation, although they also use large rocky substrates as preferred cover). This species should be able to survive long periods of no or limited flow as long as adequate SD and SS habitats are maintained. It is recommended that although they are not directly dependant on fast habitats for survival, that the maintenance of some flow will ensure longitudinal connectivity allowing movement for feeding and recruitment. Some flow will furthermore be required to sustain water quality within acceptable levels and flush waste products from the pools. Their survival in this period would depend on the maintenance of their food source, but being omnivorous and having a varied diet, they are generally able to survive stressed conditions. At the mentioned stress level, some flow will be maintained but the most important refuge areas, namely SD and SS will be available. No inundated vegetation will be available at this stress level (their preferred cover type), but under these conditions they will make use of substrate as cover to survive through the dry season. Dry Season drought BANO a moderately tolerant semi-rheophilic species with high preference for SD and SS habitats with cover of aquatic vegetation and overhang, although they also make use of large rocky substrate such as cobbles to bedrock and undercut banks, especially in periods of stress/low flows, when inundated vegetation is limited or absent. During dry season droughts, this species will be able to handle high habitat stress and survive periods of no flow, as long as some surface water remains available as pools and backwaters. This stress level will ensure maintenance of SS and SD with cover (under these conditions no inundated vegetation will be available but they will make use of substrate as cover for survival). Wet Season maintenance The optimal habitat of this species during wet season is a requirement of inundated vegetation for spawning and egg development that should ideally be provided by floods. After spawning and breeding, it is important that some level of aquatic vegetation and overhanging vegetation is maintained for a period to allow survival of larvae and juveniles. At the mentioned 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 <i>Oncorhynchus mykiss</i> (OMYK). Wet Season drought During drought in the wet season, BANO will require some SS and SD (with adequate depth) and cover to survive. At this stress there will most probably be no optimal cover available to this species in the form of overhanging vegetation and aquatic vegetations, and they should seek refuge under large substrates (especially boulders). It is also recommended that some flow should remain to ensure that pools remain connected (by Fast Shallow (FS)) and allow movement of this species and to maintain an acceptable water quality for the different life stages of this species (should spawning and egg development have taken place during floods, if occurrence during droughts), which should

be available at this stress level.

BUILDING BLOCK ¹	SEASON	STRESS DURATION	SPP STRESS	INTEG ² STRESS	FLOW (m ³ /s)
Drought	Dry	5%	9	9	0.007
Maintenance	Dry	35%	6	7.75	0.024
Drought	Wet	5%	5	7.4	0.031
Maintenance	Wet	35%	2	3.8	0.102

AEC: FISH EC B/C (ECOSTATUS B/C)

General

If the base flows is reduced significantly (especially during summer), it will have an impact on this and other semi-rheophilic species primarily related to loss of habitat and cover. Decreased flows will result in overall decrease and even absence of inundated vegetation and overhanging vegetation as cover and this species will have to retreat to substrate as the only cover available. The deterioration in water quality associated with the decreased flows may further influence BANO, especially smaller life stages (egg development, embryos and larvae, as well as juvenile survival).

Dry Season maintenance

BANO, as a moderately tolerant small semi-rheophilic has a high preference for SD and SS with cover (especially overhanging and aquatic vegetation, although they also use large rocky substrates as preferred cover). This species should be able to survive long periods of no or limited flow as long as adequate SD and SS habitats are maintained. Although they are not directly dependant on fast habitats for survival, should the flows be further reduced it very limited fast habitat will be available and therefore the connection of pools may be lost or reduced, which will limit longitudinal migration for feeding and recruitment. Less flow will furthermore result in lower water quality and a build-up of waste products in the pools, which may further reduce the water quality and therefore survival and abundance of BANO. Lower water levels may also reduce cover for this species with a greater level of predation by the alien *Micropterus salmoides* (MSAL).

Wet Season maintenance

The optimal habitat of this species during wet season is a requirement of inundated vegetation for spawning and egg development that should ideally be provided by floods. After spawning and breeding, it is important that some level of aquatic vegetation and overhanging vegetation is maintained for a period to allow survival of larvae and juveniles. At the mentioned stress level flow would probably not provide abundant inundated macrophytes and therefore very limited abundance of their preferred habitat in the form of overhanging vegetation and aquatic vegetation will be available under this stress condition. The provision of adequate cover is especially important at the site due to the presence of alien predator OMYK and due to the decreased level of cover provided at this stress level, an increased impact by OMYK can be expected, resulting in decreased FROC and abundance of BANO. Very limited fast habitats will be available and connectivity between pools may therefore also reduce with a resultant negative impact on the Frequency of Occurrence (FROC) of BANO, and a resultant decrease in the EC.

BUILDING BLOCK	SEASON	STRESS DURATION	SPP STRESS	INTEG STRESS	FLOW (m ³ /s)
Maintenance	Dry	35%	8	8.6	0.0118
Maintenance	Wet	35%	4	7	0.039

¹ Flow building block refers to drought and maintenance flows.

² Integrated

B2.2 LOW FLOW REQUIREMENTS IN TERMS OF STRESS FOR MACROINVERTEBRATES

The FDI low flow requirements are summarised in Table B8 below.

Table B8 Low flow requirements: FDI taxa

GENERAL
INDICATOR: Tricorythidae mayflies require velocities of > 0.6 m/s, but may persist at lower velocities (> 0.1 m/s); Heptageniidae mayflies require velocities of 0.3 - 0.6 m/s but will also survive at faster velocities (> 0.6 m/s), they might persist at slower velocities (0.1 - 0.3 m/s). Elmidae beetles also require velocities of 0.3 - 0.6 m/s and may persist at slower (0.1 - 0.3m/s) and faster velocities. All three taxa occur mostly on cobbles but are able to survive on vegetation and bedrock. The Heptageniidae are highly sensitive and the Tricorythidae and Elmidae moderately sensitive to water quality conditions. These taxa are not expected to tolerate wide fluctuations in flow and water

quality conditions.

PES and REC: MACROINVERTEBRATE EC: A/B (ECOSTATUS B)

Dry Season maintenance

Suitable habitat (> 0.3 m/s over coarse substrate) is required to ensure that all the selected taxa can overwinter without significant detrimental impacts on the overall population. The maximum velocity of 0.53 m/s (macroinvertebrate stress of 6) will ensure that this takes place.

Dry Season drought

Suitable habitat (> 0.1 m/s over coarse substrate, with at least some areas where the flow reaches velocities > 0.3 m/s) is required to ensure that a core of the selected taxa is able to survive a drought. The maximum velocity of 0.32 m/s (macroinvertebrate stress of 8) will ensure that this takes place.

Wet Season maintenance

During the wet season optimal habitats (> 0.6 m/s over coarse substrate) is required to ensure that a healthy population occurs during the summer. The maximum velocity of 0.83 m/s (macroinvertebrate stress of 2) ensures that this takes place.

Wet Season drought

During the wet season optimal habitats (> 0.3 m/s over coarse substrate) is required to ensure that a healthy population occurs during the summer. The maximum velocity of 0.6 m/s (macroinvertebrate stress of 4) ensures that this takes place.

BUILDING BLOCK	SEASON	STRESS DURATION	SPP STRESS	INTEG STRESS	FLOW (m ³ /s)
Drought	Dry	5%	8	8	0.019
Maintenance	Dry	35%	6	6	0.06
Drought	Wet	5%	4	4	0.09
Maintenance	Wet	35%	2	2	0.19

AEC: MACROINVERTEBRATE EC B/C (ECOSTATUS B/C)

Dry Season maintenance

Suitable habitat (> 0.3 m/s over coarse substrate) is required to ensure that all the selected taxa can overwinter without significant detrimental impacts on the overall population. The maximum velocity of 0.41 m/s (macroinvertebrate stress of 7) will ensure that this takes place.

Wet Season maintenance

During the wet season optimal habitats (> 0.6 m/s over coarse substrate) is required to ensure that a healthy population occurs during the summer. The maximum velocity of 0.75 m/s (macroinvertebrate stress of 3) ensures that this takes place.

BUILDING BLOCK	SEASON	STRESS DURATION	SPP STRESS	INTEG STRESS	FLOW (m ³ /s)
Maintenance	Dry	35%	7	7	0.039
Maintenance	Wet	35%	3	3	0.15

B2.3 LOW FLOW REQUIREMENTS IN TERMS OF RIPARIAN VEGETATION

The low flow requirements for riparian vegetation indicator species are summarised in Table B9.

Table B9 Low flow requirements: Riparian vegetation species

GENERAL
INDICATOR: <i>Juncus lomatophyllus</i>
PES and REC: RIPARIAN VEGETATION EC A (ECOSTATUS A/B)
Dry Season maintenance At a stress of species 3, leaf wilting/stress commences, but is slight. <i>Juncus</i> requires up to 20 cm rooting depth for the upper limit while the lower limit is at water level on average. For an A EC, it is not expected that a species stress of 3 is surpassed when dry season maintenance occurs (35% of the time). Dry Season drought At dry season drought (5%) riparian species stress increases to a level of 6. Unseasonal thinning or partial mortality of

above-ground parts occurs (majority of the plant/s remains viable, but water stressed).

Wet Season maintenance

It is not expected that *Juncus* is stressed under maintenance flows.

Wet Season drought

Drought at a species stress is expected (i.e. leaf wilting/stress commences, but is slight). *Juncus* requires up to 20 cm rooting depth for upper limit, while the lower limit is at water level on average).

BUILDING BLOCK	SEASON	STRESS DURATION	SPP STRESS	INTEG STRESS	FLOW (m ³ /s)
Drought	Dry	5%	6	10	0.06
Maintenance	Dry	50%	3	6.5	0.09
Drought	Wet	5%	3	6.5	0.061
Maintenance	Wet	50%	0	1.9	0.268

AEC: RIPARIAN VEGETATION EC B (ECOSTATUS B/C)

This EWR scenario was not assessed as the AEC is based on non flow related impacts.

B2.4 INSTREAM FLOOD FUNCTIONS

A description of the flood functions for biotic response is provided in Table B10.

Table B10 Functions for each Flood Class

Flood Class	Component	Function/Motivation
Class: I Range (m ³ /s): 0.6 - 2 Daily average: 1 Duration: 3	Fish	Class I floods should serve as cues for migration as well as to create adequate connections between pools to allow migration habitats. These floods will also create adequate spawning habitats through inundation of vegetation and also create nursery habitats (margins of SS and SD and especially backwaters created by flooding conditions). Water quality should also be reset through these floods. The frequency, extent and duration as recommended for the PES and AEC should be adequate to provide the functions as required to maintain the fish within the specific category.
	Macroinvertebrates	These freshets are recommended to flush organic flocculants and mobilise fines (1 - 2 mm sands) in order to improve biotope suitability. Three of these per year (Nov, Dec, and Mar), are recommended for a macroinvertebrate Category B, and two (Nov, and Mar) for a Category D.
Class: II Range (m ³ /s): 3 - 5 Daily average: 3 Duration: 3	Fish	Class II floods are similar in importance as Class I floods and have the same functionality as Class I floods. Their occurrence at lower frequency makes them less important for the fish assemblages, although they still serve important functions in especially resetting water quality and clearing habitats of fine sediment and algae. Although these substrate habitats are not optimally preferred habitat for BANO, they do utilise this habitat when adequate overhanging vegetation is not available.
	Macroinvertebrates	These freshets are recommended to stimulate hatching of eggs, clear fines, scour substrate and inundate marginal vegetation in order to create additional biotope, and reset water quality. One of these per year is recommended for both macroinvertebrate Category B and B/C in the middle of the wet season.
Class: III Range (m ³ /s): > 10	Fish	Class III floods also provide similar functions as Classes I, but due to its lower frequency become less important to the general requirements of fish assemblages in this river reach.

B2.5 EWR RULE TABLES

EWR rule tables which provide the recommended EWR flows as a duration table, showing flows which should be provided when linked to a natural trigger (natural modelled hydrology in this case) are provided for the different EWR scenarios. EWR rules are supplied for total flows as well as for low flows only.

Table B11 EWR 1 assurance rules for PES and REC: A/B

Desktop Version 2, Printed on 2009/02/04

Summary of IFR rule curves for: CE1 New Natural Flows

Determination based on defined BBM Table with site specific assurance rules.

Regional Type: E. Escarp PES = A/B

Data are given in m³/s mean monthly flow

% Points										
Month	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	0.078	0.077	0.077	0.075	0.073	0.068	0.059	0.047	0.033	0.021
Nov	0.177	0.176	0.174	0.171	0.164	0.152	0.132	0.104	0.070	0.044
Dec	0.196	0.195	0.193	0.190	0.182	0.169	0.148	0.117	0.081	0.054
Jan	0.526	0.480	0.440	0.404	0.367	0.307	0.266	0.209	0.142	0.093
Feb	0.239	0.238	0.236	0.232	0.225	0.211	0.189	0.158	0.121	0.094
Mar	0.320	0.304	0.290	0.276	0.259	0.232	0.205	0.167	0.121	0.087
Apr	0.198	0.198	0.197	0.194	0.188	0.177	0.159	0.132	0.100	0.076
May	0.165	0.165	0.164	0.161	0.157	0.148	0.133	0.110	0.083	0.062
Jun	0.136	0.136	0.135	0.133	0.130	0.122	0.110	0.090	0.066	0.048
Jul	0.109	0.109	0.108	0.107	0.104	0.098	0.088	0.072	0.051	0.036
Aug	0.085	0.085	0.084	0.083	0.080	0.075	0.067	0.053	0.037	0.025
Sep	0.072	0.072	0.071	0.070	0.067	0.063	0.055	0.044	0.030	0.019

Reserve flows without High Flows

Oct	0.078	0.077	0.077	0.075	0.073	0.068	0.059	0.047	0.033	0.021
Nov	0.111	0.111	0.110	0.108	0.104	0.097	0.086	0.070	0.051	0.037
Dec	0.133	0.132	0.131	0.129	0.124	0.116	0.103	0.085	0.063	0.047
Jan	0.188	0.187	0.185	0.182	0.175	0.164	0.147	0.122	0.093	0.072
Feb	0.239	0.238	0.236	0.232	0.225	0.211	0.189	0.158	0.121	0.094
Mar	0.207	0.206	0.205	0.201	0.195	0.183	0.164	0.137	0.104	0.080
Apr	0.198	0.198	0.197	0.194	0.188	0.177	0.159	0.132	0.100	0.076
May	0.165	0.165	0.164	0.161	0.157	0.148	0.133	0.110	0.083	0.062
Jun	0.136	0.136	0.135	0.133	0.130	0.122	0.110	0.090	0.066	0.048
Jul	0.109	0.109	0.108	0.107	0.104	0.098	0.088	0.072	0.051	0.036
Aug	0.085	0.085	0.084	0.083	0.080	0.075	0.067	0.053	0.037	0.025
Sep	0.072	0.072	0.071	0.070	0.067	0.063	0.055	0.044	0.030	0.019

Natural Duration curves

Oct	0.314	0.261	0.224	0.179	0.161	0.149	0.138	0.119	0.105	0.090
Nov	0.683	0.536	0.436	0.367	0.328	0.305	0.255	0.239	0.212	0.147
Dec	1.292	0.743	0.638	0.556	0.485	0.452	0.407	0.362	0.276	0.175
Jan	2.838	1.915	0.795	0.680	0.597	0.553	0.508	0.459	0.370	0.276
Feb	2.414	1.736	1.062	0.885	0.740	0.690	0.599	0.525	0.475	0.380
Mar	1.307	0.870	0.765	0.724	0.635	0.594	0.519	0.470	0.414	0.287
Apr	0.729	0.656	0.586	0.513	0.482	0.444	0.428	0.363	0.313	0.224
May	0.470	0.377	0.362	0.329	0.295	0.276	0.246	0.217	0.179	0.157
Jun	0.336	0.255	0.239	0.224	0.212	0.197	0.181	0.162	0.139	0.116
Jul	0.254	0.231	0.187	0.175	0.164	0.157	0.149	0.134	0.119	0.105
Aug	0.198	0.175	0.157	0.146	0.134	0.131	0.119	0.112	0.101	0.090
Sep	0.224	0.174	0.147	0.135	0.123	0.112	0.108	0.096	0.085	0.073

Table B12 EWR 1 assurance rules for AEC: B/C

Desktop Version 2, Printed on 2009/02/04

Summary of IFR rule curves for: CE1 New Natural Flows

Determination based on defined BBM Table with site specific assurance rules.

Regional Type: E. Escarp AEC = B/C

Data are given in m³/s mean monthly flow

Month	% Points									
	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	0.051	0.051	0.051	0.050	0.048	0.046	0.041	0.035	0.027	0.021
Nov	0.144	0.144	0.143	0.140	0.135	0.126	0.111	0.089	0.063	0.044
Dec	0.158	0.158	0.156	0.153	0.148	0.138	0.123	0.100	0.073	0.053
Jan	0.474	0.429	0.389	0.355	0.321	0.265	0.232	0.186	0.132	0.092
Feb	0.174	0.174	0.173	0.171	0.166	0.159	0.146	0.129	0.108	0.092
Mar	0.264	0.248	0.235	0.222	0.209	0.186	0.167	0.141	0.109	0.086
Apr	0.143	0.143	0.142	0.141	0.137	0.131	0.121	0.106	0.088	0.075
May	0.118	0.118	0.118	0.116	0.114	0.109	0.100	0.088	0.072	0.061
Jun	0.096	0.096	0.095	0.094	0.092	0.088	0.081	0.071	0.057	0.047
Jul	0.075	0.075	0.074	0.074	0.072	0.069	0.063	0.055	0.044	0.035
Aug	0.056	0.056	0.056	0.055	0.054	0.051	0.046	0.039	0.030	0.024
Sep	0.047	0.047	0.047	0.046	0.045	0.043	0.038	0.032	0.025	0.019

Reserve flows without High Flows

Oct	0.051	0.051	0.051	0.050	0.048	0.046	0.041	0.035	0.027	0.021
Nov	0.077	0.077	0.076	0.075	0.073	0.070	0.063	0.055	0.044	0.036
Dec	0.093	0.093	0.093	0.091	0.089	0.084	0.077	0.067	0.055	0.046
Jan	0.136	0.135	0.134	0.132	0.129	0.123	0.113	0.099	0.083	0.071
Feb	0.174	0.174	0.173	0.171	0.166	0.159	0.146	0.129	0.108	0.092
Mar	0.151	0.150	0.149	0.148	0.144	0.137	0.127	0.111	0.093	0.079
Apr	0.143	0.143	0.142	0.141	0.137	0.131	0.121	0.106	0.088	0.075
May	0.118	0.118	0.118	0.116	0.114	0.109	0.100	0.088	0.072	0.061
Jun	0.096	0.096	0.095	0.094	0.092	0.088	0.081	0.071	0.057	0.047
Jul	0.075	0.075	0.074	0.074	0.072	0.069	0.063	0.055	0.044	0.035
Aug	0.056	0.056	0.056	0.055	0.054	0.051	0.046	0.039	0.030	0.024
Sep	0.047	0.047	0.047	0.046	0.045	0.043	0.038	0.032	0.025	0.019

Natural Duration curves

Oct	0.314	0.261	0.224	0.179	0.161	0.149	0.138	0.119	0.105	0.090
Nov	0.683	0.536	0.436	0.367	0.328	0.305	0.255	0.239	0.212	0.147
Dec	1.292	0.743	0.638	0.556	0.485	0.452	0.407	0.362	0.276	0.175
Jan	2.838	1.915	0.795	0.680	0.597	0.553	0.508	0.459	0.370	0.276
Feb	2.414	1.736	1.062	0.885	0.740	0.690	0.599	0.525	0.475	0.380
Mar	1.307	0.870	0.765	0.724	0.635	0.594	0.519	0.470	0.414	0.287
Apr	0.729	0.656	0.586	0.513	0.482	0.444	0.428	0.363	0.313	0.224
May	0.470	0.377	0.362	0.329	0.295	0.276	0.246	0.217	0.179	0.157
Jun	0.336	0.255	0.239	0.224	0.212	0.197	0.181	0.162	0.139	0.116
Jul	0.254	0.231	0.187	0.175	0.164	0.157	0.149	0.134	0.119	0.105
Aug	0.198	0.175	0.157	0.146	0.134	0.131	0.119	0.112	0.101	0.090
Sep	0.224	0.174	0.147	0.135	0.123	0.112	0.108	0.096	0.085	0.073

**APPENDIX C: SUPPORTING INFORMATION FOR THE DETERMINATION OF STRESS
INDICES AND EWR SCENARIOS OF EWR 2: GOEDEHOOP**

C1 EWR 2: GOEDEHOOP (CROCODILE RIVER) - DETERMINATION OF STRESS INDICES

Appendix C provides supporting information for the determination of stress indices of EWR 2 Goedeheop (Chapter 5 and 6 of the Crocodile River System EWR Scenario Report: Volume 2).

C1.1 FISH INDICATOR SPECIES

Small rheophilic (SR) guild: Various small rheophilic species were present in this river stretch (*Amphilius uranoscopus* (AURA), *Amphilius natalensis* (ANAT), *Chiloglanis bifurcus* (CBIF), *Chiloglanis pretoriae* (CPRE), and *Barbus argenteus* (BARG)). These species all require flowing water over substrates during all life stages, with some stages also preferring some overhanging vegetation as cover.

The habitat requirements for the different life stages of the SR indicator fish species is summarised in Table C1. Information in Bold type face indicates crucial habitat during the given life stage.

Table C1 Habitat requirements for different life stages of indicators species included in the SR guild

Species	Spawning	Egg and embryo development	Larvae	Juveniles	Adults
AURA	Flow habitat: SS and FI (> 0.25 m). Substrate: Gravel and cobble. Spawning season: Oct - Jan. Cue: Increased temp., flow and changes in water quality (e.g. conductivity).	Flow habitat: Margins of SS (> 0.2 m, < 0.2 m/s). Substrate: Gravel and cobble. Months: Oct – Jan. > 16°C Duration: 7 days.	Flow habitat: Margins of FS, SS and overhanging vegetation. Nursery areas: > 0.20 m deep < 0.2 m/s. Duration larval period: 2 months.	Flow habitat: Mostly FD and FI (> 0.20 m deep > 0.1 m/s). Cover: Cobbles, rocks and overhanging vegetation. Duration: 3 - 6 months. Low flow refuge months: Jun – Sep. FS and FD. Cover: Cobbles and rocks.	Flow habitat: FD and FS. Cover: Cobbles and rocks. Low flow refuge months: Jun – Sep. FS and FD. Cover: Cobbles, rocks and overhanging vegetation.
BARG *	Flow habitat: SS and FI (> 0.25 m). Substrate: Gravel and cobble. Spawning season: Oct - Jan. Cue: Increased temp., flow and changes in water quality (e.g. conductivity).	Flow habitat: Margins of SS (> 0.2 m, < 0.2 m/s). Substrate: Gravel and cobble. Months: Oct – Jan. > 16°C Duration: 7 days.	Flow habitat: Margins of FS, SS and overhanging vegetation. Nursery areas: > 0.20 m deep < 0.2 m/s. Duration larval period: 2 months.	Flow habitat: FS, FI and FD.	Flow habitat: FD, FI, and FS with substrate.
CPRE	Flow habitat: FD, and FI (> 0.25 m). Substrate: Gravel and cobble. Spawning season: Oct – Jan. Cue: Increased temp., flow and changes in water quality (e.g. conductivity).	Flow habitat: Margins of FS and SS (> 0.20 m). Substrate: Gravel substrate. Months: Oct – Jan. Duration: 7 days. Breeds during summer, laying eggs between rocks and in gravel. Oviparous.	Flow habitat: Margins of FS and SS. Nursery areas: > 0.20 m. Duration larval period: 2 months.	Flow habitat: Mostly FD and FI (> 0.20 m). Cover: Cobbles and rocks. Duration: 3 - 6 months. Low flow refuge months: Jun – Sep. FI (> 0.20 m) and FD. Cover: Cobbles and rocks.	Flow habitat: FD and FS. Cover: Cobbles and rocks. Low flow refuge months: Jun – Sep. FI (> 0.30 m) and FD. Cover: Cobbles, rocks and overhanging vegetation.

* Low confidence information (derived from species with similar preferences).

C1.2 FISH STRESS INDEX

The abundance of fish velocity-depth classes are provided in Table C2.

Table C2 EWR 2: Habitat suitability for the SR guild

SR GUILD								
Depth classes	Discharges (m ³ /s)							
	0.09	0.21	0.29	0.39	0.52	0.87	1.67	2.04
Slow (<0.3 m/s) Very Shallow (<0.1 m) (SVS)	4	4	4	6	6	8	10	10
Slow (<0.3 m/s) Shallow (0.1 – 0.3 m) (SS)	4	4	4	4	4	4	6	6
Slow (<0.3 m/s) Deep (> 0.5 m) (SD)	10	10	10	10	10	10	10	10
Slow Shallow and Slow Deep	4	4	4	4	4	4	6	6
Fast (>0.3 m/s) Very Shallow (<0.1 m) (FVS)	6	6	6	6	6	8	8	10
Fast (>0.3 m/s) Shallow (0.1 – 0.3 m) (FS)	8	6	6	4	4	4	4	4
Fast (>0.3 m/s) Intermediate (0.2 – 0.3) (FI)	10	8	8	6	6	6	4	4
Fast (>0.3 m/s) Deep (> 0.3 m) (FD)	10	10	10	10	10	6	6	4
FAST TOTAL >0.1 m DEEP	10	8	8	6	6	4	4	2

The fish stress index is provided in Table C3

Table C3 Fish stress index

Habitat	Discharges (m ³ /s)							
	0.09	0.21	0.29	0.39	0.52	0.87	1.67	2.04
SMALL RHEOPHILIC (SR) GUILD								
Spawning habitat	1	1.5	2	2	2.5	3.5	4.5	5
Abundance	2	2	2	2.5	3	3.5	4.5	5
Cover	2	2	2.5	3	3.5	4.5	5	5
Connectivity (lateral & longitudinal)	2.5	3	3.5	4	4	5	5	5
Water Quality (esp. oxygen and temperature)	2	2.5	3	3.5	4	5	5	5
Species stress: AURA, BARG, CPRE	7	6	5	4	3	2	1	0

C1.3 MACROINVERTEBRATE STRESS INDEX

The habitat flow index for flow dependent macroinvertebrate (FDI) taxa is provided in Table C4 and provides the % occurrence of various velocity and substrate classes under different flow conditions.

Table C4 Habitat suitability for FDI taxa

Habitat Flow Response Index	Habitat Response	Habitat Abundance and suitability													Flow (m ³ /s)
		VSCS ¹	SCS ²	FCS ³	VFCs ⁴	VSFS ⁵	SFS ⁶	FFS ⁷	VFFS ⁸	VSBR ⁹	SBR ¹⁰	FBR ¹¹	VFBR ¹²	Veg ¹³	
0	All habitats in excess, very high quality. Very fast, very deep, very wide WP.	3	9	21	45	1	2	5	11	2	3	9	21	45	2.04
1	All plentiful, high quality. Fast, wide WP.	4	11	24	39	1	3	6	10	2	4	11	24	39	1.67
2	Critical habitats sufficient. Quality slightly reduced, fast, WP slightly reduced.	9	20	33	17	2	5	8	4	1	9	20	33	17	0.87
3	Reduced critical habitat and critical quality. Moderate velocity, fairly deep.	14	28	31	7	4	7	8	1	0	14	28	31	7	0.50
4	Critical habitats limited and of moderate quality. Moderate velocity, some deep areas. Wide WP moderately reduced.	22	35	19	4	5	9	5	1	0	22	35	19	4	0.29
5	Critical habitat very reduced, moderate/low quality. Moderate/slow velocity, few deep areas WP moderately/very reduced.	26	37	14	3	7	9	4	0	0	26	37	14	3	0.21
6	Critical habitat residual. Low quality, moderate/slow velocity.	30	38	10	2	7	10	3	0	0	30	38	10	2	0.15
7	No critical habitat, other habitats moderate quality. Slow, narrow WP.	35	37	8	0	9	9	2	0	0	35	37	8	0	0.09
8	Flowing water habitats residual and of low quality. Slow trickle, very narrow WP.	40	34	6	0	10	8	1	0	0	40	34	6	0	0.06
9		63	17	0	0	16	4	0	0	0	63	17	0	0	0.005
10	Standing water habitats only, very low quality, no flow.	80	0	0	0	20	0	0	0	0	80	0	0	0	0.000

1 Very Slow over Coarse Sediment

4 Very Fast over Coarse Sediment

7 Fast over Fine Sediment

10 Slow over Bedrock

13 Fringing vegetation

2 Slow over Coarse Sediment

5 Very Slow over Fine Sediment

8 Very Fast over Fine Sediment

11 Fast over Bedrock

3 Fast over Coarse Sediment

6 Slow over Fine Sediment

9 Very Slow over Bedrock

12 Very Fast over Bedrock

The stress index for FDI taxa is provided in Table C5 which rates the response of the species according to various biotic response metrics.

Table C5 Macroinvertebrate (FDI) stress index

Habitat characteristics					Biotic Response	Flow	Species Stress
Max depth (m)	Ave depth (m)	Max vel (m/s)	Ave vel (m/s)	WP (m)			
0.4	0.28	1.41	0.69	10.9	All indicator taxa very abundant and healthy.	2.04	0
0.38	0.26	1.31	0.6	10.9	90% indicator taxa persist.	1.67	1
0.32	0.2	1.06	0.42	10.7	Most indicator taxa persist, but slight (80%) reduction.	0.87	2
0.28	0.16	0.9	0.31	10.6	Most indicator taxa persist, but abundances reduced.	0.50	3
0.24	0.12	0.73	0.23	10.4	All life stages viable in limited areas, critical life stages of some sensitive indicator taxa at risk.	0.21	4
0.22	0.1	0.65	0.2	10.3	Critical life-stages of sensitive indicator taxa at risk or non-viable.	0.15	5
0.2	0.09	0.57	0.17	9.7	Sensitive indicator taxa rare, critical stages of sensitive indicator taxa non-viable and at risk for some less sensitive taxa.		6

Habitat characteristics					Biotic Response	Flow	Species Stress
Max depth (m)	Ave depth (m)	Max vel (m/s)	Ave vel (m/s)	WP (m)			
0.18	0.08	0.47	0.14	8.4	Some indicator taxa persist, but most disappear. All life-stages of sensitive indicator taxa at risk or non-viable.	0.09	7
0.16	0.07	0.41	0.12	7.4	Some indicator taxa persist, but at very low numbers. All life-stages of most indicator taxa at risk or non-viable.	0.06	8
0.06	0.04	0.22	0.06	2.1	Indicator taxa no longer present.	0.005	9
0.02	0.01	0.1	0.02	1.1		0.000	10

C1.4 RIPARIAN VEGETATION STRESS INDEX

A riparian vegetation stress index is provided in Table C6.

Table C6 Riparian vegetation stress index for indicator species

Biotic response		
Species Stress	Flow (m ³ /s)	<i>Juncus lomatophyllus</i>
0	0.6	Adults with full vigour and at maximum reproductive capacity. 50% of the population inundated. Upper limit rooting depth at 20 cm.
1		
2		
3	0.09	Leaf wilting/stress commences, but is slight. Up to 30 cm rooting depth for upper limit, while lower limit at water level on average.
4		Flower/fruit abortion commences.
5	0.015	Leaf wilting obvious or vegetative parts begin unseasonal discolouration; flower/fruit abortion widespread. 10 to 40 cm rooting depth for sufficient soil moisture, no inundation.
6	0	Unseasonal thinning or partial mortality of above-ground parts (majority of the plant/s remains viable, but water stressed). 15 to 50 cm rooting depth for sufficient soil moisture, mortality may occur for upper zone individuals.
7		
8		Unseasonal loss or mortality of above-ground parts (only minor portions of plants remain viable). Rootstocks/rhizomes of some species remain viable.
9		Complete mortality of small proportion of the population.
10		Widespread and complete mortality of population.

C2 EWR 2: GOEDEHOOP (CROCODILE RIVER) - DETERMINATION OF EWR SCENARIOS

C2.1 LOW FLOW REQUIREMENTS IN TERMS OF STRESS FOR FISH

The fish low flow requirements for the EWR scenarios are summarised in Table C7 for the SR guild.

Table C7 Low flow requirements: SR guild

GENERAL					
INDICATOR: The small rheophilic species at the site are the best indicators for setting flows. Various small rheophilic species are present in this river stretch (AURA, AURA, CBIF, CPRE, and BARG,) with this species comprising a large component of the fish species of this reach. These species all require flowing water over substrates during all life stages, with some stages also preferring some overhanging vegetation as cover. Optimal conditions for spawning of this guild consist of FD, FI and SS with good quality substrate (clean cobbles and grave), while the margins of the FS and SS are important for egg development and nursery areas for larvae, often with overhanging vegetation as cover. Juvenile and adult stages of this guild have a high preference for FS, FI and FD over substrates. Flows should furthermore remain adequate to allow migration between reaches, thus depth in riffle and rapids should remain adequate, especially during the wet season.					
PES and REC: FISH EC B (ECOSTATUS B)					
Dry Season maintenance Fish stress levels of 5 will result in reduced FS habitats with a resultant loss in abundance of small rheophilic species and cover and connectivity for these species, but should be adequate to maintain this guild within the PES. Dry Season drought At stress level of 6 some FS (10%) and very limited FI habitats (crucial habitats for the survival of the small rheophilic guild) will be available, which should be adequate to sustain the small rheophilic assemblage within a PES of B. It is recommended that the fish stress level of 5.25 should not be exceeded for 20% of the time to ensure that adequate fast habitats are sustained to support the small rheophilic guild and ensure the maintenance of the fish within a PES of B. Wet Season maintenance At a fish stress level of 1.5 most of the fast habitats (FI, FS and FD) will be reduced from the present conditions, although it should be adequate to support habitats for the various criteria assessed (spawning and nursery habitats, abundance, cover, connectivity and water quality) to maintain it within a PES of B. Slightly reduction in especially spawning and nursery habitats as well as abundance can be expected under this fish stress level. Adequate fast habitats with substrate, the optimally preferred habitats for the small rheophilic species should be maintained to ensure optimal or acceptable conditions. Wet Season drought At fish stress levels exceeding 3 the FD habitats will be lost but adequate FI and FS should be maintained, which should be adequate habitat for spawning of most of the rheophilic species. Abundance and cover will however be reduced but the fish stress level expected under these drought conditions in the wet season should be adequate for the maintenance of fish within the PES of B.					
BUILDING BLOCK	SEASON	STRESS DURATION	SPP STRESS	INTEG STRESS	FLOW (m ³ /s)
Drought	Dry	5%	6	6	0.21
Maintenance	Dry	35%	4.75	4.75	0.315
Additional	Dry	20%	5.25	5.25	0.27
Drought	Wet	5%	3	3	0.52
Maintenance	Wet	35%	1.5	1.5	1.27
AEC: FISH EC C (ECOSTATUS C)					
General Altered flow regime (increase low flows) will negatively impact on the FROC of species that are intolerant to no flow conditions and prefer fast habitats (ANAT, AURA, BARG, CBIF and CPRE). Altered flows (decreases) may even result in the loss of the critically endangered CBIF from this reach.					

Dry Season maintenance

At fish stress level of 5.5 the FD habitats will be lost, and FI and FS habitats will be highly reduced, which would have a negative impact on especially the abundance and availability of cover for the small rheophilic guild. This can be expected to result in decreased FROC of these species and a resultant decreased EC of a C.

Wet Season maintenance

At fish stress level of 2.5 the FD habitats will be highly reduced from natural conditions but remain within a level to meet the requirements of all life stages of the rheophilic species. Reduced FS and FI habitats will also be reduced resulting in a loss of cover and abundance, which will result in an overall decrease in FROC of the small rheophilic species.

BUILDING BLOCK	SEASON	STRESS DURATION	SPP STRESS	INTEG STRESS	FLOW (m ³ /s)
Maintenance	Dry	35%	5.5	5.5	0.25
Maintenance	Wet	35%	2.5	2.5	0.695

C2.2 LOW FLOW REQUIREMENTS IN TERMS OF STRESS FOR MACROINVERTEBRATES

The FDI low flow requirements are summarised in Table C8.

Table C8 Low flow requirements: FDI taxa

GENERAL					
INDICATOR: Perlidae and Tricorythidae mayflies require velocities of > 0.6 m/s, but may persist at lower velocities (> 0.1 m/s). Heptageniidae mayflies require velocities of 0.3 - 0.6 m/s but will also survive at faster velocities (> 0.6 m/s, they might persist at slower velocities (0.1 - 0.3 m/s). All three taxa occur mostly on cobbles. Tricorythidae and Heptageniidae are able to survive on vegetation and bedrock. The Perlidae and Heptageniidae are highly sensitive and the Tricorythidae moderately sensitive to water quality conditions. These taxa are not expected to tolerate wide fluctuations in flow and water quality conditions.					
PES and REC: MACROINVERTEBRATE EC: B (ECOSTATUS B)					
Dry Season maintenance Suitable habitat (> 0.3 m/s over coarse substrate) is required to ensure that all the selected taxa can overwinter without significant detrimental impacts on the overall population. The maximum velocity of 0.65 m/s (macroinvertebrate stress of 4) will ensure that this takes place.					
Dry Season drought Suitable habitat (> 0.1 m/s over coarse substrate, with at least some areas where the flow reaches velocities > 0.3 m/s) is required to ensure that a core of the selected taxa is able to survive a drought. The maximum velocity of 0.47 m/s (macroinvertebrate stress of 7) will ensure that this takes place.					
Wet Season maintenance During the wet season optimal habitats (> 0.6 m/s over coarse substrate) is required to ensure that a healthy population occurs during the summer. The maximum velocity of 1.06 m/s (macroinvertebrate stress of 2) ensures that this takes place.					
Wet Season drought During the wet season optimal habitats (> 0.3 m/s over coarse substrate) is required to ensure that a healthy population occurs during the summer. The maximum velocity of 0.65 m/s (macroinvertebrate stress of 4) ensures that this takes place.					
BUILDING BLOCK	SEASON	STRESS DURATION	SPP STRESS	INTEG STRESS	FLOW (m ³ /s)
Drought	Dry	5%	7	7	0.093
Maintenance	Dry	35%	4	6	0.21
Drought	Wet	5%	4	6	0.21
Maintenance	Wet	35%	2	2	0.87
AEC: INVERTEBRATE EC C (ECOSTATUS C)					
Dry Season maintenance Suitable habitat (> 0.3 m/s over coarse substrate) is required to ensure that all the selected taxa can overwinter without significant detrimental impacts on the overall population. The maximum velocity of 0.57 m/s (macroinvertebrate stress of					

5) will ensure that this takes place.

Wet Season maintenance

During the wet season optimal habitats (> 0.6 m/s over coarse substrate) is required to ensure that a healthy population occurs during the summer. The maximum velocity of 0.9 m/s (macroinvertebrate stress of 3) ensures that this takes place.

BUILDING BLOCK	SEASON	STRESS DURATION	SPP STRESS	INTEG STRESS	FLOW (m ³ /s)
Drought	Dry	5%	7	7	0.093
Maintenance	Dry	35%	5	6.5	0.152
Drought	Wet	5%	4	6	0.210
Maintenance	Wet	35%	3	3.1	0.485

C2.3 LOW FLOW REQUIREMENTS IN TERMS OF RIPARIAN VEGETATION

The low flow requirements for riparian vegetation indicator species are summarised in Table C9.

Table C9 Low flow requirements: Riparian vegetation species

GENERAL					
INDICATOR: <i>Juncus lomatophyllus</i>					
PES and REC: RIPARIAN VEGETATION EC: A/B (ECOSTATUS B)					
Dry Season maintenance At a species stress of 3, leaf wilting/stress commences, but is slight. <i>Juncus</i> requires up to 30 cm rooting depth for the upper limit and the lower limit is at water level on average. For an A/B EC, it is not expected that a species stress of 3 is surpassed when dry season maintenance occurs. Dry Season drought Riparian stress increases to a level of 8 i.e. unseasonal losses or mortality of above-ground parts (only minor portions of plants remain viable) and stolons remain largely viable. Wet Season maintenance With a species stress of 1, the upper portions of the population start water stress. Wet Season drought A species stress of 4 is expected (i.e. commencement of leaf wilting/stress. <i>Juncus</i> requires up to 30 cm rooting depth for the upper limit, and the lower limit is at water level on average. Flower and fruit abortion is widespread).					
BUILDING BLOCK	SEASON	STRESS DURATION	SPP STRESS	INTEG STRESS	FLOW (m ³ /s)
Drought	Dry	5%	8	10	0.0001
Maintenance	Dry	35%	3	7.5	0.078
Drought	Wet	5%	4	8.5	0.047
Maintenance	Wet	35%	1	3.75	0.423
AEC: RIPARIAN VEGETATION EC B (ECOSTATUS C)					
This EWR scenario was not assessed as the AEC is based on non flow related impacts.					

C2.4 INSTREAM FLOOD FUNCTIONS

A description of the flood functions for biotic response is provided in Table C10.

Table C10 Functions for each Flood Class

Flood Class	Component	Function/Motivation
Class: I Range (m ³ /s): 2 - 5 Daily average: 3 Duration: 3	Fish	Class I floods are the most important floods for fish and serves as migration cues and to maintain adequate longitudinal connectivity for migration. These floods will also flush fines and algae from substrates to ensure adequate conditions in substrates, a very important habitat for spawning of most of the species (especially rheophilic species). It should furthermore inundate some vegetation for species spawning in flooded marginal vegetation (BANO, PPHI and TSPA) and contributes to the creation of acceptable nursery areas. Some resetting of water quality will also take place, and the changes in water quality may also serve as stimulus to cue migratory activity and even gonad development. The frequency, extent and duration as recommended for the PES and AEC should be adequate to provide the functions as required to maintain the fish within the specific EC.
	Macroinvertebrates	These freshets are recommended to flush organic flocculant and mobilise fines (1 - 2 mm sands) in order to improve biotope suitability. Four of these per year, Nov, Dec, Jan and Mar/Apr, are recommended for a macroinvertebrate EC B, and three (Nov, Jan Mar/Apr) for a C EC.
Class: II Range (m ³ /s): 6 – 9 12 (Peak) Daily average: 9 Duration: 4	Fish	Class II floods are similar in importance as Class I floods and have the same functionality as Class I floods. Their occurrence at lower frequency (once per annum) makes them less important for the fish assemblages.
	Macroinvertebrates	These freshets are recommended to stimulate hatching of eggs, clear fines, scour substrate and inundate marginal vegetation in order to create additional biotope, and reset water quality. One of these per year is recommended for macroinvertebrate Category B and C in the middle of the wet season.
Class: III Range (m ³ /s): 13 – 25 (peak)	Fish	Class III floods also provide similar functions as Classes I, but due to its lower frequency it is not essential for the flood functions required by the indigenous fish species. These floods, and especially their receding periods will however be utilised by many of the fish species for migration and even spawning if takes place in within the summer season.
Class: IV Range (m ³ /s): 30 - 35 (peak)	Fish	Class IV floods also provide similar functions as Classes I, but due to its lower frequency it is not essential for the flood functions required by the indigenous fish species. These floods, and especially their receding periods will however be utilised by many of the fish species for migration and even spawning if takes place in within the summer season.

C2.5 EWR RULE TABLES

EWR rule tables which provide the recommended EWR flows as a duration table, showing flows which should be provided when linked to a natural trigger (natural modelled hydrology in this case) are provided for the different EWR scenarios. EWR rules are supplied for total flows as well as for low flows only.

Table C11 EWR 2 assurance rules for PES and REC: B

Desktop Version 2, Printed on 2009/02/04

Summary of IFR rule curves for: CE2 New Natural Flows

Determination based on defined BBM Table with site specific assurance rules.

Regional Type: E. Escarp PES = B

Data are given in m³/s mean monthly flow

% Points										
Month	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	0.459	0.458	0.455	0.449	0.436	0.413	0.373	0.316	0.246	0.194
Nov	0.876	0.873	0.865	0.849	0.819	0.764	0.674	0.544	0.390	0.275
Dec	1.017	1.013	1.004	0.984	0.947	0.882	0.776	0.623	0.444	0.310
Jan	1.518	1.467	1.416	1.360	1.286	1.160	1.016	0.812	0.576	0.401
Feb	2.828	2.649	2.488	2.333	2.164	1.876	1.632	1.280	0.867	0.559
Mar	1.657	1.608	1.559	1.502	1.427	1.296	1.139	0.911	0.640	0.438
Apr	1.263	1.260	1.250	1.229	1.188	1.112	0.986	0.799	0.574	0.405
May	1.044	1.043	1.036	1.020	0.988	0.929	0.828	0.675	0.488	0.346
Jun	0.856	0.855	0.837	0.806	0.752	0.706	0.652	0.565	0.414	0.300
Jul	0.678	0.678	0.674	0.635	0.597	0.564	0.538	0.460	0.342	0.252
Aug	0.508	0.508	0.505	0.498	0.485	0.460	0.417	0.351	0.269	0.207
Sep	0.418	0.418	0.416	0.410	0.400	0.380	0.346	0.296	0.233	0.186

Reserve flows without High Flows

Oct	0.459	0.458	0.455	0.449	0.436	0.413	0.373	0.316	0.246	0.194
Nov	0.679	0.677	0.671	0.660	0.638	0.600	0.536	0.444	0.335	0.253
Dec	0.827	0.824	0.816	0.802	0.774	0.724	0.643	0.527	0.390	0.289
Jan	1.179	1.173	1.161	1.138	1.094	1.018	0.896	0.725	0.527	0.380
Feb	1.517	1.511	1.497	1.468	1.414	1.318	1.162	0.937	0.673	0.476
Mar	1.319	1.315	1.303	1.279	1.233	1.151	1.016	0.821	0.590	0.417
Apr	1.263	1.260	1.250	1.229	1.188	1.112	0.986	0.799	0.574	0.405
May	1.044	1.043	1.036	1.020	0.988	0.929	0.828	0.675	0.488	0.346
Jun	0.856	0.855	0.837	0.806	0.752	0.706	0.652	0.565	0.414	0.300
Jul	0.678	0.678	0.674	0.635	0.597	0.564	0.538	0.460	0.342	0.252
Aug	0.508	0.508	0.505	0.498	0.485	0.460	0.417	0.351	0.269	0.207
Sep	0.418	0.418	0.416	0.410	0.400	0.380	0.346	0.296	0.233	0.186

Natural Duration curves

Oct	1.090	0.922	0.795	0.650	0.586	0.541	0.500	0.444	0.381	0.336
Nov	2.114	1.782	1.470	1.235	1.092	1.042	0.876	0.822	0.725	0.509
Dec	3.252	2.319	2.012	1.773	1.553	1.441	1.281	1.154	0.885	0.571
Jan	6.941	4.529	2.509	2.121	1.859	1.710	1.542	1.422	1.150	0.851
Feb	6.010	4.543	3.237	2.708	2.278	2.125	1.844	1.620	1.463	1.195
Mar	4.208	2.856	2.427	2.360	2.012	1.897	1.650	1.478	1.288	0.900
Apr	2.423	2.184	1.914	1.717	1.566	1.431	1.373	1.192	1.007	0.741
May	1.617	1.296	1.210	1.098	1.019	0.956	0.829	0.743	0.620	0.530
Jun	1.204	0.910	0.837	0.806	0.752	0.706	0.652	0.579	0.513	0.417
Jul	0.922	0.825	0.687	0.635	0.597	0.564	0.538	0.485	0.437	0.373
Aug	0.713	0.646	0.579	0.534	0.500	0.474	0.437	0.418	0.381	0.336
Sep	0.802	0.633	0.536	0.494	0.451	0.421	0.397	0.367	0.324	0.274

Table C12 EWR 2 assurance rules for AEC: C

Desktop Version 2, Printed on 2009/02/04

Summary of IFR rule curves for: CE2 New Natural Flows

Determination based on defined BBM Table with site specific assurance rules.

Regional Type: E. Escarp AEC = C

Data are given in m³/s mean monthly flow

Month	% Points									
	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	0.309	0.308	0.307	0.304	0.298	0.288	0.270	0.245	0.213	0.190
Nov	0.625	0.624	0.619	0.609	0.591	0.559	0.506	0.429	0.337	0.269
Dec	0.473	0.472	0.470	0.464	0.454	0.436	0.407	0.366	0.316	0.280
Jan	0.969	0.922	0.880	0.840	0.795	0.720	0.657	0.568	0.464	0.388
Feb	2.105	1.930	1.778	1.643	1.511	1.289	1.150	0.950	0.716	0.541
Mar	1.032	0.986	0.945	0.904	0.860	0.784	0.718	0.622	0.508	0.423
Apr	0.673	0.672	0.669	0.662	0.648	0.623	0.582	0.520	0.446	0.390
May	0.571	0.571	0.568	0.563	0.552	0.532	0.498	0.446	0.382	0.334
Jun	0.490	0.490	0.488	0.484	0.475	0.458	0.429	0.386	0.332	0.290
Jul	0.406	0.406	0.405	0.402	0.395	0.382	0.359	0.324	0.279	0.244
Aug	0.330	0.329	0.328	0.325	0.320	0.309	0.291	0.263	0.229	0.202
Sep	0.293	0.293	0.292	0.289	0.284	0.275	0.259	0.235	0.205	0.183

Reserve flows without High Flows

Oct	0.309	0.308	0.307	0.304	0.298	0.288	0.270	0.245	0.213	0.190
Nov	0.411	0.410	0.408	0.403	0.395	0.380	0.355	0.320	0.278	0.246
Dec	0.473	0.472	0.470	0.464	0.454	0.436	0.407	0.366	0.316	0.280
Jan	0.631	0.629	0.625	0.617	0.603	0.578	0.537	0.481	0.415	0.367
Feb	0.794	0.793	0.788	0.779	0.761	0.730	0.680	0.607	0.522	0.459
Mar	0.694	0.693	0.689	0.681	0.666	0.639	0.596	0.533	0.458	0.401
Apr	0.673	0.672	0.669	0.662	0.648	0.623	0.582	0.520	0.446	0.390
May	0.571	0.571	0.568	0.563	0.552	0.532	0.498	0.446	0.382	0.334
Jun	0.490	0.490	0.488	0.484	0.475	0.458	0.429	0.386	0.332	0.290
Jul	0.406	0.406	0.405	0.402	0.395	0.382	0.359	0.324	0.279	0.244
Aug	0.330	0.329	0.328	0.325	0.320	0.309	0.291	0.263	0.229	0.202
Sep	0.293	0.293	0.292	0.289	0.284	0.275	0.259	0.235	0.205	0.183

Natural Duration curves

Oct	1.090	0.922	0.795	0.650	0.586	0.541	0.500	0.444	0.381	0.336
Nov	2.114	1.782	1.470	1.235	1.092	1.042	0.876	0.822	0.725	0.509
Dec	3.252	2.319	2.012	1.773	1.553	1.441	1.281	1.154	0.885	0.571
Jan	6.941	4.529	2.509	2.121	1.859	1.710	1.542	1.422	1.150	0.851
Feb	6.010	4.543	3.237	2.708	2.278	2.125	1.844	1.620	1.463	1.195
Mar	4.208	2.856	2.427	2.360	2.012	1.897	1.650	1.478	1.288	0.900
Apr	2.423	2.184	1.914	1.717	1.566	1.431	1.373	1.192	1.007	0.741
May	1.617	1.296	1.210	1.098	1.019	0.956	0.829	0.743	0.620	0.530
Jun	1.204	0.910	0.837	0.806	0.752	0.706	0.652	0.579	0.513	0.417
Jul	0.922	0.825	0.687	0.635	0.597	0.564	0.538	0.485	0.437	0.373
Aug	0.713	0.646	0.579	0.534	0.500	0.474	0.437	0.418	0.381	0.336
Sep	0.802	0.633	0.536	0.494	0.451	0.421	0.397	0.367	0.324	0.274

**APPENDIX D: SUPPORTING INFORMATION FOR THE DETERMINATION OF STRESS
INDICES AND EWR SCENARIOS OF EWR 3: POPLAR CREEK**

D1 EWR 3: POPLAR CREEK (CROCODILE RIVER) - DETERMINATION OF STRESS INDICES

Appendix D provides supporting information for the determination of stress indices of EWR 3 Poplar Creek (Chapter 7 and 8 of the Main Report).

D1.1 FISH INDICATOR SPECIES

Small rheophilic (SR) guild: Various small rheophilic species were present in this river stretch (*Amphilius uranoscopus* (AURA), *Amphilius natalensis* (ANAT), *Chiloglanis bifurcus* (CBIF), *Chiloglanis pretoriae* (CPRE), and *Barbus argenteus* (BARG)). These species all require flowing water over substrates during all life stages, with some stages also preferring some overhanging vegetation as cover.

The habitat requirements for the different life stages of the SR indicator fish species is summarised in Appendix C, Table C1.

D1.2 FISH STRESS INDEX

The abundance of fish velocity-depth classes are provided in Table D1.

Table D1 EWR 3: Habitat suitability for the SR guild

SR GUILD										
Depth classes	Discharges (m ³ /s)									
	0.36	0.76	1.13	1.58	2.11	2.73	3.08	4.26	5.17	7.30
Slow (<0.3 m/s) Very Shallow (<0.1 m) (SVS)	6	6	6	6	8	8	8	8	10	8
Slow (<0.3 m/s) Shallow (0.1 – 0.3 m) (SS)	4	4	4	4	4	4	4	6	6	6
Slow (<0.3 m/s) Deep (> 0.5 m) (SD)	10	10	8	6	6	6	6	6	6	6
Slow Shallow and Slow Deep	4	4	4	4	4	4	4	4	4	4
Fast (>0.3 m/s) Very Shallow (<0.1 m) (FVS)	8	8	8	8	8	8	8	8	8	8
Fast (>0.3 m/s) Shallow (0.1 – 0.3 m) (FS)	8	6	6	6	6	6	6	6	6	6
Fast (>0.3 m/s) Intermediate (0.2 – 0.3) (FI)	8	8	6	6	6	6	6	8	6	8
Fast (>0.3 m/s) Deep (> 0.3 m) (FD)	8	8	6	6	6	4	4	4	4	4
FAST TOTAL >0.1 m DEEP	8	6	6	6	4	4	4	4	4	4

The fish stress index is provided in Table D2.

Table D2 Fish stress index

Habitat	Discharges (m ³ /s)									
	0.36	0.76	1.13	1.58	2.11	2.73	3.08	4.26	5.17	7.30
SMALL RHEOPHILIC (SR) GUILD										
Spawning habitat	0	1	2	3	3	3.5	4	4.5	5	5
Abundance	0.5	0.5	1	1.5	2	2.5	3	4	4.5	5
Cover	0.5	1	1.5	2	2.5	3	3.5	4	4.5	5
Connectivity (lateral & longitudinal)	0.5	1.5	2.5	3	3.5	4	4.5	5	5	5

Habitat	Discharges (m ³ /s)									
	0.36	0.76	1.13	1.58	2.11	2.73	3.08	4.26	5.17	7.30
Water Quality (esp. oxygen and temperature)	0.5	2	3	3.5	4	4	4.5	5	5	5
Species stress: AURA, BARG, CPRE	9	8	6	5	4	3	2	1	1	0

D1.3 MACROINVERTEBRATE STRESS INDEX

The habitat flow index for flow dependent macroinvertebrate (FDI) taxa is provided in Table B4 and provides the % occurrence of various velocity and substrate classes under different flow conditions.

Table D3 Habitat suitability for FDI taxa

Habitat Flow Response Index	Habitat Response	Habitat Abundance and suitability													Flow (m ³ /s)
		VSCS ¹	SCS ²	FCS ³	VFCs ⁴	VSFS ⁵	SFS ⁶	FFS ⁷	VFFS ⁸	VSBR ⁹	SBR ¹⁰	FBR ¹¹	VFBR ¹²	Veg ¹³	
0	All habitats in excess, very high quality. Very fast, very deep, very wide WP.	8	15	23	23	1	2	3	3	1	2	2	2	15	6.18
1	All plentiful, high quality. Fast, wide WP.	11	19	26	15	1	2	3	2	2	3	4	2	11	4.23
2	Critical habitats sufficient. Quality slightly reduced, fast, WP slightly reduced.	19	24	23	7	2	3	3	1	3	4	3	1	7	2.4
3	Reduced critical habitat and critical quality. Moderate velocity, fairly deep.	25	29	17	5	3	4	2	1	3	3	2	1	5	1.575
4	Critical habitats limited and of moderate quality. Moderate velocity, some deep areas. Wide WP moderately reduced.	30	31	13	3	4	4	2	0	4	4	2	0	4	1.1
5	Critical habitat very reduced, moderate/low quality. Moderate/slow velocity, few deep areas WP moderately/very reduced.	33	32	11	2	4	4	1	0	4	4	1	0	3	0.94
6	Critical habitat residual. Low quality, moderate/slow velocity.	50	26	4	0	6	3	0	0	7	4	1	0	0	0.36
7	No critical habitat, other habitats moderate quality. Slow, narrow WP.	56	22	1	0	7	3	0	0	8	3	0	0	0	0.26
8	Flowing water habitats residual and of low quality. Slow trickle, very narrow WP.	63	17	0	0	8	2	0	0	8	2	0	0	0	0.183
9	Standing water habitats only, very low quality, no flow.	76	4	0	0	10	0	0	0	10	1	0	0	0	0.07
10	Only hyporheic refugia, no surface water.	80	0	0	0	10	0	0	0	10	0	0	0	0	0.000

1 Very Slow over Coarse Sediment

4 Very Fast over Coarse Sediment

7 Fast over Fine Sediment

10 Slow over Bedrock

13 Fringing vegetation

2 Slow over Coarse Sediment

5 Very Slow over Fine Sediment

8 Very Fast over Fine Sediment

11 Fast over Bedrock

3 Fast over Coarse Sediment

6 Slow over Fine Sediment

9 Very Slow over Bedrock

12 Very Fast over Bedrock

The stress index for FDI taxa is provided in Table D4 which rates the response of the species according to various biotic response metrics.

Table D4 Macroinvertebrate (FDI) stress index

Habitat characteristics					Biotic Response	Flow	Species Stress
Max depth (m)	Ave depth (m)	Max vel (m/s)	Ave vel (m/s)	WP (m)			
0.8	0.5	1.47	0.49	29.2	All indicator taxa very abundant and healthy.	6.18	0
0.72	0.43	1.26	0.4	28.3	90% indicator taxa persist.	4.23	1
0.62	0.35	0.96	0.29	26.5	Most indicator taxa persist, but slight (80%) reduction.	2.4	2
0.56	0.3	0.78	0.23	25.4	Most indicator taxa persist, but abundances reduced.		3
0.52	0.27	0.66	0.19	24.1	All life stages viable in limited areas, critical life stages of some sensitive indicator taxa at risk.	1.575	4
0.5	0.26	0.59	0.17	23.7	Critical life-stages of sensitive indicator taxa at risk or non-viable.	1.1	5
0.42	0.19	0.34	0.09	21.5	Sensitive indicator taxa rare, critical stages of sensitive indicator taxa non-viable and at risk for some less sensitive taxa.	0.94	6
0.4	0.18	0.27	0.08	20.3	Some indicator taxa persist, but most disappear. All life-stages of sensitive indicator taxa at risk or non-viable.	0.36	7
0.38	0.17	0.21	0.06	19.8	Some indicator taxa persist, but at very low numbers. All life stages of most indicator taxa at risk or non-viable.		8
0.34	0.14	0.11	0.03	17.9	Indicator taxa no longer present.	0.26	9
0.28	0.13	0.01	0	12.5	Standing water only, no flow dependent macroinvertebrates present.	0.001	10

D1.4 RIPARIAN VEGETATION STRESS INDEX

A riparian vegetation stress index is provided in Table D5.

Table D5 Riparian vegetation stress index for indicator species

Biotic response		
Species Stress	Flow (m ³ /s)	<i>Salix mucronata</i> and <i>Cliffortia</i>
0	2.5	Adults with full vigour and at maximum reproductive capacity. 50% <i>Salix</i> population inundated, upper limit rooting depth at 15 to 25 cm. <i>Cliffortia</i> upper limit at 75 cm rooting depth.
1		
2		
3	0.55	Leaf wilting/stress commences, but is slight. <i>Salix</i>: 30 to 40 cm rooting depth for upper limit. Lower limit at water level on average. <i>Cliffortia</i>: Up to 90 cm rooting depth.
4		Flower/fruit abortion commences.
5	0.09	Leaf wilting obvious, or vegetative parts begin unseasonal discolouration. Flower/fruit abortion widespread. <i>Salix</i>: 10 to 40 cm rooting depth for sufficient soil moisture, no inundation (10 cm lower limit). <i>Cliffortia</i>: up to 1 m rooting depth.
6	0	Unseasonal thinning or partial mortality of above-ground parts (majority of the plant/s remains viable, but water stressed). <i>Salix</i>: 15 to 60 cm rooting depth for sufficient soil moisture, mortality may occur for upper zone individuals. <i>Cliffortia</i>: up to 110 cm rooting depth - some mortality may occur at the upper limit.
7		
8		Unseasonal loss or mortality of above-ground parts (only minor portions of plants remain viable); rootstocks/rhizomes of some species remain viable.
9		Complete mortality of small proportion of the population.
10		Widespread and complete mortality of population.

D2 EWR 3: POPLAR CREEK (CROCODILE RIVER) - DETERMINATION OF EWR SCENARIOS

D2.1 LOW FLOW REQUIREMENTS IN TERMS OF STRESS FOR FISH

The fish low flow requirements for the EWR scenarios are summarised in Table D6 for the SR guild.

Table D6 Low flow requirements: SR guild

GENERAL					
INDICATOR: The small rheophilic species at the site are the best indicators for setting flows. Various small rheophilic species are present in this river stretch (AURA, ANAT, CBIF, CPRE, and BARG) with this species comprising a large component of the fish species of this reach. These species all requires flowing water over substrates during all life stages, with some stages also preferring some overhanging vegetation as cover. Optimal conditions for spawning of this guild consist of FD, FI and SS with good quality substrate (clean cobbles and grave), while the margins of the FS and SS are important for egg development and nursery areas for larvae, often with overhanging vegetation as cover. Juvenile and adult stages of this guild have a high preference for FS, FI and FD over substrates. Flows should furthermore remain adequate to allow migration between reaches, thus depth in riffle and rapids should remain adequate, especially during the wet season.					
PES: FISH EC B (ECOSTATUS B/C)					
Dry Season maintenance Moving towards a fish stress level of 3 (increased flows) would result in decreased availability of slow habitats, which will have a negative impact on the species with preference for this habitat type (especially TSPA, PPHI). It can also be expected that one of the indicator species, BARG, that have some preference for SD and SS, may therefore also be influence by a loss in slow habitats.					
Dry Season drought At fish stress level of 8 enough FD, FS and FI habitats will still be available to maintain required habitats for the maintenance of some abundance of the small rheophilic species at the site.					
Wet Season maintenance Fish stress levels exceeding 3 will result in large decrease in abundance of the small rheophilic species, due to a loss in abundance of their preferred habitats (FD, FI and FS). Although these habitats will still be available at higher than stress levels of 3, their abundance will be reduced to a level where the frequency of occurrence of the rheophilic species may be influenced, which will result in a deterioration of the PES.					
Wet Season drought At fish stress level of 6.5, adequate FD, FI and FS will be maintained to allow for limited breeding and maintenance of some abundance.					
BUILDING BLOCK	SEASON	STRESS DURATION	SPP STRESS	INTEG STRESS	FLOW (m ³ /s)
Drought	Dry	5%	8	8	0.76
Maintenance	Dry	35%	3	3	2.73
Drought	Wet	5%	6.5	6.5	1.038
Maintenance	Wet	35%	3	3	2.73
REC: FISH EC B (ECOSTATUS B)					
The Fish EC is the same as for the PES.					
AEC: FISH EC C (ECOSTATUS C/D)					
Not applicable for fish at this site.					

D2.2 LOW FLOW REQUIREMENTS IN TERMS OF STRESS FOR MACROINVERTEBRATES

The FDI low flow requirements are summarised in Table D7.

Table D7 Low flow requirements: FDI taxa

GENERAL					
INDICATOR: Psephenidae beetles and Tricorythidae mayflies require velocities of > 0.6 m/s, but may persist at lower velocities (> 0.1 m/s). Heptageniidae mayflies require velocities of 0.3 - 0.6 m/s but will also survive at faster velocities (> 0.6 m/s, they might persist at slower velocities (0.1 - 0.3 m/s). All three taxa occur mostly on cobbles. Tricorythidae and Heptageniidae are able to survive on vegetation and bedrock. The Heptageniidae are highly sensitive and the Tricorythidae and Psephenidae moderately sensitive to water quality conditions. These taxa are not expected to tolerate wide fluctuations in flow and water quality conditions.					
PES: MACROINVERTEBRATE EC: C (ECOSTATUS B/C)					
Dry Season maintenance Suitable habitat (> 0.3 m/s over coarse substrate) is required to ensure that all the selected taxa can overwinter without significant detrimental impacts on the overall population. The maximum velocity of 0.96 m/s (macroinvertebrate stress of 2) will ensure that this takes place.					
Dry Season drought Suitable habitat (> 0.1 m/s over coarse substrate, with at least some areas where the flow reaches velocities > 0.3 m/s) is required to ensure that a core of the selected taxa is able to survive a drought. The maximum velocity of 0.66 m/s (macroinvertebrate stress of 5) will ensure that this takes place.					
Wet Season maintenance During the wet season optimal habitats (> 0.6 m/s over coarse substrate) is required to ensure that a healthy population occurs during the summer. The maximum velocity of 0.96 m/s (macroinvertebrate stress of 2) ensures that this takes place.					
Wet Season drought During the wet season optimal habitats (> 0.3 m/s over coarse substrate) is required to ensure that a healthy population occurs during the summer. The maximum velocity of 0.78 m/s (macroinvertebrate stress of 4) ensures that this takes place.					
BUILDING BLOCK	SEASON	STRESS DURATION	SPP STRESS	INTEG STRESS	FLOW (m ³ /s)
Drought	Dry	5%	5	6	1.13
Maintenance	Dry	35%	2	3.5	2.42
Drought	Wet	5%	4	5	1.58
Maintenance	Wet	35%	2	3.5	2.42
REC: MACROINVERTEBRATE EC B (ECOSTATUS B)					
Dry Season maintenance Suitable habitat (> 0.3 m/s over coarse substrate) is required to ensure that all the selected taxa can overwinter without significant detrimental impacts on the overall population. The maximum velocity of 0.93 m/s (macroinvertebrate stress of 3) will ensure that this takes place.					
Wet Season maintenance During the wet season optimal habitats (> 0.6 m/s over coarse substrate) is required to ensure that a healthy population occurs during the summer. The maximum velocity of 1.26 m/s (macroinvertebrate stress of 1) ensures that this takes place.					
BUILDING BLOCK	SEASON	STRESS DURATION	SPP STRESS	INTEG STRESS	FLOW (m ³ /s)
Maintenance	Dry	35%	3	4.2	2.004
Maintenance	Wet	35%	1	1.5	4.961

D2.3 LOW FLOW REQUIREMENTS IN TERMS OF RIPARIAN VEGETATION

The low flow requirements for riparian vegetation indicator species are summarised in Table D8.

Table D8 Low flow requirements: Riparian vegetation species

GENERAL					
INDICATOR: <i>Salix mucronata</i> and <i>Cliffortia</i> spp.					
PES: RIPARIAN VEGETATION EC: C (ECOSTATUS B/C)					
Dry Season maintenance At a species stress of 1, adults with full vigour and at maximum reproductive capacity are present. 50% <i>S. mucronata</i> population is inundated and upper limit rooting depth at 15 to 25 cm. <i>Cliffortia</i> upper limit at 75 cm rooting depth. Dry Season drought Riparian stress increases to a level of 5. Leaf wilting obvious, or vegetative parts begin unseasonal discolouration. Flower/fruit abortion widespread. <i>S. mucronata</i>: 10 to 40 cm rooting depth for sufficient soil moisture, no inundation (10 cm lower limit). <i>Cliffortia</i>: up to 1 m rooting depth. Wet Season maintenance The riparian vegetation species are not stressed and population should be healthy. Wet Season drought At a species stress of 3, leaf wilting/stress commences, but is slight. <i>S. mucronata</i> has a 30 to 40 cm rooting depth for the upper limit and the lower limit is at water level on average. <i>Cliffortia</i> spp. has up to 90 cm rooting depth.					
BUILDING BLOCK	SEASON	STRESS DURATION	SPP STRESS	INTEG STRESS	FLOW (m ³ /s)
Drought	Dry	5%	5	9.75	0.091
Maintenance	Dry	35%	1	4.5	1.845
Drought	Wet	5%	3	8.75	0.460
Maintenance	Wet	35%	0	3.5	2.42
REC: RIPARIAN VEGETATION EC B (ECOSTATUS B)					
Dry Season maintenance The riparian species are minimally stressed and should be healthy. Wet Season maintenance The riparian vegetation species are not stressed and population should be healthy.					
BUILDING BLOCK	SEASON	STRESS DURATION	SPP STRESS	INTEG STRESS	FLOW (m ³ /s)
Maintenance	Dry	35%	2	5.75	1.242
Maintenance	Wet	35%	0	3.5	2.42

D2.4 INSTREAM FLOOD FUNCTIONS

A description of the flood functions for biotic response is provided in Table D9.

Table D9 Functions for each Flood Class

Flood Class	Component	Function/Motivation
Class: I Range (m ³ /s): 10 – 13 (peak) Daily average: 8 Duration: 3	Fish	Class I floods are the most important floods for fish and serves as migration cues and to maintain adequate longitudinal connectivity for migration. These floods will also flush fines and algae from substrates to ensure adequate conditions in substrates, a very important habitat for spawning of most of the species (especially rheophilic species). It should furthermore inundate some vegetation for species spawning in flooded marginal vegetation (BANO, PPHI and TSPA) and contributes to the creation of acceptable nursery areas. Some resetting of

Flood Class	Component	Function/Motivation
		water quality will also take place, and the changes in water quality may also serve as stimulus to cue migratory activity and even gonad development. The frequency, extent and duration as recommended for the PES and AEC should be adequate to provide the functions as required to maintain the fish within the specific EC.
	Macroinvertebrates	These freshets are recommended to flush organic flocculants and mobilise fines (1 - 2 mm sands) in order to improve biotope suitability they will also reset water quality and scour the substrate. Another function is to inundate the sedges to provide extra habitat for vegetation dwelling macroinvertebrates. Four of these per year, Nov, Dec, Jan and Mar/Apr), are recommended for both the PES and the REC.
Class: II Range (m ³ /s): 20 - 30 (peak) Daily average: 15 Duration: 4	Fish	Class II floods are similar in importance as Class I floods and have the same functionality as Class I floods. Their occurrence at lower frequency (once per annum) makes them less important for the fish assemblages.
	Macroinvertebrates	These freshets are recommended to stimulate hatching of eggs, clear fines, scour substrate and inundate small cobbles on the edge of the channel in order to create additional biotope, and reset water quality. Two of these per year are recommended for macroinvertebrate Category B and C in the middle of the wet season.
Class: III Range (m ³ /s): 38 – 60 (peak) Daily average: 30 Duration: 5	Fish	Class III floods also provide similar functions as Classes I, but due to its lower frequency it is not essential for the flood functions required by the indigenous fish species. These floods, and especially their receding periods will however be utilised by many of the fish species for migration and even spawning if takes place in within the summer season.
Class: IV Range (m ³ /s): > 90 (peak)	Fish	Class IV floods also provide similar functions as Classes I, but due to its lower frequency it is not essential for the flood functions required by the indigenous fish species. These floods, and especially their receding periods will however be utilised by many of the fish species for migration and even spawning if takes place in within the summer season.

D2.5 EWR RULE TABLE

An EWR rule table which provide the recommended EWR flows as a duration table, showing flows which should be provided when linked to a natural trigger (natural modelled hydrology in this case) are provided for the different EWR scenarios. EWR rules are supplied for total flows as well as for low flows only.

Table D10 EWR 3 assurance rules for PES: B/C

Desktop Version 2, Printed on 2008/07/16

Summary of IFR rule curves for: CE3 PD Flows

Determination based on defined BBM Table with site specific assurance rules.

Regional Type: E. Escarp PES = B/C

Data are given in m³/s mean monthly flow

% Points										
Month	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	2.799	2.792	2.769	2.721	2.627	2.454	2.165	1.737	1.222	0.835
Nov	4.563	4.546	4.499	4.404	4.222	3.896	3.360	2.585	1.665	0.978
Dec	3.206	3.193	3.163	3.101	2.985	2.780	2.445	1.966	1.401	0.981
Jan	3.745	3.612	3.482	3.340	3.160	2.853	2.514	2.036	1.481	1.070
Feb	8.298	7.633	7.051	6.518	5.976	5.062	4.411	3.477	2.377	1.559
Mar	4.974	4.704	4.459	4.219	3.952	3.493	3.078	2.477	1.763	1.231
Apr	3.554	3.547	3.518	3.460	3.345	3.134	2.780	2.258	1.629	1.156
May	2.888	2.885	2.865	2.824	2.740	2.584	2.316	1.912	1.417	1.042
Jun	3.047	3.045	3.026	2.985	2.900	2.739	2.461	2.037	1.512	1.113
Jul	2.980	2.980	2.964	2.927	2.850	2.700	2.434	2.019	1.498	1.097
Aug	3.031	3.029	3.010	2.969	2.886	2.728	2.453	2.035	1.519	1.126
Sep	2.981	2.977	2.955	2.910	2.818	2.645	2.349	1.904	1.358	0.945

Reserve flows without High Flows

Oct	2.799	2.792	2.769	2.721	2.627	2.454	2.165	1.737	1.222	0.835
Nov	2.843	2.833	2.806	2.752	2.647	2.460	2.153	1.708	1.180	0.786
Dec	2.686	2.676	2.652	2.603	2.511	2.348	2.083	1.703	1.256	0.923
Jan	2.843	2.830	2.802	2.748	2.648	2.473	2.196	1.804	1.350	1.014
Feb	3.366	3.354	3.325	3.267	3.157	2.961	2.643	2.186	1.649	1.249
Mar	3.000	2.991	2.966	2.916	2.820	2.648	2.365	1.955	1.469	1.106
Apr	3.018	3.011	2.989	2.942	2.850	2.680	2.397	1.979	1.475	1.096
May	2.888	2.885	2.865	2.824	2.740	2.584	2.316	1.912	1.417	1.042
Jun	3.047	3.045	3.026	2.985	2.900	2.739	2.461	2.037	1.512	1.113
Jul	2.980	2.980	2.964	2.927	2.850	2.700	2.434	2.019	1.498	1.097
Aug	3.031	3.029	3.010	2.969	2.886	2.728	2.453	2.035	1.519	1.126
Sep	2.981	2.977	2.955	2.910	2.818	2.645	2.349	1.904	1.358	0.945

Natural Duration curves

Oct	6.213	5.544	5.137	4.536	3.622	3.039	2.277	1.762	1.266	0.922
Nov	6.381	5.401	4.074	3.557	3.152	2.415	2.041	1.821	1.335	0.934
Dec	10.204	5.470	4.219	3.569	2.684	2.270	1.956	1.714	1.538	1.131
Jan	16.207	8.367	5.839	4.749	4.055	3.304	2.591	1.882	1.639	1.075
Feb	23.690	14.964	7.858	6.138	4.936	3.782	3.026	2.116	1.852	1.389
Mar	13.150	9.756	7.743	5.548	4.275	3.577	2.714	2.117	1.747	1.232
Apr	8.318	7.230	5.941	5.382	4.541	3.781	3.148	2.137	1.667	1.269
May	7.773	6.392	5.529	4.917	4.275	3.973	3.327	2.871	2.024	1.232
Jun	8.376	7.184	6.798	6.111	5.478	4.834	4.302	3.762	2.944	1.466
Jul	8.076	7.142	6.814	6.388	5.888	5.391	4.421	3.610	2.841	1.740
Aug	7.672	7.299	6.859	6.631	6.392	6.033	5.447	4.219	2.733	1.594
Sep	6.019	5.552	5.127	4.969	4.576	3.889	3.499	2.693	1.366	0.945

**APPENDIX E: SUPPORTING INFORMATION FOR THE DETERMINATION OF STRESS
INDICES AND EWR SCENARIOS OF EWR 4: KANYAMAZANE**

E1 EWR 4: KANYAMAZANE (CROCODILE RIVER) - DETERMINATION OF STRESS INDICES

Appendix E provides supporting information for the determination of stress indices of EWR 4 Kanyamazane (Chapter 9 and 10 of the Crocodile River System EWR Scenario Report: Volume 2).

E1.1 FISH INDICATOR SPECIES

Small rheophilic (SR) guild: Various small rheophilic species were present in this river stretch and were included as indicators (*Amphilius uranoscopus* (AURA), *Chiloglanis pretoriae* (CPRE), and *Opsaridium peringueyi* (OPER)). These species all require flowing water over substrates during all life stages, with some stages also preferring some overhanging vegetation as cover.

Large semi-rheophilic (LSR) guild: The large semi-rheophilic species (especially *Labeobarbus marequensis* (BMAR), *Labeo cylindricus* (LCYL), and *Labeo molybdinus* (LMOL)) were another important indicator guild present at this EWR site. They also require overhanging vegetation as nursery habitats.

The habitat requirements for the different life stages of the SR indicator fish species (AURA and CPRE) are summarised in Appendix C, Table C1. The habitat requirements for OPER are summarised in Table E1 and the LR requirements are summarised in Table E2.

Table E1 Habitat requirements for different life stages of indicator species included in SR guild

Species	Spawning	Egg and embryo development	Larvae	Juveniles	Adults
OPER	Flow habitat: Sheltered SS, FS and FI (>0.15 m deep). Substrate: Gravel and cobble . Spawning season: Oct - Jan. Cue: Increased temp., flow and changes in water quality (e.g. conductivity).	Flow habitat: FS/FI and SS (>0.15 m deep, >0.2 m/s). Spawning season: Oct - Jan. >20°C Duration 6 - 8 days.	Nursery areas (>0.15 m deep, <0.2 m/s). Flow habitat: Margins of SS . Overhanging vegetation and macrophytes. Duration larval period: 2 months.	Flow habitat: Mostly SD and SS (>0.15 m deep, <0.2 m/s). Cover: Sand/gravel substrate with overhanging vegetation. Duration 3 - 6 months. Low flow refuge months: June - Sep. SS (>0.15 m deep, >0.15m/s) and SD . Cover: cobbles and rocks.	Flow habitat: SD, FD, FI and FS (>0.15 m, >0.2 m/s) Cover: Sheltered sandy/gravel substrate. Low flow refuge months: June - Sep. SS (>0.15 m, >0.1 m/s), SD, FS and FD . Cover: cobbles, rocks overhanging vegetation.

Table E2 Habitat requirements for different life stages of indicator species included in LSR guild

Species	Spawning	Egg and embryo development	Larvae	Juveniles	Adults
BMAR	Flow habitat: FD, FI and FS . Substrate: Gravel beds in riffles and rapids . Spawning season: Oct - April. Cue: Rain-swollen rivers.	Flow habitat: FD, FI and FS . Substrate: Gravel beds in riffles and rapids .	Nursery areas: > 0.20 m. Flow habitat: Margins of SS, SD and backwaters. Cover: Overhanging vegetation .	Flow habitat: Mostly FS, SS (>0.20 m). Cover: fringing vegetation . Flow habitat: Moderately high flows of 0.5 - 0.8 m/s - in rapid and shallow waters (20 - 30 cm), exposed bedrock substrate and riffles. Low flow refuge: SS, and FS . Cover: Combined cover, especially over cobble - overhanging vegetation .	Flow habitat: FD . Cover: Deep rocky bottom pools below rapids. Rocky runs, strong water current . Low flow refuge months: Jun - Sep. Flow habitat: FS and FD . Cover: Deep reed-fringed pools. Combined cover - overhanging vegetation especially over cobble .
LMOL LCYL	Flow habitat: SD, and SS (>0.30 m deep). Cover: Marginal vegetation . Spawning season: Oct - Jan. Cue: Increased flow. Temperature > 21°C.	Flow habitat: SD, and SS (>0.30 m deep, >0.2 m/s). Substrate: Rocks, cobbles and boulders . Spawning season: Oct - Jan. Incubation: 6 - 8 days. Temperature: >21°C.	Flow habitat: Margins of SS, and SD . Backwaters formed by increased flow . Cover: Overhanging vegetation, snags, rocks and cobbles . Nursery areas: >0.25 m deep.	Flow habitat: Mostly FD, and FI (>0.20 m deep) Cover: Cobbles and rocks. Some use of SS and SD. Duration 3 - 6 months. Low flow refuge: Jun - Sep; SS (>0.25 m deep), SD. Cover: Cobbles, rocks overhanging vegetation.	Flow habitat: FD, FI, SD and SS . Cover: In boulders, rocks and cobbles. Low flow refuge: Jun - Sep with Sep SS (>0.35 m deep), and SD. Cover: Cobbles, rocks overhanging vegetation.

Species	Spawning	Egg and embryo development	Larvae	Juveniles	Adults
			Duration larval period: 2 months	Months: Jun – Sep.	Months: Jun – Sep.

E1.2 FISH STRESS INDEX

The abundance of fish velocity-depth classes are provided in Table E3.

Table E3 EWR 4: Habitat suitability for the SR and LSR guild

SR AND LSR GUILD									
Depth classes	Discharges (m ³ /s)								
	1.29	2.93	3.44	4.71	5.2	7.95	10.15	18.59	28.89
Slow (<0.3 m/s) Very Shallow (<0.1 m) (SVS)	6	8	8	8	8	8	8	10	10
Slow (<0.3 m/s) Shallow (0.1 – 0.3 m) (SS)	4	4	4	6	6	6	8	8	8
Slow (<0.3 m/s) Deep (> 0.5 m) (SD)	10	10	8	8	8	6	6	6	6
Slow Shallow and Slow Deep	4	4	4	6	6	6	6	6	6
Fast (>0.3 m/s) Very Shallow (<0.1 m) (FVS)	6	8	6	8	8	6	6	8	8
Fast (>0.3 m/s) Shallow (0.1 – 0.3 m) (FS)	6	6	6	6	6	6	6	6	6
Fast (>0.3 m/s) Intermediate (0.2 – 0.3) (FI)	6	6	6	6	6	6	8	6	8
Fast (>0.3 m/s) Deep (> 0.3 m) (FD)	6	4	4	4	4	4	4	2	2
FAST TOTAL >0.1 m DEEP	4	4	4	4	4	4	4	2	2

The fish stress index is provided in Table E4.

Table E4 Fish stress index

Habitat	Discharges (m ³ /s)								
	1.29	2.93	3.44	4.71	5.2	7.95	10.15	18.59	28.89
SMALL RHEOPHILIC (SR) GUILD									
Spawning and Nursery habitat	2.5	3	4	4	4.5	4.5	4.5	5	5
Abundance	2	2	3	3.5	3.5	4	4.5	5	5
Cover	2	2.5	3	3.5	4	4	4.5	5	5
Connectivity (lateral & longitudinal)	2.5	2.5	3	3.5	4	4.5	4.5	5	5
Water Quality (esp. oxygen and temperature)	2	3	3	3.5	4	5	5	5	5
Species stress: AURA, CPRE, OPER	6	5	4	3	2	1	1	0	0
LARGE SEMI-RHEOPHILIC (LSR) GUILD									
Spawning and Nursery habitat	2.5	2.5	2.5	3	3.5	4	4	5	5
Abundance	2	2	2.5	3	3.5	4	4.5	4.5	5
Cover	2	2.5	2.5	3	3.5	4	4.5	5	5
Connectivity (lateral & longitudinal)	2	2.5	3	3	4	4.5	4.5	4.5	5
Water Quality (esp. oxygen and temperature)	2	2	3	3	4	5	5	5	5
Species stress: BMAR, LCYL, LMOL	6	5	4.6	4	3	2	1	0	0

E1.3 MACROINVERTEBRATE STRESS INDEX

The habitat flow index for flow dependent macroinvertebrate (FDI) taxa is provided in Table E5 and provides the % occurrence of various velocity and substrate classes under different flow conditions.

Table E5 Habitat suitability for FDI taxa

Habitat Flow Response Index	Habitat Response	Habitat Abundance and suitability													Flow (m ³ /s)
		VSCS ¹	SCS ²	FCS ³	VFCS ⁴	VSFS ⁵	SFS ⁶	FFS ⁷	VFFS ⁸	VSB ⁹	SBR ¹⁰	FBR ¹¹	VFB ¹²	Veg ¹³	
0	All habitats in excess, very high quality. Very fast, very deep, very wide WP.	2	4	8	57	1	2	3	23	0	0	0	0	0	26.83
1	All plentiful, high quality. Fast, wide WP.	2	5	10	53	1	2	4	23	0	0	0	0	0	19.43
2	Critical habitats sufficient. Quality slightly reduced, fast, WP slightly reduced.	3	5	11	51	1	2	5	22	0	0	0	0	0	15.46
3	Reduced critical habitat and critical quality. Moderate velocity, fairly deep.	5	9	16	40	2	4	7	17	0	0	0	0	0	6.05
4	Critical habitats limited and of moderate quality. Moderate velocity, some deep areas. Wide WP moderately reduced.	6	12	19	33	3	5	8	14	0	0	0	0	0	4.03
5	Critical habitat very reduced, moderate/low quality. Moderate/slow velocity, few deep areas WP moderately/very reduced.	16	22	23	8	7	9	10	4	0	0	0	0	0	1.12
6	Critical habitat residual. Low quality, moderate/slow velocity.	25	31	11	2	11	13	5	1	0	0	0	0	0	0.34
7	No critical habitat, other habitats moderate quality. Slow, narrow WP.	44	24	2	0	19	10	1	0	0	0	0	0	0	0.049
8	Flowing water habitats residual and of low quality. Slow trickle, very narrow WP.	53	17	0	0	23	7	0	0	0	0	0	0	0	0.016
9	Standing water habitats only, very low quality, no flow.	65	5	0	0	28	2	0	0	0	0	0	0	0	0.002
10	Only hyporheic refugia, no surface water.	70	0	0	0	30	0	0	0	0	0	0	0	0	0.000

1 Very Slow over Coarse Sediment

4 Very Fast over Coarse Sediment

7 Fast over Fine Sediment

10 Slow over Bedrock

13 Fringing vegetation

2 Slow over Coarse Sediment

5 Very Slow over Fine Sediment

8 Very Fast over Fine Sediment

11 Fast over Bedrock

3 Fast over Coarse Sediment

6 Slow over Fine Sediment

9 Very Slow over Bedrock

12 Very Fast over Bedrock

The stress index for FDI taxa is provided in Table E6 which rates the response of the species according to various biotic response metrics.

Table E6 Macroinvertebrate (FDI) stress index

Habitat characteristics					Biotic Response	Flow	Species Stress
Max depth (m)	Ave depth (m)	Max vel (m/s)	Ave vel (m/s)	WP (m)			
1.2	0.82	2.47	1.19	31.4	All indicator taxa very abundant and healthy.	15.46	0
1.04	0.7	2.28	1.07	30.0	90% indicator taxa persist.		1
0.94	0.62	2.16	0.99	29.1	Most indicator taxa persist, but slight (80%) reduction.	6.05	2
0.62	0.4	1.95	0.74	24.0	Most indicator taxa persist, but abundances reduced.		3
0.54	0.34	1.81	0.61	22.9	All life stages viable in limited areas, critical life stages of some sensitive indicator taxa at risk.	1.12	4
0.38	0.22	1.03	0.31	18.7	Critical life-stages of sensitive indicator taxa at risk or non-viable.		5

Habitat characteristics					Biotic Response	Flow	Species Stress
Max depth (m)	Ave depth (m)	Max vel (m/s)	Ave vel (m/s)	WP (m)			
0.26	0.14	0.63	0.19	14.2	Sensitive indicator taxa rare, critical stages of sensitive indicator taxa non-viable and at risk for some less sensitive taxa.	0.34	6
0.14	0.06	0.32	0.09	8.9	Some indicator taxa persist, but most disappear. All life-stages of sensitive indicator taxa at risk or non-viable.		7
0.1	0.04	0.24	0.07	5.7	Some indicator taxa persist, but at very low numbers. All life stages of most indicator taxa at risk or non-viable.	0.05	8
0.06	0.02	0.12	0.04	3.5	Indicator taxa no longer present.	0.02	9
0.02	0.01	0.07	0.02	0.1		0.00	10

E1.4 RIPARIAN VEGETATION STRESS INDEX

A riparian vegetation stress index is provided in Table E7.

Table E7 Riparian vegetation stress index for indicator species

Biotic response		
Species Stress	Flow (m ³ /s)	<i>Ludwigia octovalvis</i>
0	16.6	Adults with full vigour and at maximum reproductive capacity. 50% population inundated, upper limit rooting depth at 14 cm.
1		
2		
3	11.6	Leaf wilting/stress commences, but is slight. Up to 30 cm rooting depth for upper limit, lower limit at water level on average.
4		Flower/fruit abortion commences.
5	5.5	Leaf wilting obvious, or vegetative parts begin unseasonal discolouration. Flower/fruit abortion widespread. 30 to 60 cm rooting depth for sufficient soil moisture, no inundation, 1 - 2 times the natural range.
6	2.3	Unseasonal thinning or partial mortality of above-ground parts (majority of the plant/s remains viable, but water stressed). 30 – 90 cm rooting depth for sufficient soil moisture, mortality may occur for lower zone individuals.
7		
8	1.75	Unseasonal loss or mortality of above-ground parts (only minor portions of plants remain viable). Rootstocks/rhizomes of some species remain viable. 75 cm to 1 m rooting depth, individuals at upper limit likely to begin dying.
9	1.2	Complete mortality of small proportion of the population.
10		Widespread and complete mortality of population.

E2 EWR 4: KANYAMAZANE (CROCODILE RIVER) - DETERMINATION OF EWR SCENARIOS

E2.1 LOW FLOW REQUIREMENTS IN TERMS OF STRESS FOR FISH

The fish low flow requirements for the EWR scenarios are summarised in Table E8 for the SR guild and Table E9 for LSR guild.

Table E8 Low flow requirements: SR guild

GENERAL					
INDICATOR: The small rheophilic species at the site are the best indicators for setting flows (AURA, CPRE, and OPER). These species all requires flowing water over substrates during all life stages, with some stages also preferring some overhanging vegetation as cover. Optimal conditions for spawning of this guild consist of FD, FI, FS and SS with good quality substrate (clean cobbles and gravel), while the margins of the FS and SS are important for egg development and nursery areas for larvae, often with overhanging vegetation as cover. Juvenile and adult stages of this guild have a high preference for FS, FI and FD over substrates. Flows should furthermore remain adequate to allow migration between reaches, thus depth in riffle and rapids should remain adequate, especially during the wet season.					
PES and REC: FISH EC B (ECOSTATUS C and B)					
Dry Season maintenance At this fish stress level adequate fast habitats will be maintained to ensure preservation of abundance and cover for maintenance of fish in a B EC during the dry season. It is essential that adequate flowing conditions should be maintained (even in the dry season) for the protection of this rheophilic group, requiring adequate flow during all phases of its life cycle for survival.					
Dry Season drought This stress level provides adequate flows to maintain enough fast habitats to support viable populations of this indicator group for survival during drought conditions and allow recovery afterwards. It is essential that adequate flowing conditions should be maintained (even in the dry season) for the protection of this rheophilic group, requiring adequate flow during al phases of its life cycle for survival.					
Wet Season maintenance At this stress level abundant habitat for spawning and nursery habitats will be provided and it will maintain abundance and connectivity to keep this fish guild within a composition reflecting a B EC, which indicates good integrity.					
Wet Season drought The fish stress level given is the maximum stress level where this group can still reproduce successfully and ensure survival of this guild in this reach of the river.					
BUILDING BLOCK	SEASON	STRESS DURATION	SPP STRESS	INTEG STRESS	FLOW (m ³ /s)
Drought	Dry	5%	6	6.8	1.31
Maintenance	Dry	35%	3.5	4.5	4.1
Drought	Wet	5%	4	5	3.5
Maintenance	Wet	35%	2	3.5	5.1
AEC: FISH EC C (ECOSTATUS C/D)					
General Further alterations in flow regime will result in increased sedimentations of riffle/rapids and especially pools. Sedimentation of riffle/rapid areas will deteriorate conditions for species which have preference for substrate of good quality (AURA, CPRE, BEUT, LCYL, LMOL, OPER, and BMAR). This scenario will also result in decreased availability of pools (slow habitats) and overhanging vegetation (albeit temporary) and may also lead to decreased FROC for fish with preference for slower habitats and this cover type (esp. BPAU, BVIV, MACU, MMAC, PWES, PPHI and TSPA).					
Dry Season maintenance At the recommended fish stress level of 5 most aspects will deteriorate (abundance, cover, and connectivity) with a resulting decrease in ecological state of this indicator guild (reduced FROC).					
Wet Season maintenance At the recommended fish stress level of 3.5 some spawning habitat will still be available for these species but reduced					

abundance and cover will occur, resulting in stress on this group and a reduction in EC would most probably occur as a result of reduced FROC.

BUILDING BLOCK	SEASON	STRESS DURATION	SPP STRESS	INTEG STRESS	FLOW (m ³ /s)
Maintenance	Dry	35%	5	5.3	2.975
Maintenance	Wet	35%	3.5	4.6	3.98

Table E9 Low flow requirements: LSR guild

GENERAL					
INDICATOR: The LSR species (especially BMAR, LCYL, and LMOL) are another important indicator guild present at this EWR site. The habitat requirements for BMAR should be adequate to support the requirements of other species within this guild. This species utilises most habitats (SD, SS, FD, FI and FS) with substrate and water column as preferred cover. They also require overhanging vegetation as nursery habitats. Flows should furthermore remain adequate to allow migration between reaches, thus depth in riffle and rapids should remain adequate, especially during the wet season.					
PES and REC: FISH EC B (ECOSTATUS C and B)					
Dry Season maintenance The recommended stress level should maintain adequate habitat to support abundance and cover for this guild to ensure maintenance within the PES of B. Dry Season drought This stress level will allow adequate flows to maintain enough fast habitats to support viable populations of this indicator group to recover after drought. Abundance and cover will be greatly reduced but adequate to maintain a viable population. Wet Season maintenance This stress level will allow good habitats for spawning and suitable habitats for all life stages of this indicator guild. Wet Season drought This stress level will maintain adequate habitat to at least allow some spawning to take place. Although abundance and cover will be reduced an adequate population will be maintained to allow recovery and maintenance of this group.					
BUILDING BLOCK	SEASON	STRESS DURATION	SPP STRESS	INTEG STRESS	FLOW (m ³ /s)
Drought	Dry	5%	6.5	7.9	0.87
Maintenance	Dry	35%	4.5	4.5	4.1
Drought	Wet	5%	4.5	4.5	4.1
Maintenance	Wet	35%	2	2.6	7.94
AEC: FISH EC C (ECOSTATUS C/D)					
General Further alterations in flow regime (decreased floods) will result in increased sedimentations of riffle/rapids and especially pools. Sedimentation of riffle / rapid areas will deteriorate conditions for species which have preference for substrate of good quality (AURA, CPRE, BEUT, LCYL, LMOL, OPER, and BMAR). This scenario will also result in decreased availability of pools (slow habitats) and overhanging vegetation (albeit temporary) and may lead to decreased FROC for fish with preference for slower habitats and this cover type (esp. BPAU, BVIV, MACU, MMAC, PWES, PPHI and TSPA). Dry Season maintenance This recommended stress level will reduced all preferred habitats for this fish guild and a reduced FROC, and thus a lower EC can be expected. Wet Season maintenance This fish stress level will s create some spawning habitat but the reduced cover and abundance will result in an overall reduced FROC and thus a C EC.					
BUILDING BLOCK	SEASON	STRESS DURATION	SPP STRESS	INTEG STRESS	FLOW (m ³ /s)
Maintenance	Dry	35%	5.5	5.6	2.625
Maintenance	Wet	35%	4	4	4.7

E2.2 LOW FLOW REQUIREMENTS IN TERMS OF STRESS FOR MACROINVERTEBRATES

The FDI low flow requirements are summarised in Table E10 below.

Table E10 Low flow requirements: FDI taxa

GENERAL					
INDICATOR: Stonefly family: Perlidae preferring velocities > 0.6 m/s. Mayfly family: Heptageniidae preferring velocities between 0.3 and 0.6 m/s. Beetle family: Elmidae also preferring velocities between 0.3 and 0.6 m/s.					
PES: MACROINVERTEBRATE EC: C (ECOSTATUS C)					
Dry Season maintenance Suitable habitat (> 0.3 m/s over coarse substrate) is required to ensure that all the selected taxa can overwinter without significant detrimental impacts on the overall population. The maximum velocity of 0.77 m/s (macroinvertebrate stress of 5) will ensure that this takes place.					
Dry Season drought Suitable habitat (> 0.1 m/s over coarse substrate, with at least some areas where the flow reaches velocities > 0.3 m/s) is required to ensure that a core of the selected taxa is able to survive a drought. The maximum velocity of 0.5 m/s (macroinvertebrate stress of 7) will ensure that this takes place.					
Wet Season maintenance During the wet season optimal habitats (> 0.6 m/s over coarse substrate) is required to ensure that a healthy population occurs during the summer. The maximum velocity of 0.99 m/s (macroinvertebrate stress of 4) ensures that this takes place.					
Wet Season drought During the wet season optimal habitats (> 0.3 m/s over coarse substrate) is required to ensure that a healthy population occurs during the summer. The maximum velocity of 0.54 m/s (macroinvertebrate stress of 6) ensures that this takes place.					
BUILDING BLOCK	SEASON	STRESS DURATION	SPP STRESS	INTEG STRESS	FLOW (m ³ /s)
Drought	Dry	5%	7	9.5	0.2
Maintenance	Dry	35%	5	8.5	0.6
Drought	Wet	5%	6	9.4	0.24
Maintenance	Wet	35%	4	7.5	1.0
REC: MACROINVERTEBRATE EC B (ECOSTATUS B)					
Dry Season maintenance Suitable habitat (> 0.3 m/s over coarse substrate) is required to ensure that all the selected taxa can overwinter without significant detrimental impacts on the overall population. The average velocity of 0.31 m/s (macroinvertebrate stress of 4) will ensure that this takes place.					
Wet Season maintenance During the wet season optimal habitats (> 0.6 m/s over coarse substrate) is required to ensure that a healthy population occurs during the summer. The average velocity of 0.74 m/s (macroinvertebrate stress of 2) ensures that this takes place.					
BUILDING BLOCK	SEASON	STRESS DURATION	SPP STRESS	INTEG STRESS	FLOW (m ³ /s)
Maintenance	Dry	35%	4	7.5	1.0
Maintenance	Wet	35%	2	2.9	6.11
AEC: MACROINVERTEBRATE EC D (ECOSTATUS CD)					
Dry Season maintenance Suitable habitat (> 0.3 m/s over coarse substrate) is required to ensure that all the selected taxa can overwinter without significant detrimental impacts on the overall population. The maximum velocity of 0.54 m/s (macroinvertebrate stress of 6) will ensure that this takes place.					

Wet Season maintenance

During the wet season optimal habitats (> 0.6 m/s over coarse substrate) is required to ensure that a healthy population occurs during the summer. The maximum velocity of 0.77 m/s (macroinvertebrate stress of 5) ensures that this takes place.

BUILDING BLOCK	SEASON	STRESS DURATION	SPP STRESS	INTEG STRESS	FLOW (m ³ /s)
Maintenance	Dry	35%	6	9.4	0.24
Maintenance	Wet	35%	5	8.5	0.6

E2.3 LOW FLOW REQUIREMENTS IN TERMS OF RIPARIAN VEGETATION

The low flow requirements for riparian vegetation indicator species was not assessed due to the low confidence in the results.

E2.4 INSTREAM FLOOD FUNCTIONS

Table E11 Functions for each Flood Class

Flood Class	Component	Function/Motivation
Class: I Range (m ³ /s): 25 - 40 Daily average: 25 Duration: 10	Fish	Class I floods are very important floods for fish and serves as migration cues and to maintain adequate longitudinal connectivity for migration. These floods will also flush fines and algae from substrates to ensure adequate conditions in substrates, a very important habitat for spawning of many of the species. It should furthermore inundate some vegetation for species spawning in flooded marginal vegetation and contributes to the creation of acceptable nursery areas. Some resetting of water quality will also take place, and the changes in water quality may also serve as stimulus to cue migratory activity and even gonad development. The frequency, extent and duration as recommended for the PES and AEC should be adequate to provide the functions as required to maintain the fish within the specific category.
	Macroinvertebrates	These freshets are recommended to stimulate hatching of eggs, flush organic flocculants and mobilise fines (1 - 2 mm sands) in order to improve biotope suitability they will also reset water quality. Another function is to inundate the sedges to provide extra habitat for vegetation dwelling macroinvertebrates. Four of these per year, Nov, Dec, Jan and Mar/Apr), are recommended for both the PES and the REC.
Class: II Range (m ³ /s): 40 Daily average: 40 Duration: 4	Fish	Class II floods are similar in importance as Class I floods and have the same functionality as Class I floods. Their occurrence at lower frequency makes them only slightly less important for the fish assemblages than Class I.
	Macroinvertebrates	These freshets are recommended to clear fines, scour substrate and inundate additional cobbles on the edge of the channel in order to create additional biotope, and reset water quality. Two of these per year are recommended for macroinvertebrate Category B and one for Categories C and D in the middle of the wet season.
Class: III Range (m ³ /s): 60 - 110 Daily average: 70 Duration: 5	Fish	Class III floods also provide similar functions as Classes I, but due to its lower frequency it is not essential for the flood functions required by the indigenous fish species. These floods, and especially their receding limbs will however be utilised by many of the fish species for migration and even spawning if takes place within the summer season.
	Macroinvertebrates	These freshets are recommended to scour substrate and inundate the reed beds in order to create additional biotope, and reset water quality. One Class III flood is recommended for categories B and C.
Class: IV Range (m ³ /s): 170 - 220	Fish	Class IV floods also provide similar functions as Class I, but due to its lower frequency it is not essential for the flood functions required by the indigenous fish species. These floods, and especially their receding periods will however be utilised by many of the fish species for migration and even spawning if takes place in within the summer season.
Class: V Range (m ³ /s):	Fish	Class V floods also provide similar functions as Class I, but due to its lower frequency it is not essential for the flood functions required by the indigenous fish

Flood Class	Component	Function/Motivation
330+		species. These floods, and especially their receding limbs will however be utilised by many of the fish species for migration and even spawning if takes place within the summer season.

E2.5 EWR RULE TABLES

EWR rule tables which provide the recommended EWR flows as a duration table, showing flows which should be provided when linked to a natural trigger (natural modelled hydrology in this case) are provided for the different EWR scenarios. EWR rules are supplied for total flows as well as for low flows only.

Table E12 EWR 4 assurance rules for PES and REC B:

Desktop Version 2, Printed on 2008/07/17

Summary of IFR rule curves for: CE4 Natural Flows

Determination based on defined BBM Table with site specific assurance rules.

Regional Type: E. Escarp PES/REC = B

Data are given in m³/s mean monthly flow

% Points										
Month	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	4.998	4.987	4.944	4.854	4.679	4.358	3.819	3.025	2.067	1.347
Nov	8.183	8.153	8.073	7.909	7.596	7.035	6.114	4.781	3.198	2.017
Dec	9.435	9.396	9.300	9.110	8.749	8.108	7.068	5.576	3.818	2.510
Jan	23.306	21.438	19.797	18.273	16.700	14.064	12.133	9.411	6.251	3.914
Feb	18.940	18.119	17.344	16.540	15.570	13.905	12.186	9.720	6.816	4.654
Mar	17.379	16.646	15.951	15.230	14.360	12.855	11.286	9.015	6.319	4.307
Apr	13.086	13.057	12.947	12.721	12.277	11.463	10.098	8.084	5.657	3.831
May	9.275	9.263	9.196	9.054	8.767	8.229	7.308	5.920	4.220	2.930
Jun	7.948	7.941	7.886	7.768	7.526	7.067	6.271	5.060	3.564	2.424
Jul	6.404	6.404	6.364	6.276	6.091	5.730	5.088	4.091	2.836	1.871
Aug	5.339	5.335	5.296	5.213	5.044	4.723	4.167	3.320	2.273	1.476
Sep	4.903	4.896	4.858	4.777	4.614	4.309	3.785	2.996	2.029	1.296

Reserve flows without High Flows

Oct	4.998	4.987	4.944	4.854	4.679	4.358	3.819	3.025	2.067	1.347
Nov	6.269	6.247	6.189	6.070	5.843	5.436	4.769	3.802	2.655	1.798
Dec	7.582	7.553	7.480	7.335	7.059	6.570	5.777	4.638	3.297	2.299
Jan	9.639	9.590	9.491	9.296	8.935	8.308	7.309	5.901	4.266	3.057
Feb	13.113	13.064	12.942	12.699	12.239	11.423	10.097	8.195	5.955	4.288
Mar	12.117	12.078	11.971	11.755	11.342	10.601	9.385	7.625	5.535	3.975
Apr	11.172	11.148	11.059	10.874	10.511	9.846	8.731	7.086	5.104	3.612
May	9.275	9.263	9.196	9.054	8.767	8.229	7.308	5.920	4.220	2.930
Jun	7.948	7.941	7.886	7.768	7.526	7.067	6.271	5.060	3.564	2.424
Jul	6.404	6.404	6.364	6.276	6.091	5.730	5.088	4.091	2.836	1.871
Aug	5.339	5.335	5.296	5.213	5.044	4.723	4.167	3.320	2.273	1.476
Sep	4.903	4.896	4.858	4.777	4.614	4.309	3.785	2.996	2.029	1.296

Natural Duration curves

Oct	15.468	12.705	9.872	9.099	8.165	6.907	6.620	5.865	5.167	4.413
Nov	28.669	23.912	20.914	18.939	15.112	13.526	12.064	11.505	9.228	7.238
Dec	61.925	39.072	33.565	28.267	23.309	21.106	18.567	16.207	12.806	8.744
Jan	95.979	63.336	47.846	40.864	33.479	27.539	22.760	20.135	18.395	13.306
Feb	123.173	91.253	61.653	42.617	38.075	30.961	27.327	23.698	20.312	16.563
Mar	95.158	57.523	46.237	39.572	31.493	25.508	23.159	20.688	16.935	13.881
Apr	41.678	37.562	28.974	25.525	22.515	20.301	18.731	17.666	13.924	10.594
May	23.503	18.679	16.973	16.036	14.979	13.870	12.657	11.148	9.621	7.553
Jun	16.501	13.341	12.199	11.825	10.856	10.258	9.375	8.816	7.508	6.273
Jul	12.829	11.040	9.487	8.822	8.404	8.106	7.609	7.071	6.067	5.290
Aug	10.122	8.905	7.736	7.176	6.963	6.739	6.280	6.052	5.238	4.850
Sep	10.251	8.306	7.388	6.813	6.219	5.995	5.787	5.505	4.823	4.240

Table E13 EWR 4 assurance rules for AEC: C/D

Desktop Version 2, Printed on 2008/07/17

Summary of IFR rule curves for: CE4 Natural Flows

Determination based on defined BBM Table with site specific assurance rules.

Regional Type: E. Escarp AEC = C/D

Data are given in m³/s mean monthly flow

Month	% Points									
	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	3.366	3.359	3.335	3.284	3.186	3.004	2.700	2.252	1.712	1.305
Nov	6.061	6.041	5.988	5.879	5.671	5.298	4.686	3.800	2.749	1.964
Dec	6.080	6.033	5.935	5.748	5.423	4.917	4.231	3.453	2.766	2.390
Jan	16.672	14.423	12.536	10.853	8.223	7.118	5.858	4.693	3.871	3.499
Feb	13.089	11.560	10.265	9.074	7.364	6.509	5.653	4.975	4.568	4.405
Mar	11.826	10.663	9.660	8.722	7.256	6.514	5.669	4.887	4.336	4.086
Apr	5.596	5.568	5.511	5.402	5.213	4.919	4.520	4.067	3.667	3.449
May	5.234	5.230	5.205	5.151	5.042	4.838	4.488	3.961	3.316	2.826
Jun	4.789	4.786	4.762	4.709	4.602	4.399	4.047	3.510	2.847	2.342
Jul	4.145	4.145	4.124	4.079	3.984	3.798	3.468	2.955	2.308	1.812
Aug	3.616	3.613	3.592	3.545	3.449	3.268	2.953	2.474	1.882	1.431
Sep	3.566	3.561	3.537	3.485	3.381	3.186	2.851	2.347	1.730	1.262

Reserve flows without High Flows

Oct	3.366	3.359	3.335	3.284	3.186	3.004	2.700	2.252	1.712	1.305
Nov	3.886	3.876	3.848	3.791	3.682	3.486	3.166	2.701	2.150	1.739
Dec	4.091	4.067	4.016	3.920	3.753	3.493	3.140	2.740	2.387	2.194
Jan	4.722	4.682	4.600	4.455	4.228	3.920	3.569	3.245	3.016	2.912
Feb	5.981	5.926	5.813	5.615	5.323	4.964	4.605	4.320	4.150	4.081
Mar	5.775	5.731	5.642	5.483	5.233	4.895	4.510	4.154	3.903	3.789
Apr	5.596	5.568	5.511	5.402	5.213	4.919	4.520	4.067	3.667	3.449
May	5.234	5.230	5.205	5.151	5.042	4.838	4.488	3.961	3.316	2.826
Jun	4.789	4.786	4.762	4.709	4.602	4.399	4.047	3.510	2.847	2.342
Jul	4.145	4.145	4.124	4.079	3.984	3.798	3.468	2.955	2.308	1.812
Aug	3.616	3.613	3.592	3.545	3.449	3.268	2.953	2.474	1.882	1.431
Sep	3.566	3.561	3.537	3.485	3.381	3.186	2.851	2.347	1.730	1.262

Natural Duration curves

Oct	15.468	12.705	9.872	9.099	8.165	6.907	6.620	5.865	5.167	4.413
Nov	28.669	23.912	20.914	18.939	15.112	13.526	12.064	11.505	9.228	7.238
Dec	61.925	39.072	33.565	28.267	23.309	21.106	18.567	16.207	12.806	8.744
Jan	95.979	63.336	47.846	40.864	33.479	27.539	22.760	20.135	18.395	13.306
Feb	123.173	91.253	61.653	42.617	38.075	30.961	27.327	23.698	20.312	16.563
Mar	95.158	57.523	46.237	39.572	31.493	25.508	23.159	20.688	16.935	13.881
Apr	41.678	37.562	28.974	25.525	22.515	20.301	18.731	17.666	13.924	10.594
May	23.503	18.679	16.973	16.036	14.979	13.870	12.657	11.148	9.621	7.553
Jun	16.501	13.341	12.199	11.825	10.856	10.258	9.375	8.816	7.508	6.273
Jul	12.829	11.040	9.487	8.822	8.404	8.106	7.609	7.071	6.067	5.290
Aug	10.122	8.905	7.736	7.176	6.963	6.739	6.280	6.052	5.238	4.850
Sep	10.251	8.306	7.388	6.813	6.219	5.995	5.787	5.505	4.823	4.240

**APPENDIX F: SUPPORTING INFORMATION FOR THE DETERMINATION OF STRESS
INDICES AND EWR SCENARIOS OF EWR 5: MALALANE**

F1 EWR 5: MALALANE (CROCODILE RIVER) - DETERMINATION OF STRESS INDICES

Appendix F provides supporting information for the determination of stress indices of EWR 5 Malelane (Chapter 11 and 12 of the Crocodile River System EWR Scenario Report: Volume 2).

F1.1 FISH INDICATOR SPECIES

Small rheophilic (SR) guild: Various small rheophilic species were present in this river stretch and were included as indicators (*Chiloglanis pretoriae* (CPRE), *Chiloglanis swierstrai* (CSWI) and *Opsaridium peringueyi* (OPER)). These species all require flowing water over substrates during all life stages, with some stages also preferring some overhanging vegetation as cover.

Large semi-rheophilic (LSR) guild: The large semi-rheophilic species (especially *Labeobarbus marequensis* (BMAR), *Hydrocynus vittatus* (HVIT), and *Labeo congoro* (LCON)) were another important indicator guild present at this EWR site. They also require overhanging vegetation as nursery habitats.

The habitat requirements for the different life stages of (CPRE) are summarised in Appendix C, Table C1 while the habitat requirements for OPER are summarised in Appendix E, Table E1 and CSWI in Table F1. The LSR requirements for BMAR are summarised in Appendix E, Table E2 and in Table F2 for HVIT and LCON.

Table F1 Habitat requirements for different life stages of indicator species included in SR guild

Species	Spawning	Egg and embryo development	Larvae	Juveniles	Adults
CSWI	Flow habitat: FD, FI, and FS (> 0.15 m). Substrate: Sand. Spawning season: Oct - Jan. Cue: Increased temp., flow and changes in water quality (e.g. conductivity).	Flow habitat: Margins of FS / FI & SS (> 0.20 m). Substrate: Sandy. Months: Oct - Jan. Duration: 7 days.	Nursery areas (> 0.20 m). Margins of FS and SS. Duration larval period: 2 months.	Flow habitat: Mostly FD, FI, and FS (> 0.20 m). Cover: Sand. Duration: 3 - 6 months. Low flow refuge months: Jun - Sep. FS/FI (> 0.15 m). Cover: Sand.	Flow habitat: FD, FI, and FS. Cover: Sand. Low flow refuge months: Jun - Sep. FS, FI, and FD (> 0.20 m) Cover: Sand.

Table F2 Habitat requirements for different life stages of indicator species included in LSR guild

Species	Spawning	Egg and embryo development	Larvae	Juveniles	Adults
HVIT	Flow habitat: SD, FS/FI (>0.25 m deep). Substrate: Gravel/sand . Spawning season: Oct - Jan. Cue: Increased flow. Temperature > 21°C.	Flow habitat: SD . Substrate: Sand and gravel substrate. Months: Oct - Jan. Incubation: 3 - 4 days. Temperature: >21°C.	Nursery areas: Backwaters formed by increased flow. Cover: Overhanging vegetation . Duration larval period: 2 months.	Flow habitat: Mostly SD . Cover: Marginal vegetation . Duration: 3 - 6 months. Low flow refuge months: Jun - Sep. SD . Cover: Overhanging vegetation, water column .	Flow habitat: SD . Cover: Water column . Duration: 3 - 6 months. Low flow refuge months: Jun - Sep. SD . Cover: Water column .
LCON	Flow habitat: FD, and SD FS/FI (0.7 - 0.8 m/s). Substrate: Gravel/cobble . Cover: Water column. Spawning season: Oct - Jan. Cue: Increased flow.	Flow habitat: FD, and FI, FS/FI (0.7 - 0.8 m/s). Substrate: Gravel . Months: Oct - Jan. Incubation: 3 - 4 days. Temperature: >24°C.	Nursery areas: >0.25 m deep. Flow habitat: Margins of FD, SD and backwaters . Cover: Rocks and cobbles . Duration larval period: 2 months.	Flow habitat: Mostly SD . Cover: Cobbles, rocks and water column . Duration: 3 - 6 months. Low flow refuge months: Jun - Sep. SD . Cover: Water column cobbles, rocks, undercut banks .	Flow habitat: FD, and SD . Cover: Water column cobbles and rocks . Low flow refuge months: Jun - Sep. SD . Cover: Water column, rocks .

F1.2 FISH STRESS INDEX

The abundance of fish velocity-depth classes are provided in Table F3.

Table F3 EWR 5: Habitat suitability for the SR and LSR guild

SR AND LSR GUILD								
Depth classes	Discharges (m ³ /s)							
	2.04	3.46	4.05	5.36	6.92	12.03	28.97	37.45
Slow (<0.3 m/s) Very Shallow (<0.1 m) (SVS)	6	6	6	8	8	10	8	8
Slow (<0.3 m/s) Shallow (0.1 – 0.3 m) (SS)	4	6	6	6	6	6	8	6
Slow (<0.3 m/s) Deep (> 0.5 m) (SD)	10	10	10	10	10	6	6	6
Slow Shallow and Slow Deep	4	6	6	6	6	6	6	6
Fast (>0.3 m/s) Very Shallow (<0.1 m) (FVS)	6	6	6	6	6	8	6	6
Fast (>0.3 m/s) Shallow (0.1 – 0.3 m) (FS)	4	4	4	4	4	6	6	6
Fast (>0.3 m/s) Intermediate (0.2 – 0.3) (FI)	6	6	6	6	6	6	8	6
Fast (>0.3 m/s) Deep (> 0.3 m) (FD)	10	6	6	4	4	4	4	4
FAST TOTAL >0.1 m DEEP	6	4	4	4	4	4	4	4

The fish stress index is provided in Table F4

Table F4 Fish stress index

Habitat	Discharges (m ³ /s)							
	2.04	3.46	4.05	5.36	6.92	12.03	28.97	37.45
SMALL RHEOPHILIC (SR) GUILD								
Spawning habitat	0.5	1.5	2.5	4	4.5	5	5	5
Abundance	0	0.5	1	2.5	2.5	4	4.5	5
Cover	0	0.5	1	3	3.5	4	5	5
Connectivity (lateral & longitudinal)	0.5	1	1.5	3	3.5	4	4.5	5
Water Quality (esp. oxygen and temperature)	0.5	1	2	3.5	3.5	4	5	5
Species stress: CPRE, CSWI, OPER	9	8	7	4	3	2	1	0
LARGE SEMI-RHEOPHILIC (LSR) GUILD								
Spawning habitat	0	1	2	3.5	4.5	5	5	5
Abundance	0.5	0.5	0.5	2	3	4	4.5	5
Cover	0.5	1	1	2.5	3	4	5	5
Connectivity (lateral & longitudinal)	0	1	1	2.5	3	4	4.5	5
Water Quality (esp. oxygen and temperature)	0.5	1	1.5	2.5	3	4	5	5
Species stress: BMAR, HVIT, LCON	9	8	7	5	4	2	1	0

F1.3 MACROINVERTEBRATE STRESS INDEX

The habitat flow index for flow dependent macroinvertebrate (FDI) taxa and marginal vegetation macroinvertebrate taxa (MVI) is provided in Table F5 and Table F6 respectively and provides the % occurrence of various velocity and substrate classes under different flow conditions.

Table F5 Habitat suitability for FDI taxa

Habitat Flow Response Index	Habitat Response	Habitat Abundance and suitability													Flow (m ³ /s)
		VSCS ¹	SCS ²	FCS ³	VFCS ⁴	VSFS ⁵	SFS ⁶	FFS ⁷	VFFS ⁸	VSBR ⁸	SBR ¹⁰	FBR ¹¹	VFBR ¹²	Veg ¹³	
0	All habitats in excess, very high quality. Very fast, very deep, very wide WP.	1	3	6	11	3	8	15	27	0	0	0	0	26	33.021
1	All plentiful, high quality. Fast, wide WP.	2	3	7	12	3	8	16	28	0	0	0	0	22	30.95
2	Critical habitats sufficient. Quality slightly reduced, fast, WP slightly reduced.	2	5	9	16	4	9	17	28	0	0	0	0	10	23.5
3	Reduced critical habitat and critical quality. Moderate velocity, fairly deep.	2	5	10	16	4	9	18	29	0	0	0	0	7	21.92
4	Critical habitats limited and of moderate quality. Moderate velocity, some deep areas. Wide WP moderately reduced.	2	6	11	17	4	9	18	28	0	0	0	0	5	16.14
5	Critical habitat very reduced, moderate/low quality. Moderate/slow velocity, few deep areas WP moderately/very reduced.	2	6	12	18	4	9	19	28	0	0	0	0	4	12.57
6	Critical habitat residual. Low quality, moderate/slow velocity.	3	6	13	17	4	9	19	26	0	0	0	0	2	8.12
7	No critical habitat, other habitats moderate quality. Slow, narrow WP.	3	8	16	12	5	12	24	19	0	0	0	0	1	4.66
8	Flowing water habitats residual and of low quality. Slow trickle, very narrow WP.	5	11	17	7	8	17	25	10	0	0	0	0	1	2.04
9	Standing water habitats only, very low quality, no flow.	26	14	1	0	38	21	0	0	0	0	0	0	0	0.014
10	Only hyporheic refugia, no surface water.	32	8	0	0	48	12	0	0	0	0	0	0	0	0.002

1 Very Slow over Coarse Sediment

2 Slow over Coarse Sediment

3 Fast over Coarse Sediment

4 Very Fast over Coarse Sediment

5 Very Slow over Fine Sediment

6 Slow over Fine Sediment

7 Fast over Fine Sediment

8 Very Fast over Fine Sediment

9 Very Slow over Bedrock

10 Slow over Bedrock

11 Fast over Bedrock

12 Very Fast over Bedrock

13 Fringing vegetation

Table F6 Habitat suitability for MVI taxa

Habitat Flow Response Index	Habitat Response	Habitat Abundance and suitability													Flow (m ³ /s)
		VSCS	SCS	FCS	VFCS	VSFS	SFS	FFS	VFFS	VSBR	SBR	FBR	VFBR	Veg	
0	All habitats in excess, very high quality. Very fast, very deep, very wide WP.	1	3	6	11	3	8	15	27	0	0	0	0	26	33.021
1	All plentiful, high quality. Fast, wide WP.	2	3	7	12	3	8	16	28	0	0	0	0	22	30.95
2	Critical habitats sufficient. Quality slightly reduced, fast, WP slightly reduced.	2	5	9	16	4	9	17	28	0	0	0	0	10	23.5
3	Reduced critical habitat and critical quality. Moderate velocity, fairly deep.	2	5	10	16	4	9	18	29	0	0	0	0	7	21.92
4	Critical habitats limited and of moderate quality. Moderate velocity, some deep	2	6	11	17	4	9	18	28	0	0	0	0	5	16.14

Habitat Flow Response Index	Habitat Response	Habitat Abundance and suitability													Flow (m ³ /s)
		VSCS	SCS	FCS	VFCS	VSFS	SFS	FFS	VFFS	VSBR	SBR	FBR	VFBR	Veg	
	areas. Wide WP moderately reduced.														
5	Critical habitat very reduced, moderate/low quality. Moderate/slow velocity, few deep areas WP moderately/very reduced.	2	6	12	18	4	9	19	28	0	0	0	0	4	12.57
6	Critical habitat residual. Low quality, moderate/slow velocity.	3	6	13	17	4	9	19	26	0	0	0	0	2	8.12
7	No critical habitat, other habitats moderate quality. Slow, narrow WP.	3	8	16	12	5	12	24	19	0	0	0	0	1	4.66
8	Flowing water habitats residual and of low quality. Slow trickle, very narrow WP.	5	11	17	7	8	17	25	10	0	0	0	0	1	2.04
9	Standing water habitats only, very low quality, no flow.	26	14	1	0	38	21	0	0	0	0	0	0	0	0.014
10	Only hyporheic refugia, no surface water.	32	8	0	0	48	12	0	0	0	0	0	0	0	0.002

The stress index for FDI taxa (Table F7) and the MVI taxa (Table F8) rates the response of the species according to various biotic response metrics.

Table F7 Macroinvertebrate (FDI) stress index

Habitat characteristics					Biotic Response	Flow	Species Stress
Max depth (m)	Ave depth (m)	Max vel (m/s)	Ave vel (m/s)	WP (m)			
1.14	0.64	1.43	0.63	82.9	All indicator taxa very abundant and healthy.	12.57	0
1.1	0.64	1.45	0.63	77.5	90% indicator taxa persist.	8.12	1
0.94	0.63	1.4	0.62	61.2	Most indicator taxa persist, but slight (80%) reduction.	4.66	2
0.9	0.62	1.38	0.62	58.2	Most indicator taxa persist, but abundances reduced.	2.04	3
0.74	0.53	1.36	0.6	51.8	All life stages viable in limited areas, critical life stages of some sensitive indicator taxa at risk.		4
0.62	0.42	1.32	0.6	50.0	Critical life-stages of sensitive indicator taxa at risk or non-viable.		5
0.48	0.3	1.27	0.57	48.2	Sensitive indicator taxa rare, critical stages of sensitive indicator taxa non-viable and at risk for some less sensitive taxa.		6
0.38	0.21	1.13	0.49	45.3	Some indicator taxa persist, but most disappear. All life-stages of sensitive indicator taxa at risk or non-viable.		7
0.28	0.14	1.03	0.38	37.0	Some indicator taxa persist, but at very low numbers. All life stages of most indicator taxa at risk or non-viable.		8
0.04	0.02	0.28	0.09	10.1	Indicator taxa no longer present.	0.014	9
0.02	0.01	0.21	0.06	3.5			10

Table F8 Macroinvertebrate (MVI) stress index

Habitat characteristics					Biotic Response	Flow	Species Stress
Max depth (m)	Ave depth (m)	Max vel (m/s)	Ave vel (m/s)	WP (m)			
1.14	0.64	1.43	0.63	82.9	All indicator taxa very abundant and healthy.	33.021	0
1.1	0.64	1.45	0.63	77.5	90% indicator taxa persist.	30.95	1
0.94	0.63	1.4	0.62	61.2	Most indicator taxa persist, but slight (80%) reduction.		2

0.9	0.62	1.38	0.62	58.2	Most indicator taxa persist, but abundances reduced.	23.50	3
0.74	0.53	1.36	0.6	51.8	All life stages viable in limited areas, critical life stages of some sensitive indicator taxa at risk.	21.92	4
0.62	0.42	1.32	0.6	50.0	Critical life-stages of sensitive indicator taxa at risk or non-viable.	16.14	5
0.48	0.3	1.27	0.57	48.2	Sensitive indicator taxa rare, critical stages of sensitive indicator taxa non-viable and at risk for some less sensitive taxa.	8.12	6
0.38	0.21	1.13	0.49	45.3	Some indicator taxa persist, but most disappear. All life-stages of sensitive indicator taxa at risk or non-viable.	4.66	7
0.28	0.14	1.03	0.38	37.0	Some indicator taxa persist, but at very low numbers. All life stages of most indicator taxa at risk or non-viable.	2.04	8
0.04	0.02	0.28	0.09	10.1	Indicator taxa no longer present.	0.014	9
0.02	0.01	0.21	0.06	3.5			10

F1.4 RIPARIAN VEGETATION STRESS INDEX

A riparian vegetation stress index is provided in Table F9.

Table F9 Riparian vegetation stress index for indicator species

Biotic response		
Species Stress	Flow (m ³ /s)	<i>Cyperus/Juncus</i>
0	8.75	Adults with full vigour and at maximum reproductive capacity. 50% population inundated, upper limit rooting depth at 14 cm.
1		
2		
3	6.9	Leaf wilting/stress commences, but is slight. Up to 20 cm rooting depth for upper limit, lower limit at water level on average.
4		Flower/fruit abortion commences.
5	3.75	Leaf wilting obvious, or vegetative parts begin unseasonal discolouration. Flower/fruit abortion widespread. 10 to 30 cm rooting depth for sufficient soil moisture, no inundation.
6	1.6	Unseasonal thinning or partial mortality of above-ground parts (majority of the plant/s remains viable, but water stressed). 15 to 40 cm rooting depth for sufficient soil moisture, mortality may occur for lower zone individuals.
7		
8	0.18	Unseasonal loss or mortality of above-ground parts (only minor portions of plants remain viable). Rootstocks/rhizomes of some species remain viable. 30 to 55 cm.
9	0	Complete mortality of small proportion of the population.
10		Widespread and complete mortality of population.

F2 EWR 5: MALALANE (CROCODILE RIVER) - DETERMINATION OF EWR SCENARIOS

F2.1 LOW FLOW REQUIREMENTS IN TERMS OF STRESS FOR FISH

The fish low flow requirements for the EWR scenarios are summarised in Table F10 for the SR guild and Table F11 for LSR guild.

Table F10 Low flow requirements: SR guild

GENERAL					
INDICATOR: The small rheophilic species at the site are the best indicators for setting flows (CPRE, CSWI, and OPER). These species all requires flowing water over substrates during all life stages, with some stages also preferring some overhanging vegetation as cover. Optimal conditions for spawning of this guild consist of FD, FI, FS and SS with good quality substrate (clean cobbles and gravel), while the margins of the FS and SS are important for egg development and nursery areas for larvae, often with overhanging vegetation as cover. Juvenile and adult stages of this guild have a high preference for FS, FI and FD over substrates. Flows should furthermore remain adequate to allow migration between reaches, thus depth in riffle and rapids should remain adequate, especially during the wet season.					
PES: FISH EC C (ECOSTATUS C)					
Dry Season maintenance The recommended fish stress level will maintain adequate FD, FI and abundant FS for maintenance of viable populations of this indicator guild during the dry season to ensure management within a category C.					
Dry Season drought This is the maximum allowable fish stress level where this indicator guild will be able to sustain viable populations during a dry period drought to enable recovery when conditions improve.					
Wet Season maintenance This is the maximum allowable stress level to facilitate spawning and nursery habitats for this indicator group. Exceedance of this level will result in significant reduction in abundance and also cover and connectivity will be reduced. This stress level should provide adequate habitat to allow for the required life stages to maintain within a category C.					
Wet Season drought Adequate fast habitats will still be available to allow some spawning and although highly decreased abundance can be expected, they should be able to maintain adequate populations to recover after drought period.					
BUILDING BLOCK	SEASON	STRESS DURATION	SPP STRESS	INTEG STRESS	FLOW (m ³ /s)
Drought	Dry	5%	7	7.6	3.98
Maintenance	Dry	35%	5.5	7	4.7
Drought	Wet	5%	5	7	4.7
Maintenance	Wet	35%	2.5	5.8	9.6
REC: FISH EC B (ECOSTATUS B)					
General: Improved flows (higher low flows, less regulated flows) will improve quality and abundance of FS and FD habitats, with a positive impact on the FROC of some species with high preference for these habitats (esp. CPAR, CPRE, LCON, LCYL, LMOL and OPER).					
Dry Season maintenance These stress levels will result in improvement of preferred habitats for this indicator group during the dry season which should be reflected by increased abundance and overall improved FROC that will result in an improved ecological category.					
Wet Season maintenance Increased availability and abundance of critical habitats required during the wet season (especially spawning and nursery) should be reflected by improved reproduction potential and an overall improvement in the composition of this indicator group in this river reach, with an expected improvement towards a category B.					
BUILDING BLOCK	SEASON	STRESS DURATION	SPP STRESS	INTEG STRESS	FLOW (m ³ /s)

Maintenance	Dry	35%	4	6.7	5.69
Maintenance	Wet	35%	2	5.5	12
AEC: FISH EC D (ECOSTATUS D)					
General: Decreased low flows and periods of zero flow in some stretches will have a radical impact on flow dependant species (BEUT, CPRE, CSWI and OPER). Increased nutrients (as a result of reduced dilution) will further degrade the available substrate through excessive algal growth, affecting species with a preference for substrate of good quality. A further decrease in the FROC of BEUT, BMAR, CPAR, CPRE, MACU and OPER can therefore be expected. Further deterioration in water quality will result in decreased FROC and even absence of species intolerant to water quality alterations (MMAC, and possible loss of OPER).					
Dry Season maintenance At this stress level the preferred habitats as refuge during the dry period will be greatly reduced and only adequate to sustain this indicator group in the reach. Decreased abundance and cover will be reflected by an overall decrease in FROC of these species within this river reach with a resultant deterioration in EC.					
Wet Season maintenance Minimal habitats will be available for the critical life stages during the wet season, namely spawning, egg development and nursery areas, which will be reflected in overall decreased abundance and FROC of all these species within this guild.					
BUILDING BLOCK	SEASON	STRESS DURATION	SPP STRESS	INTEG STRESS	FLOW (m ³ /s)
Maintenance	Dry	35%	6.5	7.4	4.22
Maintenance	Wet	35%	4	6.7	5.69

Table F11 Low flow requirements: LSR guild

GENERAL					
INDICATOR: The large semi-rheophilic species (especially BMAR, HVIT, LCON,) are another important indicator guild present at this EWR site. These species utilises most habitats (SD, SS, FD, FI and FS) with substrate and water column as preferred cover. They also require overhanging vegetation as nursery habitats. Flows should furthermore remain adequate to allow migration between reaches, thus depth in riffle and rapids should remain adequate, especially during the wet season.					
PES: FISH EC C (ECOSTATUS C)					
Dry Season maintenance This fish stress level will maintain adequate FD, FI and abundant FS for maintenance of viable populations of this indicator guild during the dry season to maintain within a category C.					
Dry Season drought This is the maximum stress level allowable where this fish guild will survive through dry drought periods without undue stress on their populations and to allow their recovery afterwards.					
Wet Season maintenance This is the allowable stress level to allow adequate conditions for spawning and nursery habitats. Exceedance of this level will result in significant reduction in abundance and also cover and connectivity will be reduced. The recommended stress level should provide adequate habitat to allow for the required life stages to maintain within a category C.					
Wet Season drought Adequate fast habitats will still be available to allow some spawning of these species and although highly decreased abundance can be expected, they should be able to maintain adequate populations to recover after the drought period.					
BUILDING BLOCK	SEASON	STRESS DURATION	SPP STRESS	INTEG STRESS	FLOW (m ³ /s)
Drought	Dry	5%	6.5	7.4	4.22
Maintenance	Dry	35%	5	6.8	5.36
Drought	Wet	5%	5	6.8	5.36
Maintenance	Wet	35%	3.5	5.9	8.8
REC: FISH EC B (ECOSTATUS B)					
General Improved flows (higher low flows, less regulated flows) will improve quality and abundance of FS and FD habitats, with a					

positive impact on the FROC of some species with high preference for these habitats (esp. CPAR, CPRE, LCON, LCYL, LMOL and OPER).

Dry Season maintenance

These stress levels will result in improvement of preferred habitats for this indicator group during the dry season which should be reflected by increased abundance and overall improved FROC that will result in an improved ecological category.

Wet Season maintenance

Increased availability and abundance of critical habitats required during the wet season (especially spawning and nursery) should be reflected by improved reproduction potential and an overall improvement in the composition of this indicator group in this river reach, with an expected improvement towards a category B.

BUILDING BLOCK	SEASON	STRESS DURATION	SPP STRESS	INTEG STRESS	FLOW (m ³ /s)
Maintenance	Dry	35%	4	6.4	6.68
Maintenance	Wet	35%	2	5.5	12

AEC: FISH EC D (ECOSTATUS D)

General

Decreased low flows and periods of zero flow in some stretches will have a radical impact on flow dependant species and most probably also on species moderately intolerant to no flow conditions (BMAR, CPAR, LCON, LCYL, LMOL and MACU and probably also HVIT). Loss of deep channels, becoming sandier shallow channel will affect especially species like HVIT and LCON negatively. Increased nutrients will further degrade the available substrate through excessive algal growth, affecting species with a preference for substrate of good quality. A further decrease in the FROC of BEUT, BMAR, CPAR, CPRE, MACU and OPER can therefore be expected. Increased algal growth may benefit some a species like LCON.

Dry Season maintenance

At this stress level the preferred habitats as refuge during the dry period will be greatly reduced and only adequate to sustain this indicator group in the reach. Decreased abundance and cover will be reflected by an overall decrease in FROC of these species within this river reach with a resultant deterioration in EC.

Wet Season maintenance

Very limited habitats will be available for the critical life stages during the wet season, namely spawning, egg development and nursery areas, which will be reflected in overall decreased abundance and FROC of all these species within this guild.

BUILDING BLOCK	SEASON	STRESS DURATION	SPP STRESS	INTEG STRESS	FLOW (m ³ /s)
Maintenance	Dry	35%	6	7	4.7
Maintenance	Wet	35%	5	6.8	6.8

F2.2 LOW FLOW REQUIREMENTS IN TERMS OF STRESS FOR MACROINVERTEBRATES

The FDI and MVI low flow requirements are summarised in Table F12 and Table F13 respectively.

Table F12 Low flow requirements: FDI taxa

GENERAL
INDICATOR: The flow dependent cobble dwelling macroinvertebrate taxa used for this site (Elmidae and Libellulidae) both prefer velocities between 0.3 and 0.6 m/s although they can also survive at other velocity categories and live on other substrates. Elmidae are moderately sensitive to water quality whereas the Libellulidae have a low sensitivity to water quality.
PES: MACROINVERTEBRATE EC: C (ECOSTATUS C)
Dry Season maintenance Suitable habitat (> 0.3 m/s over coarse substrate) is required to ensure that all the selected taxa can overwinter without significant detrimental impacts on the overall population. The average velocity of 0.36 m/s (macroinvertebrate stress of 5) will ensure that this takes place.
Dry Season drought Suitable habitat (> 0.1 m/s over coarse substrate, with at least some areas where the flow reaches velocities > 0.3 m/s) is required to ensure that a core of the selected taxa is able to survive a drought. The maximum velocity of 0.77

m/s (macroinvertebrate stress of 8) will ensure that this takes place.

Wet Season maintenance

During the wet season optimal habitats (> 0.6 m/s over coarse substrate) is required to ensure that a healthy population occurs during the summer. The maximum velocity of 1.03 m/s (macroinvertebrate stress of 4) ensures that this takes place.

Wet Season drought

During the wet season optimal habitats (> 0.3 m/s over coarse substrate) is required to ensure that a healthy population occurs during the summer. The maximum velocity of 0.99 m/s (macroinvertebrate stress of 6) ensures that this takes place.

BUILDING BLOCK	SEASON	STRESS DURATION	SPP STRESS	INTEG STRESS	FLOW (m ³ /s)
Drought	Dry	5%	8	9.8	0.480
Maintenance	Dry	35%	5	9.4	0.841
Drought	Wet	5%	6	9.5	1.05
Maintenance	Wet	35%	4	9.2	1.68

REC: MACROINVERTEBRATE EC B (ECOSTATUS B)

Dry Season maintenance

Suitable habitat (> 0.3 m/s over coarse substrate) is required to ensure that all the selected taxa can overwinter without significant detrimental impacts on the overall population. The average velocity of 0.38 m/s (macroinvertebrate stress of 3) will ensure that this takes place.

Wet Season maintenance

During the wet season optimal habitats (> 0.3 m/s over coarse substrate) is required to ensure that a healthy population occurs during the summer. The maximum velocity of 0.99 m/s (macroinvertebrate stress of 6) ensures that this takes place.

BUILDING BLOCK	SEASON	STRESS DURATION	SPP STRESS	INTEG STRESS	FLOW (m ³ /s)
Maintenance	Dry	35	3	9	2.1
Maintenance	Wet	35	2	7	4.66

AEC: MACROINVERTEBRATE EC D (ECOSTATUS D)

Dry Season maintenance

Suitable habitat (> 0.3 m/s over coarse substrate) is required to ensure that all the selected taxa can overwinter without significant detrimental impacts on the overall population. The average velocity of 0.31 m/s (macroinvertebrate stress of 7) will ensure that this takes place.

Wet Season maintenance

During the wet season optimal habitats (> 0.6 m/s over coarse substrate) is required to ensure that a healthy population occurs during the summer. The maximum velocity of 1.02 m/s (macroinvertebrate stress of 5) ensures that this takes place.

BUILDING BLOCK	SEASON	STRESS DURATION	SPP STRESS	INTEG STRESS	FLOW (m ³ /s)
Maintenance	Dry	35%	7	9.7	0.841
Maintenance	Wet	35%	5	9.4	1.47

Table F13 Low flow requirements: MVI taxa

GENERAL
INDICATOR: The vegetation dwelling macroinvertebrate taxa used for this site (Coenagrionidae and Atyidae) are both able to also survive on other substrata such as Cobbles. Atyidae are moderately sensitive to water quality changes while Coenagrionidae have a low sensitivity to water quality changes.
PES: MACROINVERTEBRATE EC: C (ECOSTATUS C)
Dry Season maintenance Enough inundated vegetation is required to ensure that the Atyidae and Coenagrionidae can overwinter without significant detrimental impacts on the overall population. At an invertebrate stress of 7 only 1% fringing vegetation is inundated but enough aquatic vegetation will be available to provide adequate habitat for the selected taxa.
Dry Season drought

Enough inundated vegetation is required to ensure that the Atyidae and Coenagrionidae can overwinter during the drought conditions. At a macroinvertebrate stress of 8 only 1% fringing vegetation is inundated but enough aquatic vegetation will be available to provide adequate habitat for the selected taxa.

Wet Season maintenance

Enough inundated vegetation is required to ensure that the Atyidae and Coenagrionidae can thrive. At an invertebrate stress of 5.5 4% fringing vegetation is inundated as well as aquatic vegetation will be available to provide adequate habitat for the selected taxa.

Wet Season drought

Enough inundated vegetation is required to ensure that the Atyidae and Coenagrionidae can survive during the drought conditions. At a macroinvertebrate stress of 7 only 1% fringing vegetation is inundated but enough aquatic vegetation will be available to provide adequate habitat for the selected taxa.

BUILDING BLOCK	SEASON	STRESS DURATION	SPP STRESS	INTEG STRESS	FLOW (m ³ /s)
Drought	Dry	5%	8	9	2.1
Maintenance	Dry	35%	7	7	4.7
Drought	Wet	5%	7	7	4.7
Maintenance	Wet	35%	5.5	5.5	12

REC: MACROINVERTEBRATE EC B (ECOSTATUS B)

Dry Season Maintenance

Enough inundated vegetation is required to ensure that the Atyidae and Coenagrionidae can overwinter without significant detrimental impacts on the overall population. At a macroinvertebrate stress of 6.5 only 2% fringing vegetation is inundated but enough aquatic vegetation will be available to provide adequate habitat for the selected taxa.

Wet Season Maintenance

Enough inundated vegetation is required to ensure that the Atyidae and Coenagrionidae can thrive. At an invertebrate stress of 4.5 5% fringing vegetation is inundated as well as aquatic vegetation will be available to provide adequate habitat for the selected taxa.

BUILDING BLOCK	SEASON	STRESS DURATION	SPP STRESS	INTEG STRESS	FLOW (m ³ /s)
Maintenance	Dry	35%	6.5	6.5	6.35
Maintenance	Wet	35%	4.5	4.5	19

AEC: MACROINVERTEBRATE EC D (ECOSTATUS CD)

Dry Season Maintenance

Enough inundated vegetation is required to ensure that the Atyidae and Coenagrionidae can overwinter without significant detrimental impacts on the overall population. At a macroinvertebrate stress of 7.5 only 1% fringing vegetation is inundated but enough aquatic vegetation will be available to provide adequate habitat for the selected taxa.

Wet Season Maintenance

Enough inundated vegetation is required to ensure that the Atyidae and Coenagrionidae can thrive. At an invertebrate stress of 6.5 2% fringing vegetation is inundated as well as aquatic vegetation will be available to provide adequate habitat for the selected taxa.

BUILDING BLOCK	SEASON	STRESS DURATION	SPP STRESS	INTEG STRESS	FLOW (m ³ /s)
Maintenance	Dry	35%	7.5	8.1	3.36
Maintenance	Wet	35%	6.5	6.5	6.35

F2.3 INSTREAM FLOOD FUNCTIONS

Table F14 Functions for each Flood Class

Flood Class	Component	Function/Motivation
Class: I Range (m ³ /s): 15 - 20 Daily average: 8 Duration: 4	Fish	Class I floods are very important floods for fish and serves as migration cues and to maintain adequate longitudinal connectivity for migration. These floods will also flush fines and algae from substrates to ensure adequate conditions in substrates, a very important habitat for spawning of many of the species. It should furthermore inundate some vegetation for species spawning in flooded marginal vegetation and contributes to the creation of acceptable nursery areas. Some resetting of water quality will also take place, and the changes in water quality may also serve as stimulus to cue migratory activity and even gonad development. The frequency, extent and duration as recommended for the PES and AEC should be adequate to provide the functions as required to maintain the fish within the specific category.
	Macroinvertebrates	These freshets are recommended to stimulate hatching of eggs. Another function is to inundate the sedges to provide extra habitat for vegetation dwelling macroinvertebrates. Six of these per year are recommended for the REC, four for the PES and two for the AEC.
Class: II Range (m ³ /s): 22 – 50 (30) Daily average: 30 Duration: 4	Fish	Class II floods are similar in importance as Class I floods and have the same functionality as Class I floods. Their occurrence at lower frequency makes them only slightly less important for the fish assemblages than Class I.
	Macroinvertebrates	These freshets are recommended to stimulate breeding clear fines, inundate additional reed beds on the edge of the channel in order to create additional biotope, and reset water quality. Three of these per year are recommended for the REC and two for the PES and AEC.
Class: III Range (m ³ /s): 60	Fish	Class III floods also provide similar functions as Classes I, but due to its lower frequency it is not essential for the flood functions required by the indigenous fish species. These floods, and especially their receding limbs will however be utilised by many of the fish species for migration and even spawning if takes place within the summer season.
	Macroinvertebrates	These freshets are recommended to stimulate breeding clear fines, scour substrate, inundate additional reed beds on the edge of the channel in order to create additional biotope, and reset water quality. Three of these per year are recommended for the REC, two for the PES and one for the AEC.
Class: IV Range (m ³ /s): 30 - 35 (peak)	Fish	Class IV floods also provide similar functions as Classes I, but due to its lower frequency it is not essential for the flood functions required by the indigenous fish species. These floods, and especially their receding periods will however be utilised by many of the fish species for migration and even spawning if takes place in within the summer season.
Class: V Range (m ³ /s): 370 (340)	Fish	Class V floods also provide similar functions as Classes I, but due to its lower frequency it is not essential for the flood functions required by the indigenous fish species. These floods, and especially their receding limbs will however be utilised by many of the fish species for migration and even spawning if takes place within the summer season.

F2.4 EWR RULE TABLES

EWR rule tables which provide the recommended EWR flows as a duration table, showing flows which should be provided when linked to a natural trigger (natural modelled hydrology in this case) are provided for the different EWR scenarios. EWR rules are supplied for total flows as well as for low flows only.

Table F15 EWR 5 assurance rules for PES: C

Desktop Version 2, Printed on 2008/07/17

Summary of IFR rule curves for: CE5 Natural Flows

Determination based on defined BBM Table with site specific assurance rules.

Regional Type: E. Escarp PES = C

Data are given in m³/s mean monthly flow

% Points										
Month	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	6.101	6.086	6.060	6.010	5.920	5.761	5.484	5.025	4.327	3.549
Nov	7.860	7.831	7.769	7.650	7.429	7.045	6.433	5.571	4.569	3.829
Dec	11.950	11.893	11.775	11.546	11.120	10.381	9.203	7.543	5.616	4.191
Jan	11.647	11.459	11.242	10.949	10.501	9.731	8.679	7.197	5.475	4.202
Feb	35.997	32.995	30.372	27.962	25.512	21.412	18.539	14.491	9.790	6.314
Mar	24.424	22.820	21.388	20.015	18.530	16.032	13.975	11.075	7.708	5.218
Apr	12.142	12.085	11.969	11.742	11.320	10.589	9.423	7.781	5.873	4.463
May	10.455	10.408	10.312	10.124	9.777	9.172	8.210	6.854	5.278	4.114
Jun	8.778	8.743	8.671	8.530	8.269	7.816	7.094	6.076	4.895	4.021
Jul	7.151	7.126	7.074	6.972	6.783	6.455	5.932	5.195	4.339	3.706
Aug	6.228	6.213	6.185	6.134	6.042	5.879	5.594	5.123	4.407	3.608
Sep	5.869	5.856	5.832	5.789	5.710	5.569	5.325	4.920	4.305	3.619

Reserve flows without High Flows

Oct	6.101	6.086	6.060	6.010	5.920	5.761	5.484	5.025	4.327	3.549
Nov	7.220	7.194	7.142	7.040	6.850	6.520	5.995	5.254	4.394	3.759
Dec	8.879	8.842	8.766	8.617	8.342	7.865	7.104	6.031	4.785	3.864
Jan	10.594	10.546	10.449	10.258	9.903	9.288	8.308	6.926	5.322	4.136
Feb	13.953	13.886	13.750	13.483	12.988	12.128	10.759	8.830	6.589	4.932
Mar	12.846	12.784	12.658	12.410	11.952	11.156	9.888	8.101	6.026	4.492
Apr	12.142	12.085	11.969	11.742	11.320	10.589	9.423	7.781	5.873	4.463
May	10.455	10.408	10.312	10.124	9.777	9.172	8.210	6.854	5.278	4.114
Jun	8.778	8.743	8.671	8.530	8.269	7.816	7.094	6.076	4.895	4.021
Jul	7.151	7.126	7.074	6.972	6.783	6.455	5.932	5.195	4.339	3.706
Aug	6.228	6.213	6.185	6.134	6.042	5.879	5.594	5.123	4.407	3.608
Sep	5.869	5.856	5.832	5.789	5.710	5.569	5.325	4.920	4.305	3.619

Natural Duration curves

Oct	21.666	17.712	13.489	12.616	11.402	9.577	9.237	8.438	7.643	6.429
Nov	39.545	34.093	28.904	24.985	21.069	18.403	17.018	15.687	11.825	10.123
Dec	78.666	55.201	43.018	37.605	30.376	28.390	25.246	22.177	17.156	11.932
Jan	120.942	77.752	58.124	52.464	43.631	36.746	29.996	26.800	24.194	16.417
Feb	159.164	113.980	75.723	54.320	46.152	41.419	35.156	30.928	25.769	22.028
Mar	121.767	67.600	57.042	49.220	40.965	33.897	29.652	26.243	21.938	17.622
Apr	59.626	45.980	39.691	33.557	29.934	27.029	24.174	23.191	17.770	13.889
May	30.623	25.706	22.861	21.517	20.359	18.784	17.309	16.118	13.232	10.181
Jun	22.531	19.402	17.164	16.397	15.525	14.776	13.476	12.616	10.594	9.286
Jul	18.735	15.506	13.975	12.907	12.563	11.955	11.104	10.215	9.024	7.732
Aug	15.367	13.239	11.268	10.529	10.353	9.946	9.274	8.774	7.755	6.806
Sep	14.672	11.890	10.910	9.877	9.267	8.862	8.337	7.859	6.906	6.103

Table F16 EWR 5 assurance rules for REC: B

Desktop Version 2, Printed on 2008/07/17

Summary of IFR rule curves for: CE5 Natural Flows

Determination based on defined BBM Table with site specific assurance rules.

Regional Type: E. Escarp REC = B

Data are given in m³/s mean monthly flow

Month	% Points									
	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	8.262	8.236	8.188	8.098	7.936	7.648	7.147	6.319	5.058	3.652
Nov	10.698	10.648	10.545	10.344	9.971	9.323	8.291	6.836	5.147	3.898
Dec	15.247	15.166	15.000	14.675	14.073	13.027	11.361	9.013	6.287	4.271
Jan	28.099	26.232	24.558	22.942	21.178	18.208	15.710	12.190	8.101	5.078
Feb	43.277	39.954	37.015	34.249	31.335	26.442	22.662	17.335	11.148	6.574
Mar	29.967	28.220	26.626	25.036	23.226	20.168	17.356	13.392	8.789	5.385
Apr	16.688	16.599	16.415	16.057	15.393	14.238	12.400	9.808	6.799	4.574
May	14.472	14.396	14.241	13.937	13.374	12.397	10.840	8.645	6.096	4.212
Jun	12.106	12.046	11.925	11.689	11.250	10.487	9.272	7.560	5.572	4.102
Jul	9.892	9.847	9.755	9.574	9.238	8.655	7.726	6.417	4.897	3.773
Aug	8.306	8.280	8.231	8.142	7.980	7.693	7.194	6.367	5.110	3.707
Sep	7.897	7.874	7.830	7.749	7.602	7.340	6.886	6.134	4.991	3.715

Reserve flows without High Flows

Oct	8.262	8.236	8.188	8.098	7.936	7.648	7.147	6.319	5.058	3.652
Nov	10.114	10.067	9.972	9.786	9.441	8.843	7.889	6.545	4.984	3.829
Dec	12.431	12.369	12.240	11.989	11.524	10.716	9.429	7.615	5.509	3.951
Jan	14.652	14.575	14.417	14.109	13.538	12.545	10.964	8.736	6.148	4.235
Feb	19.102	18.998	18.786	18.370	17.600	16.262	14.130	11.126	7.637	5.057
Mar	17.567	17.471	17.275	16.892	16.181	14.946	12.979	10.207	6.988	4.607
Apr	16.688	16.599	16.415	16.057	15.393	14.238	12.400	9.808	6.799	4.574
May	14.472	14.396	14.241	13.937	13.374	12.397	10.840	8.645	6.096	4.212
Jun	12.106	12.046	11.925	11.689	11.250	10.487	9.272	7.560	5.572	4.102
Jul	9.892	9.847	9.755	9.574	9.238	8.655	7.726	6.417	4.897	3.773
Aug	8.306	8.280	8.231	8.142	7.980	7.693	7.194	6.367	5.110	3.707
Sep	7.897	7.874	7.830	7.749	7.602	7.340	6.886	6.134	4.991	3.715

Natural Duration curves

Oct	21.666	17.712	13.489	12.616	11.402	9.577	9.237	8.438	7.643	6.429
Nov	39.545	34.093	28.904	24.985	21.069	18.403	17.018	15.687	11.825	10.123
Dec	78.666	55.201	43.018	37.605	30.376	28.390	25.246	22.177	17.156	11.932
Jan	120.942	77.752	58.124	52.464	43.631	36.746	29.996	26.800	24.194	16.417
Feb	159.164	113.980	75.723	54.320	46.152	41.419	35.156	30.928	25.769	22.028
Mar	121.767	67.600	57.042	49.220	40.965	33.897	29.652	26.243	21.938	17.622
Apr	59.626	45.980	39.691	33.557	29.934	27.029	24.174	23.191	17.770	13.889
May	30.623	25.706	22.861	21.517	20.359	18.784	17.309	16.118	13.232	10.181
Jun	22.531	19.402	17.164	16.397	15.525	14.776	13.476	12.616	10.594	9.286
Jul	18.735	15.506	13.975	12.907	12.563	11.955	11.104	10.215	9.024	7.732
Aug	15.367	13.239	11.268	10.529	10.353	9.946	9.274	8.774	7.755	6.806
Sep	14.672	11.890	10.910	9.877	9.267	8.862	8.337	7.859	6.906	6.103

Table F17 EWR 5 assurance rules for AEC: D

Desktop Version 2, Printed on 2008/07/17

Summary of IFR rule curves for: CE5 Natural Flows

Determination based on defined BBM Table with site specific assurance rules.

Regional Type: E. Escarp AEC = D

Data are given in m³/s mean monthly flow

Month	% Points									
	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	5.284	5.268	5.242	5.196	5.118	4.990	4.781	4.458	3.996	3.505
Nov	7.232	7.207	7.155	7.055	6.869	6.546	6.031	5.306	4.464	3.841
Dec	9.865	9.822	9.735	9.565	9.250	8.703	7.831	6.602	5.175	4.120
Jan	11.620	10.985	10.420	9.885	9.314	8.354	7.590	6.513	5.262	4.337
Feb	18.170	16.831	15.666	14.602	13.535	11.750	10.545	8.845	6.872	5.413
Mar	9.139	8.905	8.679	8.431	8.115	7.579	6.986	6.150	5.180	4.462
Apr	7.539	7.516	7.467	7.373	7.198	6.894	6.410	5.728	4.936	4.351
May	6.981	6.959	6.915	6.827	6.666	6.384	5.936	5.305	4.571	4.029
Jun	6.500	6.481	6.443	6.368	6.229	5.987	5.603	5.061	4.431	3.965
Jul	5.850	5.834	5.801	5.737	5.618	5.410	5.080	4.615	4.074	3.674
Aug	5.198	5.184	5.159	5.117	5.045	4.926	4.734	4.435	4.009	3.554
Sep	4.894	4.883	4.863	4.829	4.771	4.675	4.520	4.279	3.935	3.569

Reserve flows without High Flows

Oct	5.270	5.217	5.108	4.918	4.636	4.290	3.943	3.669	3.505	3.439
Nov	6.117	6.089	6.021	5.879	5.621	5.224	4.724	4.226	3.861	3.699
Dec	6.600	6.567	6.488	6.321	6.019	5.555	4.970	4.387	3.960	3.771
Jan	7.015	6.980	6.896	6.719	6.398	5.905	5.282	4.663	4.209	4.008
Feb	8.307	8.266	8.166	7.956	7.576	6.992	6.255	5.521	4.985	4.746
Mar	7.560	7.523	7.432	7.241	6.895	6.364	5.693	5.025	4.537	4.320
Apr	7.539	7.502	7.411	7.221	6.876	6.346	5.677	5.011	4.524	4.308
May	6.981	6.947	6.863	6.687	6.367	5.876	5.257	4.640	4.189	3.989
Jun	6.500	6.470	6.398	6.247	5.973	5.551	5.020	4.490	4.103	3.931
Jul	5.850	5.825	5.763	5.633	5.398	5.036	4.580	4.125	3.793	3.645
Aug	5.186	5.137	5.036	4.860	4.600	4.280	3.960	3.706	3.554	3.493
Sep	4.878	4.816	4.687	4.477	4.208	3.940	3.730	3.601	3.539	3.517

Natural Duration curves

Oct	21.666	17.712	13.489	12.616	11.402	9.577	9.237	8.438	7.643	6.429
Nov	39.545	34.093	28.904	24.985	21.069	18.403	17.018	15.687	11.825	10.123
Dec	78.666	55.201	43.018	37.605	30.376	28.390	25.246	22.177	17.156	11.932
Jan	120.942	77.752	58.124	52.464	43.631	36.746	29.996	26.800	24.194	16.417
Feb	159.164	113.980	75.723	54.320	46.152	41.419	35.156	30.928	25.769	22.028
Mar	121.767	67.600	57.042	49.220	40.965	33.897	29.652	26.243	21.938	17.622
Apr	59.626	45.980	39.691	33.557	29.934	27.029	24.174	23.191	17.770	13.889
May	30.623	25.706	22.861	21.517	20.359	18.784	17.309	16.118	13.232	10.181
Jun	22.531	19.402	17.164	16.397	15.525	14.776	13.476	12.616	10.594	9.286
Jul	18.735	15.506	13.975	12.907	12.563	11.955	11.104	10.215	9.024	7.732
Aug	15.367	13.239	11.268	10.529	10.353	9.946	9.274	8.774	7.755	6.806
Sep	14.672	11.890	10.910	9.877	9.267	8.862	8.337	7.859	6.906	6.103

**APPENDIX G: SUPPORTING INFORMATION FOR THE DETERMINATION OF STRESS
INDICES AND EWR SCENARIOS OF EWR 6: NKONGOMA**

G1 EWR 6: NKONGOMA (CROCODILE RIVER) - DETERMINATION OF STRESS INDICES

Appendix G provides supporting information for the determination of stress indices of EWR 6 Nkongoma (Chapter 13 and 14 of the Main Report).

G1.1 FISH INDICATOR SPECIES

Small rheophilic (SR) guild: Various small rheophilic species were present in this river stretch and were included as indicators (*Chiloglanis pretoriae* (CPRE) and *Chiloglanis swierstrai* (CSWI)). These species all require flowing water over substrates during all life stages, with some stages also preferring some overhanging vegetation as cover.

Large semi-rheophilic (LSR) guild: The large semi-rheophilic species (especially *Labeobarbus marequensis* (BMAR), *Hydrocynus vittatus* (HVIT), and *Labeo congoro* (LCON)) were another important indicator guild present at this EWR site. They also require overhanging vegetation as nursery habitats.

The habitat requirements for the different life stages of (CPRE) are summarised in Appendix C, Table C1 while the habitat requirements for CSWI are summarised in Appendix F, Table F1. The LR requirements for BMAR are summarised in Appendix E, Table E2 and in Appendix F, Table F2 for HVIT and LCON.

G1.2 FISH STRESS INDEX

The abundance of fish velocity-depth classes are provided in Table G1.

Table G1 EWR 6: Habitat suitability for the SR and LSR guild

SR AND LSR GUILD											
Depth classes	Discharges (m ³ /s)										
	0.00	0.54	1.70	3.83	5.32	6.55	7.25	9.68	15.15	22.83	33.33
Slow (<0.3 m/s) Very Shallow (<0.1 m) (SVS)	0	4	6	6	6	6	6	6	8	8	8
Slow (<0.3 m/s) Shallow (0.1 – 0.3 m) (SS)	10	4	4	4	4	4	4	4	4	6	10
Slow (<0.3 m/s) Deep (> 0.5 m) (SD)	10	8	6	6	6	6	6	6	6	6	6
Slow Shallow and Slow Deep	10	4	4	4	4	4	4	4	4	4	4
Fast (>0.3 m/s) Very Shallow (<0.1 m) (FVS)	10	8	8	6	6	6	8	8	8	8	8
Fast (>0.3 m/s) Shallow (0.1 – 0.3 m) (FS)	10	8	8	6	6	6	6	6	6	6	10
Fast (>0.3 m/s) Intermediate (0.2 – 0.3) (FI)	10	8	8	8	8	8	8	8	6	8	6
Fast (>0.3 m/s) Deep (> 0.3 m) (FD)	10	8	8	6	6	6	6	6	4	4	4
FAST TOTAL >0.1 m DEEP	10	8	8	6	6	6	6	6	4	4	4

The fish stress index is provided in Table G2

Table G2 Fish stress index

Habitat	Discharges (m ³ /s)										
	0.00	0.54	1.70	3.83	5.32	6.55	7.25	9.68	15.15	22.83	33.33
SMALL RHEOPHILIC (SR) GUILD											
Spawning habitat and nursery habitat	0	0	0.5	1	1	1.5	2	3	4.5	5	5
Abundance	0	0	0.5	1	1.5	2	2.5	3.5	5	5	5
Cover	0	0	0.5	1	2	2	2.5	3.5	4.5	5	5
Connectivity (lateral & longitudinal)	0	0	0.5	1	2	2.5	2.5	3.5	4.5	5	5
Water Quality (esp. oxygen and temperature)	0	0	0.5	1	2	2	2.5	3.5	5	5	5
Species stress: CPRE, CSWI	10	10	9	8	7	6	5	3	1	0	0
LARGE SEMI RHEOPHILIC (LSR) GUILD											
Spawning habitat and nursery habitat	0	0	0	1	1.5	1.5	2	3	4	5	5
Abundance	0	0.5	0.5	1	1.5	1.5	2	3	4	5	5
Cover	0	0.5	1	1	1.5	2	2	2.5	3.5	5	5
Connectivity (lateral & longitudinal)	0	0	0	0.5	1	1	1.5	2.5	3.5	4.5	5
Water Quality (esp. oxygen and temperature)	0	0	0.5	0.5	1	1.5	2	3	5	5	5
Species stress: BMAR, HVIT, LCON	10	10	9	8	7	7	6	4	2	0	0

G1.3 MACROINVERTEBRATE STRESS INDEX

The habitat flow index for flow dependent macroinvertebrate (FDI) taxa is provided in Table G3 and provides the % occurrence of various velocity and substrate classes under different flow conditions.

Table G3 Habitat suitability for FDI taxa

Habitat Flow Response Index	Habitat Response	Habitat Abundance and suitability													Flow (m ³ /s)
		VSCS ¹	SCS ²	FCS ³	VFCS ⁴	VSFS ⁵	SFS ⁶	FFS ⁷	VFFS ⁸	VSBR ⁹	SBR ¹⁰	FSR ¹¹	VFSR ¹²	Veg ¹³	
0	All habitats in excess, very high quality. Very fast, very deep, very wide WP.	1	1	2	2	2	4	7	6	6	6	13	13	37	35.83
1	All plentiful, high quality. Fast, wide WP.	1	2	3	2	3	5	8	5	5	10	14	10	33	26.66
2	Critical habitats sufficient. Quality slightly reduced, fast, WP slightly reduced.	1	2	3	1	3	6	8	4	6	12	18	6	30	21.1
3	Reduced critical habitat and critical quality. Moderate velocity, fairly deep.	2	3	3	1	5	8	8	2	10	14	14	5	25	12.73
4	Critical habitats limited and of moderate quality. Moderate velocity, some deep areas. Wide WP moderately reduced.	2	3	2	1	7	9	6	2	12	18	12	6	20	8.0
5	Critical habitat very reduced, moderate/low quality. Moderate/slow velocity, few deep areas WP moderately/very reduced.	3	4	2	0	9	11	5	1	17	23	12	0	13	4.29
6	Critical habitat residual. Low quality, moderate/slow velocity.	3	4	1	0	10	12	4	1	20	27	7	0	11	3.22
7	No critical habitat, other habitats moderate quality. Slow, narrow WP.	5	4	1	0	14	12	3	0	29	23	6	0	3	1.94
8	Flowing water habitats residual and of low quality. Slow trickle, very narrow WP.	7	3	0	0	20	9	1	0	42	18	0	0	0	0.48
9	Standing water habitats only, very low quality, no flow.	9	1	0	0	28	2	0	0	54	6	0	0	0	0.02
10	Only hyporheic refugia, no surface water.	10	0	0	0	30	0	0	0	60	0	0	0	0	0.001

1 Very Slow over Coarse Sediment
 4 Very Fast over Coarse Sediment
 7 Fast over Fine Sediment
 10 Slow over Bedrock
 13 Fringing vegetation

2 Slow over Coarse Sediment
 5 Very Slow over Fine Sediment
 8 Very Fast over Fine Sediment
 11 Fast over Bedrock

3 Fast over Coarse Sediment
 6 Slow over Fine Sediment
 9 Very Slow over Bedrock
 12 Very Fast over Bedrock

The stress index for FDI taxa is provided in Table G4 which rates the response of the species according to various biotic response metrics.

Table G4 Macroinvertebrate (FDI) stress index

Habitat characteristics					Biotic Response	Flow	Species Stress
Max depth (m)	Ave depth (m)	Max vel (m/s)	Ave vel (m/s)	WP (m)			
1.36	0.59	1.35	0.5	125.7	All indicator taxa very abundant and healthy.	21.10	0
1.28	0.52	1.22	0.43	122.2	90% indicator taxa persist.		1
1.22	0.47	1.16	0.38	119.6	Most indicator taxa persist, but slight (80%) reduction.	12.70	2
1.1	0.4	0.94	0.3	106.1	Most indicator taxa persist, but abundances reduced.	8.00	3
1	0.34	0.8	0.25	96.9	All life stages viable in limited areas, critical life stages of some sensitive indicator taxa at risk.	4.29	4
0.88	0.28	0.67	0.2	77.7	Critical life-stages of sensitive indicator taxa at risk or non-viable.	3.22	5
0.84	0.27	0.6	0.17	69.3	Sensitive indicator taxa rare, critical stages of sensitive indicator taxa non-viable and at risk for some less sensitive taxa.		6
0.76	0.27	0.49	0.14	53.3	Some indicator taxa persist, but most disappear. All life-stages of sensitive indicator taxa at risk or non-viable.	1.94	7
0.54	0.23	0.3	0.09	24.8	Some indicator taxa persist, but at very low numbers. All life stages of most indicator taxa at risk or non-viable.	0.48	8
0.22	0.09	0.12	0.03	5.3	Indicator taxa no longer present.	0.02	9
0.08	0.03	0.05	0.01	1.2		0.00	10

G1.4 RIPARIAN VEGETATION STRESS INDEX

A riparian vegetation stress index is provided in Table G5.

Table G5 Riparian vegetation stress index for indicator species

Biotic response		
Species Stress	Flow (m ³ /s)	<i>Cyperus marginatus</i>
0	2.5	Adults with full vigour and at maximum reproductive capacity. 50% population inundated, upper limit rooting depth at 12 cm.
1		
2		
3	1.15	Leaf wilting/stress commences, but is slight. Up to 22 cm rooting depth for upper limit, lower limit at water level on average.
4		Flower/fruit abortion commences.
5	0.3	Leaf wilting obvious or vegetative parts begin unseasonal discolouration. Flower/fruit abortion widespread. 20 – 40 cm rooting depth for sufficient soil moisture, no inundation.
6		Unseasonal thinning or partial mortality of above-ground parts (majority of the plant/s remains viable, but water stressed).
7		
8	0.03	Unseasonal loss or mortality of above-ground parts (only minor portions of plants remain viable). Rootstocks/rhizomes of some species remain viable, 40 – 60 cm.

9	0	Complete mortality of small proportion of the population.
10		Widespread and complete mortality of population.

G2 EWR 6: NKONGOMA (CROCODILE RIVER) - DETERMINATION OF EWR SCENARIOS

G2.1 LOW FLOW REQUIREMENTS IN TERMS OF STRESS FOR FISH

The fish low flow requirements for the EWR scenarios are summarised in Table G6 for the SR guild and Table G7 for LSR guild.

Table G6 Low flow requirements: SR guild

GENERAL					
INDICATOR: The small rheophilic species at the site are the best indicators for setting flows (CPRE, and CSWI). These species all requires flowing water over substrates during all life stages, with some stages also preferring some overhanging vegetation as cover. Optimal conditions for spawning of this guild consist of FD, FI, FS and SS with good quality substrate (clean cobbles and gravel), while the margins of the FS and SS are important for egg development and nursery areas for larvae. Juvenile and adult stages of this guild have a high preference for FS, FI and FD over substrates. Flows should furthermore remain adequate to allow migration between reaches, thus depth in riffle and rapids should remain adequate, especially during the wet season.					
PES: FISH EC C (ECOSTATUS C)					
Dry Season maintenance This recommended fish stress level will maintain some FD, FI and abundant FS for maintenance of viable populations of this indicator guild during the dry season.					
Dry Season drought This is the maximum allowable fish stress level where this indicator guild will be able to sustain viable populations during a dry period drought to enable recovery when conditions improve.					
Wet Season maintenance This is the allowable fish stress level to facilitate spawning and nursery habitats. Exceedance of this stress level will result in significant reduction in abundance of this indicator group and also loss in cover and connectivity. This stress level should provide adequate habitat to allow for the required life stages to maintain within a category C.					
Wet Season drought Adequate fast habitats will be maintained to allow some spawning and although highly decreased abundance can be expected, they should be able to maintain adequate populations to recover after drought period.					
BUILDING BLOCK	SEASON	STRESS DURATION	SPP STRESS	INTEG STRESS	FLOW (m ³ /s)
Drought	Dry	5%	9.2	9.2	1.36
Maintenance	Dry	30%	8.9	8.9	1.91
Drought	Wet	5%	5.5	6.2	6.864
Maintenance	Wet	35%	3.5	4.5	9.088
REC: FISH EC B (ECOSTATUS B)					
General Improved flows (higher low flows, less regulated flows) will improve quality and abundance of FS and FD habitats, with a positive impact on the FROC of some species with high preference for these habitats (esp. AMOS, BMAR, CPAR, CSWI, HVIT and LCON).					
Dry Season maintenance These stress levels will result in improvement of preferred habitats for this indicator group during the dry season which should be reflected by increased abundance and overall improved FROC that will result in an improved ecological category.					
Wet Season maintenance Increased availability and abundance of critical habitats required during the wet season (especially spawning and nursery) should be reflected by improved reproduction potential and an overall improvement in the composition of this indicator group in this river reach, with an expected improvement towards a category B.					
BUILDING BLOCK	SEASON	STRESS DURATION	SPP STRESS	INTEG STRESS	FLOW (m ³ /s)

Maintenance	Dry	30%	7.7	7.7	4.277
Maintenance	Wet	35%	2	3	12.35
AEC: FISH EC D (ECOSTATUS D)					
General: Decreased low flows and longer periods of zero flow in some stretches will have a radical impact on flow dependant species and result in decreased FROC of species such as BMAR, CPAR, HVIT, LCON, LCYL, LMOL and MACU and a possible loss of CPRE, CSWI from this stretch under extreme conditions). Increased nutrients will further degrade the available substrate through excessive algal growth, affecting species with a preference for substrate of good quality. Dry Season maintenance At this stress level the preferred habitats as refuge during the dry period will be greatly reduced and only adequate to sustain this indicator group in the reach. Decreased abundance and cover will be reflected by an overall decrease in FROC of these species within this river reach with a resultant deterioration in EC. Dry Season drought At this stress level the habitat suitability to maintain abundance, provide cover, connectivity and adequate water quality will be very poor to critical and extreme stress on this fish guild will result in critical deterioration in the PES. It can be expected that this fish guild may not be able to survive at this stress level and may require recolonisation from other reaches or the downstream Komati River after conditions recover. Wet Season maintenance Minimal habitats will be available for the critical life stages during the wet season, namely spawning, egg development and nursery areas, which will be reflected in overall decreased abundance and FROC of all these species within this guild.					
BUILDING BLOCK	SEASON	STRESS DURATION	SPP STRESS	INTEG STRESS	FLOW (m ³ /s)
Drought	Dry	5%	9.6	9.6	0.681
Maintenance	Dry	30%	9.3	9.3	1.19
Maintenance	Wet	35%	5.5	6.2	6.864

Table G7 Low flow requirements: LSR guild

GENERAL					
INDICATOR: The large semi-rheophilic species (especially BMAR, HVIT, and LCON,) are another important indicator guild present at this EWR site. BMAR, HVIT and LCON were therefore used as indicators for the large semi-rheophilic guild. These species utilises most habitats (SD, SS, FD, FI and FS) with substrate and water column as preferred cover. They also require overhanging vegetation as nursery habitats. Flows should furthermore remain adequate to allow migration between reaches, thus depth in riffle and rapids should remain adequate, especially during the wet season.					
PES: FISH EC C (ECOSTATUS C)					
Dry Season maintenance This recommended fish stress level will maintain some FD, FI and abundant FS for maintenance of viable populations of this indicator guild during the dry season to ensure an overall PES of C for fish at this site. Dry Season drought This is the maximum stress level allowable where this fish guild will survive through dry drought periods without undue stress on their populations and to allow their recovery afterwards. Wet Season maintenance This flow and stress level will allow moderate conditions for all requirements (spawning, nursery habitat, cover and abundance, water quality and connectivity). These favourable conditions during the wet season will ensure that the PES is maintained at this site. Wet Season drought Adequate fast habitats will be available at this stress level to still allow some spawning and although highly decreased abundance can be expected, they should be able to maintain adequate populations to recover after drought period.					
BUILDING BLOCK	SEASON	STRESS DURATION	SPP STRESS	INTEG STRESS	FLOW (m ³ /s)
Drought	Dry	5%	9	9	1.7
Maintenance	Dry	30%	8.9	8.9	1.91
Drought	Wet	5%	6	6	7.25

Maintenance	Wet	30%	3.6	3.6	10.76
REC: FISH EC B (ECOSTATUS B)					
General Improved flows (higher low flows, less regulated flows) will improve quality and abundance of FS and FD habitats, with a positive impact on the FROC of some species with high preference for these habitats (esp. AMOS, BMAR, CPAR, CSWIE, HVIT and LCON). Dry Season maintenance These stress levels will result in improvement of preferred habitats for this indicator group during the dry season which should be reflected by increased abundance and overall improved FROC that will result in an improved ecological category. Wet Season maintenance Increased availability and abundance of critical habitats required during the wet season (especially spawning and nursery) should be reflected by improved reproduction potential and an overall improvement in the composition of this indicator group in this river reach, with an expected improvement towards a category B.					
BUILDING BLOCK	SEASON	STRESS DURATION	SPP STRESS	INTEG STRESS	FLOW (m ³ /s)
Maintenance	Dry	30%	7.5	7.5	4.575
Maintenance	Wet	35%	1.9	1.9	15.84[P
AEC: FISH EC D (ECOSTATUS D)					
General Decreased low flows and longer periods of zero flow in some stretches will have a radical impact on flow dependant species and result in decreased FROC of species such as BMAR, CPAR, HVIT, LCON, LCYL, LMOL and MACU and a possible loss of CPRE, CSWI from this stretch under extreme conditions). Loss of deep channels, becoming sandier shallow channel will affect especially species like HVIT and LCON negatively. Increased nutrients will further degrade the available substrate through excessive algal growth, affecting species with a preference for substrate of good quality. A further decrease in the FROC of BMAR, CPAR, and GGIU can therefore be expected. Increased algal growth may benefit some a species like LCON. Impact on species with preference for substrate as cover will be aggravated by increased sedimentation as a result of fewer floods. Dry Season maintenance At this stress level the preferred habitats as refuge during the dry period will be greatly reduced and only adequate to sustain this indicator group in the reach. Decreased abundance and cover will be reflected by an overall decrease in FROC of these species within this river reach with a resultant deterioration in EC. Dry Season drought At this stress level the habitat suitability to maintain abundance, provide cover, connectivity and adequate water quality will be very poor and extreme stress on this fish guild will result in a deterioration in the PES of one EC. Wet Season maintenance Very limited habitats will be available for the critical life stages during the wet season, namely spawning, egg development and nursery areas, which will be reflected in overall decreased abundance and FROC of all these species within this guild.					
BUILDING BLOCK	SEASON	STRESS DURATION	SPP STRESS	INTEG STRESS	FLOW (m ³ /s)
Dry	Dry	5%	9.6	9.6	0.681
Maintenance	Dry	30%	9.3	9.3	1.19
Maintenance	Wet	30%	5.5	5.5	7.862

G2.2 LOW FLOW REQUIREMENTS IN TERMS OF STRESS FOR MACROINVERTEBRATES

The FDI low flow requirements are summarised in Table G8 below.

Table G8 Low flow requirements: FDI taxa

GENERAL					
INDICATOR: The requirements for the indicator taxa Tricorythidae, Elmidae and Libellulidae are described for sites EWR 1 – 4.					
PES: MACROINVERTEBRATE EC: C (ECOSTATUS C)					
Dry Season maintenance Suitable habitat (> 0.3 m/s over coarse substrate) is required to ensure that all the selected taxa can overwinter without significant detrimental impacts on the overall population. The maximum velocity of 0.49 m/s (macroinvertebrate stress of 7) will ensure that this takes place. At this flow there are 1% FCS and 6% FBR available Dry Season drought Suitable habitat (> 0.1 m/s over coarse substrate,) is required to ensure that a core of the selected taxa is able to survive a drought. The maximum velocity of 0.12 m/s (macroinvertebrate stress of 9) will ensure that this takes place. Wet Season maintenance During the wet season optimal habitats (> 0.6 m/s over coarse substrate) is required to ensure that a healthy population occurs during the summer. The maximum velocity of 0.67 m/s (macroinvertebrate stress of 4) ensures that this takes place. At this flow 2% FCS and 12% FBR are available. Wet Season drought During the wet season optimal habitats (> 0.3 m/s over coarse substrate) is required to ensure that a healthy population occurs during the summer. The maximum velocity of 0.55 m/s (macroinvertebrate stress of 6) ensures that this takes place. At this flow 1% FCS and 7% FBR are available.					
BUILDING BLOCK	SEASON	STRESS DURATION	SPP STRESS	INTEG STRESS	FLOW (m ³ /s)
Drought	Dry	5%	9	9.9	0.1709
Maintenance	Dry	35%	7	8.9	1.931
Drought	Wet	5%	6	8.5	2.765
Maintenance	Wet	35%	4	7.5	4.575
REC: MACROINVERTEBRATE EC B (ECOSTATUS B)					
Dry Season maintenance Suitable habitat (> 0.3 m/s over coarse substrate) is required to ensure that all the selected taxa can overwinter without significant detrimental impacts on the overall population. The maximum velocity of 0.67 m/s (macroinvertebrate stress of 4) will ensure that this takes place. At this flow 2% FCS and 12% FBR is available. Wet Season maintenance During the wet season optimal habitats (> 0.6 m/s over coarse substrate) is required to ensure that a healthy population occurs during the summer. The average velocity of 0.3 m/s (macroinvertebrate stress of 2) ensures that this takes place. At this flow 3% FCS, 1% VFCS, 14% FBR and 5% VFBR is available.					
BUILDING BLOCK	SEASON	STRESS DURATION	SPP STRESS	INTEG STRESS	FLOW (m ³ /s)
Maintenance	Dry	35%	4	7.5	4.575
Maintenance	Wet	35%	2	3	12.35
AEC: MACROINVERTEBRATE EC D (ECOSTATUS CD)					
Dry Season maintenance Suitable habitat (> 0.3 m/s over coarse substrate) is required to ensure that all the selected taxa can overwinter without significant detrimental impacts on the overall population. The maximum velocity of 0.63 m/s (macroinvertebrate stress of 8) will ensure that this takes place. At this flow 4% FCS and 6% FBR are available. Wet Season maintenance During the wet season optimal habitats (> 0.6 m/s over coarse substrate) is required to ensure that a healthy population occurs during the summer. The maximum velocity of 0.88 m/s (macroinvertebrate stress of 5) ensures that this takes place. This flow 1% FCS and 7% FBR are available.					
BUILDING BLOCK	SEASON	STRESS DURATION	SPP STRESS	INTEG STRESS	FLOW (m ³ /s)
Maintenance	Dry	35%	8	9.8	0.341
Maintenance	Wet	35%	5	8.1	3.03

G2.3 LOW FLOW REQUIREMENTS IN TERMS OF RIPARIAN VEGETATION

The low flow requirements for riparian vegetation indicator species are summarised in Table D8.

Table G9 Low flow requirements: Riparian vegetation species

GENERAL					
INDICATOR: <i>Cyperus marginatus</i> .					
PES: RIPARIAN VEGETATION EC: C (ECOSTATUS C)					
Dry Season maintenance At a species stress of 4.5, leaf wilting/stress commences. <i>C. marginatus</i> requires up to 30 cm rooting depth for upper limit while the lower limit is at water level on average.					
Dry Season drought Riparian stress increases to a level of 8 i.e. unseasonal loss or mortality of above-ground parts (only minor portions of plants remain viable) therefore the rhizomes remain largely viable.					
Wet Season maintenance At a species stress of 3 <i>C. marginatus</i> starts water stress in the upper portions of the population.					
Wet Season drought At a species stress of 6 unseasonal thinning or partial mortality of above-ground parts occurs. The majority of the plant/s remains viable, but is water stressed).					
BUILDING BLOCK	SEASON	STRESS DURATION	SPP STRESS	INTEG STRESS	FLOW (m ³ /s)
Drought	Dry	5%	8	10	0.001
Maintenance	Dry	35%	4.5	9.75	0.426
Drought	Wet	5%	6	9.8	0.341
Maintenance	Wet	35%	3	9.25	1.275
REC: RIPARIAN VEGETATION EC B (ECOSTATUS B)					
Dry Season maintenance The riparian species are slightly less stressed than under PES conditions.					
Wet Season maintenance The population exhibits no or very little stress at a species stress of 1.					
BUILDING BLOCK	SEASON	STRESS DURATION	SPP STRESS	INTEG STRESS	FLOW (m ³ /s)
Maintenance	Dry	35%	4	9.7	0.511
Maintenance	Wet	35%	1	9	1.7
AEC: RIPARIAN VEGETATION EC D (ECOSTATUS D)					
Dry Season maintenance The riparian species are slightly more stressed than under PES conditions.					
Wet Season maintenance At a species stress of 4, flower/fruit abortion commences					
BUILDING BLOCK	SEASON	STRESS DURATION	SPP STRESS	INTEG STRESS	FLOW (m ³ /s)
Maintenance	Dry	35%	5	9.8	0.341
Maintenance	Wet	35%	4	9.7	0.511

G2.4 INSTREAM FLOOD FUNCTIONS

Table G10 Functions for each Flood Class

Flood Class	Component	Function/Motivation
Class: I Range (m ³ /s): 20 - 30 Daily average: 12 Duration: 4	Fish	Class I floods are very important floods for fish and serves as migration cues and to maintain adequate longitudinal connectivity for migration. These floods will also flush fines and algae from substrates to ensure adequate conditions in substrates, a very important habitat for spawning of many of the species. It should furthermore inundate some vegetation for species spawning in flooded marginal vegetation and contributes to the creation of acceptable nursery areas. Some resetting of water quality will also take place, and the changes in water quality may also serve as stimulus to cue migratory activity and even gonad development. The frequency, extent and duration as recommended for the PES and AEC should be adequate to provide the functions as required to maintain the fish within the specific category.
	Macroinvertebrates	These freshets are recommended to flush organic flocculants and mobilise fines (1 - 2 mm sands) in order to improve biotope suitability they will also reset water quality. Another function is to inundate the sedges to provide extra habitat for vegetation dwelling macroinvertebrates.
Class: II Range (m ³ /s): 60 – 100 (70) Daily average: 60 Duration: 4	Fish	Class II floods are similar in importance as Class I floods and have the same functionality as Class I floods. Their occurrence at lower frequency makes them only slightly less important for the fish assemblages than Class I.
	Macroinvertebrates	These freshets are recommended to clear fines, scour substrate and inundate additional cobbles on the edge of the channel in order to create additional biotope, and reset water quality. They are also required to flush the exotic snails (Thiaridae).
Class: III Range (m ³ /s): 130 – 160 (130) Daily average: 120 Duration: 6	Fish	Class III floods also provide similar functions as Classes I, but due to its lower frequency it is not essential for the flood functions required by the indigenous fish species. These floods, and especially their receding limbs will however be utilised by many of the fish species for migration and even spawning if takes place within the summer season.
Class: IV Range (m ³ /s): 200 -350 (340)	Fish	Class IV floods also provide similar functions as Classes I, but due to its lower frequency it is not essential for the flood functions required by the indigenous fish species. These floods, and especially their receding limbs will however be utilised by many of the fish species for migration and even spawning if takes place within the summer season.

G2.5 EWR RULE TABLES

EWR rule tables which provide the recommended EWR flows as a duration table, showing flows which should be provided when linked to a natural trigger (natural modelled hydrology in this case) are provided for the different EWR scenarios. EWR rules are supplied for total flows as well as for low flows only.

Table G11 EWR 6 assurance rules for PES: C

Desktop Version 2, Printed on 2008/07/18

Summary of IFR rule curves for: CE6 Natural Flows

Determination based on defined BBM Table with site specific assurance rules.

Regional Type: E. Escarp PES = C

Data are given in m³/s mean monthly flow

Month	% Points									
	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	4.375	4.367	4.338	4.278	4.160	3.945	3.584	3.052	2.409	1.927
Nov	11.449	11.410	11.302	11.084	10.665	9.915	8.685	6.904	4.789	3.211
Dec	12.370	12.323	12.206	11.974	11.533	10.752	9.483	7.662	5.518	3.922
Jan	17.712	16.422	15.295	14.260	13.208	11.446	10.213	8.475	6.457	4.965
Feb	33.523	30.574	28.030	25.764	23.567	19.877	17.616	14.374	10.555	7.713
Mar	20.019	18.747	17.625	16.593	15.531	13.728	12.389	10.450	8.150	6.432
Apr	9.652	9.638	9.586	9.478	9.267	8.879	8.229	7.269	6.112	5.242
May	7.968	7.961	7.922	7.837	7.667	7.348	6.801	5.978	4.969	4.204
Jun	6.961	6.957	6.923	6.850	6.700	6.415	5.922	5.172	4.244	3.538
Jul	5.689	5.689	5.663	5.606	5.487	5.253	4.839	4.195	3.384	2.761
Aug	4.746	4.743	4.717	4.662	4.549	4.334	3.962	3.396	2.696	2.163
Sep	4.324	4.320	4.294	4.239	4.128	3.919	3.562	3.025	2.366	1.867

Reserve flows without High Flows

Oct	4.375	4.367	4.338	4.278	4.160	3.945	3.584	3.052	2.409	1.927
Nov	5.436	5.422	5.385	5.309	5.163	4.902	4.474	3.854	3.119	2.569
Dec	6.551	6.532	6.488	6.398	6.229	5.929	5.441	4.741	3.916	3.302
Jan	8.239	8.211	8.152	8.038	7.825	7.457	6.870	6.042	5.081	4.371
Feb	11.465	11.436	11.365	11.224	10.956	10.481	9.709	8.601	7.296	6.325
Mar	10.547	10.524	10.462	10.338	10.098	9.670	8.966	7.947	6.738	5.835
Apr	9.652	9.638	9.586	9.478	9.267	8.879	8.229	7.269	6.112	5.242
May	7.968	7.961	7.922	7.837	7.667	7.348	6.801	5.978	4.969	4.204
Jun	6.961	6.957	6.923	6.850	6.700	6.415	5.922	5.172	4.244	3.538
Jul	5.689	5.689	5.663	5.606	5.487	5.253	4.839	4.195	3.384	2.761
Aug	4.746	4.743	4.717	4.662	4.549	4.334	3.962	3.396	2.696	2.163
Sep	4.324	4.320	4.294	4.239	4.128	3.919	3.562	3.025	2.366	1.867

Natural Duration curves

Oct	22.050	17.992	14.147	13.068	11.667	9.950	9.506	8.617	7.788	6.709
Nov	41.597	35.799	29.398	25.204	21.508	18.646	17.365	15.984	12.068	10.255
Dec	83.318	56.720	43.533	38.937	31.112	28.726	25.646	22.450	17.346	12.056
Jan	131.414	78.091	60.040	53.080	44.011	37.321	31.373	27.718	25.239	16.532
Feb	174.115	124.921	77.005	54.741	46.631	41.803	35.615	31.105	26.066	22.264
Mar	135.189	68.679	60.667	51.934	41.144	34.155	30.048	26.493	22.133	17.749
Apr	60.035	46.481	40.394	33.962	30.262	27.427	24.441	23.376	17.998	14.016
May	30.907	26.202	23.171	21.980	20.527	18.993	17.671	16.543	13.366	10.282
Jun	22.994	19.796	17.523	16.991	15.999	15.085	14.005	12.809	10.737	9.487
Jul	19.194	15.797	14.277	13.292	12.911	12.186	11.268	10.413	9.185	7.874
Aug	15.853	13.504	11.634	10.962	10.652	10.279	9.521	8.987	7.878	6.937
Sep	15.123	12.203	11.269	10.019	9.525	9.163	8.584	8.052	7.014	6.223

Table G12 EWR 6 assurance rules for REC: B

Desktop Version 2, Printed on 2008/07/18

Summary of IFR rule curves for: CE6 Natural Flows

Determination based on defined BBM Table with site specific assurance rules.

Regional Type: E. Escarp REC = B

Data are given in m³/s mean monthly flow

Month	% Points									
	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	8.619	8.598	8.520	8.359	8.043	7.464	6.493	5.060	3.333	2.034
Nov	10.853	10.814	10.709	10.495	10.084	9.349	8.142	6.395	4.321	2.773
Dec	15.874	15.807	15.643	15.314	14.691	13.587	11.792	9.218	6.186	3.930
Jan	37.625	34.359	31.514	28.909	26.280	21.881	18.861	14.605	9.663	6.008
Feb	69.154	62.330	56.445	51.208	46.138	37.622	32.434	24.992	16.225	9.700
Mar	39.297	36.250	33.571	31.114	28.604	24.344	21.237	16.740	11.402	7.416
Apr	15.537	15.504	15.384	15.136	14.650	13.757	12.261	10.054	7.393	5.391
May	13.261	13.245	13.151	12.951	12.548	11.792	10.495	8.544	6.153	4.340
Jun	12.057	12.048	11.964	11.784	11.418	10.720	9.512	7.673	5.400	3.670
Jul	10.316	10.316	10.251	10.106	9.803	9.210	8.159	6.523	4.464	2.883
Aug	9.099	9.091	9.023	8.876	8.578	8.011	7.028	5.532	3.683	2.275
Sep	8.652	8.640	8.570	8.420	8.118	7.553	6.583	5.123	3.334	1.978

Reserve flows without High Flows

Oct	8.619	8.598	8.520	8.359	8.043	7.464	6.493	5.060	3.333	2.034
Nov	10.087	10.052	9.955	9.759	9.383	8.709	7.604	6.003	4.104	2.685
Dec	11.429	11.384	11.274	11.053	10.636	9.895	8.693	6.968	4.936	3.423
Jan	13.610	13.543	13.405	13.136	12.636	11.768	10.386	8.438	6.175	4.502
Feb	18.095	18.030	17.871	17.551	16.946	15.873	14.129	11.628	8.682	6.490
Mar	16.592	16.542	16.403	16.122	15.583	14.618	13.034	10.740	8.019	5.986
Apr	15.537	15.504	15.384	15.136	14.650	13.757	12.261	10.054	7.393	5.391
May	13.261	13.245	13.151	12.951	12.548	11.792	10.495	8.544	6.153	4.340
Jun	12.057	12.048	11.964	11.784	11.418	10.720	9.512	7.673	5.400	3.670
Jul	10.316	10.316	10.251	10.106	9.803	9.210	8.159	6.523	4.464	2.883
Aug	9.099	9.091	9.023	8.876	8.578	8.011	7.028	5.532	3.683	2.275
Sep	8.652	8.640	8.570	8.420	8.118	7.553	6.583	5.123	3.334	1.978

Natural Duration curves

Oct	22.050	17.992	14.147	13.068	11.667	9.950	9.506	8.617	7.788	6.709
Nov	41.597	35.799	29.398	25.204	21.508	18.646	17.365	15.984	12.068	10.255
Dec	83.318	56.720	43.533	38.937	31.112	28.726	25.646	22.450	17.346	12.056
Jan	131.414	78.091	60.040	53.080	44.011	37.321	31.373	27.718	25.239	16.532
Feb	174.115	124.921	77.005	54.741	46.631	41.803	35.615	31.105	26.066	22.264
Mar	135.189	68.679	60.667	51.934	41.144	34.155	30.048	26.493	22.133	17.749
Apr	60.035	46.481	40.394	33.962	30.262	27.427	24.441	23.376	17.998	14.016
May	30.907	26.202	23.171	21.980	20.527	18.993	17.671	16.543	13.366	10.282
Jun	22.994	19.796	17.523	16.991	15.999	15.085	14.005	12.809	10.737	9.487
Jul	19.194	15.797	14.277	13.292	12.911	12.186	11.268	10.413	9.185	7.874
Aug	15.853	13.504	11.634	10.962	10.652	10.279	9.521	8.987	7.878	6.937
Sep	15.123	12.203	11.269	10.019	9.525	9.163	8.584	8.052	7.014	6.223

Table G13 EWR 6 assurance rules for AEC:D

Desktop Version 2, Printed on 2008/07/18

Summary of IFR rule curves for: CE6 Natural Flows

Determination based on defined BBM Table with site specific assurance rules.

Regional Type: E. Escarp AEC = D

Data are given in m³/s mean monthly flow

Month	% Points									
	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	3.344	3.339	3.322	3.287	3.218	3.091	2.878	2.564	2.185	1.900
Nov	5.942	5.926	5.884	5.797	5.632	5.335	4.849	4.144	3.309	2.684
Dec	5.332	5.312	5.269	5.180	5.015	4.744	4.356	3.897	3.481	3.252
Jan	18.662	16.440	14.588	12.930	10.285	9.092	7.667	6.304	5.327	4.888
Feb	37.142	31.988	27.682	23.870	17.916	15.499	12.743	10.194	8.397	7.582
Mar	11.213	10.746	10.295	9.789	8.967	8.281	7.461	6.676	6.114	5.862
Apr	8.491	8.460	8.391	8.249	7.987	7.554	6.937	6.206	5.543	5.180
May	7.368	7.363	7.329	7.258	7.114	6.845	6.383	5.687	4.835	4.189
Jun	6.187	6.184	6.158	6.100	5.984	5.762	5.377	4.792	4.069	3.518
Jul	4.814	4.814	4.796	4.755	4.671	4.505	4.212	3.755	3.180	2.738
Aug	3.759	3.757	3.741	3.706	3.635	3.500	3.267	2.911	2.472	2.137
Sep	3.235	3.232	3.217	3.186	3.123	3.005	2.802	2.497	2.122	1.839

Reserve flows without High Flows

Oct	3.344	3.339	3.322	3.287	3.218	3.091	2.878	2.564	2.185	1.900
Nov	4.480	4.471	4.446	4.394	4.296	4.120	3.831	3.413	2.916	2.545
Dec	5.332	5.312	5.269	5.180	5.015	4.744	4.356	3.897	3.481	3.252
Jan	6.685	6.645	6.559	6.393	6.113	5.713	5.234	4.776	4.448	4.301
Feb	9.670	9.593	9.438	9.163	8.731	8.147	7.481	6.865	6.430	6.233
Mar	8.939	8.886	8.770	8.548	8.175	7.639	6.999	6.386	5.947	5.751
Apr	8.491	8.460	8.391	8.249	7.987	7.554	6.937	6.206	5.543	5.180
May	7.368	7.363	7.329	7.258	7.114	6.845	6.383	5.687	4.835	4.189
Jun	6.187	6.184	6.158	6.100	5.984	5.762	5.377	4.792	4.069	3.518
Jul	4.814	4.814	4.796	4.755	4.671	4.505	4.212	3.755	3.180	2.738
Aug	3.759	3.757	3.741	3.706	3.635	3.500	3.267	2.911	2.472	2.137
Sep	3.235	3.232	3.217	3.186	3.123	3.005	2.802	2.497	2.122	1.839

Natural Duration curves

Oct	22.050	17.992	14.147	13.068	11.667	9.950	9.506	8.617	7.788	6.709
Nov	41.597	35.799	29.398	25.204	21.508	18.646	17.365	15.984	12.068	10.255
Dec	83.318	56.720	43.533	38.937	31.112	28.726	25.646	22.450	17.346	12.056
Jan	131.414	78.091	60.040	53.080	44.011	37.321	31.373	27.718	25.239	16.532
Feb	174.115	124.921	77.005	54.741	46.631	41.803	35.615	31.105	26.066	22.264
Mar	135.189	68.679	60.667	51.934	41.144	34.155	30.048	26.493	22.133	17.749
Apr	60.035	46.481	40.394	33.962	30.262	27.427	24.441	23.376	17.998	14.016
May	30.907	26.202	23.171	21.980	20.527	18.993	17.671	16.543	13.366	10.282
Jun	22.994	19.796	17.523	16.991	15.999	15.085	14.005	12.809	10.737	9.487
Jul	19.194	15.797	14.277	13.292	12.911	12.186	11.268	10.413	9.185	7.874
Aug	15.853	13.504	11.634	10.962	10.652	10.279	9.521	8.987	7.878	6.937
Sep	15.123	12.203	11.269	10.019	9.525	9.163	8.584	8.052	7.014	6.223

**APPENDIX H: SUPPORTING INFORMATION FOR THE DETERMINATION OF STRESS
INDICES AND EWR SCENARIOS OF EWR 7: HONEYBIRD**

H1 EWR 7: HONEYBIRD (KAAP RIVER) - DETERMINATION OF STRESS INDICES

Appendix H provides supporting information for the determination of stress indices of EWR 7 Kaap (Chapter 15 and 16 of the Main Report).

H1.1 FISH INDICATOR SPECIES

Small rheophilic (SR) guild: *Chiloglanis pretoriae* (CPRE) and *Opsaridium peringueyi* (OPER) are the best indicators for setting flows. These species all require flowing water over substrates during all life stages, with some stages also preferring some overhanging vegetation as cover.

Large semi-rheophilic (LSR) guild: The large semi-rheophilic species (especially *Labeobarbus marequensis* (BMAR), *Labeo cylindricus* (LCYL), and *Labeo molybdinus* (LMOL)) are another important indicator guild present at this EWR site. They also require overhanging vegetation as nursery habitats.

The habitat requirements for the different life stages of the SR indicator fish species (CPRE and OPER) are summarised in Appendix C, Table C1 and Appendix E, Table E1 respectively. The habitat requirements for the LR guild are summarized in Appendix E, Table E2.

H1.2 FISH STRESS INDEX

The abundance of fish velocity-depth classes are provided in Table H1.

Table H1 EWR 7: Habitat suitability for the SR and LSR guild

SR AND LSR GUILD								
Depth classes	Discharges (m ³ /s)							
	0.086	0.431	0.799	1.154	1.371	2.211	2.564	5.016
Slow (<0.3 m/s) Very Shallow (<0.1 m) (SVS)	6	6	6	8	8	8	8	8
Slow (<0.3 m/s) Shallow (0.1 – 0.3 m) (SS)	4	4	6	6	6	8	8	8
Slow (<0.3 m/s) Deep (> 0.5 m) (SD)	10	10	10	10	10	10	10	8
Slow Shallow and Slow Deep	4	4	6	6	6	8	8	8
Fast (>0.3 m/s) Very Shallow (<0.1 m) (FVS)	6	6	4	4	6	6	6	6
Fast (>0.3 m/s) Shallow (0.1 – 0.3 m) (FS)	4	4	4	4	4	4	4	4
Fast (>0.3 m/s) Intermediate (0.2 – 0.3) (FI)	6	6	4	6	6	6	6	6
Fast (>0.3 m/s) Deep (> 0.3 m) (FD)	10	10	8	6	6	6	6	4
FAST TOTAL >0.1 m DEEP	6	6	4	4	4	4	4	4

The fish stress index is provided in Table H2.

Table H2 Fish stress index

Habitat	Discharges (m ³ /s)							
	0.086	0.431	0.799	1.154	1.371	2.211	2.564	5.016
SMALL RHEOPHILIC (SR) GUILD								
Spawning and Nursery habitat	1	2	3	3.5	4	4.5	5	5
Abundance	1	2	3	3.5	4	4.5	5	5
Cover	1	2.5	3	3	3.5	4	4.5	5
Connectivity (lateral & longitudinal)	0.5	2	2.5	2.5	3	3.5	4	5
Water Quality (esp. oxygen and temperature)	1	3	3.5	3.5	4	4.5	5	5
Species stress: CPRE, OPER	8	5	4	4	3	2	1	0
LARGE SEMI-RHEOPHILIC (LSR) GUILD								
Spawning and Nursery habitat	0.5	2	2.5	3	3.5	4	4.5	5
Abundance	0.5	2.5	2.5	3	3.5	4	4.5	5
Cover	0.5	2	2.5	2.5	3	4	5	5
Connectivity (lateral & longitudinal)	0.5	2	2.5	2.5	3	4	4.5	5
Water Quality (esp. oxygen and temperature)	0.5	3	3	3.5	4	4.5	5	5
Species stress: BMAR, LCYL, LMOL	9	6	5	4	3	2	1	0

H1.3 MACROINVERTEBRATE STRESS INDEX

The habitat flow index for flow dependent macroinvertebrate (FDI) taxa is provided in Table H3 and provides the % occurrence of various velocity and substrate classes under different flow conditions.

Table H3 Habitat suitability for FDI taxa

Habitat Flow Response Index	Habitat Response	Habitat Abundance and suitability													Flow (m ³ /s)
		VSCS ¹	SCS ²	FCS ³	VFCs ⁴	VSFS ⁵	SFS ⁶	FFS ⁷	VFFS ⁸	VSBR ⁹	SBR ¹⁰	FBR ¹¹	VFB ¹²	Veg ¹³	
0	All habitats in excess, very high quality. Very fast, very deep, very wide WP.	0	0	1	8	0	0	0	4	0	0	9	68	10	5.6
1	All plentiful, high quality. Fast, wide WP.	0	0	1	8	0	0	0	4	0	0	9	73	5	2.56
2	Critical habitats sufficient. Quality slightly reduced, fast, WP slightly reduced.	0	1	1	8	0	0	1	4	0	8	8	67	1	1.62
3	Reduced critical habitat and critical quality. Moderate velocity, fairly deep.	0	1	1	8	0	0	1	4	0	9	9	68	0	1.37
4	Critical habitats limited and of moderate quality. Moderate velocity, some deep areas. Wide WP moderately reduced.	0	1	2	7	0	0	1	4	0	9	17	60	0	0.96
5	Critical habitat very reduced, moderate/low quality. Moderate/slow velocity, few deep areas WP moderately/very reduced.	1	2	3	4	1	1	2	2	8	17	25	34	0	0.25
6	Critical habitat residual. Low quality, moderate/slow velocity.	2	3	3	1	1	2	2	1	19	28	28	9	0	0.09
7	No critical habitat, other habitats moderate quality. Slow, narrow WP.	3	4	3	1	1	2	1	0	23	31	23	8	0	0.05
8	Flowing water habitats residual and of low quality. Slow trickle, very narrow WP.	6	4	0	0	3	2	0	0	51	34	0	0	0	0.006
9		8	2	0	0	4	1	0	0	68	17	0	0	0	0.002

Habitat Flow Response Index	Habitat Response	Habitat Abundance and suitability													Flow (m ³ /s)
		VSCS ¹	SCS ²	FCS ³	VFCS ⁴	VSFS ⁵	SFS ⁶	FFS ⁷	VFFS ⁸	VSBR ⁹	SBR ¹⁰	FBR ¹¹	VFBR ¹²	Veg ¹³	
10	Standing water habitats only, very low quality, no flow.	10	0	0	0	5	0	0	0	85	0	0	0	0	-

1 Very Slow over Coarse Sediment

2 Slow over Coarse Sediment

3 Fast over Coarse Sediment

4 Very Fast over Coarse Sediment

5 Very Slow over Fine Sediment

6 Slow over Fine Sediment

7 Fast over Fine Sediment

8 Very Fast over Fine Sediment

9 Very Slow over Bedrock

10 Slow over Bedrock

11 Fast over Bedrock

12 Very Fast over Bedrock

13 Fringing vegetation

The stress index for FDI taxa is provided in Table H4 which rates the response of the species according to various biotic response metrics.

Table H4 Macroinvertebrate (FDI) stress index

Habitat characteristics					Biotic Response	Flow	Species Stress
Max depth (m)	Ave depth (m)	Max vel (m/s)	Ave vel (m/s)	WP (m)			
0.7	0.3	3.85	1.86	11.6	All indicator taxa very abundant and healthy.	1.37	0
0.58	0.22	2.78	1.35	9.7	90% indicator taxa persist.	0.96	1
0.52	0.21	2.4	1.13	7.9	Most indicator taxa persist, but slight (80%) reduction.		2
0.5	0.2	2.29	1.06	7.4	Most indicator taxa persist, but abundances reduced.	0.25	3
0.46	0.17	2.04	0.92	6.7	All life stages viable in limited areas, critical life stages of some sensitive indicator taxa at risk.	0.09	4
0.34	0.16	1.48	0.52	3.4	Critical life-stages of sensitive indicator taxa at risk or non-viable.		5
0.26	0.14	0.97	0.3	2.4	Sensitive indicator taxa rare, critical stages of sensitive indicator taxa non-viable and at risk for some less sensitive taxa.		6
0.22	0.12	0.78	0.24	1.9	Some indicator taxa persist, but most disappear. All life-stages of sensitive indicator taxa at risk or non-viable.	0.05	7
0.12	0.05	0.32	0.09	1.4	Some indicator taxa persist, but at very low numbers. All life stages of most indicator taxa at risk or non-viable.	0.006	8
0.1	0.03	0.21	0.06	1.3	Indicator taxa no longer present.	0.002	9
0.02	0.01	0.09	0.03	0.1		0.00	10

H1.4 RIPARIAN VEGETATION STRESS INDEX

Table H5 Riparian vegetation stress index for indicator species

Biotic response		
Species Stress	Flow (m ³ /s)	<i>Phragmites mauritanus</i>
0	1.4	Adults with full vigour and at maximum reproductive capacity. 50% population inundated, upper limit rooting depth at 28 cm.
1		
2		
3	0.29	Leaf wilting/stress commences, but is slight. Up to 43 cm rooting depth for upper limit, lower limit is at water level on average.
4		Flower/fruit abortion commences.
5		Leaves wilting obvious or vegetative parts begin unseasonal discolouration. Flower/fruit abortion

Biotic response		
Species Stress	Flow (m ³ /s)	<i>Phragmites mauritianus</i>
		widespread.
6	0.001	Unseasonal thinning or partial mortality of above-ground parts (majority of the plant/s remains viable, but water stressed). Up to 75 cm rooting depth for sufficient soil moisture, no inundation at lower limit. Rhizomes at upper limits may begin thinning.
7		
8		Unseasonal loss or mortality of above-ground parts (only minor portions of plants remain viable). Rootstocks/rhizomes of some species remain viable.
9	0	Complete mortality of small proportion of the population.
10		Widespread and complete mortality of population.

H2 EWR 7: HONEYBIRD (KAAP RIVER) - DETERMINATION OF EWR SCENARIOS

H2.1 LOW FLOW REQUIREMENTS IN TERMS OF STRESS FOR FISH

The fish low flow requirements for the EWR scenarios are summarised in Table H6 for the SR guild and Table H7 for LSR guild.

Table H6 Low flow requirements: SR guild

GENERAL					
INDICATOR: The small rheophilic species at the site are the best indicators for setting flows (CPRE, and OPER). These species all requires flowing water over substrates during all life stages, with some stages also preferring some overhanging vegetation as cover. Optimal conditions for spawning of this guild consist of FD, FI, FS and SS with good quality substrate (clean cobbles and gravel), while the margins of the FS and SS are important for egg development and nursery areas for larvae, often with overhanging vegetation as cover. Juvenile and adult stages of this guild have a high preference for FS, FI and FD over substrates. Flows should furthermore remain adequate to allow migration between reaches, thus depth in riffle and rapids should remain adequate, especially during the wet season.					
PES: FISH EC C (ECOSTATUS C)					
Dry Season maintenance This fish stress level will maintain adequate FS and some FI and FD to support refuge habitats for the small rheophilic species at the site during dry period. (Flow must be maintained at all times).					
Dry Season drought This is the maximum fish stress level allowed where some FS and very limited FI will be maintained. FD will be lost at this stress level, but limited FI and FS habitats will support small population that should be able to recover after drought.					
Wet Season maintenance This fish stress level will maintain adequate FD, FI and FS to allow successful breeding and habitats for all life stages. Due to the high stress conditions during dry period it is eminent to maintain adequate conditions during the wet season to ensure the survival of this indicator guild at this site.					
Wet Season drought This is the maximum fish stress level where this group will still be able to spawn and breed successfully and ensure adequate maintenance of this fish guild in this river section.					
BUILDING BLOCK	SEASON	STRESS DURATION	SPP STRESS	INTEG STRESS	FLOW (m ³ /s)
Drought	Dry	5%	8	9	0.086
Maintenance	Dry	35%	5.5	6.5	0.373
Drought	Wet	5%	4.5	5	0.615
Maintenance	Wet	35%	3	3	1.37
REC: FISH EC B (ECOSTATUS B)					
General Improved hydrological regime (closer to natural) which maintains perennial status, increase low flows and less impact on moderate flows may result in improved FROC on a variety of species, including species with requirement for FS and FD habitats and that are intolerant to no flow conditions (OPER, CPAR and BMAR).					
Dry Season maintenance This is the fish stress level where FD habitats decrease visibly from those observed under reference dry period conditions, and should therefore reflect conditions for this guild within a B EC.					
Wet Season maintenance High abundance of FD, FI and FS will be available at this fish stress level to provide excellent habitat for this fish guild to complete all their life stages successfully. Abundance will however be lower than under natural (category A) conditions and it can therefore be expected that the EC will remain within a B EC at this stress level.					
BUILDING BLOCK	SEASON	STRESS DURATION	SPP STRESS	INTEG STRESS	FLOW (m ³ /s)

Maintenance	Dry	35%	4	4	0.8
Maintenance	Wet	35%	1.5	1.5	2.23
AEC: FISH EC D (ECOSTATUSD)					
General Altered hydrological regime, with much less flows (lower base flows) will lead to reduced riffle / rapid / run habitats, with reduced FROC of species with preference for FD, FS habitats (BEUT, BMAR, CPAR, CPRE, CSWIE, LCYL, LMOL, MACU and OPER). This may even lead to total loss of OPER from this section. Less floods and riffles becoming sandier will negatively impact some species with high preference for substrate of good quality (esp. BEUT, and CPRE). Degradation of overhanging vegetation will also result in decrease in FROC of species with a preference for this cover type, namely BTRI, BUNI, BVIV and PPHI).					
Dry Season maintenance This fish stress level will maintain some FS while FI and FD may be lost which may be reflected by a critical decrease in abundance, resulting in decreased FROC and therefore reduced EC.					
Wet Season maintenance At this fish stress level especially FS habitats will be reduced, with some FD and FI still available. It can be expected that this change in habitats (from present conditions) will result in decreased FROC of this fish guild with a resultant decrease in EC.					
BUILDING BLOCK	SEASON	STRESS DURATION	SPP STRESS	INTEG STRESS	FLOW (m ³ /s)
Maintenance	Dry	35%	7	8.2	1.178
Maintenance	Wet	35%	4	4	0.8

Table H7 Low flow requirements: LSR guild

GENERAL					
INDICATOR: The large semi-rheophilic species (especially BMAR, LCYL, and LMOL) are another important indicator guild present at this EWR site. This species utilises most habitats (SD, SS, FD, FI and FS) with substrate and water column as preferred cover. They also require overhanging vegetation as nursery habitats. Flows should furthermore remain adequate to allow migration between reaches, thus depth in riffle and rapids should remain adequate, especially during the wet season.					
PES: FISH EC C (ECOSTATUS C)					
Dry Season maintenance Although this indicator species/guild can survive without flow, at this stress level some fast habitats will be maintained to ensure adequate water quality and habitat to maintain viable populations during the dry season within a category C.					
Dry Season drought This reflects the maximum stress level allowed where some FS will be maintained to ensure maintenance of acceptable water quality (enough oxygen and limited temperature fluctuations) and allow adequate recovery after the stressed period.					
Wet Season maintenance This fish stress level will maintain adequate FD, FI and FS to allow successful breeding and habitats for all life stages. Due to the high stress conditions during dry period it is eminent to maintain adequate conditions during the wet season to ensure the survival of this indicator guild at this site.					
Wet Season Drought: This stress level will maintain adequate habitat to at least allow some spawning to take place. Although abundance and cover will be reduced an adequate population will be maintained to allow recovery and maintenance of this group.					
BUILDING BLOCK	SEASON	STRESS DURATION	SPP STRESS	INTEG STRESS	FLOW (m ³ /s)
Drought	Dry	5%	9	9	0.086
Maintenance	Dry	35%	6.5	6.5	0.373
Drought	Wet	5%	4.5	4.5	0.708
Maintenance	Wet	35%	3	3	1.37
REC: FISH EC B (ECOSTATUS B)					
General Improved hydrological regime (closer to natural) which maintains perennial status, increase low flows and have less					

impact on moderate flows may result in improved FROC on a variety of species, including species with requirement for FS and FD habitats and that are intolerant to no flow conditions (OPER, CPAR and BMAR). This may also lead to the more tolerant species utilising this section optimally, with their FROC returning close to natural state (BTRI, BUNI, and BVIV).

Dry Season maintenance

At this fish stress level the fast habitats will decrease significantly from reference conditions and a decrease in abundance of habitat will be reflected by decreased abundance and FROC of this species with a resultant lower than reference composition of this guild, falling within a category B.

Wet Season maintenance

High abundance of FD, FI and FS will be available to provide excellent habitat for this fish guild to complete all their life stages successfully. Abundance will however be lower than under natural (category A) conditions and it can therefore be expected that the EC will remain within a B EC at this stress level.

BUILDING BLOCK	SEASON	STRESS DURATION	SPP STRESS	INTEG STRESS	FLOW (m ³ /s)
Maintenance	Dry	35%	4.2	4.2	0.763
Maintenance	Wet	35%	2	2	1.9

AEC: FISH EC D (ECOSTATUS D)

General

Altered hydrological regime, with much less flows (lower base flows) will lead to reduced riffle / rapid / run habitats, with reduced FROC of species with preference for FD, FS habitats (BEUT, BMAR, CPAR, CPRE, CSWIE, LCYL, LMOL, MACU and OPER). This may even lead to total loss of OPER from this section. Less floods and riffles becoming sandier will negatively impact some species with high preference for substrate of good quality (esp. BEUT, CPRE). Degradation of overhanging vegetation will also result in decrease in FROC of species with a preference for this cover type, namely BTRI, BUNI, BVIV and PPHI).

Dry Season maintenance

At this stress level no FD habitats will be available but some FI and FS will be maintained to ensure some preferred habitats for the juvenile and adult stages of this species. Water quality should also be maintained although lower than present. Decreased abundance will occur and overall decreased FROC will result in decreased EC.

Wet Season maintenance

At this flow especially FS habitats will be reduced from present, with some FD and FI still available. It can be expected that this change in habitats (from present conditions) will result in decreased FROC of this fish guild with a resultant decrease in EC.

BUILDING BLOCK	SEASON	STRESS DURATION	SPP STRESS	INTEG STRESS	FLOW (m ³ /s)
Maintenance	Dry	35%	8.5	8	0.144
Maintenance	Wet	35%	4	4	0.8

H2.2 LOW FLOW REQUIREMENTS IN TERMS OF STRESS FOR MACROINVERTEBRATES

The FDI low flow requirements are summarised in Table H8 below.

Table H8 Low flow requirements: FDI taxa

GENERAL
INDICATOR: Stonefly family: Perlidae preferring velocities > 0.6 m/s. Mayfly family: Heptageniidae preferring velocities between 0.3 and 0.6 m/s. Beetle family: Elmidae also preferring velocities between 0.3 and 0.6 m/s. Beetle family: Psephenidae requiring velocities of > 0.6 m/s, but may persist at lower velocities (> 0.1 m/s).
PES and REC: MACROINVERTEBRATE EC: B (ECOSTATUS B)
Dry Season maintenance Suitable habitat (> 0.3 m/s over coarse substrate) is required to ensure that all the selected taxa can overwinter without significant detrimental impacts on the overall population. The average velocity of 0.52 m/s (macroinvertebrate stress of 3) will ensure that this takes place. At this flow there are 7% FCS, VFCS and 59% FBR, VFBR available.

Dry Season drought

Suitable habitat (> 0.1 m/s over coarse substrate, with at least some areas where the flow reaches velocities > 0.3 m/s) is required to ensure that a core of the selected taxa is able to survive a drought. The maximum velocity of 0.78 m/s (macroinvertebrate stress of 7) will ensure that this takes place. At this flow there are 4% FCS, VFCS and 31% FBR, VFBR available.

Wet Season maintenance

During the wet season optimal habitats (> 0.6 m/s over coarse substrate) is required to ensure that a healthy population occurs during the summer. The average velocity of approximately 0.75 m/s (macroinvertebrate stress of 2) ensures that this takes place. At this flow there are 8% FCS, VFCS and 68% FBR, VFBR available.

Wet Season drought

During the wet season optimal habitats (> 0.3 m/s over coarse substrate) is required to ensure that a healthy population occurs during the summer. The maximum velocity of approximately 0.85 m/s (macroinvertebrate stress of 5) ensures that this takes place. At this flow there are 4% FCS, VFCS and 31% FBR, VFBR available.

BUILDING BLOCK	SEASON	STRESS DURATION	SPP STRESS	INTEG STRESS	FLOW (m ³ /s)
Drought	Dry	5%	7	9.5	0.044
Maintenance	Dry	35%	3	7.5	0.258
Drought	Wet	5%	5	9	0.086
Maintenance	Wet	35%	2	5.1	0.577

AEC: MACROINVERTEBRATE EC C (ECOSTATUS D)**Dry Season maintenance**

Suitable habitat (> 0.3 m/s over coarse substrate) is required to ensure that all the selected taxa can overwinter without significant detrimental impacts on the overall population. The average velocity of approximately 0.27 m/s (macroinvertebrate stress of 5) will ensure that this takes place. At this flow there are 4% FCS, VFCS and 31% FBR, VFBR available.

Wet Season maintenance

During the wet season optimal habitats (> 0.6 m/s over coarse substrate) is required to ensure that a healthy population occurs during the summer. The maximum velocity of 1.48 m/s (macroinvertebrate stress of 3) ensures that this takes place. At this flow there are 7% FCS, VFCS and 59% FBR, VFBR available.

BUILDING BLOCK	SEASON	STRESS DURATION	SPP STRESS	INTEG STRESS	FLOW (m ³ /s)
Maintenance	Dry	35%	5	9	0.086
Maintenance	Wet	35%	3	7.5	0.258

H2.3 LOW FLOW REQUIREMENTS IN TERMS OF RIPARIAN VEGETATION

The low flow requirements for riparian vegetation indicator species are summarised in Table H9.

Table H9 Low flow requirements: Riparian vegetation species

GENERAL
INDICATOR: <i>Phragmites mauritianus</i>
PES: RIPARIAN VEGETATION EC: C/D (ECOSTATUS C)
Dry Season maintenance At a stress of 4, leaf wilting/stress commences. <i>P. mauritianus</i> requires up to 30 – 40 cm rooting depth for the upper limit, and the lower limit is at water level on average. It is not expected that a species stress of 4 is surpassed when dry season maintenance occurs. Dry Season drought Riparian stress increases to a level of 6. Unseasonal loss or mortality of above-ground parts (only minor portions of plants remain viable) and the rhizomes remain largely viable. Wet Season maintenance At a species stress of 3, the upper portions of the <i>P. mauritianus</i> population start water stress (slight leaf wilting). Wet Season drought

At a species stress of 5, leaf wilting is obvious or vegetative parts begin unseasonal discolouration. Flower/fruit abortion is widespread with 20 – 40 cm rooting depth for sufficient soil moisture and no inundation occurs.

BUILDING BLOCK	SEASON	STRESS DURATION	SPP STRESS	INTEG STRESS	FLOW (m ³ /s)
Drought	Dry	5%	6	10	0.001
Maintenance	Dry	35%	4	8.5	0.144
Drought	Wet	5%	5	9	0.086
Maintenance	Wet	35%	3	7.5	0.258

REC: RIPARIAN VEGETATION EC: B/C (ECOSTATUS B)

Dry Season maintenance

At a species stress of 3, the upper portions of the *P. mauritanus* population start water stress (slight leaf wilting).

Wet Season maintenance

With a species stress of 2, the population is under very little stress.

BUILDING BLOCK	SEASON	STRESS DURATION	SPP STRESS	INTEG STRESS	FLOW (m ³ /s)
Maintenance	Dry	35%	3	7.5	0.258
Maintenance	Wet	35%	2	5	0.615

AEC: RIPARIAN VEGETATION EC: D (ECOSTATUS D)

Dry Season maintenance

At a species stress of 5, leaf wilting is obvious or vegetative parts begin unseasonal discolouration. Flower/fruit abortion is widespread with 20 – 40 cm rooting depth for sufficient soil moisture and no inundation occurs.

Wet Season maintenance

Species stress will increase to 4, where flower/fruit abortion commences, as a result of wet season base flow reductions.

BUILDING BLOCK	SEASON	STRESS DURATION	SPP STRESS	INTEG STRESS	FLOW (m ³ /s)
Maintenance	Dry	35%	5	9	0.086
Maintenance	Wet	35%	4	8.5	0.144

H2.4 INSTREAM FLOOD FUNCTIONS

Table H10 Functions for each Flood Class

Flood Class	Component	Function/Motivation
Class: I Range (m ³ /s): 5 - 8 Daily average: 5 Duration: 3	Fish	Class I floods are very important floods for fish and serves as migration cues and to maintain adequate longitudinal connectivity for migration. These floods will also flush fines and algae from substrates to ensure adequate conditions in substrates, a very important habitat for spawning of many of the species. It should furthermore inundate some vegetation for species spawning in flooded marginal vegetation and contributes to the creation of acceptable nursery areas. Some resetting of water quality will also take place, and the changes in water quality may also serve as stimulus to cue migratory activity and even gonad development. The frequency, extent and duration as recommended for the PES and AEC should be adequate to provide the functions as required to maintain the fish within the specific category.
	Macroinvertebrates	These freshets are recommended to scour substrate, flush organic flocculant, reach or inundate marginal vegetation and mobilise fines (1 - 2 mm sands) in order to improve biotope suitability, as well as to improve water quality. Four of these per year (Nov, Dec, Jan and Mar/Apr), are recommended for a macroinvertebrate Category B, and three (Nov, Dec, Mar/Apr) for a Category C.
Class: II Range (m ³ /s): 8 – 12 (8) Daily average: 8 Duration: 3	Fish	Class II floods are similar in importance as Class I floods and have the same functionality as Class I floods. Their occurrence at lower frequency makes them only slightly less important for the fish assemblages than Class I.
	Macroinvertebrates	These freshets are recommended to clear fines, scour substrate and inundate marginal vegetation in order to create additional biotope, as well as to reset water quality. Two of these per year are recommended for macroinvertebrate Category

Flood Class	Component	Function/Motivation
		B and C in the middle of the wet Season.
Class: III Range (m ³ /s): 17 Daily average: 20 Duration: 4	Fish	Class III floods also provide similar functions as Class I, but due to its lower frequency it is not essential for the flood functions required by the indigenous fish species. These floods, and especially their receding limbs will however be utilised by many of the fish species for migration and even spawning if takes place within the summer season.
Class: IV Range (m ³ /s): 25 – 80 (34)	Fish	Class IV floods also provide similar functions as Class I, but due to its lower frequency it is not essential for the flood functions required by the indigenous fish species. These floods, and especially their receding limbs will however be utilised by many of the fish species for migration and even spawning if takes place within the summer season.
Class: V Range (m ³ /s): >130	Fish	Class V floods also provide similar functions as Class I, but due to its lower frequency it is not essential for the flood functions required by the indigenous fish species. These floods, and especially their receding limbs will however be utilised by many of the fish species for migration and even spawning if takes place within the summer season.

H2.5 EWR RULE TABLES

EWR rule tables which provide the recommended EWR flows as a duration table, showing flows which should be provided when linked to a natural trigger (natural modelled hydrology in this case) are provided for the different EWR scenarios. EWR rules are supplied for total flows as well as for low flows only.

Table H11 EWR 7 assurance rules for PES: C

Desktop Version 2, Printed on 2008/07/18

Summary of IFR rule curves for: CE7 Natural Flows

Determination based on defined BBM Table with site specific assurance rules.

Regional Type: E. Escarp PES = C

Data are given in m³/s mean monthly flow

Month	% Points									
	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	0.521	0.520	0.515	0.504	0.484	0.447	0.385	0.294	0.184	0.101
Nov	1.126	1.122	1.110	1.087	1.043	0.963	0.833	0.644	0.420	0.252
Dec	1.371	1.365	1.352	1.324	1.272	1.180	1.030	0.816	0.563	0.374
Jan	2.754	2.553	2.375	2.207	2.032	1.736	1.509	1.189	0.818	0.543
Feb	5.665	5.139	4.683	4.275	3.874	3.201	2.772	2.158	1.434	0.895
Mar	2.243	2.163	2.087	2.005	1.903	1.726	1.533	1.253	0.920	0.672
Apr	1.591	1.588	1.576	1.551	1.503	1.415	1.266	1.048	0.784	0.586
May	1.382	1.380	1.371	1.351	1.311	1.235	1.106	0.912	0.674	0.493
Jun	1.259	1.258	1.250	1.232	1.196	1.127	1.008	0.827	0.603	0.432
Jul	0.991	0.991	0.985	0.972	0.945	0.891	0.796	0.648	0.461	0.318
Aug	0.705	0.704	0.699	0.688	0.664	0.620	0.544	0.427	0.284	0.174
Sep	0.510	0.509	0.504	0.495	0.475	0.439	0.377	0.283	0.168	0.081

Reserve flows without High Flows

Oct	0.521	0.520	0.515	0.504	0.484	0.447	0.385	0.294	0.184	0.101
Nov	0.768	0.765	0.758	0.743	0.715	0.665	0.582	0.462	0.320	0.214
Dec	1.025	1.021	1.011	0.992	0.957	0.893	0.790	0.642	0.467	0.337
Jan	1.288	1.282	1.269	1.245	1.199	1.119	0.992	0.813	0.605	0.451
Feb	1.736	1.730	1.715	1.685	1.628	1.528	1.364	1.129	0.853	0.648
Mar	1.679	1.674	1.660	1.633	1.580	1.485	1.329	1.104	0.836	0.637
Apr	1.591	1.588	1.576	1.551	1.503	1.415	1.266	1.048	0.784	0.586
May	1.382	1.380	1.371	1.351	1.311	1.235	1.106	0.912	0.674	0.493
Jun	1.259	1.258	1.250	1.232	1.196	1.127	1.008	0.827	0.603	0.432
Jul	0.991	0.991	0.985	0.972	0.945	0.891	0.796	0.648	0.461	0.318
Aug	0.705	0.704	0.699	0.688	0.664	0.620	0.544	0.427	0.284	0.174
Sep	0.510	0.509	0.504	0.495	0.475	0.439	0.377	0.283	0.168	0.081

Natural Duration curves

Oct	4.238	3.498	2.908	2.531	2.281	2.035	1.885	1.755	1.591	1.269
Nov	8.704	7.141	6.130	5.077	4.209	3.777	3.299	2.739	2.234	1.725
Dec	12.918	9.745	7.908	6.388	5.798	5.178	4.488	3.592	3.185	1.915
Jan	14.374	10.831	9.300	8.165	6.821	6.093	5.220	4.898	4.133	2.740
Feb	24.053	14.645	9.487	8.366	7.130	6.225	5.605	5.084	3.840	2.980
Mar	18.179	11.324	8.778	7.295	6.467	5.884	4.869	4.435	3.756	2.841
Apr	10.197	7.442	6.555	6.088	5.498	4.842	4.255	3.885	3.407	2.589
May	5.970	5.108	4.592	4.275	4.152	3.678	3.375	3.024	2.677	1.997
Jun	4.776	4.124	3.796	3.603	3.434	3.187	2.901	2.604	2.296	1.744
Jul	3.931	3.431	3.140	2.905	2.763	2.614	2.490	2.154	1.912	1.464
Aug	3.345	2.867	2.591	2.460	2.326	2.214	2.046	1.863	1.699	1.314
Sep	3.160	2.662	2.373	2.234	2.049	1.910	1.829	1.667	1.528	1.285

Table H12 EWR 7 assurance rules for REC: B

Desktop Version 2, Printed on 2008/07/18

Summary of IFR rule curves for: CE7 Natural Flows

Determination based on defined BBM Table with site specific assurance rules.

Regional Type: E. Escarp REC = B

Data are given in m³/s mean monthly flow

Month	% Points									
	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	1.095	1.092	1.081	1.057	1.010	0.923	0.779	0.566	0.309	0.115
Nov	1.765	1.758	1.738	1.699	1.623	1.486	1.263	0.939	0.555	0.268
Dec	2.589	2.577	2.547	2.489	2.377	2.179	1.858	1.397	0.854	0.450
Jan	5.576	5.103	4.687	4.302	3.905	3.239	2.754	2.070	1.276	0.688
Feb	7.406	6.778	6.227	5.721	5.206	4.335	3.709	2.811	1.753	0.966
Mar	3.194	3.110	3.021	2.915	2.766	2.505	2.173	1.692	1.122	0.696
Apr	2.527	2.521	2.498	2.451	2.359	2.190	1.908	1.491	0.988	0.610
May	2.236	2.233	2.215	2.177	2.099	1.953	1.703	1.326	0.865	0.515
Jun	2.087	2.085	2.069	2.034	1.962	1.827	1.591	1.233	0.790	0.453
Jul	1.718	1.718	1.706	1.679	1.622	1.512	1.317	1.013	0.631	0.337
Aug	1.340	1.339	1.327	1.303	1.252	1.157	0.991	0.739	0.428	0.191
Sep	1.094	1.092	1.082	1.059	1.014	0.930	0.785	0.566	0.299	0.096

Reserve flows without High Flows

Oct	1.095	1.092	1.081	1.057	1.010	0.923	0.779	0.566	0.309	0.115
Nov	1.437	1.431	1.415	1.384	1.322	1.212	1.032	0.771	0.462	0.231
Dec	1.763	1.755	1.736	1.697	1.624	1.494	1.282	0.979	0.622	0.356
Jan	2.112	2.100	2.075	2.027	1.937	1.780	1.531	1.180	0.773	0.471
Feb	2.749	2.737	2.709	2.652	2.543	2.351	2.039	1.592	1.065	0.673
Mar	2.630	2.620	2.594	2.542	2.442	2.263	1.969	1.543	1.038	0.660
Apr	2.527	2.521	2.498	2.451	2.359	2.190	1.908	1.491	0.988	0.610
May	2.236	2.233	2.215	2.177	2.099	1.953	1.703	1.326	0.865	0.515
Jun	2.087	2.085	2.069	2.034	1.962	1.827	1.591	1.233	0.790	0.453
Jul	1.718	1.718	1.706	1.679	1.622	1.512	1.317	1.013	0.631	0.337
Aug	1.340	1.339	1.327	1.303	1.252	1.157	0.991	0.739	0.428	0.191
Sep	1.094	1.092	1.082	1.059	1.014	0.930	0.785	0.566	0.299	0.096

Natural Duration curves

Oct	4.238	3.498	2.908	2.531	2.281	2.035	1.885	1.755	1.591	1.269
Nov	8.704	7.141	6.130	5.077	4.209	3.777	3.299	2.739	2.234	1.725
Dec	12.918	9.745	7.908	6.388	5.798	5.178	4.488	3.592	3.185	1.915
Jan	14.374	10.831	9.300	8.165	6.821	6.093	5.220	4.898	4.133	2.740
Feb	24.053	14.645	9.487	8.366	7.130	6.225	5.605	5.084	3.840	2.980
Mar	18.179	11.324	8.778	7.295	6.467	5.884	4.869	4.435	3.756	2.841
Apr	10.197	7.442	6.555	6.088	5.498	4.842	4.255	3.885	3.407	2.589
May	5.970	5.108	4.592	4.275	4.152	3.678	3.375	3.024	2.677	1.997
Jun	4.776	4.124	3.796	3.603	3.434	3.187	2.901	2.604	2.296	1.744
Jul	3.931	3.431	3.140	2.905	2.763	2.614	2.490	2.154	1.912	1.464
Aug	3.345	2.867	2.591	2.460	2.326	2.214	2.046	1.863	1.699	1.314
Sep	3.160	2.662	2.373	2.234	2.049	1.910	1.829	1.667	1.528	1.285

Table H13 EWR 7 assurance rules for AEC: D

Desktop Version 2, Printed on 2008/07/18

Summary of IFR rule curves for: CE7 Natural Flows

Determination based on defined BBM Table with site specific assurance rules.

Regional Type: E. Escarp AEC = D

Data are given in m³/s mean monthly flow

Month	% Points									
	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	0.279	0.278	0.276	0.272	0.263	0.247	0.219	0.179	0.131	0.095
Nov	0.431	0.429	0.427	0.421	0.409	0.389	0.355	0.307	0.249	0.206
Dec	1.108	1.104	1.094	1.073	1.035	0.967	0.857	0.699	0.512	0.373
Jan	2.331	2.118	1.935	1.773	1.615	1.353	1.198	0.979	0.725	0.537
Feb	4.954	4.432	3.985	3.596	3.231	2.622	2.298	1.833	1.285	0.877
Mar	1.668	1.577	1.497	1.422	1.344	1.212	1.111	0.965	0.792	0.662
Apr	0.936	0.934	0.930	0.921	0.904	0.871	0.817	0.738	0.642	0.570
May	0.808	0.807	0.804	0.796	0.782	0.754	0.706	0.634	0.546	0.479
Jun	0.732	0.732	0.728	0.722	0.708	0.682	0.637	0.568	0.483	0.418
Jul	0.568	0.568	0.566	0.561	0.550	0.529	0.492	0.435	0.363	0.307
Aug	0.393	0.392	0.390	0.385	0.375	0.356	0.324	0.274	0.213	0.166
Sep	0.271	0.270	0.268	0.264	0.255	0.239	0.210	0.167	0.115	0.075

Reserve flows without High Flows

Oct	0.279	0.278	0.276	0.272	0.263	0.247	0.219	0.179	0.131	0.095
Nov	0.431	0.429	0.427	0.421	0.409	0.389	0.355	0.307	0.249	0.206
Dec	0.588	0.587	0.583	0.576	0.562	0.538	0.499	0.442	0.376	0.327
Jan	0.752	0.750	0.745	0.736	0.718	0.688	0.641	0.574	0.496	0.438
Feb	1.021	1.019	1.014	1.003	0.983	0.946	0.888	0.803	0.704	0.630
Mar	0.992	0.990	0.985	0.975	0.956	0.922	0.867	0.786	0.691	0.620
Apr	0.936	0.934	0.930	0.921	0.904	0.871	0.817	0.738	0.642	0.570
May	0.808	0.807	0.804	0.796	0.782	0.754	0.706	0.634	0.546	0.479
Jun	0.732	0.732	0.728	0.722	0.708	0.682	0.637	0.568	0.483	0.418
Jul	0.568	0.568	0.566	0.561	0.550	0.529	0.492	0.435	0.363	0.307
Aug	0.393	0.392	0.390	0.385	0.375	0.356	0.324	0.274	0.213	0.166
Sep	0.271	0.270	0.268	0.264	0.255	0.239	0.210	0.167	0.115	0.075

Natural Duration curves

Oct	4.238	3.498	2.908	2.531	2.281	2.035	1.885	1.755	1.591	1.269
Nov	8.704	7.141	6.130	5.077	4.209	3.777	3.299	2.739	2.234	1.725
Dec	12.918	9.745	7.908	6.388	5.798	5.178	4.488	3.592	3.185	1.915
Jan	14.374	10.831	9.300	8.165	6.821	6.093	5.220	4.898	4.133	2.740
Feb	24.053	14.645	9.487	8.366	7.130	6.225	5.605	5.084	3.840	2.980
Mar	18.179	11.324	8.778	7.295	6.467	5.884	4.869	4.435	3.756	2.841
Apr	10.197	7.442	6.555	6.088	5.498	4.842	4.255	3.885	3.407	2.589
May	5.970	5.108	4.592	4.275	4.152	3.678	3.375	3.024	2.677	1.997
Jun	4.776	4.124	3.796	3.603	3.434	3.187	2.901	2.604	2.296	1.744
Jul	3.931	3.431	3.140	2.905	2.763	2.614	2.490	2.154	1.912	1.464
Aug	3.345	2.867	2.591	2.460	2.326	2.214	2.046	1.863	1.699	1.314
Sep	3.160	2.662	2.373	2.234	2.049	1.910	1.829	1.667	1.528	1.285

SABIE-SAND RIVER SYSTEM**TABLE OF CONTENTS**

REFERENCES	i
ACKNOWLEDGEMENTS	ii
LIST OF APPENDICES	iii
ABBREVIATIONS AND ACRONYMS	iv
ACKNOWLEDGEMENTS	2
ACKNOWLEDGEMENTS	106
I1 OBJECTIVES	107
I2 ECOHYDRAULIC INFORMATION FOR ENVIRONMENTAL WATER ASSESSMENT ALONG THE SABIE RIVER SYSTEM	108
I2.1 DATA COLLECTION	108
I2.2 MODELLING	109
I3 RESULTS	110
I3.1 CROSS-SECTIONAL PROFILES	110
I3.2 LOOKUP TABLES	114
I4 TWO-DIMENSIONAL HYDRAULIC MODELLING AT EWR 3 ON THE SABIE RIVER	115
I4.1 BACKGROUND	115
I4.2 APPLICATION	116
I5 CONFIDENCE IN THE HYDRAULIC CHARACTERISATIONS	119
I6 REFERENCES	120
J1 EWR 1: UPPER SABIE (SABIE RIVER) - DETERMINATION OF STRESS INDICES	123
J1.1 FISH INDICATOR SPECIES	123
J1.2 FISH STRESS INDEX	124
J1.3 MACROINVERTEBRATE STRESS INDEX	124
J1.4 RIPARIAN VEGETATION STRESS INDEX	126
J2 EWR 1: UPPER SABIE: DETERMINATION OF EWR SCENARIOS	128
J2.1 LOW FLOW REQUIREMENTS IN TERMS OF STRESS FOR FISH	128
J2.2 LOW FLOW REQUIREMENTS IN TERMS OF STRESS FOR MACROINVERTEBRATES	130
J2.3 LOW FLOW REQUIREMENTS IN TERMS OF RIPARIAN VEGETATION	131
J2.4 INSTREAM FLOOD FUNCTIONS	132
J2.5 EWR RULE TABLES	134
K1 EWR 2: AAN DE VLIET (SABIE RIVER) - DETERMINATION OF STRESS INDICES	138
K1.1 FISH INDICATOR SPECIES	138
K1.2 FISH STRESS INDEX	139
K1.3 MACROINVERTEBRATE STRESS INDEX	140
K1.4 RIPARIAN VEGETATION STRESS INDEX	141
K2 EWR 2: AAN DE VLIET (SABIE RIVER) – DETERMINATION OF EWR SCENARIOS	143
K2.1 LOW FLOW REQUIREMENTS IN TERMS OF STRESS FOR FISH	143
K2.2 LOW FLOW REQUIREMENTS IN TERMS OF STRESS FOR MACROINVERTEBRATES	145
K2.3 LOW FLOW REQUIREMENTS IN TERMS OF RIPARIAN VEGETATION	147
K2.4 INSTREAM FLOOD FUNCTIONS	148
K2.5 EWR RULE TABLES	149
L1 EWR 3: KIDNEY (SABIE RIVER) - DETERMINATION OF STRESS INDICES	153
L1.1 FISH INDICATOR SPECIES	153
L1.2 FISH STRESS INDEX	153
L1.3 MACROINVERTEBRATE STRESS INDEX	154
L1.4 RIPARIAN VEGETATION STRESS INDEX	156

L2	EWR 3: KIDNEY (SABIE RIVER) – DETERMINATION OF EWR SCENARIOS	157
L2.1	LOW FLOW REQUIREMENTS IN TERMS OF STRESS FOR FISH.....	157
L2.2	LOW FLOW REQUIREMENTS IN TERMS OF STRESS FOR MACROINVERTEBRATES	159
L2.3	LOW FLOW REQUIREMENTS IN TERMS OF RIPARIAN VEGETATION	160
L2.4	INSTREAM FLOOD FUNCTIONS.....	161
L2.5	EWR RULE TABLES	162
M1	EWR 4: MAC MAC (MAC MAC RIVER) - DETERMINATION OF STRESS INDICES..	166
M1.1	FISH INDICATOR SPECIES	166
M1.2	FISH STRESS INDEX.....	166
M1.3	MACROINVERTEBRATE STRESS INDEX.....	167
M1.4	RIPARIAN VEGETATION STRESS INDEX	168
M2	EWR 4: MAC MAC (MAC MAC RIVER) – DETERMINATION OF EWR SCENARIOS	170
M2.1	LOW FLOW REQUIREMENTS IN TERMS OF STRESS FOR FISH.....	170
M2.2	LOW FLOW REQUIREMENTS IN TERMS OF STRESS FOR MACROINVERTEBRATES	172
M2.3	LOW FLOW REQUIREMENTS IN TERMS OF RIPARIAN VEGETATION	173
M2.4	INSTREAM FLOOD FUNCTIONS.....	173
M2.5	EWR RULE TABLES	175
N1	EWR 5: MARITE (MARITE RIVER) - DETERMINATION OF STRESS INDICES.....	178
N1.1	FISH INDICATOR SPECIES	178
N1.2	FISH STRESS INDEX.....	178
N1.3	MACROINVERTEBRATE STRESS INDEX.....	179
N1.4	RIPARIAN VEGETATION STRESS INDEX	180
N2	EWR 5: MARITE (MARITE RIVER) - DETERMINATION OF EWR SCENARIOS	182
N2.1	LOW FLOW REQUIREMENTS IN TERMS OF STRESS FOR FISH.....	182
N2.2	LOW FLOW REQUIREMENTS IN TERMS OF STRESS FOR MACROINVERTEBRATES	184
N2.3	LOW FLOW REQUIREMENTS IN TERMS OF RIPARIAN VEGETATION	185
N2.4	INSTREAM FLOOD FUNCTIONS.....	186
N2.5	EWR RULE TABLES	187
P1	EWR 7: TLULANDZITEKA (TLULANDZITEKA RIVER) - DETERMINATION OF STRESS INDICES.....	207
P1.1	FISH INDICATOR SPECIES	207
P1.2	FISH STRESS INDEX.....	207
P1.3	MACROINVERTEBRATE STRESS INDEX.....	208
P1.4	RIPARIAN VEGETATION STRESS INDEX	209
P2	EWR 7: TLULANDZITEKA (TLULANDZITEKA RIVER) - DETERMINATION OF EWR SCENARIOS	211
P2.1	LOW FLOW REQUIREMENTS IN TERMS OF STRESS FOR FISH.....	211
P2.2	LOW FLOW REQUIREMENTS IN TERMS OF STRESS FOR MACROINVERTEBRATES	214
P2.3	LOW FLOW REQUIREMENTS IN TERMS OF RIPARIAN VEGETATION	215
P2.4	INSTREAM FLOOD FUNCTIONS.....	216
P2.5	EWR RULE TABLES	217
Q1	EWR 8: LOWER SAND (SAND RIVER) - DETERMINATION OF STRESS INDICES..	222
Q1.1	FISH INDICATOR SPECIES	222
Q1.2	FISH STRESS INDEX.....	222
Q1.3	MACROINVERTEBRATE STRESS INDEX.....	223
Q1.4	RIPARIAN VEGETATION STRESS INDEX	225
Q2	EWR 8: LOWER SAND (SAND RIVER) - DETERMINATION OF EWR SCENARIOS.	226
Q2.1	LOW FLOW REQUIREMENTS IN TERMS OF STRESS FOR FISH.....	226
Q2.2	LOW FLOW REQUIREMENTS IN TERMS OF STRESS FOR MACROINVERTEBRATES	228
Q2.3	LOW FLOW REQUIREMENTS IN TERMS OF RIPARIAN VEGETATION	230

Q2.4	INSTREAM FLOOD FUNCTIONS.....	231
Q2.5	EWR RULE TABLES	232

LIST OF TABLES

APPENDIX I ECOHYDROLOGY OF THE SABIE RIVER SYSTEM

Table I1	Hydraulic data collected at EWR sites on the Sabie River system	108
Table I2	Confidence ratings for the hydraulic characterisations for sites on the Sabie/Sand River system	119

APPENDIX J SUPPORTING INFORMATION FOR THE DETERMINATION OF STRESS INDICES AND EWR SCENARIOS OF EWR 1: UPPER SABIE

Table J1	Habitat requirements for different life stage of indicator species included in LR guild.....	123
Table J2	Habitat requirements for different life stage of indicator species included in SR guild.....	123
Table J3	EWR 1: Habitat suitability for the SR and LR guild.....	124
Table J4	Fish stress index.....	124
Table J5	Habitat suitability for FDI taxa	125
Table J6	Macroinvertebrate (FDI) stress index.....	126
Table J7	Riparian vegetation stress index for indicator species.....	126
Table J8	Low flow requirements: SR guild.....	128
Table J9	Low flow requirements: LR guild.....	129
Table J10	Low flow requirements: FDI taxa.....	130
Table J11	Low flow requirements: Riparian vegetation species.....	131
Table J12	Functions for each Flood Class.....	133
Table J13	EWR 1 assurance rules for PES: B/C	134
Table J14	EWR 1 assurance rules for REC: B	135
Table J15	EWR 1 assurance rules for AEC: C/D.....	136

APPENDIX K SUPPORTING INFORMATION FOR THE DETERMINATION OF STRESS INDICES AND EWR SCENARIOS OF EWR 2: AAN DE VLIET

Table K1	Habitat requirements for different life stages of indicators species included in the SR guild	138
Table K2	EWR 2: Habitat suitability for the SR and LR guild.....	139
Table K3	Fish stress index.....	140
Table K4	Habitat suitability for FDI taxa	140
Table K5	Macroinvertebrate (FDI) stress index.....	141
Table K6	Riparian vegetation stress index for indicator species.....	141
Table K7	Low flow requirements: SR guild.....	143
Table K8	Low flow requirements: LR guild	144
Table K9	Low flow requirements: FDI taxa.....	145
Table K10	Low flow requirements: Riparian vegetation species.....	147

Table K11	Functions for each Flood Class.....	148
Table K12	EWR 2 assurance rules for PES: C.....	149
Table K13	EWR 2 assurance rules for REC: B	150
Table K14	EWR 2 assurance rules for AEC: C/D.....	151

APPENDIX L SUPPORTING INFORMATION FOR THE DETERMINATION OF STRESS INDICES AND EWR SCENARIOS OF EWR 3: KIDNEY

Table L1	Habitat requirements for different life stages of indicators species included in the LSR guild	153
Table L2	EWR 3: Habitat suitability for the SR and LSR guild.....	154
Table L3	Fish stress index.....	154
Table L4	Habitat suitability for FDI taxa	155
Table L5	Macroinvertebrate (FDI) stress index.....	155
Table L6	Riparian vegetation stress index for indicator species.....	156
Table L7	Low flow requirements: SR guild.....	157
Table L8	Low flow requirements: LSR guild.....	158
Table L9	Low flow requirements: FDI taxa.....	159
Table L10	Low flow requirements: Riparian vegetation species.....	160
Table L11	Functions for each Flood Class.....	161
Table L12	EWR 3 assurance rules for PES: A/B	162
Table L13	EWR 3 assurance rules for REC: B	163
Table L14	EWR 3 assurance rules for AEC: C/D.....	164

APPENDIX M SUPPORTING INFORMATION FOR THE DETERMINATION OF STRESS INDICES AND EWR SCENARIOS OF EWR 4: MAC MAC

Table M1	EWR 4: Habitat suitability for the SR and LR guild.....	166
Table M2	Fish stress index.....	167
Table M3	Habitat suitability for FDI taxa	167
Table M4	Macroinvertebrate (FDI) stress index.....	168
Table M5	Riparian vegetation stress index for indicator species.....	168
Table M6	Low flow requirements: SR guild.....	170
Table M7	Low flow requirements: LR guild.....	171
Table M8	Low flow requirements: FDI taxa.....	172
Table M9	Low flow requirements: Riparian vegetation species.....	173
Table M10	Functions for each Flood Class.....	174
Table M11	EWR 4 assurance rules for PES: B.....	175
Table M12	EWR 4 assurance rules for AEC: C	176

APPENDIX N SUPPORTING INFORMATION FOR THE DETERMINATION OF STRESS INDICES AND EWR SCENARIOS OF EWR 5: MARITE

Table N1	EWR 5: Habitat suitability for the SR and LR guild.....	178
Table N2	Fish stress index.....	179
Table N3	Habitat suitability for FDI taxa	179
Table N4	Macroinvertebrate (FDI) stress index.....	180
Table N5	Riparian vegetation stress index for indicator species.....	181

Table N6	Low flow requirements: SR guild.....	182
Table N7	Low flow requirements: LR guild	183
Table N8	Low flow requirements: FDI taxa.....	184
Table N9	Low flow requirements: Riparian vegetation species.....	186
Table N10	Functions for each Flood Class.....	186
Table N11	EWR 5 assurance rules for PES: B/C	188
Table N12	EWR 5 assurance rules for REC: B	189
Table N13	EWR 5 assurance rules for AEC: C/D.....	190

APPENDIX O SUPPORTING INFORMATION FOR THE DETERMINATION OF STRESS INDICES AND EWR SCENARIOS OF EWR 6: MUTLUMUVI

Table O1	EWR 6: Habitat suitability for the SR and LSR guild.....	192
Table O2	Fish stress index.....	193
Table O3	Habitat suitability for FDI taxa	193
Table O4	Macroinvertebrate (FDI) stress index.....	194
Table O5	Riparian vegetation stress index for indicator species.....	194
Table O6	Low flow requirements: SR guild.....	196
Table O7	Low flow requirements: LSR guild.....	198
Table O8	Low flow requirements: FDI taxa.....	199
Table O9	Low flow requirements: Riparian vegetation species.....	201
Table O10	Functions for each Flood Class.....	202
Table O11	EWR 6 assurance rules for PES: C.....	203
Table O12	EWR 6 assurance rules for REC: B	204
Table O13	EWR 6 assurance rules for AEC: C/D.....	205

APPENDIX P SUPPORTING INFORMATION FOR THE DETERMINATION OF STRESS INDICES AND EWR SCENARIOS OF EWR 7: THULANDZITEKA

Table P1	EWR 7: Habitat suitability for the SR and LSR guild.....	207
Table P2	Fish stress index.....	208
Table P3	Habitat suitability for FDI taxa	208
Table P4	Macroinvertebrate (FDI) stress index.....	209
Table P5	Riparian vegetation stress index for indicator species.....	209
Table P6	Low flow requirements: SR guild.....	211
Table P7	Low flow requirements: LSR guild.....	212
Table P8	Low flow requirements: FDI taxa.....	214
Table P9	Low flow requirements: Riparian vegetation species.....	215
Table P10	Functions for each Flood Class.....	216
Table P11	EWR 7 assurance rules for PES: C.....	218
Table P12	EWR 7 assurance rules for REC: B	219
Table P13	EWR 7 assurance rules for AEC: D	220

APPENDIX Q SUPPORTING INFORMATION FOR THE DETERMINATION OF STRESS INDICES AND EWR SCENARIOS OF EWR 8: SAND

Table Q1	EWR 8: Habitat suitability for the SR and LSR guild.....	222
Table Q2	Fish stress index.....	223

Table Q3	Habitat suitability for FDI and MVI taxa	223
Table Q4	Macroinvertebrate (FDI) stress index	224
Table Q5	Macroinvertebrate (MVI) stress index	225
Table Q6	Riparian vegetation stress index for indicator species.....	225
Table Q7	Low flow requirements: SR guild.....	226
Table Q8	Low flow requirements: LSR guild.....	227
Table Q9	Low flow requirements: FDI taxa.....	228
Table Q10	Low flow requirements: MVI taxa	229
Table Q11	Low flow requirements: Riparian vegetation species.....	230
Table Q12	Functions for each Flood Class.....	231
Table Q13	EWR 8 assurance rules for REC: B	233
Table Q14	EWR 8 assurance rules for AEC: C	234

LIST OF FIGURES

APPENDIX I ECOHYDROLOGY OF THE SABIE RIVER SYSTEM

Figure I1	Cross-sectional profile for EWR 1 (Sabie River), showing the water level (WL) surveyed on 3 Sep. '07 and the position of vegetation (Veg.) markers.....	110
Figure I2	Cross-sectional profile for EWR 2 (Sabie River), showing the water level (WL) surveyed on 5 Sep. '07 and the position of vegetation (Veg.) markers.....	110
Figure I3	Cross-sectional profile for EWR 3 (Sabie River), showing the water level (WL) surveyed on 4 Sep. '07 and the position of vegetation (Veg.) markers (MSL - Mean Sea Level).....	111
Figure I4	Cross-sectional profile for EWR 4 (Mac Mac River), showing the water level (WL) surveyed on 3 Sep. '07 and the position of vegetation (Veg.) markers.....	111
Figure I5	Cross-sectional profile for EWR 5 (Marite River), showing the water level (WL) surveyed on 7 Sep. '07 and the position of vegetation (Veg.) markers.....	112
Figure I6	Cross-sectional profile for EWR 6 (Mutlumuvi River), showing the water (WL) level surveyed on 6 Sep. '07 and the position of vegetation (Veg.) markers.....	112
Figure I7	Cross-sectional profile for EWR 7 (Tlulandziteka River), showing the water (WL) level surveyed on 6 Sep. '07 and the position of vegetation (Veg.) markers.....	113
Figure I8	Cross-sectional profile for EWR 8 (Sand River), showing the water level (WL) surveyed on 5 Sep. '07 and the position of vegetation (Veg.) markers.....	113
Figure I9	Distributary channels in the multi-thread mixed-anastomosing channel-type at EWR 3 on the Sabie River (refer to Figure A10) (<i>Photograph D Louw</i>) (after Birkhead, in press).....	117
Figure I10	Modelled (HABFLO: 1-D uniform, and River2D: 2-D non-uniform) abundance of important hydraulic habitats for rheophilic fish at EWR 3 on the Sabie River, expressed using channel width (FI=Fast/Intermediate and FD=Fast/Deep - refer to 'Abbreviations and Acronyms') (after Birkhead, in press)	118
Figure I11	Aerial photograph of EWR 3 (mixed-anastomosing channel-type) along the Sabie River (Kruger National Park, South Africa: 24°59'12"S 31°17'34"E). The extent of the modelled area (using River2D) is indicated in red with the upstream boundary in green. The inundated region for a discharge of 7.8 m ³ /s is rendered using the 'hot-cold' shading representing velocity magnitude (after Birkhead, in press).....	118

APPENDIX I: ECOHYDRAULICS OF THE SABIE RIVER

Dr AL Birkhead, Streamflow Solutions

ACKNOWLEDGEMENTS

The contributions to site selection and data collection by Delana Louw (Water for Africa), Mark Rountree (Fluvius Environmental Consultants), James Mackenzie (BioRiver Solutions), Mandy Uys (Laughing Waters), Shael Koekemoer (Koekemoer Aquatic Services) and Piet Kotze (Clean Stream Biological Services) is gratefully acknowledged.

I1 OBJECTIVES

The objectives of the ecohydraulic component of this study are to provide geomorphologically and ecologically relevant hydraulic information (data collection, analysis and results) for assessing the Environmental Water Requirements (EWRs) at eight sites along the Sabie River system.

12 ECOHYDRAULICS INFORMATION FOR ENVIRONMENTAL WATER ASSESSMENT ALONG THE SABIE RIVER SYSTEM

The application of holistic methods for ecological flow determination (refer to Tharme, 1996) requires environmental flow requirements to be expressed as discharge rates (including its temporal characteristics) through assessments of the presence of suitable habitat for certain biota at different flows. The interface between the way in which flow requirements are assessed and expressed is through the results of hydraulic measurements, analyses and modelling at sites along rivers. The primary product of these hydraulic analyses are relationships between discharge and the following determinants, which have been found over the course of numerous flow assessments, to be the most useful: depth (maximum and average), velocity (average), wetted perimeter, and width of the water surface. The discharge-depth (or rating) relationship is fundamental to hydraulic analysis, and is generally derived from a combination of measured and synthesized data (refer to Rowston *et al.*, 2000; Birkhead, 1999; Jordanova *et al.*, 2004; Hirschowitz *et al.*, 2007 and Birkhead (in press) for descriptions of procedures for deriving hydraulic information for use in EWRs in South Africa). Once the rating relationship for a river section has been developed, the relationships between discharge and the other hydraulic parameters (listed above) may readily be computed using the cross-sectional geometry, and are generally provided in tabular format using look-up tables (refer to Section I2).

The cross-sectional profile plots and look-up tables comprise the “standard hydraulic data” used in Ecological Water Requirement (EWR) determinations in South Africa. Ecologists use these standard hydraulic data with the aid of site assessments and photographs to determine the quantity and quality of hydraulic habitat at different flows. Substantial experience and interpretation are required to provide assessments of site-based and reach-based biological habitats using cross-sectional surveys and the results of one-dimensional hydraulic analyses (biological habitat refers to the integration of the different components defining habitat (e.g. hydraulic, substrate and cover attributes for fish). Procedures have therefore been developed for using standard hydraulic information as the basis for quantifying hydraulic habitat for fish (refer to Hirschowitz *et al.*, 2007 and Birkhead (in press) for an explanation of the method). The method allows the assessment of abundance of different flow classes to be applied more consistently in EWRs, and has been used in this study.

12.1 DATA COLLECTION

The measured discharge and flow depth data are provided in Table I1 for the Sabie River sites, together with the dates when the data were collected.

Table I1 Hydraulic data collected at EWR sites on the Sabie River system

River	Site no.	Date	Discharge Q (m ³ /s)	Max. flow depth y (m)	Stage AMSL z (m)
Sabie	1	03/09/07	1.6	0.76	NA
		07/09/00 ⁵	3.1	0.90	
		06/11/07	4.9	1.04	
		30/01/08	9.8	1.19	

River	Site no.	Date	Discharge Q (m ³ /s)	Max. flow depth y (m)	Stage AMSL z (m)
Sabie	2	05/09/07	1.5	0.32	NA
		06/11/07	6.0	0.56	
		30/01/08	14.6	0.95	
		17/01/08 ¹	29	1.28	
		27/01/06	73+ ⁴	3.2	
Sabie	3 ²	27/08/04	1.9	0.35	366.51
		04/09/07	2.3	0.36	366.52
		11/07/06	7.8	0.54	366.70
		07/11/07	14.0	0.67	366.83
		31/01/08	25	0.94	367.10
		17/03/06	334	3.54	369.70
Mac Mac	4	03/09/07	0.51	0.48	NA
		06/11/07	1.5	0.63	
		30/01/08	3.7	0.78	
Marite	5	07/09/07	0.70	0.48	NA
		06/11/07	1.4	0.57	
		31/01/08	5.2	0.77	
Mutlumuvi	6 ³	06/09/07	0.016	0.45	NA
		25/08/97	0.024	0.44	
		1996	0.50	0.57	
		27/11/97	0.67	0.63	
		1996	0.71	0.65	
		1996	1.8	0.83	
Tlulandziteka	7	06/09/07	0.059	0.15	NA
		31/01/08	1.4	0.47	
Sand	8	05/09/07	0.0001	0.25	NA
		07/11/07	0.074	0.36	
		31/01/08	5.2	0.78	

1 Peak

2 2-D hydraulic modelling site - refer to Section A4

3 Data originally collected in 1996 and 1997 for an IFR assessment

4 In excess of gauging capacity

5 Data collected in 2000 as part of a WRC study

NA - Not Applicable (local datum used)

12.2 MODELLING

Predicted resistance coefficients, energy slopes and modelled rating relationships are archived electronically in Corel Quattro Pro and MS Excel, and included in the EWR ecohydraulics database (Birkhead *et al*, in prep.).

I3 RESULTS

I3.1 CROSS-SECTIONAL PROFILES

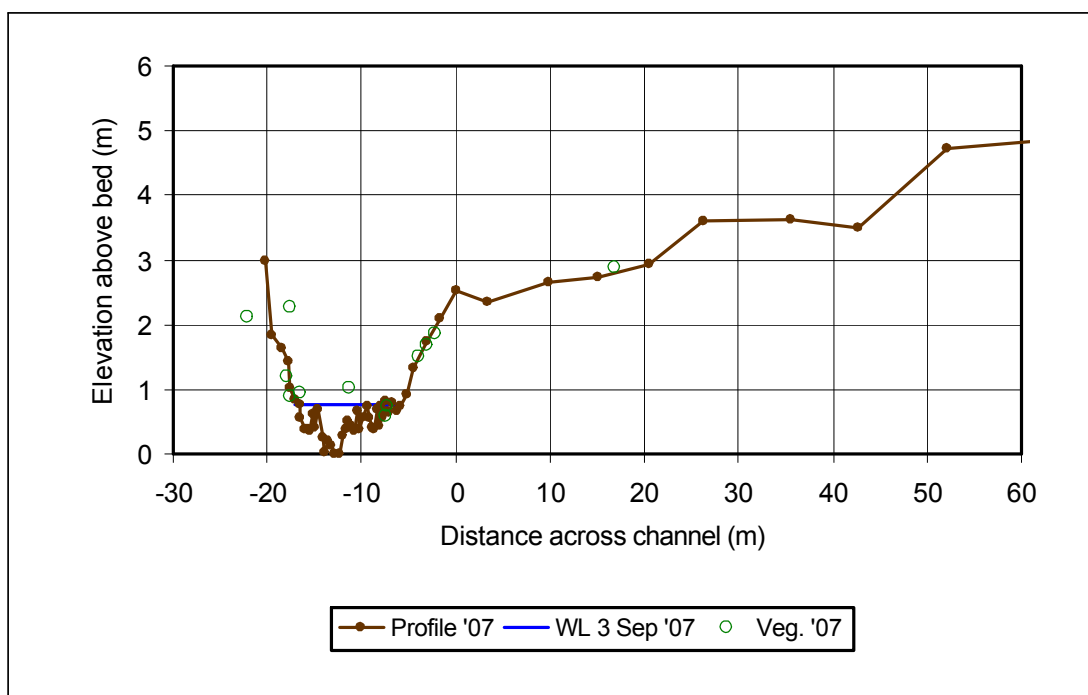


Figure I1 Cross-sectional profile for EWR 1 (Sabie River), showing the water level (WL) surveyed on 3 Sep. '07 and the position of vegetation (Veg.) markers

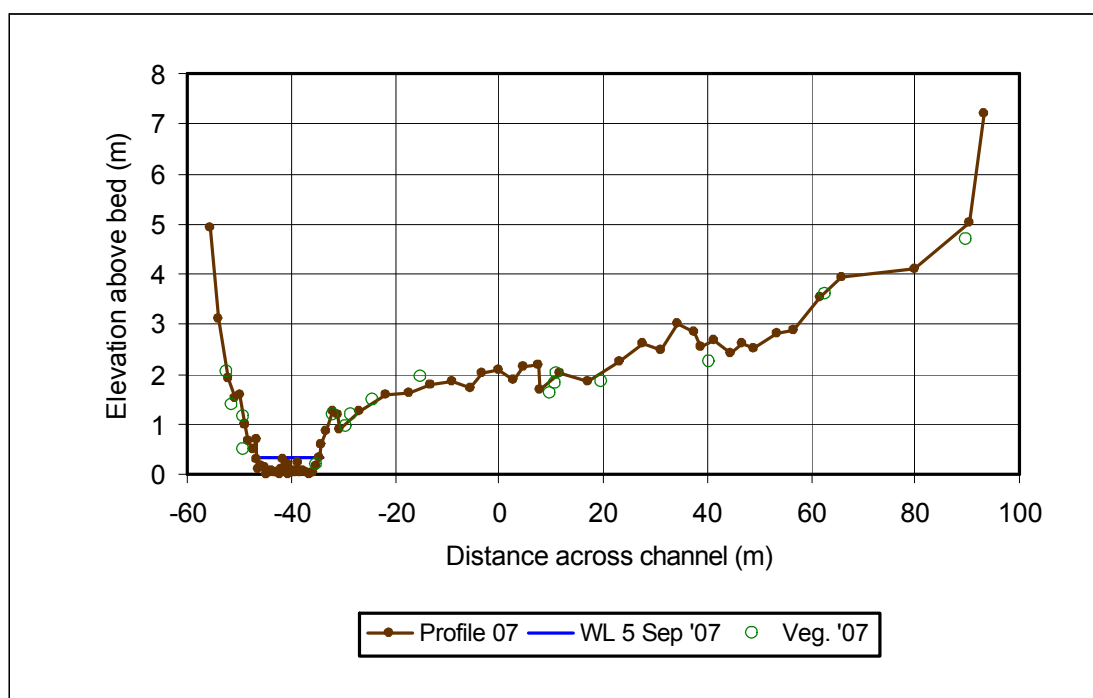


Figure I2 Cross-sectional profile for EWR 2 (Sabie River), showing the water level (WL) surveyed on 5 Sep. '07 and the position of vegetation (Veg.) markers

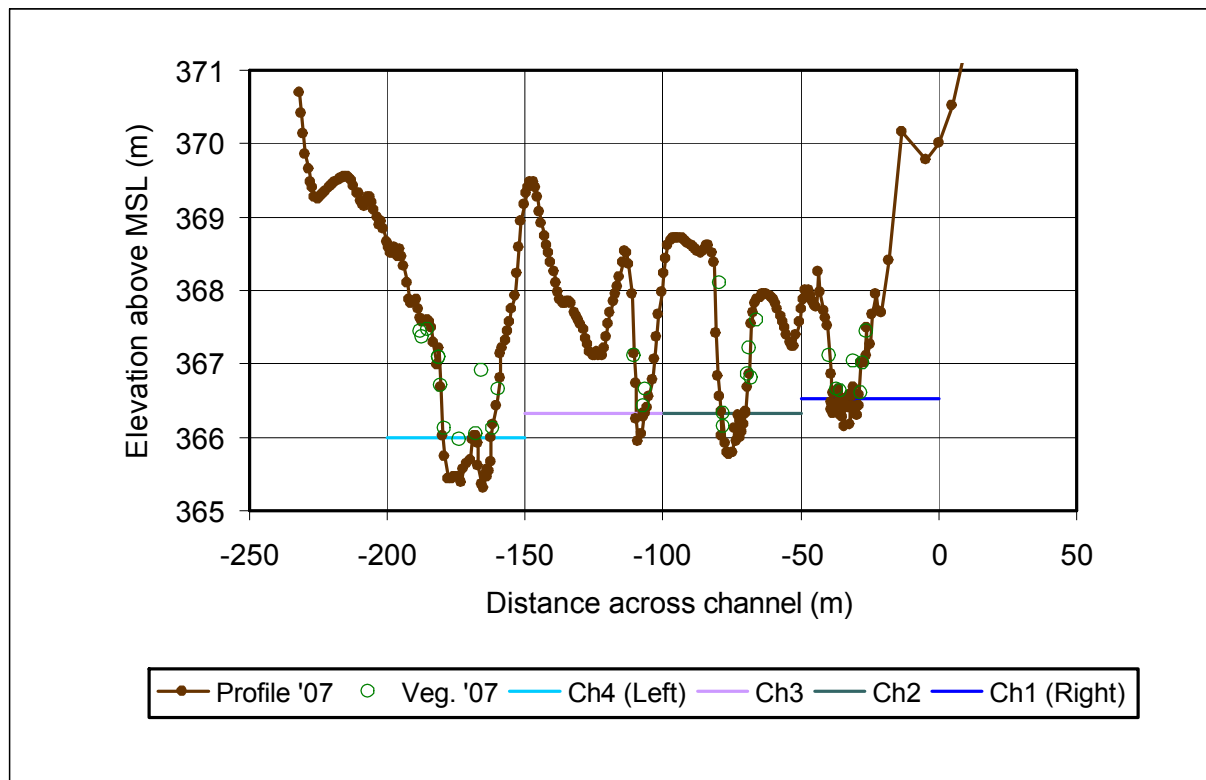


Figure 13 Cross-sectional profile for EWR 3 (Sabie River), showing the water level (WL) surveyed on 4 Sep. '07 and the position of vegetation (Veg.) markers (MSL - Mean Sea Level)

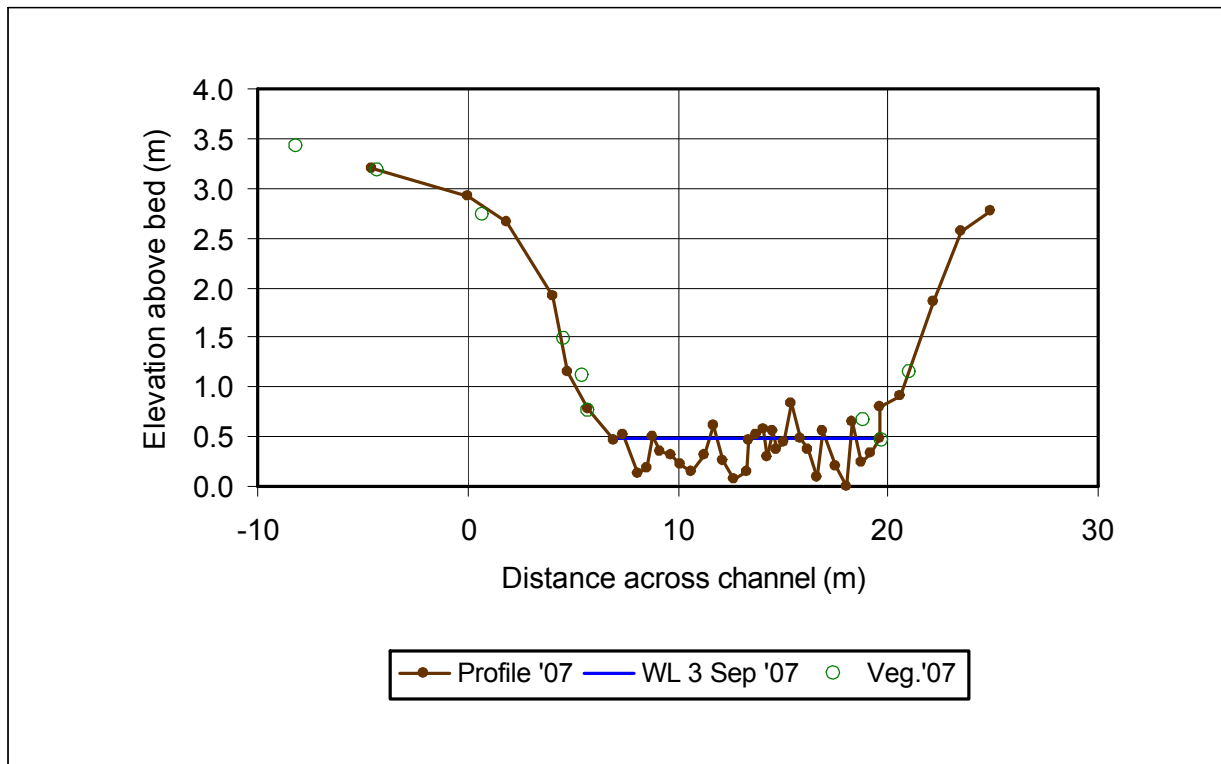


Figure 14 Cross-sectional profile for EWR 4 (Mac Mac River), showing the water level (WL) surveyed on 3 Sep. '07 and the position of vegetation (Veg.) markers

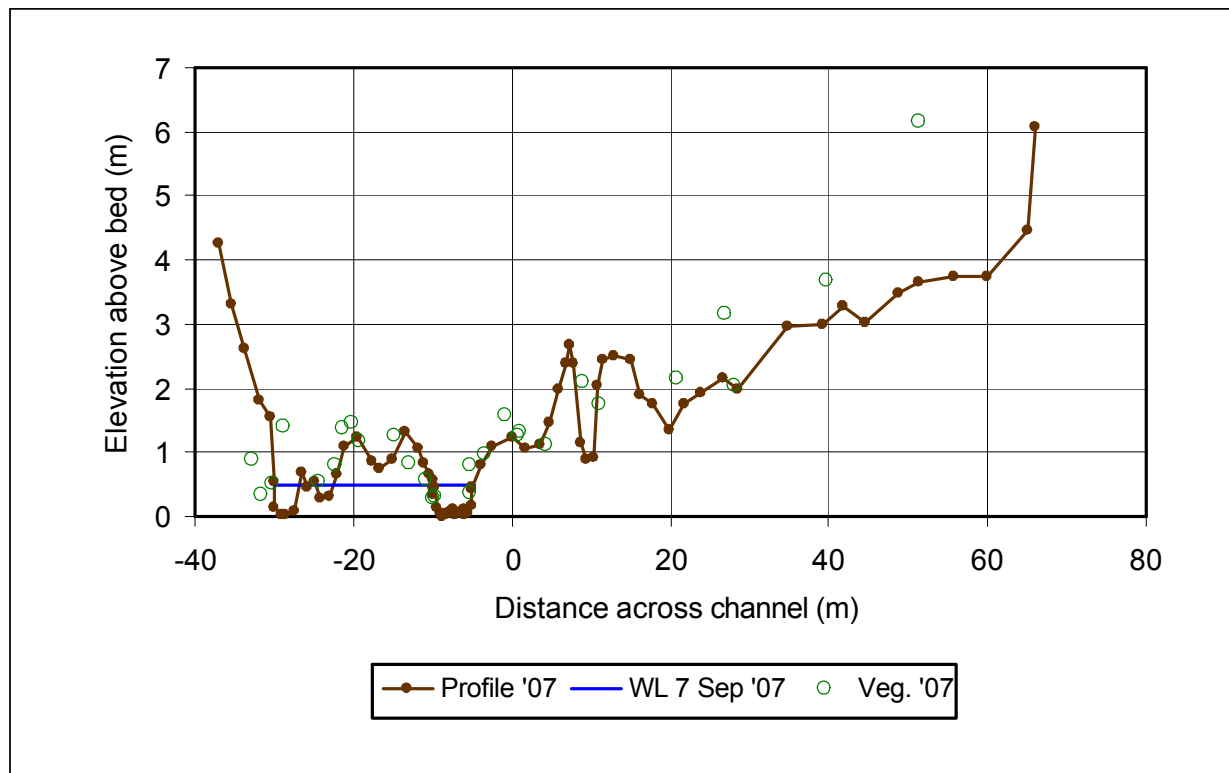


Figure 15 Cross-sectional profile for EWR 5 (Marite River), showing the water level (WL) surveyed on 7 Sep. '07 and the position of vegetation (Veg.) markers

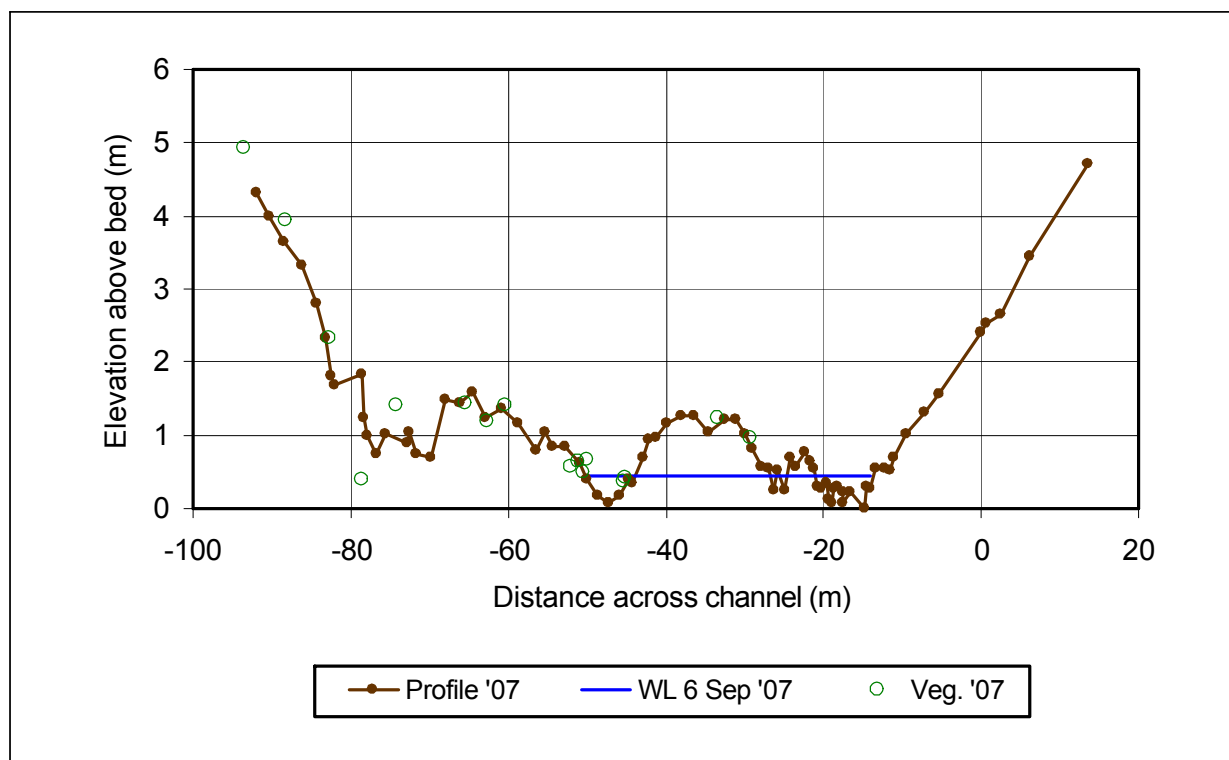


Figure 16 Cross-sectional profile for EWR 6 (Mutlumuvi River), showing the water (WL) level surveyed on 6 Sep. '07 and the position of vegetation (Veg.) markers

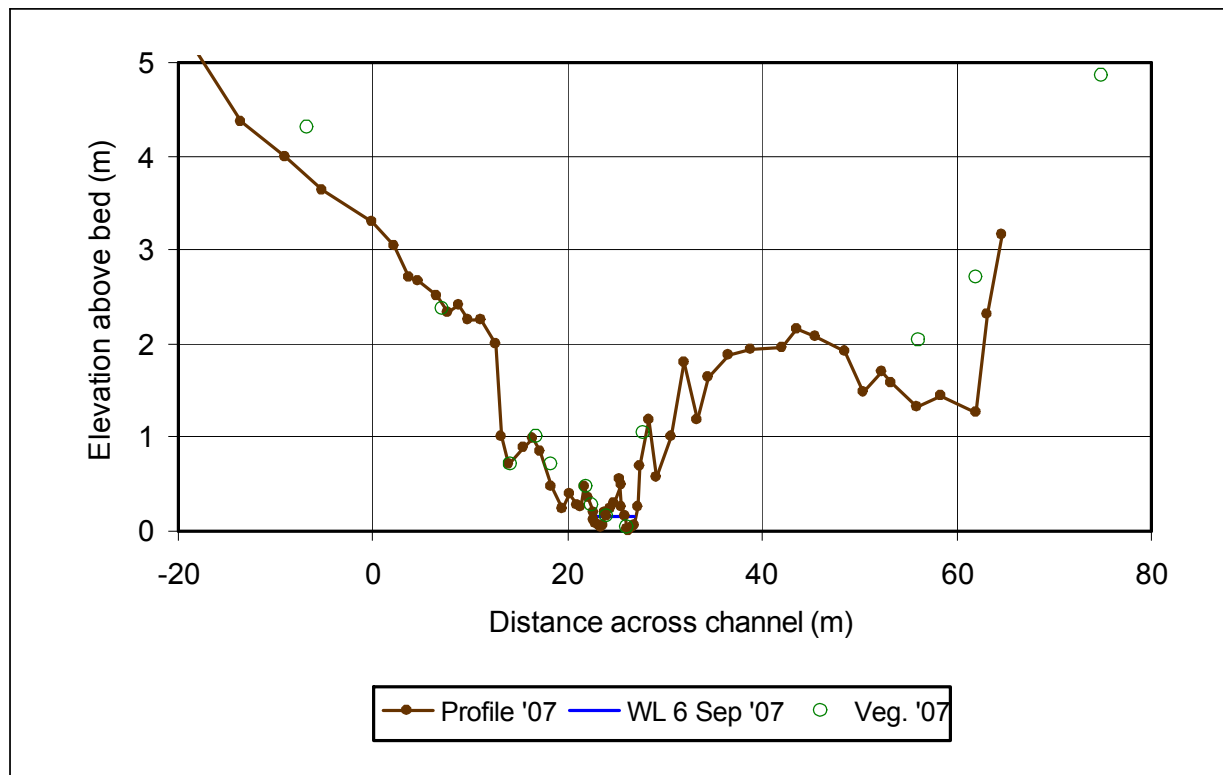


Figure 17 Cross-sectional profile for EWR 7 (Tlulandziteka River), showing the water (WL) level surveyed on 6 Sep. '07 and the position of vegetation (Veg.) markers

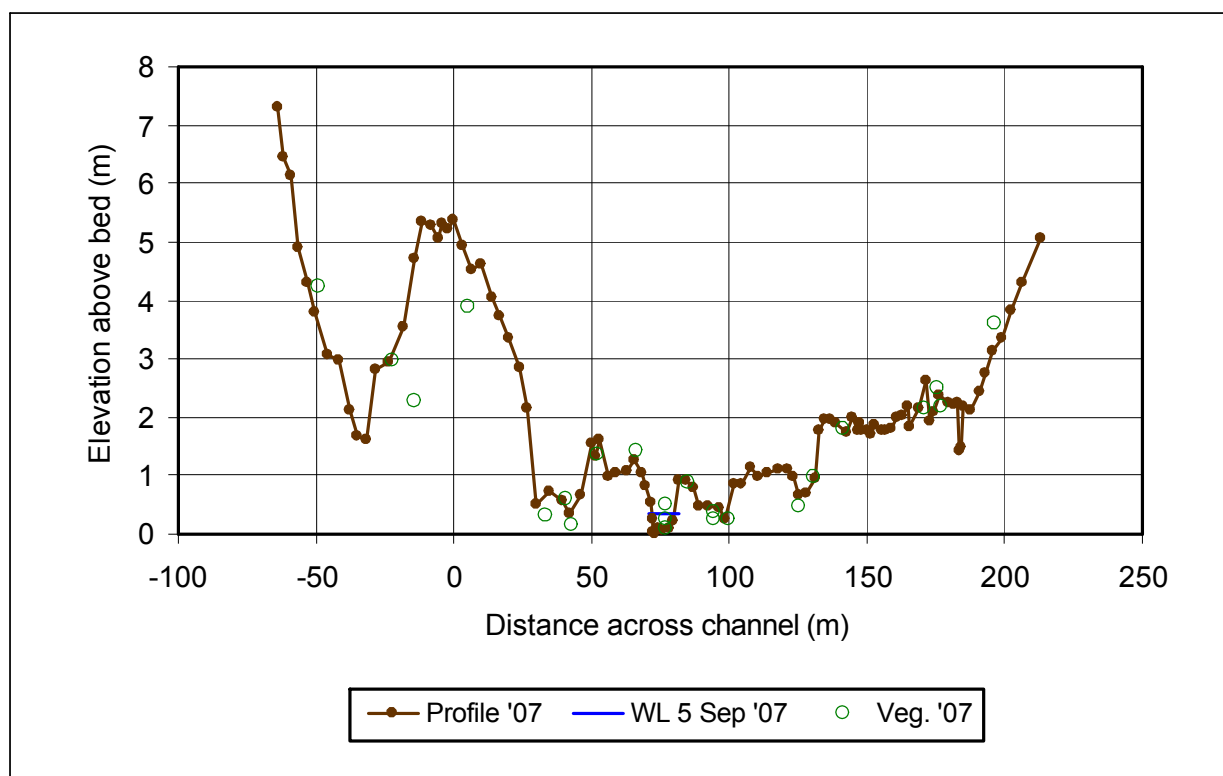


Figure 18 Cross-sectional profile for EWR 8 (Sand River), showing the water level (WL) surveyed on 5 Sep. '07 and the position of vegetation (Veg.) markers

I3.2 LOOKUP TABLES

Lookup tables (hydraulic variables and flow-classes) are archived electronically in MS Excel.

14 TWO-DIMENSIONAL HYDRAULIC MODELLING AT EWR 3 ON THE SABIE RIVER

The following discussion - background to two-dimensional (2-D) hydraulic modelling and application to EWR 3 on the Sabie River - is an edited version of that provided by Birkhead (in press).

14.1 BACKGROUND

Two-dimensional hydraulic analyses account for both longitudinal and lateral flow components, and require three-dimensional (3-D) topographical information. The analyses are suitable where lateral flows are appreciable or where sites have divided channels at low flows with different stages or average velocities (as indicated in Figure 14), and where the region of interest is not extensive.

Diversity of hydraulic conditions and hence the suitability for assessing ecological flows increases with hydraulic complexity, which, in turn, is associated with increasingly complex flow patterns. Most 2-D models are based on the St Venant Equations (which neglect vertical velocities and accelerations) and also assume a hydrostatic vertical pressure distribution. This limits accuracy in areas of steep slopes and rapid changes in bed slope (Steffler and Blackburn, 2006), conditions generally associated with rapids and riffles at low flows. It is therefore necessary to assess the value to ecological flow assessments of employing more sophisticated and rigorous methods of analysis (*viz.* 2-D or even 3-D). Kondolf *et al.* (2000) maintain that highly accurate hydraulic modelling may not be feasible for rivers with complex topography, and that it cannot resolve flow patterns at the spatial scales at which fish often respond to the environment.

Sites where one-dimensional (1-D) analyses can sensibly be applied are favoured for Reserve determination purposes in South Africa, due to resource constraints. For more hydraulically complex sites, the preference is for collection of additional field data rather than more rigorous hydraulic modelling. Additional data are associated with higher level Reserves.

Due to limited data collection in Rapid III assessments, they are best suited to sites with relatively simple hydraulic characteristics (*viz.* horizontal cross-river stage in a single channel, low and uniform flow resistance, uniform flow conditions and a site that is dry at the cessation of flow), which are nonetheless useful for flow assessment. At the Comprehensive level of assessment, 2-D hydraulic modelling may be appropriate where, for example, there are no sites suitable for 1-D analysis, or where ecological importance justifies more detailed descriptions and reduced uncertainty. Two-dimensional analyses use more representative topographical information (3-D Digital Terrain Models to model spatially-explicit depth and depth-averaged velocity. These are used (through frequency analyses) to provide direct estimates of the composition and abundance of flow classes. Furthermore, 2-D modelling allows an assessment of depth connectivity, useful for assessing fish passage, but not provided for by cross-sectional profiles and characteristic depth-frequency distributions.

Hirschowitz *et al.* (2007) provide an assessment of various 2-D hydraulic models with reference to general characteristics, data and their use (topographical, boundary and initial conditions, and hydraulic calibration), and hydraulic limitations (simulation times, flow regime, rapidly-varied flow profiles, wetting and drying, and flow resistance). Based on these considerations, the authors give

certain reasons for selecting River2D (a finite-element hydraulic and habitat simulation model) for local use in ecohydraulic studies.

River2D, developed at the University of Alberta (Canada), is a 2-D depth-averaged finite element hydrodynamic model that has been customised for fish habitat evaluation studies. It comprises three modules relevant to South African conditions, one each for editing bed topography, for generating triangular finite element meshes, and for flow and habitat analyses, mesh editing and refinement. A broad discussion of these is provided by Hirschowitz *et al.* (2007). Two of the reasons cited for selecting River2D are worthy of further discussion - the recurrent problem of wetting and drying, and the value of nested spatial scales.

As water levels change, areas of the channel become wet or dry, and flows through these areas must be added or removed from the computation in a manner that does not compromise conservation of mass or computational stability (adapted from Wright, 2001). Several methods have been developed to account for this, some of which can accommodate changes within an element (a discrete area within the modelled region), but have difficulties when extending over several elements (Quecedo and Pastor, 2002). In Reserve studies, considerable attention is focussed on the low-flow component of the flow regime, where sites are typically characterised by large roughness elements. This requires the analysis of shallow flows with complex boundaries, which, in turn, produces computational instabilities. Accurate modelling requires detailed topographical surveys and the use of a dense mesh (lattice between elements), since flow through a number of adjacent nodes is required for numerical solutions. Furthermore, meshes may need to be reconstructed for different flows due to changes in the position of boundaries and orientation of streamlines (Panfil and Jacobson, 1999). River2D accounts for wetting and drying by using a continuous water surface that is either above or below bed level, with the subsurface conditions treated as flow through porous media. Although the wet-dry transition is treated well, velocities at the water's edge may be inaccurate (Hirschowitz *et al.* 2007).

Two-dimensional modelling may be applied at different spatial scales, depending on the required resolution. For a given resolution, the spatial extent is limited by the maximum number of elements that can realistically be included (due to program limitations and long simulation times). At a coarse resolution, a long river stretch may be modelled, whereas at a fine resolution, only a small section may be analysed. River2D includes the useful capability of nesting spatial scales - a finer resolution may be used where higher accuracy is required, or a modelled region may be extracted and reanalysed at a finer resolution.

14.2 APPLICATION

River2D was applied in this study Comprehensive Reserve assessment at EWR 3 on the Sabie River. Although hydraulically complex sites such as this (refer to Figures I9 and I10) would normally be avoided even at the Comprehensive level, this site was selected because of the diverse and critical hydraulic habitat for rheophilic biota associated with such bedrock influenced channel-types, and the availability of Light Detection and Ranging (LIDAR) data. The site's inclusion is necessary given the ecological importance and sensitivity of the Sabie River, a contributing factor being that the Lower Sabie River lies within the Kruger National Park. The LIDAR data (for a low discharge of 1.9 m³/s) were used with a conventional active channel cross-sectional survey to estimate bed elevations, since LIDAR does not penetrate water. A coarse 2-D model was developed with rating data collected over the discharge range 1.9 m³/s to 334 m³/s

(refer to Table I1). The mapped velocity magnitudes for a discharge of $7.8 \text{ m}^3/\text{s}$ are superimposed on an aerial photograph in Figure I10, with the cross-section (as indicated in Figure I10) plotted in Figure I4.

River2D results may be exported in text file format - a useful feature for the post-processing of point hydraulic variables (e.g. velocity and shear velocity magnitudes, depth, stage, Froude number). For Reserve analyses using flow classes, such as in this study, this is necessary for statistical analysis of depth-velocity point values. For analyses to be statistically valid, values are best exported using a regular grid. Furthermore, modelled values may also be extracted to text files for any location within the modelled region - a necessary feature for comparing modelled and measured data for selected flows, as well as for extracting hydraulic information, such as rating data.



Figure I9 **Distributary channels in the multi-thread mixed-anastomosing channel-type at EWR 3 on the Sabie River (refer to Figure A10) (*Photograph D Louw*) (after Birkhead, in press)**

Two important velocity-depth classes for assessing flow requirements for rheophilic fish at this site are fast/intermediate (FI) and fast/deep (FD). These were modelled for EWR 3 using 1-D (HABFLO) and 2-D (River2D) analyses, and the comparative results plotted in Figure I11. Given that a site of this complexity would usually not be selected for 1-D uniform flow analysis, the results compare surprisingly well for this complex site over the low-flow range (although the surveyed cross-sectional profile (Figure I4) was used to infer bed levels for use in the 2-D modelling).

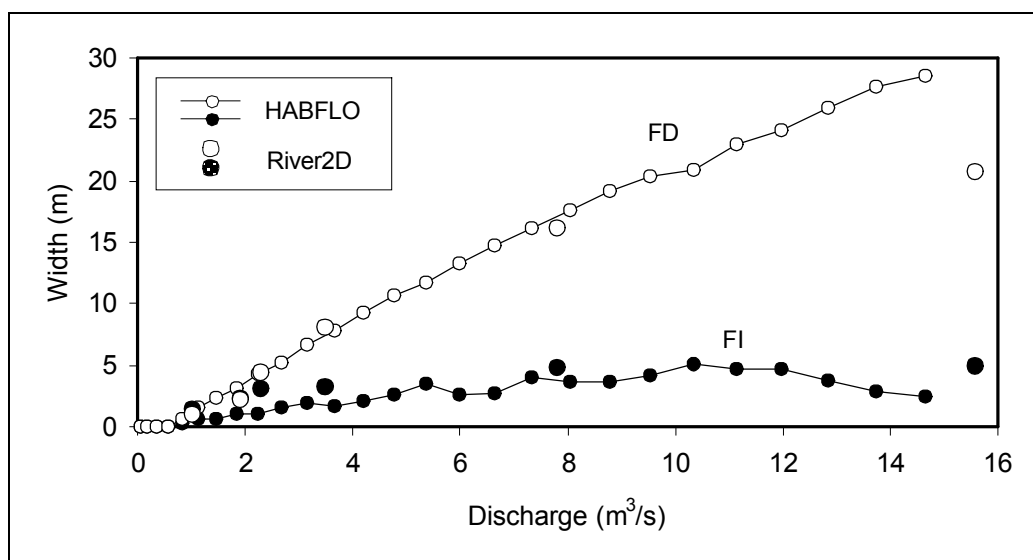


Figure I10 Modelled (HABFLO: 1-D uniform, and River2D: 2-D non-uniform) abundance of important hydraulic habitats for rheophilic fish at EWR 3 on the Sabie River, expressed using channel width (FI=Fast/Intermediate and FD=Fast/Deep - refer to 'Abbreviations and Acronyms') (after Birkhead, in press)

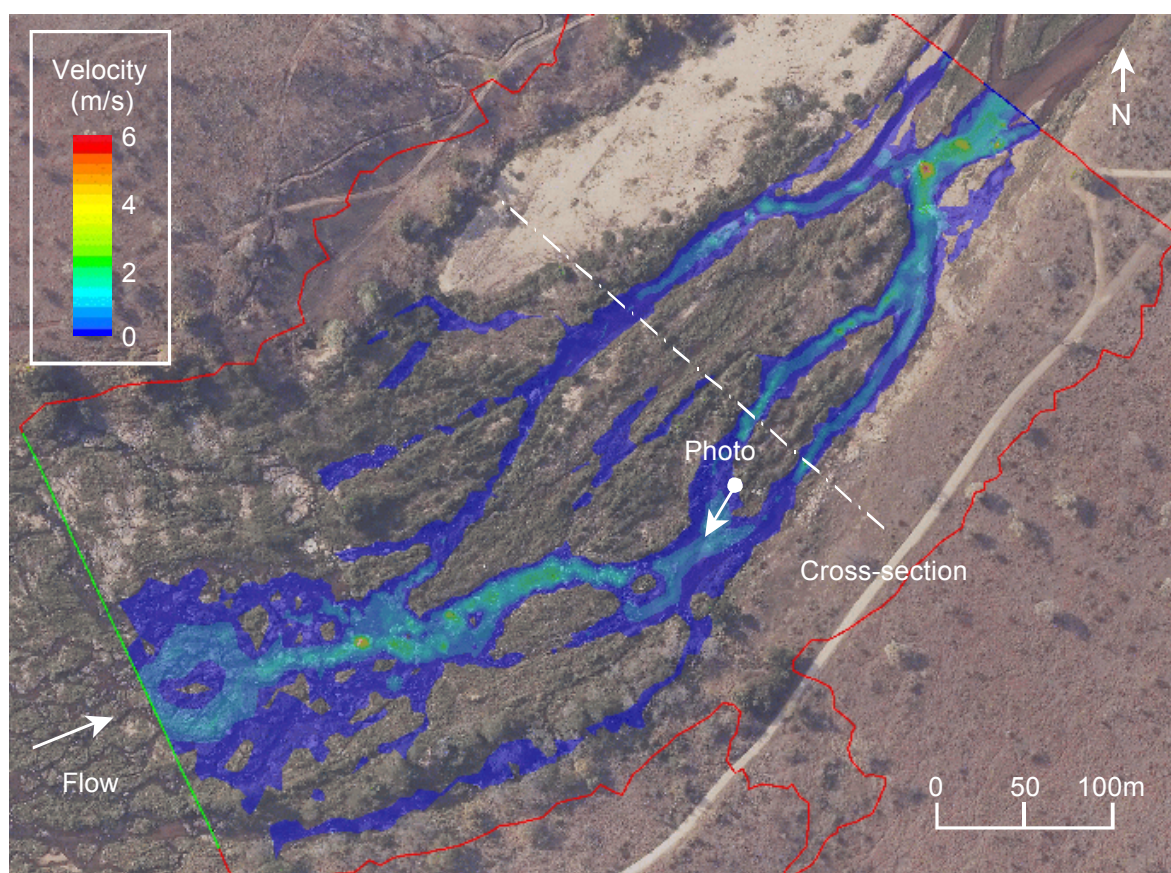


Figure I11 Aerial photograph of EWR 3 (mixed-anastomosing channel-type) along the Sabie River (Kruger National Park, South Africa: 24°59'12"S 31°17'34"E). The extent of the modelled area (using River2D) is indicated in red with the upstream boundary in green. The inundated region for a discharge of 7.8 m³/s is rendered using the 'hot-cold' shading representing velocity magnitude (after Birkhead, in press)

15 CONFIDENCE IN THE HYDRAULIC CHARACTERISATIONS

Table I2 Confidence ratings for the hydraulic characterisations for sites on the Sabie/Sand River system

Site	REC	Season (dry/wet low & high flows)		Discharge, Q (m ³ /s)			Rating	Comments
				Exceedance (%)		Meas. range		
				95 ¹	65/40 ²			
1	B	Low	Dry	0.50	1.1	1.6 - 9.8	3	Below meas. min. Q. Non-uniform flow conditions.
			Wet	0.80	2.5		4	
		High	6, 15, 30 ³				3	Above max. meas. Q. Non-uniform flow conditions.
2	B	Low	Dry	0.85	1.6	1.5 - 29	3	Below meas. min. Q.
			Wet	1.5	2.9		4	
		High	10, 20, 50 ³				3	Complex site. Above max. meas. Q.
3	A/B	Low	Dry	1.5	2.3	1.9 - 334	3	Uncertainty with low-flow 2-D modelling.
			Wet	2.8	7.1		4	
		High	8, 20, 40, 80 ³				4	Complex site: multi-distributary channels.
4	B	Low	Dry	0.20	0.45	0.51 - 3.7	4	Below meas. min. Q.
			Wet	0.50	1.1		4	
		High	4, 15, 25 - 35 ^{3, 5}				3	Above max. meas. Q. Downstream bridge.
5	B	Low	Dry	0.32	0.75	0.70 - 5.2	3	Below meas. min. Q. Two channels at different stages.
			Wet	0.60	1.9		4	
		High	4, 8, 25 ³ , 63 ⁴				3	Above max. meas. Q.
6	C	Low	Dry	0.08	0.22	0.016 - 5.6	4	Complex site: distributary channels, bedrock influence. Uncertainty flow class modelling.
			Wet	0.38	0.69		4	
		High	1.6, 10, 16 ³				3	Complex site. Above meas. max. Q.
7	C	Low	Dry	0.09	0.17	0.059, 1.4	4	Single meas. low Q. Two channels.
			Wet	0.19	0.36		3	
		High	1.5, 4, 9, 28 ³				3	Above meas. max. Q.
8	B	Low	Dry	0.0035	0.36	0.0001, 0.074, 5.2	2	Minimal meas. low Q. Mobile bed and channel. Backup. Uncertainty flow class modelling.
			Wet	0.21	1.34		2	
		High	5, 30, 160 ³				3	Above meas. max. Q. Vegetation resistance.

Rating: 0 - none, 1 - Low, 2 - Low/Medium, 3 - Medium, 4 - Medium/High, 5 - High

1 Drought conditions, 2 Maintenance conditions (65/40% for Sabie (EWR 1 - 5)/Sand (EWR 6 - 8) River sites, respectively - refer to main report)

3 1:2 4 1:3 5 Peak

REC-Recommended Ecological Category

High flows are daily averages unless otherwise noted

Low - 'base' flows

I6 REFERENCES

- Birkhead, A.L. 1999. The procedure for generating hydraulic data for the Intermediate and Comprehensive Ecological Reserve (Quantity), Appendix R17. Water Resource Protection Policy Implementation, Resource Directed Measures for protection of Water Resources, Volume 3: River Ecosystems (Version 1.0). <http://www.dwaf.gov.za/documents.asp>
- Birkhead, A.L. (in press). The role of Ecohydraulics in the South African Ecological Reserve. In: Ecohydraulics for South African Rivers, James, C.S. and King, J.M. (eds), Water Research Commission report no. TT K5/1767/1, Pretoria, South Africa.
- Birkhead, A.L., Desai, A. and Louw, M.D. (in prep). Synthesis of hydraulic information collected over the past decade in Southern Africa to inform Environmental Flow Requirements. WRC Project K8/795/2.
- Hirschowitz, P.M., Birkhead, A.L. and James, C.S. 2007. Hydraulic modelling for ecological studies for South African Rivers. WRC Report No. 1508/1/07, Water Research Commission, Pretoria. 250pp. <http://www.wrc.org.za/publications/reports.htm>
- Jordanova, A.A., Birkhead, A.L., James, C.S. and Kleynhans, C.L. 2004. Hydraulics for determination of the ecological Reserve for rivers. Report to the Water Research Commission on the project "Hydraulic analyses for the determination of the ecological Reserve for rivers". WRC Report no. 1174/0/1.
- Kondolf, GM, Larsen, E.W. and Williams, J.G. 2000. Measuring and modelling the hydraulic environment for assessing instream flow. North American Journal of Fisheries Management, **20**, 1016-1028.
- Panfil, S. and Jacobson, R.B. 1999. Hydraulic modelling of in-channel habitats in the Ozark Highlands of Missouri: Assessment of the physical habitat sensitivity to environmental change. River studies station publications of the USGS CERC (Colombia Environmental Research Centre) river corridor habitat dynamics project. <http://www.cerc.usgs.gov/rss/rfmodel/>
- Quecedo, M. and Pastor, M. 2002. A reappraisal of the Taylor-Galerkin algorithm for drying-wetting areas in shallow water computations. International Journal for Numerical Methods in Fluids **38**, 515-531.
- Rowlston, B., Jordanova, A.A. and Birkhead A.L. 2000. Hydraulics In: Environmental flow assessment for rivers: Manual for the Building Block Methodology, King, J.M., Tharme, R.E. and de Villiers, M.S., (eds), Water Research Commission report No.TT 131/00, Pretoria, South Africa.
- Steffler, P. and Blackburn, J. 2006. River2D: Two-dimensional depth averaged model of river hydrodynamics and fish habitat. Introduction to depth-averaged modelling and user's manual. University of Alberta, Edmonton Alberta, Canada. <http://www.river2d.ualberta.ca>
- Tharme, R.E. 1996. Review of international methodologies for the quantification of the instream flow requirements of rivers. Water law review. Final report for policy development. Commissioned

by the Department of Water Affairs and Forestry, Pretoria. Freshwater Research Unit, University of Cape Town, Cape Town. 116pp.

Wright, N.G. 2001. Conveyance Implications for 2-D and 3-D Modelling. Part of scoping study for reducing uncertainty in river flood conveyance. Prepared for HR Wallingford and the Environment Agency (refer to Wallingford software, 2004).

**APPENDIX J: SUPPORTING INFORMATION FOR THE DETERMINATION OF STRESS
INDICES AND EWR SCENARIOS OF EWR 1: UPPER SABIE**

J1 EWR 1: UPPER SABIE (SABIE RIVER) - DETERMINATION OF STRESS INDICES

Appendix J provides supporting information for the determination of stress indices and EWR scenarios of EWR 1: Upper Sabie (Chapter 3 and 4 of the Sabie-Sand River System EWR Scenario Report: Volume 1).

J1.1 FISH INDICATOR SPECIES

Large rheophilic (LR) guild: *Varicorhinus nelspruitensis* (VNEL) is the most important indicator species regarding the setting of flows as it is the biggest species at the site having a requirement for continuous flowing water for all of its life stages (Table J1).

Small rheophilic (SR) guild: *Amphilius uranoscopus* (AURA) and *Chiloglanis anoterus* (CANO) are good indicators for setting flows as a result of their high requirement for flowing water (Table J2).

Table J1 Habitat requirements for different life stage of indicator species included in LR guild

Species	Spawning	Egg and embryo development	Larvae	Juveniles	Adults	Optimal general habitat
VNEL	Flow habitat: FD, FI and gravel beds in riffles and rapids . Spawning season: Oct – Apr. Cue: Rain-swollen rivers.	Flow habitat: FD, FI and gravel beds in riffles and rapids . Spawning season: Oct – Apr.	Nursery areas (>0.20 m), Margins of FS, SS, SD and backwaters. Cover: Overhanging vegetation .	Flow habitat: FI, FD with substrates . Preferred velocity: 0 - 0.6 m/s. Preferred depth: 20 - 80 cm. Preferred substrate: Boulder to bedrock. Preferred cover: Visual or combined visual/velocity shelter.	Flow habitat: FI, FD with substrate . Favors cool rocky flowing water habitats, scrapes 'aufwuchs' ¹ and benthic macroinvertebrates from rocks). 0.63 ± 0.24 m/s. (max = 0.9 m/s).	Flow habitat: FD and FS with substrate.

¹ **Aufwuchs** is a term used to cover the small animals and plants that encrust hard substrates, such as rocks, in aquatic environments (www.wikipedia.org).

Table J2 Habitat requirements for different life stage of indicator species included in SR guild

Species	Spawning	Egg and embryo development	Larvae	Juveniles	Adults
AURA	Flow habitat: SS, FI (>0.25 m). Substrate: Gravel and cobble. Spawning season: Oct – Jan. Cue: Increased temp., flow and changes in water quality (e.g. conductivity).	Flow habitat: Margins of SS (>0.2 m, <0.2 m/s). Substrate: Gravel, cobble. Oct – Jan. Cue: >16°C. Duration: 7 days.	Flow habitat: Margins of FS, SS and overhanging vegetation. Nursery areas: (>0.20 m, <0.2 m/s). Larval period: 2 months.	Flow habitat: Mostly FD, FI (>0.20 m deep >0.1 m/s). Cover: Cobbles, rocks and overhanging vegetation. Duration 3 - 6 months. Low flow refuge (June - Sep): FS, FD . Cover: Cobbles, rocks.	Flow habitat: FD, FS . Cover: Cobbles and rocks. Low flow refuge (June - Sep): FS and FD . Cover: cobbles, rocks overhanging vegetation.
CANO	Flow habitat: FD, FI (>0.25 m). Substrate: Gravel, cobble . Spawning season: summer (Oct - Jan). Cue: Increased temp., flow and changes in water quality (e.g. conductivity).	Flow habitat: Margins of FS and SS (>0.20 m). Substrate: Gravel substrate . Oct – Jan. Duration 7 days. Breeds during summer, laying eggs between rocks and in gravel . Oviparous.	Nursery areas (>0.20 m). Margins of FS and SS . Larval period: 2 months.	Flow habitat: Mostly FD, FI (>0.20m). Cover: Cobbles and rocks . Duration 3 - 6 months. Low flow refuge (Jun – Sep): FI (>0.20 m), FD . Cover: Cobbles, rocks . Preferred substrate: Gravel/Pebble. Preferred velocity: >1.4 m/s. Preferred depth: 15 - 35 cm. Cover: Combined velocity and visual cover.	Flow habitat: FD, FS . Cover: Cobbles and rocks . Low flow refuge: (Jun – Sep), FI (>0.30 m), FD . Cover: Cobbles, rocks overhanging vegetation . Preferred substrate: Gravel/Pebble. Preferred velocity: >1.4 m/s. Preferred depth: 20 - 50 cm. Cover: Combined velocity and visual cover. Among rocks in clear, swift-flowing streams where the water is well-aerated. Rocky riffles and rapids. Sexual maturity – 50 mm

J1.2 FISH STRESS INDEX

The abundance of fish velocity-depth classes are provided in Table J3.

Table J3 EWR 1: Habitat suitability for the SR and LR guild

SR and LR GUILD													
Depth classes	Discharges (m ³ /s)												
	0.20	0.41	0.60	0.69	0.78	0.98	1.25	1.70	1.88	2.52	3.03	3.62	5.05
Slow (<0.3m/s) Very Shallow (<0.1m) (SVS)	6	8	8	8	8	8	8	8	8	8	8	8	8
Slow (<0.3m/s) Shallow (0.1 – 0.3m) (SS)	6	6	6	6	6	6	6	6	6	8	8	8	8
Slow (<0.3m/s) Deep (> 0.5m) (SD)	10	8	8	8	8	8	8	8	8	8	8	8	8
Slow Shallow and Slow Deep	6	4	4	4	4	6	6	6	6	6	6	6	8
Fast (>0.3m/s) Very Shallow (<0.1m) (FVS)	8	8	8	8	8	8	8	8	8	8	8	8	8
Fast (>0.3m/s) Shallow (0.1 – 0.3m) (FS)	8	8	8	8	8	8	8	8	8	8	8	8	8
Fast (>0.3m/s) Intermediate (0.2 – 0.3) (FI)	8	8	8	8	8	8	8	8	8	8	8	8	8
Fast (>0.3m/s) Deep (> 0.3m) (FD)	8	8	8	8	8	10	6	6	6	6	4	4	2
FAST TOTAL >0.1 m DEEP	8	8	6	6	6	6	6	4	4	4	4	2	2

The fish stress index is provided in Table J4.

Table J4 Fish stress index

Habitat	Discharges (m ³ /s)												
	0.20	0.41	0.60	0.69	0.78	0.98	1.25	1.70	1.88	2.52	3.03	3.62	5.05
SMALL RHEOPHILIC (SR) GUILD													
Spawning habitat	0	0	1	1.5	2	2.5	3.5	4	4	4.5	5	5	5
Nursery habitat	0.5	1	2	2.5	3	3.5	4	4.5	4.5	4.5	4.5	5	5
Abundance	1	1	1.5	2	2	2.5	3	3	3.5	4	4.5	5	5
Cover	1	1	1.5	2	2	2.5	3	3	3.5	4	4.5	5	5
Connectivity (lateral and longitudinal)	0.5	1	2	2.5	2.5	3	3	3.5	4	5	5	5	5
Water quality (especially oxygen and temp)	0.5	1	1.5	2	2.5	3	3	3.5	3.5	4	4.5	5	5
Species stress: AURA and CANO	9	8	7	6	5	4	4	3	2	1	1	0	0
LARGE RHEOPHILIC (LR) GUILD													
Spawning habitat	0	0	0.5	1	1.5	2	2.5	3	3.5	3.5	4	4.5	5
Nursery habitat	0	0.5	1	1.5	2.5	3	4	4.5	4.5	5	5	5	5
Abundance	0.5	0.5	1	1.5	1.5	2	2	2.5	3	3.5	4	4.5	5
Cover	0.5	0.5	1	1.5	1.5	2	2	2.5	3	3.5	4	4.5	5
Connectivity (lateral & longitudinal)	0	0.5	1	1	1.5	2	2	2.5	3	4	5	5	5
Water quality (especially oxygen & temp)	0.5	1	1.5	2	2.5	3	3.5	4	4.5	4.5	5	5	5
Species stress: VNEL	10	9	8	7	6	5	5	4	3	2	1	0	0

J1.3 MACROINVERTEBRATE STRESS INDEX

The habitat flow index for Flow Dependent macroinvertebrate (FDI) taxa is provided in Table J5 and provides the % occurrence of various velocity and substrate classes under different flow conditions.

Table J5 Habitat suitability for FDI taxa

Habitat Flow Response Index	Habitat Response	HABITAT ABUNDANCE AND SUITABILITY (%)													FLOW (m ³ /s)
		VSCS ¹	SCS ²	FCS ³	VFCs ⁴	VSFS ⁵	SFS ⁶	FFS ⁷	VFFS ⁸	VSBR ⁹	SBR ¹⁰	FBR ¹¹	VFBR ¹²	VEG ¹³	
0	All habitat in excess, very high quality: very fast, deep, very wide wetted perimeter. Vegetation plentiful (particularly in pool downstream of cross section).	1	3	4	14	2	4	6	18	1	4	5	19	18	5.0
1	All plentiful dominant habitat comprises boulders and cobbles in moderate to fast flow, high quality; fast, wide wetted perimeter, inundated and hanging vegetation reduced.	2	4	6	11	3	5	8	14	3	6	9	16	13	3.03
2	Critical habitats sufficient; quality slightly reduced. Fast, wetted perimeter (WP) slightly reduced, vegetation further reduced.	3	5	7	10	3	6	9	12	4	7	10	14	10	2.29
3	Slightly reduced critical habitat, reduced quality of critical habitat; moderate velocity, fairly deep areas. Marginal vegetation inundated (on islands etc.), largely hanging stems.	4	6	9	9	4	6	9	9	5	8	12	12	8	1.6
4	Critical habitats limited; moderate quality. Moderate velocity, Some deep areas. Wetted perimeter moderately reduced. Vegetation still inundated.	6	9	10	4	6	9	10	4	8	12	14	6	2	0.87
5	Critical habitat reduced, almost equivalent flow and non-flow habitats present. Moderate/ low quality; moderate velocity, few deep areas wetted perimeter moderately reduced.	9	11	8	3	9	11	8	3	11	13	10	4	0	0.41
6	Critical habitat reduced. Majority of habitat comprises boulders and cobbles in slow to moderate flow conditions. Reduced habitat quality; moderate to slow velocity. No vegetation inundated.	10	12	6	2	10	12	6	2	13	16	8	3	0	0.23
7	Critical habitat further reduced other habitats moderate quality; wetted perimeter reduced in width. Depth reduced. Flow velocities moderate to low. No vegetation inundated	11	12	5	1	11	12	5	1	16	17	7	1	0	0.11
8	Flowing water habitats diminished and low quality. Slow trickle, wetted perimeter markedly reduced in width. No inundated vegetation.	15	12	3	0	15	12	3	0	20	16	4	0	0	0.035
9	Flow reduced to a trickle. Slow to very slow or standing water. No vegetation inundated.	22	8	0	0	22	8	0	0	29	11	0	0	0	0.006
10	Zero flow. Only available habitat is standing water over coarse, fine or very fine sediments.	29	1	0	0	29	1	0	0	39	1	0	0	0	0.00

1 Very Slow over Coarse Sediment

4 Very Fast over Coarse Sediment

7 Fast over Fine Sediment

10 Slow over Bedrock

13 Fringing vegetation

2 Slow over Coarse Sediment

5 Very Slow over Fine Sediment

8 Very Fast over Fine Sediment

11 Fast over Bedrock

3 Fast over Coarse Sediment

6 Slow over Fine Sediment

9 Very Slow over Bedrock

12 Very Fast over Bedrock

The stress index for FDI taxa is provided in Table J6 which rates the response of the species according to various biotic response metrics.

Table J6 Macroinvertebrate (FDI) stress index

Habitat characteristics					Biotic Response	Flow	Species Stress
Max depth (m)	Ave depth (m)	Max vel (m/s)	Ave vel (m/s)	WP (m)			
1.02	0.50	0.80	2.19	14.7	All indicator taxa (Perlids and Elmids) very abundant and healthy.	3.03	0
0.9	0.41	0.63	1.91	14.0	Perlids and Elmids persist in a healthy condition.	2.29	1
0.84	0.36	0.55	1.73	13.6	Most indicator taxa persist, but slight reduction in abundances.	1.60	2
0.78	0.32	0.49	1.50	12.8	Most Perlids and Elmids persist, but abundances reduced, particularly of the more flow-sensitive Perlids.	1.11	3
0.68	0.28	0.35	1.11	10.6	All life stages of Elmids viable in limited areas. Critical life stages of the more sensitive indicators, Perlids, at risk.	0.87	4
0.56	0.23	0.26	0.87	7.9	Critical life-stages of sensitive indicator taxa at risk or non-viable.	0.41	5
0.48	0.2	0.21	0.72	6.2	Perlids rare with critical stages of sensitive indicator taxa non-viable, and at risk for the less sensitive Elmids.	0.23	6
0.34	0.23	0.2	0.68	2.7	Some Elmids persist, but most disappear. All life-stages of Perlids and Elmids at risk or non-viable.	0.11	7
0.22	0.14	0.13	0.44	2.3	Few Elmids persist, and at very low numbers. All life stages of most indicator taxa at risk or non-viable.	0.04	8
0.10	0.07	0.07	0.26	1.3	Perlids and Elmids absent.	0.01	9
0.02	0.02	0.03	0.1	0.6	Perlids and Elmids absent.	0.00	10

J1.4 RIPARIAN VEGETATION STRESS INDEX

The riparian vegetation stress index is based on two selected indicator species *Phragmites mauritanus* and *Ficus sur* and provided in Table J7.

Table J7 Riparian vegetation stress index for indicator species

Biotic response				
Species Stress	Flow (m ³ /s)	<i>Phragmites mauritanus</i>	Flow (m ³ /s)	<i>Ficus sur</i>
0	3.6	Adults with full vigour and at maximum reproductive capacity. 50% of population inundated, upper limit rooting depth at 20 – 30 cm.	1	Adults with full vigour and at maximum reproductive capacity. 25 – 50 cm rooting depth required for inundated soils. Supports maximum physiological requirements.
1		Adults with full vigour and at maximum reproductive capacity.		Adults with full vigour and at maximum reproductive capacity.
2		Leaf wilting/stress commences in adults, but is slight.		Leaf wilting/stress commences in adults, but is slight.
3	1.2	Leaf wilting/stress commences, but is slight. Up to 40 - 50cm rooting depth for upper limit, lower limit at water level on average.		Leaf wilting/stress commences, but is slight.
4		Flower/fruit abortion commences.	0.2	Flower/fruit abortion commences. 50 – 75 cm rooting depth required for inundated soils; high-energy functions taper off.
5		Leaf wilting obvious or vegetative parts begin unseasonal discolouration; flower/fruit abortion widespread.	0.03	Leaf wilting obvious or vegetative parts begin unseasonal discolouration; flower/fruit abortion widespread. 75 cm to 1 m rooting depth required for inundation; vegetative parts show visible signs of water stress.
6	0.2	Unseasonal thinning or partial mortality of above-ground parts (majority of the plant/s remains viable, but water stressed). Up to 75cm rooting depth for sufficient soil moisture, no inundation at lower limit, rhizomes at upper limits may begin	0	Unseasonal thinning or partial mortality of above-ground parts (majority of the plant/s remains viable, but water stressed). >1 m rooting depth to pools, if persistent mortality will commence.

Biotic response				
Species Stress	Flow (m ³ /s)	<i>Phragmites mauritianus</i>	Flow (m ³ /s)	<i>Ficus sur</i>
		thinning.		
7				
8	0.03	Unseasonal loss or mortality of above-ground parts (only minor portions of plants remain viable); rootstocks/rhizomes of some species remain viable/dormant. Up to 1 m rooting depth for sufficient soil moisture, rhizome mortality commences.		Unseasonal loss or mortality of above-ground parts (only minor portions of plants remain viable). Rootstocks/rhizomes of some species remain viable.
9		Complete mortality of small proportion of the population.		Complete mortality of small proportion of the population.
10	0	Widespread and complete mortality of population.		Widespread and complete mortality of population.

J2 EWR 1: UPPER SABIE: DETERMINATION OF EWR SCENARIOS

J2.1 LOW FLOW REQUIREMENTS IN TERMS OF STRESS FOR FISH

The fish low flow requirements for the EWR scenarios are summarised in Table J8 for the SR guild and Table J9 for LR guild.

Table J8 Low flow requirements: SR guild

GENERAL					
INDICATOR: The SR species <i>Amphilius uranoscopus</i> (AURA) and <i>Chiloglanis anoterus</i> (CANO) at the site are good indicators for setting flows as a result of their high requirement for flowing water. These species all require flowing water over substrates during all life stages, with some stages also preferring some overhanging vegetation as cover. Optimal conditions for spawning of this guild consist of FD, FI, FS and SS with good quality substrate (clean cobbles and gravel), while the margins of the FS and SS are important for egg development and nursery areas for larvae, often with overhanging vegetation as cover. Juvenile and adult stages of this guild have a high preference for FS, FI and FD over substrates.					
PES: FISH EC B/C (ECOSTATUS B/C)					
Dry Season drought At this fish stress level some FS (12% on cross-section), very limited FI (3% on cross-section) and some FD (11% on cross-section) will be maintained to ensure the survival of this fish guild. At these proportions of habitats available at the site, this species should be able to survive through drought periods in the dry season and enable recovery once conditions improve and remain within the PES.					
Dry Season maintenance At this fish stress level, adequate FS (11% on cross-section), FI (12% on cross-section) and some FD (14% on cross-section) will be maintained, the most critical habitats for the survival of this species. This habitat composition should maintain this fish guild in the present Ecological Category (EC)					
Wet Season drought At a fish stress level of 5.5 much reduced spawning habitats will be available for this fish guild, but it should be adequate to maintain some habitats to meet requirements of all life stages to ensure survival of these species during the wet season and allow recovery after drought period.					
Wet Season maintenance This fish stress level will maintain adequate FS (10%) and FI (11%) and abundant FD (32%), the most important habitat required by all life stages to fulfil all required biological processes during the wet season (spawning, nursery habitats as well as adequate feeding and refuge habitats for juvenile and adult specimens) to maintain this fish guild within the current EC.					
BUILDING BLOCK ¹	SEASON	STRESS DURATION	SPP STRESS	INTEG ² STRESS	FLOW (m ³ /s)
Drought	Dry	5%	8	9	0.4
Maintenance	Dry	35%	6	6.9	0.71
Drought	Wet	5%	5.5	6.5	0.75
Maintenance	Wet	35%	3	4	1.7
REC: FISH EC B (ECOSTATUS B)					
General Slightly modified conditions may improve fish to a higher EC.					
Dry Season maintenance At this recommended stress level, increased abundance of fast habitats (FS and FD) will be available, which would result in improved abundance of this fish guild and therefore improved frequency of occurrence (FROC).					
Wet Season maintenance At this stress level FS – FI – FD habitats will be available as 12% – 10% – 40% of the cross-section, respectively. This improvement from the present condition can be expected to improved habitat for especially spawning, and also increased nursery, abundance and thus improvement to a higher EC.					
BUILDING	SEASON	STRESS	SPP STRESS	INTEG ² STRESS	FLOW (m ³ /s)

BLOCK ¹		DURATION			
Maintenance	Dry	35%	5	6	0.8
Maintenance	Wet	35%	2.5	3.5	1.8
AEC: FISH EC C/D (ECOSTATUS C/D)					
General Decreased low flows will result in reduced fast habitats (riffles, rapids, runs) with a resultant loss or decreased frequency of occurrence of rheophilic and semi-rheophilic species (VNEL, AURA, CANO, BBRI). Increased sediments and nutrients will reduce quality of habitat in especially riffles and rapids (interstitial spaces) with negative impact on above-mentioned species. Increased temperatures may also affect FROC of some species.					
Dry Season maintenance This stress level will maintain some FS and FI, but no more FD habitats will be available. It can be expected that this guild will be stressed more than presently and result in decreased abundance and overall FROC, with a resultant decreased EC.					
Wet Season maintenance At this fish stress level, fast habitats (FS, FI and FD) will be available at a much reduced quantity than present wet conditions, but it should still be adequate to maintain all life stages although reduced abundance and FROC can be expected, and a resultant decrease in EC may occur.					
BUILDING BLOCK ¹	SEASON	STRESS DURATION	SPP STRESS	INTEG ² STRESS	FLOW (m ³ /s)
Maintenance	Dry	35%	7	8	0.63
Maintenance	Wet	35%	4.5	5.5	1.1

¹ Flow building block refers to drought and maintenance flows.

² Integrated

Table J9 Low flow requirements: LR guild

GENERAL					
INDICATOR: The LR species, <i>Varicorhinus nelspruitensis</i> (VNEL) is the most important indicator species regarding flows as it is the biggest species at the site having a requirement for continuous flows. VNEL is intolerant to no flow and requires flowing habitat (FI and FD) with substrate and water column as preferred cover for most of its life stage. They also require margins of FS, SS and SD with overhanging vegetation as nursery habitats. Flows should furthermore remain adequate to allow migration between reaches, thus depth in riffle and rapids should remain adequate, especially during the wet season.					
PES: FISH EC B/C (ECOSTATUS B/C)					
Dry Season drought At this fish stress level, some FI (8% on cross-section) and FD (12% on cross-section) will be maintained, the two most critical habitats for the survival of this species. At these proportions of habitats available at the site, this species should be able to survive through drought period in the dry season and enable recovery once conditions improve.					
Dry Season maintenance At this fish stress level, adequate (13% on cross-section) fast intermediate (FI) (0.2 – 0.3 m and >0.3 m/s) and fast deep (FD) (>0.3 m and >0.3 m/s) (16% on cross-section) will be maintained, the two most critical habitats for the survival of this species. This composition of FI and FD habitat should maintain the species in this EC during the dry season.					
Wet Season drought At fish stress level of 6 the preferred and most critical habitats of this species will be greatly reduced (13% FI and 16% FD), adequate to allow spawning and maintain other life stages to recover after this stress period.					
Wet Season maintenance This fish stress level will maintain adequate FI (10% on cross-section) and FD (40% on cross-section), the most important habitats required for most life stages and biological process requirements during the wet season (spawning, nursery habitats, and adequate habitats for juvenile and adult specimens) to maintain within current EC.					
BUILDING BLOCK	SEASON	STRESS DURATION	SPP STRESS	INTEG STRESS	FLOW (m ³ /s)
Drought	Dry	5%	8.5	8.5	0.5
Maintenance	Dry	35%	6	6	0.8
Drought	Wet	5%	6	6	0.8

Maintenance	Wet	35%	3	3	1.9
REC: FISH EC B (ECOSTATUS B)					
General This indicator group is at present (PES) in an excellent condition and improved flows may have a minimal impact on this species. It is however estimated that increased flows will result in higher abundance of cover and habitat for this species, which should result in improved abundance of this species and therefore increased FROC (frequency of occurrence), with a resultant improvement in EC.					
Dry Season maintenance Improved FI and FD habitats may improve the maintenance of higher abundance of this species during the dry season, which is the most stressed period for this large rheophilic species. This may result in an overall improved FROC of this species with a resultant improvement in EC.					
Wet Season maintenance Improved FI and FD habitats will result in improved habitat for especially spawning, and also increased nursery, abundance and thus an improvement to a higher EC.					
BUILDING BLOCK	SEASON	STRESS DURATION	SPP STRESS	INTEG STRESS	FLOW (m ³ /s)
Maintenance	Dry	35%	5.75	5.75	1
Maintenance	Wet	35%	2	2	2.5
AEC: FISH EC C/D (ECOSTATUS C/D)					
General Decreased low flows will result in reduced fast habitats (riffles, rapids, runs) with a resultant loss or decreased FROC of rheophilic and semi-rheophilic species (VNEL, AURA, CANO, BBRI). Increased sediments and nutrients will reduce quality of habitat in especially riffles and rapids (interstitial spaces) with negative impact on above-mentioned species. Increased temperatures may also affect FROC of species such as TSPA, VNEL, BBRI and BANO. Increased toxin levels as a result of reduced dilution will also have significant impact as large proportion of species is intolerant to modified water quality.					
Dry Season maintenance This fish stress level will maintain adequate FI (10% on cross-section) and FD (13% on cross-section) for survival of this species, but reduced abundance can be expected as habitats will be reduced from the present conditions, which may result in decreased FROC, and thus the overall EC.					
Wet Season maintenance Decreased FI and FD habitats will occur at this fish stress level when compared to present habitat composition, but it should still be adequate to maintain all life stages, albeit available in much reduced quantity, and therefore reduced abundance and FROC can be expected with a resultant decreased EC.					
BUILDING BLOCK	SEASON	STRESS DURATION	SPP STRESS	INTEG STRESS	FLOW (m ³ /s)
Maintenance	Dry	35%	7.5	7.5	(0.67)
Maintenance	Wet	35%	4.5	4.5	1.55

J2.2 LOW FLOW REQUIREMENTS IN TERMS OF STRESS FOR MACROINVERTEBRATES

The FDI low flow requirements are summarised in Table J10 below.

Table J10 Low flow requirements: FDI taxa

GENERAL
INDICATOR: Two indicator taxa were selected for this site: Perlidae and Elmidae. Perlid stoneflies prefer velocities of >0.6 m/s, but will persist at moderate velocities of 0.3 - 0.6 m/s and will even survive lower flows (in low abundances) if water quality is not compromised. Their preferred substrate is cobbles, again it is necessary that this habitat is clean (i.e. not covered with fines). Elmid beetles prefer velocities of 0.3 - 0.6 m/s higher velocities. Their preferred substrate is cobbles. Their requirement is for moderate to high water quality. For both taxa, early summer breeding requires maintenance of high quality water (low in organics and high clarity).
PES: MACROINVERTEBRATE EC: B (ECOSTATUS B/C)
Dry Season maintenance Consistent average velocities of >0.3 m/s and maximum velocities of >0.6 m/s required to maintain viable population of

Perlids. This will cater for Elmid requirements. The stresses set here will provide for this current speed in limited cobble areas. Water quality will remain sufficiently high to support healthy breeding populations.

Dry Season drought

Adequate depth (average 0.2 m) and current over coarse substrate (cobbles) is required to ensure that the indicator taxa persist through drought months. Adequate velocities (> 0.2 m/s, max > 0.6 m/s) are required to ensure maintenance of water quality.

Wet Season maintenance

The requirement for healthy Perlid and Elmid populations during late summer wet season is for high water quality and average velocities of > 0.3 m/s, with max velocities of > 0.6 m/s over cobbles, with average depths in the vicinity of 0.3 m. These flow conditions will ensure flushing and thus maintenance of the critical habitat.

Wet Season drought

During March (late summer), it is possible that emergence of Perlid adults occurs. Perlid requirements will cater for Elmids. Average velocities of > 0.2 m/s, with maximum velocities > 0.6 m/s are preferred, with average depths > 0.2 m.

BUILDING BLOCK	SEASON	STRESS DURATION	SPP STRESS	INTEG STRESS	FLOW (m ³ /s)
Drought	Dry	5%	7	9.8	0.08
Maintenance	Dry	35%	4	5.9	0.86
Drought	Wet	5%	6	9.5	0.2
Maintenance	Wet	35%	3	5.5	1.1

AEC: MACROINVERTEBRATE EC: C (ECOSTATUS C/D)

Dry Season maintenance

Consistent maximum velocities of > 0.6 m/s required to maintain viable population of Perlids. This will cater for Elmid requirements. The stresses set here will provide for this current speed in limited cobble areas. Water quality will remain sufficiently high to support healthy breeding populations.

Dry Season drought

Adequate depth (average 0.2 m) and current over coarse substrate (cobbles) is required to ensure that the indicator taxa persist through drought months. Adequate velocities (> 0.2 m/s, max > 0.6 m/s) are required to ensure maintenance of water quality.

Wet Season maintenance

The requirement to maintain viable populations of Perlids and Elmids is for moderate to fast velocities (0.3 - > 0.6 m/s) and depths of > 0.15 m over the critical habitat. These conditions will enable the populations of both indicator taxa to persist and breed, although in lower abundances than at a PES of B.

Wet Season drought

During March (late summer), it is possible that emergence of Perlid adults occurs. Perlid requirements will cater for Elmids. Average velocities of > 0.2 m/s, with maximum velocities > 0.6 m/s are preferred, with average depths > 0.2 m.

BUILDING BLOCK	SEASON	STRESS DURATION	SPP STRESS	INTEG STRESS	FLOW (m ³ /s)
Maintenance	Dry	35%	6	9.5	0.2
Maintenance	Wet	35%	5	9	0.4

J2.3 LOW FLOW REQUIREMENTS IN TERMS OF RIPARIAN VEGETATION

The low flow requirements for riparian vegetation indicator species are summarised in Table J11.

Table J11 Low flow requirements: Riparian vegetation species

GENERAL
INDICATOR: <i>Phragmites mauritanus</i> and <i>Ficus sur</i> .
PES: RIPARIAN VEGETATION EC B/C (ECOSTATUS B/C)
Dry Season maintenance In order that the PES is maintained, population stress would not be expected to exceed 4 during dry season maintenance flows. At a stress of 4, leaf wilting/stress commences but is slight, and flower/fruit abortion commences (which is unlikely to occur in dry season).

Dry Season drought

It is not expected that the average population experiences a stress of more than 6 during natural drought in the dry season. *Ficus* species stress of 6 equates to unseasonal thinning or partial mortality of above-ground parts (majority of the plant/s remain/s viable, but water stressed). A thinning of the population can be expected for reeds.

Wet Season maintenance

In order that the PES is maintained, population stress would not be expected to exceed 2 during wet (growing) season maintenance flows. At a species stress of 2, leaf wilting/stress commences in adults, but is slight; the population is essentially unhampered in reproductive capacity.

Wet Season drought

It is not expected that the average population experiences a stress of more than 5 during natural drought in the wet season. A species stress of 5 equates to obvious leaf wilting or vegetative parts begin unseasonal discolouration and widespread flower/fruit abortion.

BUILDING BLOCK	SEASON	STRESS DURATION	SPP STRESS <i>Phragmites</i>	INTEG STRESS	SPP STRESS <i>Ficus</i>	INTEG STRESS	FLOW (m ³ /s)
Drought	Dry	5%	6	9.75	6	10	0.1
Maintenance	Dry	35%	4	5.75	4	9.5	0.95
Drought	Wet	5%	5	8.5	5	10	0.515
Maintenance	Wet	35%	2	2.75	2	8.25	2.5

PES: RIPARIAN VEGETATION EC B (ECOSTATUS B)**Dry Season maintenance**

Similar to dry maintenance under PES, but with slightly less stress associated with slightly more flow.

Wet Season maintenance

In order that the REC is maintained, population stress would not be expected to exceed 1 or 1.5 during wet (growing) season maintenance flows. At a species stress of 1, adults have full vigour and operate at maximum reproductive capacity and the population is essentially unstressed.

BUILDING BLOCK	SEASON	STRESS DURATION	SPP STRESS <i>Cyperus</i>	INTEG STRESS	SPP STRESS <i>Gomphostigma</i>	INTEG STRESS	FLOW (m ³ /s)
Maintenance	Dry	35%	3.5	5.5	3	9	1.1
Maintenance	Wet	35%	1	1.5	1.5	7	2.75

PES: RIPARIAN VEGETATION EC C/D (ECOSTATUS C/D)**Dry Season maintenance**

Similar to PES dry season maintenance, but with reeds showing slightly more wilting stress as a result of reduced base flows.

Wet Season maintenance

In order that the AEC is maintained, population stress would not be expected to exceed 3 during wet (growing) season maintenance flows. At a species stress of 3, leaf wilting/stress commences but is slight, and the population remains reproductively active.

BUILDING BLOCK	SEASON	STRESS DURATION	SPP STRESS <i>Cyperus</i>	INTEG STRESS	SPP STRESS <i>Gomphostigma</i>	INTEG STRESS	FLOW (m ³ /s)
Maintenance	Dry	50%	5	8.5	4	9.5	0.515
Maintenance	Wet	50%	3	5.25	3	9	1.25

J2.4 INSTREAM FLOOD FUNCTIONS

A description of the flood functions for biotic response is provided in Table J12.

Table J12 Functions for each Flood Class

Flood Class	Component	Function/Motivation
Class: I Range (m ³ /s): 5 - 7 Daily average: 6 Duration: 4	Fish	Class I floods are very important floods for fish and serves as migration cues and to maintain adequate longitudinal connectivity for migration. These floods will also flush fines and algae from substrates to ensure adequate conditions in substrates, a very important habitat for spawning of many of the species. It should furthermore inundate some vegetation for species spawning in flooded marginal vegetation and contributes to the creation of acceptable nursery areas. Some resetting of water quality will also take place, and the changes in water quality may also serve as stimulus to cue migratory activity and even gonad development. The frequency, extent and duration as recommended for the PES and AEC should be adequate to provide the functions as required to maintain the fish within the specific category.
	Macroinvertebrates	These freshettes are recommended to flush fines, improve or reset water quality, provide early and mid-summer breeding cues, scour algae off rock surfaces and undersides, and inundate broad areas of marginal vegetation. For a B EC, four are recommended per year, in the months of October, December, February and April. For a C EC, three are recommended, in the months of October, December and March
Class: II Range (m ³ /s): 10 - 20 Daily average: 15 Duration: 5	Fish	Class II floods are similar in importance as class I floods and have the same functionality as class I floods. Their occurrence at lower frequency makes them only slightly less important for the fish assemblages than Class I.
	Macroinvertebrates	These floods are recommended to fulfil all of the functions performed by the freshettes, plus to shift and reset coarse substrate components. For a B EC and C, one a year is required, in the month of February or March.
Class: III Range (m ³ /s): 35 – 55 Daily average: 30	Fish	Class III floods also provide similar functions as class I, but due to its lower frequency it is not essential for the flood functions required by the indigenous fish species. These floods, and especially their receding limbs will however be utilised by many of the fish species for migration and even spawning if takes place within the summer season.
CLASS: IV <70	Fish	Class IV floods also provide similar functions as class I, but due to its lower frequency of occurrence it is not essential for the flood functions required by the indigenous fish species. These floods, and especially their receding limbs will however be utilised by many of the fish species for migration and even spawning if takes place within the summer season.

J2.5 EWR RULE TABLES

EWR rule tables which provide the recommended EWR flows as a duration table, showing flows which should be provided when linked to a natural trigger (natural modelled hydrology in this case) are provided for the different EWR scenarios. EWR rules are supplied for total flows as well as for low flows only.

Table J13 EWR 1 assurance rules for PES: B/C

Desktop Version 2, Printed on 2008/07/30

Summary of IFR rule curves for: SB1 Natural Flows

Determination based on defined BBM Table with site specific assurance rules.

Regional Type: E. Escarp PES = B/C

Data are given in m³/s mean monthly flow

Month	% Points									
	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	1.650	1.646	1.627	1.585	1.502	1.356	1.135	0.860	0.602	0.460
Nov	1.408	1.402	1.385	1.349	1.280	1.161	0.986	0.772	0.574	0.466
Dec	2.082	2.072	2.043	1.983	1.867	1.673	1.389	1.046	0.731	0.559
Jan	4.379	3.988	3.648	3.326	2.751	2.438	1.991	1.463	0.984	0.721
Feb	3.535	3.375	3.219	3.044	2.724	2.438	2.021	1.518	1.056	0.802
Mar	3.321	3.177	3.037	2.878	2.586	2.318	1.922	1.441	0.996	0.751
Apr	2.382	2.376	2.349	2.290	2.172	1.964	1.649	1.257	0.890	0.688
May	2.099	2.095	2.075	2.028	1.931	1.755	1.482	1.134	0.804	0.622
Jun	1.950	1.949	1.931	1.890	1.803	1.644	1.392	1.070	0.760	0.589
Jul	1.617	1.617	1.605	1.575	1.509	1.384	1.181	0.915	0.655	0.510
Aug	1.383	1.382	1.369	1.341	1.282	1.174	1.002	0.782	0.571	0.454
Sep	1.259	1.258	1.246	1.220	1.165	1.067	0.913	0.718	0.533	0.430

Reserve flows without High Flows

Oct	1.198	1.195	1.182	1.155	1.100	1.004	0.858	0.676	0.506	0.413
Nov	1.408	1.402	1.385	1.349	1.280	1.161	0.986	0.772	0.574	0.466
Dec	1.630	1.622	1.601	1.556	1.472	1.329	1.121	0.869	0.638	0.512
Jan	1.975	1.962	1.933	1.874	1.764	1.583	1.325	1.020	0.742	0.591
Feb	2.592	2.579	2.545	2.472	2.333	2.097	1.754	1.340	0.960	0.751
Mar	2.469	2.458	2.427	2.360	2.230	2.007	1.679	1.278	0.908	0.705
Apr	2.382	2.376	2.349	2.290	2.172	1.964	1.649	1.257	0.890	0.688
May	2.099	2.095	2.075	2.028	1.931	1.755	1.482	1.134	0.804	0.622
Jun	1.950	1.949	1.931	1.890	1.803	1.644	1.392	1.070	0.760	0.589
Jul	1.617	1.617	1.605	1.575	1.509	1.384	1.181	0.915	0.655	0.510
Aug	1.383	1.382	1.369	1.341	1.282	1.174	1.002	0.782	0.571	0.454
Sep	1.259	1.258	1.246	1.220	1.165	1.067	0.913	0.718	0.533	0.430

Natural Duration curves

Oct	2.599	2.266	1.971	1.732	1.534	1.456	1.359	1.273	1.116	0.971
Nov	5.694	4.001	3.576	3.171	2.805	2.485	2.157	1.825	1.470	1.138
Dec	8.714	7.116	5.727	4.966	4.085	3.562	3.147	2.789	2.431	1.665
Jan	14.363	10.488	8.020	6.369	5.608	5.141	4.096	3.726	3.091	2.767
Feb	20.685	16.100	11.760	7.688	6.758	6.114	4.952	4.415	3.191	2.501
Mar	16.831	10.895	8.621	8.094	6.160	4.884	4.238	3.775	3.338	2.263
Apr	8.931	7.222	6.046	5.285	4.699	4.109	3.789	3.383	3.090	2.153
May	4.540	4.088	3.864	3.539	3.442	3.017	2.722	2.550	2.296	1.725
Jun	3.546	3.079	2.859	2.735	2.689	2.600	2.265	2.068	1.867	1.454
Jul	2.819	2.483	2.352	2.147	2.050	1.968	1.826	1.669	1.508	1.292
Aug	2.236	2.087	1.874	1.807	1.688	1.620	1.512	1.441	1.325	1.094
Sep	2.211	2.060	1.690	1.609	1.520	1.447	1.366	1.300	1.188	1.003

Table J14 EWR 1 assurance rules for REC: B

Desktop Version 2, Printed on 2008/07/30

Summary of IFR rule curves for: SB1 Natural Flows

Determination based on defined BBM Table with site specific assurance rules.

Regional Type: E. Escarp REC = B

Data are given in m³/s mean monthly flow

Month	% Points									
	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	1.938	1.932	1.909	1.732	1.534	1.456	1.299	0.959	0.640	0.464
Nov	2.251	2.241	2.210	2.144	2.017	1.798	1.476	1.083	0.720	0.520
Dec	2.594	2.580	2.542	2.461	2.308	2.049	1.671	1.215	0.796	0.567
Jan	4.911	4.515	4.165	3.820	3.204	2.822	2.278	1.634	1.049	0.729
Feb	4.287	4.121	3.951	3.747	3.371	2.991	2.436	1.766	1.151	0.814
Mar	3.284	3.268	3.223	3.125	2.936	2.612	2.134	1.552	1.013	0.718
Apr	3.564	3.553	3.508	3.410	3.214	2.868	2.344	1.694	1.084	0.748
May	2.687	2.682	2.654	2.588	2.454	2.209	1.828	1.345	0.885	0.631
Jun	2.508	2.505	2.480	2.422	2.301	2.078	1.725	1.272	0.838	0.598
Jul	2.030	2.030	2.013	1.972	1.882	1.711	1.434	1.070	0.714	0.517
Aug	1.720	1.718	1.702	1.664	1.584	1.436	1.203	0.904	0.618	0.460
Sep	1.553	1.550	1.535	1.499	1.426	1.293	1.086	0.823	0.573	0.435

Reserve flows without High Flows

Oct	1.493	1.489	1.472	1.434	1.359	1.227	1.027	0.778	0.546	0.417
Nov	1.792	1.784	1.760	1.710	1.613	1.446	1.200	0.901	0.624	0.472
Dec	2.150	2.138	2.107	2.043	1.920	1.712	1.408	1.041	0.704	0.520
Jan	2.508	2.490	2.450	2.368	2.217	1.968	1.612	1.190	0.808	0.599
Feb	3.343	3.325	3.277	3.175	2.980	2.650	2.169	1.588	1.055	0.763
Mar	3.284	3.268	3.223	3.125	2.936	2.612	2.134	1.552	1.013	0.718
Apr	3.105	3.095	3.057	2.973	2.806	2.510	2.063	1.507	0.986	0.700
May	2.687	2.682	2.654	2.588	2.454	2.209	1.828	1.345	0.885	0.631
Jun	2.508	2.505	2.480	2.422	2.301	2.078	1.725	1.272	0.838	0.598
Jul	2.030	2.030	2.013	1.972	1.882	1.711	1.434	1.070	0.714	0.517
Aug	1.720	1.718	1.702	1.664	1.584	1.436	1.203	0.904	0.618	0.460
Sep	1.553	1.550	1.535	1.499	1.426	1.293	1.086	0.823	0.573	0.435

Natural Duration curves

Oct	2.599	2.266	1.971	1.732	1.534	1.456	1.359	1.273	1.116	0.971
Nov	5.694	4.001	3.576	3.171	2.805	2.485	2.157	1.825	1.470	1.138
Dec	8.714	7.116	5.727	4.966	4.085	3.562	3.147	2.789	2.431	1.665
Jan	14.363	10.488	8.020	6.369	5.608	5.141	4.096	3.726	3.091	2.767
Feb	20.685	16.100	11.760	7.688	6.758	6.114	4.952	4.415	3.191	2.501
Mar	16.831	10.895	8.621	8.094	6.160	4.884	4.238	3.775	3.338	2.263
Apr	8.931	7.222	6.046	5.285	4.699	4.109	3.789	3.383	3.090	2.153
May	4.540	4.088	3.864	3.539	3.442	3.017	2.722	2.550	2.296	1.725
Jun	3.546	3.079	2.859	2.735	2.689	2.600	2.265	2.068	1.867	1.454
Jul	2.819	2.483	2.352	2.147	2.050	1.968	1.826	1.669	1.508	1.292
Aug	2.236	2.087	1.874	1.807	1.688	1.620	1.512	1.441	1.325	1.094
Sep	2.211	2.060	1.690	1.609	1.520	1.447	1.366	1.300	1.188	1.003

Table J15 EWR 1 assurance rules for AEC: C/D

Desktop Version 2, Printed on 2008/07/30

Summary of IFR rule curves for: SB1 Natural Flows

Determination based on defined BBM Table with site specific assurance rules.

Regional Type: E. Escarp AEC = C/D

Data are given in m³/s mean monthly flow

Month	% Points									
	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	1.356	1.353	1.339	1.307	1.244	1.134	0.966	0.758	0.563	0.455
Nov	1.050	1.046	1.036	1.013	0.970	0.896	0.786	0.652	0.528	0.460
Dec	1.770	1.762	1.739	1.691	1.599	1.444	1.217	0.943	0.692	0.554
Jan	3.967	3.580	3.249	2.944	2.401	2.141	1.770	1.331	0.933	0.715
Feb	2.189	2.179	2.151	2.094	1.985	1.801	1.531	1.207	0.908	0.745
Mar	2.884	2.744	2.611	2.469	2.208	1.994	1.679	1.294	0.940	0.744
Apr	1.954	1.949	1.929	1.885	1.796	1.640	1.403	1.109	0.833	0.681
May	1.720	1.718	1.702	1.667	1.595	1.463	1.259	0.999	0.752	0.616
Jun	1.564	1.562	1.550	1.520	1.458	1.343	1.162	0.929	0.706	0.583
Jul	1.251	1.251	1.243	1.222	1.178	1.094	0.957	0.777	0.602	0.504
Aug	1.017	1.016	1.009	0.991	0.955	0.889	0.784	0.649	0.520	0.448
Sep	0.939	0.938	0.930	0.914	0.880	0.819	0.724	0.604	0.489	0.425

Reserve flows without High Flows

Oct	0.837	0.835	0.829	0.814	0.784	0.731	0.651	0.551	0.458	0.407
Nov	1.050	1.046	1.036	1.013	0.970	0.896	0.786	0.652	0.528	0.460
Dec	1.251	1.246	1.232	1.202	1.146	1.051	0.912	0.744	0.590	0.506
Jan	1.564	1.555	1.534	1.492	1.415	1.287	1.104	0.888	0.692	0.584
Feb	2.189	2.179	2.151	2.094	1.985	1.801	1.531	1.207	0.908	0.745
Mar	2.032	2.025	2.001	1.950	1.852	1.683	1.435	1.132	0.852	0.698
Apr	1.954	1.949	1.929	1.885	1.796	1.640	1.403	1.109	0.833	0.681
May	1.720	1.718	1.702	1.667	1.595	1.463	1.259	0.999	0.752	0.616
Jun	1.564	1.562	1.550	1.520	1.458	1.343	1.162	0.929	0.706	0.583
Jul	1.251	1.251	1.243	1.222	1.178	1.094	0.957	0.777	0.602	0.504
Aug	1.017	1.016	1.009	0.991	0.955	0.889	0.784	0.649	0.520	0.448
Sep	0.939	0.938	0.930	0.914	0.880	0.819	0.724	0.604	0.489	0.425

Natural Duration curves

Oct	2.599	2.266	1.971	1.732	1.534	1.456	1.359	1.273	1.116	0.971
Nov	5.694	4.001	3.576	3.171	2.805	2.485	2.157	1.825	1.470	1.138
Dec	8.714	7.116	5.727	4.966	4.085	3.562	3.147	2.789	2.431	1.665
Jan	14.363	10.488	8.020	6.369	5.608	5.141	4.096	3.726	3.091	2.767
Feb	20.685	16.100	11.760	7.688	6.758	6.114	4.952	4.415	3.191	2.501
Mar	16.831	10.895	8.621	8.094	6.160	4.884	4.238	3.775	3.338	2.263
Apr	8.931	7.222	6.046	5.285	4.699	4.109	3.789	3.383	3.090	2.153
May	4.540	4.088	3.864	3.539	3.442	3.017	2.722	2.550	2.296	1.725
Jun	3.546	3.079	2.859	2.735	2.689	2.600	2.265	2.068	1.867	1.454
Jul	2.819	2.483	2.352	2.147	2.050	1.968	1.826	1.669	1.508	1.292
Aug	2.236	2.087	1.874	1.807	1.688	1.620	1.512	1.441	1.325	1.094
Sep	2.211	2.060	1.690	1.609	1.520	1.447	1.366	1.300	1.188	1.003

**APPENDIX K: SUPPORTING INFORMATION FOR THE DETERMINATION OF STRESS
INDICES AND EWR SCENARIOS OF EWR 2: AAN DE VLIET**

K1 EWR 2: AAN DE VLIET (SABIE RIVER) - DETERMINATION OF STRESS INDICES

Appendix K provides supporting information for the determination of stress indices and EWR scenarios of EWR 2: Aan de Vliet (Chapter 5 and 6 of the Sabie-Sand River System EWR Scenario Report: Volume 1)

K1.1 FISH INDICATOR SPECIES

Large rheophilic (LR) guild: *Varicorhinus nelspruitensis* (VNEL) is the most important indicator species regarding the setting of flows as it is the biggest species at the site having a requirement for continuous flowing water for all of its life stages.

Small rheophilic (SR) guild: *Amphilius uranoscopus* (AURA), *Chiloglanis anoterus* (CANO) and *Opsaridium peringueyi* (OPER) at the site are also good indicators for setting flows as a result of their high requirement for flowing water. These species all requires flowing water over substrates during all life stages, with some stages also preferring overhanging vegetation as cover.

The habitat requirements for the different life stages of the LR indicator fish species is summarised in Appendix J, Table J1 in Table K1 for the SR guild. Information in Bold type face indicates crucial habitat during the given life stage.

Table K1 Habitat requirements for different life stages of indicators species included in the SR guild

Species	Spawning	Egg and embryo development	Larvae	Juveniles	Adults
AURA	Flow habitat: SS, FI (>0.25 m). Substrate: Gravel and cobble. Spawning season: Oct - Jan Cue: Increased temp., flow and changes in water quality (e.g. conductivity).	Flow habitat: Margins of SS (>0.2 m, <0.2 m/s). Substrate: Gravel, cobble. Oct – Jan. Cue: >16°C. Duration: 7 days.	Flow habitat: Margins of FS, SS and overhanging vegetation. Nursery areas: (>0.20 m, <0.2 m/s). Larval period: 2 months.	Flow habitat: Mostly FD, FI (>0.20 m deep >0.1 m/s). Cover: Cobbles, rocks and overhanging vegetation. Duration 3 - 6 months. Low flow refuge (June - Sep): FS, FD . Cover: Cobbles, rocks.	Flow habitat: FD, FS . Cover: Cobbles and rocks. Low flow refuge (June - Sep): FS and FD . Cover: cobbles, rocks overhanging vegetation.
CANO	Flow habitat: FD, FI (>0.25 m). Substrate: Gravel and cobble . Spawning season: Summer (Oct - Jan). Cue: Increased temp., flow and changes in water quality (e.g. conductivity).	Flow habitat: Margins of FS and SS (>0.20 m). Substrate: Gravel . Oct – Jan. Duration: 7 days. Breeds during summer, laying eggs between rocks and in gravel . Oviparous.	Nursery area depth - >0.20m. Flow habitat: Margins of FS and SS . Larval period: 2 months.	Flow habitat: Mostly FD, FI (>0.20m). Cover: Cobbles and rocks . Duration: 3 - 6 months. Low flow refuge (Jun – Sep). FI (>0.20m/s), FD. Cover: Cobbles, rocks . Preferred substrate: Gravel/Pebble. Preferred velocity: >1.4 m/s. Preferred depth: 15 - 35 cm. Cover: Combined velocity and visual cover.	Flow habitat: FD and FS . Cover: Cobbles and rocks . Low flow refuge (Jun – Sep). FI (>0.30m/s), FD . Cover: cobbles, rocks overhanging vegetation . Preferred substrate: Gravel/Pebble. Preferred velocity: >1.4 m/s. Preferred depth: 20 - 50 cm. Cover: Combined velocity and visual cover. Amongst rocks in clear, swift-flowing streams where the water is well-aerated. Rocky riffles and rapids. Sexual maturity – 50 mm.
OPER	Flow habitat: Sheltered SS, FS, FI (>0.15 m deep). Substrate: Gravel, cobble. Spawning season: Oct - Jan (summer). Cue: Increased temp., flow and changes in water quality (e.g. conductivity). Probably spawns on	Flow habitat: FS/FI and SS (>0.15 m deep, >0.3 m/s). Substrate: Sheltered sandy/gravel. Oct – Jan. >20°C. Duration 6 - 8 days.	Nursery areas (>0.15 m deep, <0.2 m/s). Flow habitat: Margins of SS . Overhanging vegetation and macrophytes. Larval period: 2 months.	Flow habitat: Mostly SD and SS (>0.15 m deep, <0.2 m/s). Cover: Sand/gravel substrate with overhanging vegetation. Duration 3 - 6 months. Low flow refuge (Jun – Sep).	Flow habitat: SD, FD, FI, FS (>0.15 m, >0.2 m/s). Cover: Sheltered sandy/gravel substrate. Low flow refuge Jun – Sep. SS (>0.15 m, >0.1 m/s), SD, FS, FD . Cover: Cobbles, rocks overhanging vegetation.

Species	Spawning	Egg and embryo development	Larvae	Juveniles	Adults
	floodplains. Sexual development occurs at a length of 76 mm. Breeds in spring and summer, spawning several times during the season.			SS (>0.15 m deep, >0.15 m/s), SD. Cover: Cobbles, rocks. Preferred substrate: Gravel/Pebble. Preferred velocity: 0.2 - 0.7m/s. Preferred depth: 10 – 30 cm. Cover: Visual cover. Prefer medium flows (0.55 m/s) in shallow waters (22 cm).	Various habitats: Well-aerated reaches of strongly flowing water, shallow sandy pools below rocky rapids, swift, clear and well aerated waters. Shoals – protected inshore habitats when tigerfish are present. Feeds on bottom and on drifting insects and small organisms.

K1.2 FISH STRESS INDEX

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

Table K2 EWR 2: Habitat suitability for the SR and LR guild

SR AND LR GUILD															
Depth classes	Discharges (m ³ /s)														
	0.30	0.67	1.04	1.27	1.50	1.74	2.00	2.29	2.60	2.93	5.43	5.79	6.16	7.34	9.11
Slow (<0.3 m/s) Very Shallow (<0.1 m) (SVS)	8	8	8	8	8	8	8	10	8	10	10	8	8	8	8
Slow (<0.3 m/s) Shallow (0.1 – 0.3 m) (SS)	4	4	6	6	6	6	6	6	8	8	8	8	8	8	8
Slow (<0.3 m/s) Deep (> 0.5 m) (SD)	10	10	10	10	10	10	10	10	10	10	8	8	8	8	8
Slow Shallow and Slow Deep	4	4	6	6	6	6	6	6	8	8	8	8	8	8	8
Fast (>0.3 m/s) Very Shallow (<0.1 m) (FVS)	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8
Fast (>0.3 m/s) Shallow (0.1 – 0.3 m) (FS)	6	6	8	8	8	8	8	8	8	8	8	8	8	8	8
Fast (>0.3 m/s) Intermediate (0.2 – 0.3) (FI)	10	6	4	4	4	6	6	10	8	8	8	8	8	8	8
Fast (>0.3 m/s) Deep (> 0.3 m) (FD)	10	10	10	8	8	6	4	4	4	2	0	0	0	0	2
FAST TOTAL >0.1 m DEEP	10	6	4	4	4	4	2	2	2	2	0	0	0	0	0

The fish stress index is provided in Table K3

Table K3 Fish stress index

Habitat	Discharges (m ³ /s)														
	0.30	0.67	1.04	1.27	1.50	1.74	2.00	2.29	2.60	2.93	5.43	5.79	6.16	7.34	9.11
SMALL RHEOPHILIC (SR) GUILD															
Spawning habitat	0	0.5	1	1.5	2	2.5	3	3.5	3.5	4	4.5	5	5	5	5
Nursery habitat	0.5	1	1.5	2	2	2.5	3	3.5	4	4	4.5	5	5	5	5
Abundance	0.5	1	1.5	1.5	2	2.5	3	3.5	3.5	4	4.5	5	5	5	5
Cover	0.5	1	1.5	1.5	2	2.5	3	3.5	3.5	4	4.5	5	5	5	5
Connectivity (lateral & longitudinal)	0	0.5	1	2	2	3	3	3.5	4	4	4.5	5	5	5	5
Water Quality (esp. oxygen and temperature)	0.5	1.5	2	2.5	3	3	3	3.5	4	4.5	5	5	5	5	5
Species stress: AURA, CANO, OPER	9	8	7	6	6	5	4	3	3	2	1	0	0	0	0
LARGE RHEOPHILIC (LR) GUILD															
Spawning habitat	0	0.5	1	1.5	1.5	2	2.5	3	3.5	4	4.5	4.5	5	5	5
Nursery habitat	0.5	1	1.5	2	2	2.5	3	3.5	4	4	4.5	5	5	5	5
Abundance	0	0.5	1.5	2	2.5	3	3	3.5	3.5	4	4.5	5	5	5	5
Cover	0	0.5	1.5	2	2.5	3	3	3.5	3.5	4	4.5	5	5	5	5
Connectivity (lateral & longitudinal)	0	0	0.5	1.5	2	2.5	3	3.5	4	4	4.5	5	5	5	5
Water Quality (espec oxygen and temperature)	0.5	1.5	2	2.5	3	3	3	3.5	4	4.5	5	5	5	5	5
Species stress: VNEL	10	9	7	6	6	5	4	3	3	2	1	0	0	0	0

K1.3 MACROINVERTEBRATE STRESS INDEX

The habitat flow index for flow dependent macroinvertebrate (FDI) taxa is provided in Table K4 and provides the % occurrence of various velocity and substrate classes under different flow conditions.

Table K4 Habitat suitability for FDI taxa

Habitat Flow Response Index	Habitat Response	Habitat Abundance and suitability													Flow (m ³ /s)
		VSCS ¹	SCS ²	FCS ³	VFCs ⁴	VSFS ⁵	SFS ⁶	FFS ⁷	VFFS ⁸	VSBR ⁸	SBR ¹⁰	FBR ¹¹	VFBR ¹²	Veg ¹³	
0	All habitat in excess, very high quality. Very fast, very deep, very wide WP.	2	4	10	54	1	2	4	23	0	0	0	0		7.34
1	All plentiful, high quality. Fast, wide WP.	2	5	12	51	1	2	5	22	0	0	0	0		4.97
2	Critical habitats sufficient. Quality slightly reduced. Fast, WP slightly reduced	4	9	17	40	2	4	7	17	0	0	0	0		2.93
3	Reduced critical habitat, reduced critical quality. Moderate velocity, fairly deep.	7	14	23	26	3	6	10	11	0	0	0	0		1.50
4	Critical habitats limited; moderate quality. Moderate velocity, some deep areas, wide WP moderately reduced.	10	17	26	17	4	7	11	7	0	0	0	0		1.04
5	Critical habitat very reduced; moderate/ low quality. Moderate/slow velocity, few deep areas WP moderately/very reduced.	14	21	26	9	6	9	11	4	0	0	0	0		0.67
6	Critical habitat residual and of low quality. Moderate/slow velocity.	18	26	21	5	8	11	9	2	0	0	0	0		0.40
7	No critical habitat, other habitats moderate quality. Slow, narrow wetted perimeter.	22	31	13	3	10	14	6	1	0	0	0	0		0.22

Habitat Flow Response Index	Habitat Response	Habitat Abundance and suitability													Flow (m ³ /s)
		VSCS ¹	SCS ²	FCS ³	VFCS ⁴	VSFS ⁵	SFS ⁶	FFS ⁷	VFFS ⁸	VSBR ⁹	SBR ¹⁰	FBR ¹¹	VFBR ¹²	Veg ¹³	
8	Flowing water habitats residual low quality. Slow trickle, very narrow WP.	28	33	8	1	12	14	3	0	0	0	0	0		0.11
9	Standing and very slow flowing habitats only, very low quality, no flow.	54	16	0	0	23	7	0	0	0	0	0	0		0.013
10	Only hyporheic refugia, no surface water.	69	1	0	0	30	0	0	0	0	0	0	0		0.0

1 Very Slow over Coarse Sediment

2 Slow over Coarse Sediment

3 Fast over Coarse Sediment

4 Very Fast over Coarse Sediment

5 Very Slow over Fine Sediment

6 Slow over Fine Sediment

7 Fast over Fine Sediment

8 Very Fast over Fine Sediment

9 Very Slow over Bedrock

10 Slow over Bedrock

11 Fast over Bedrock

12 Very Fast over Bedrock

13 Fringing vegetation

The stress index for FDI taxa is provided in Table K5 which rates the response of the species according to various biotic response metrics.

Table K5 Macroinvertebrate (FDI) stress index

Habitat characteristics					Biotic Response	Flow	Species Stress
Max depth (m)	Ave depth (m)	Max vel (m/s)	Ave vel (m/s)	WP (m)			
0.64	0.5	1.07	2.16	14.7	All indicator taxa very abundant and healthy.	4.970	0
0.52	0.42	0.94	1.96	13.4	90% indicator taxa persist.	2.930	1
0.42	0.34	0.72	1.65	12.8	Most indicator taxa persist, but slight (80%) reduction.	1.500	2
0.32	0.24	0.52	1.48	12.5	Most indicator taxa persist, but abundances reduced.	1.040	3
0.28	0.21	0.43	1.31	12.2	All life stages viable in limited areas, critical life stages of some sensitive indicator taxa at risk.	0.670	4
0.24	0.17	0.34	1.06	11.9	Critical life-stages of sensitive indicator taxa at risk or non-viable.	0.400	5
0.2	0.14	0.27	0.87	11.5	Sensitive indicator taxa rare, critical stages of sensitive indicator taxa non-viable, and at risk for some less sensitive taxa.	0.220	6
0.16	0.1	0.2	0.67	10.9	Some indicator taxa persist, but most disappear. All life-stages of sensitive indicator taxa at risk or non-viable.	0.165	7
0.12	0.08	0.16	0.52	9.2	Some indicator taxa persist, but at very low numbers; All life stages of most indicator taxa at risk or non-viable.	0.110	8
0.06	0.03	0.07	0.23	7.4	Indicator taxa no longer present.	0.013	9
0.02	0.01	0.02	0.09	1.6	No surface water.	0.0	10

K1.4 RIPARIAN VEGETATION STRESS INDEX

A riparian vegetation stress index is provided in Table K6.

Table K6 Riparian vegetation stress index for indicator species

Biotic response				
Species Stress	Flow (m ³ /s)	<i>Phragmites mauritanus</i>	Flow (m ³ /s)	<i>Breonadia salicina</i>
0	8.6	Adults with full vigour and at maximum reproductive capacity. 50% population inundated, upper limit rooting depth up to 50 cm.	4.5	Lower limit of marginal zone population inundated (low/1), no water stress.
1		Adults with full vigour and at maximum reproductive capacity.		
2		Leaf wilting/stress commences in adults, but is slight.		

Biotic response				
Species Stress	Flow (m ³ /s)	<i>Phragmites mauritianus</i>	Flow (m ³ /s)	<i>Breonadia salicina</i>
3	5.5	Leaf wilting/stress commences, but is slight. Up to 65 cm rooting depth for upper limit, lower limit 30 cm inundated on average.	0.7	Lower limit requires 25 cm (low/2) substrate depth to inundation.
4		Flower/fruit abortion commences.		
5		Leaf wilting obvious or vegetative parts begin unseasonal discolouration. Flower/fruit abortion widespread.		
6	3.5	Unseasonal thinning or partial mortality of above-ground parts (majority of the plant/s remains viable, but water stressed). Up to 75 cm rooting depth for sufficient soil moisture, 25 cm inundation at lower limit, rhizomes at upper limits may begin thinning.	0.25	Lower limit requires up to 37 cm (low/4) substrate depth to inundation.
7				
8	0.4	Unseasonal loss or mortality of above-ground parts (only minor portions of plants remain viable). Rootstocks/rhizomes of some species remain viable/dormant. Up to 1 m rooting depth for sufficient soil moisture, rhizome mortality commences.	0.15	Lower limit requires up to 44 cm (low/8) substrate depth to inundation.
9		Complete mortality of small proportion of the population.		
10	0	Widespread and complete mortality of population.	0.065	Lower limit requires up to 45 cm (low/10) substrate depth to inundation.

K2 EWR 2: AAN DE VLIET (SABIE RIVER) – DETERMINATION OF EWR SCENARIOS

K2.1 LOW FLOW REQUIREMENTS IN TERMS OF STRESS FOR FISH

The fish low flow requirements for the EWR scenarios are summarised in Table K7 for the SR guild and Table K8 for LR guild.

Table K7 Low flow requirements: SR guild

GENERAL					
INDICATOR: The small rheophilic species <i>Amphilius uranoscopus</i> (AURA), <i>Chiloglanis anoterus</i> (CANO) and <i>Opsaridium peringueyi</i> (OPER) at the site are also good indicators for setting flows as a result of their high requirement for flowing water. These species all requires flowing water over substrates during all life stages, with some stages also preferring overhanging vegetation as cover. Optimal conditions for spawning of this guild consist of FD, FI, FS and SS with good quality substrate (clean cobbles and gravel), while the margins of the FS and SS are important for egg development and nursery areas for larvae, often with overhanging vegetation as cover. Juvenile and adult stages of this guild have a high preference for FS, FI and FD over substrates.					
PES: FISH EC B/C (ECOSTATUS C)					
Dry Season maintenance At this fish stress level, adequate FS (15% on cross-section), FI (46% on cross-section) and some FD (1% on cross-section) will be maintained, the most critical habitats for the survival of this species. This habitat composition should maintain this fish guild in present ecological category.					
Dry Season drought At this fish stress level adequate FS (23% on cross-section) and FI (21% on cross-section) will be maintained to ensure the survival of this fish guild (no FD will be available on cross-section at this stress level). At these proportions of habitats available at the site, this fish guild should be able to survive through drought period in the dry season and enable recovery once conditions improve to remain within the PES.					
Wet Season maintenance This fish stress level will maintain adequate FS (7%) and FI (23%) and abundant FD (43%), the most important habitat required by all life stages to fulfil all required biological processes during the wet season (spawning, nursery habitats as well as adequate feeding and refuge habitats for juvenile and adult specimens) to maintain this fish guild within current ecological category.					
Wet Season drought At a fish stress level of 7 much reduced spawning habitats will be available for this fish guild (15% FS, 43% FI and 0% FD on cross-section), but it should be adequate to maintain some habitats to meet requirements of all life stages to ensure survival of these species during the wet season and allow recovery after drought period.					
BUILDING BLOCK	SEASON	STRESS DURATION	SPP STRESS	INTEG STRESS	FLOW (m ³ /s)
Drought	Dry	5%	8	9	0.66
Maintenance	Dry	35%	6.5	6.5	1.26
Drought	Wet	5%	7	7	1.03
Maintenance	Wet	35%	4	4	2
REC: FISH EC B (ECOSTATUS B)					
General Improvement of low flows to reflect natural hydrological regimes will ensure that species that use this ecotone from time to time will have more natural FROC within this area.					
Dry Season maintenance At this recommended stress level, increased abundance of fast habitats (FS, FI and FD) will be available when compared to present conditions, which would result in improved abundance of this fish guild and therefore improved FROC.					
Wet Season maintenance At this stress level FS – FI - FD habitats will be available as 5% - 15% - 61% of the cross-section, respectively. This improvement from the present condition can be expected to improved habitat for especially spawning, and also increased nursery, abundance and thus improvement to a higher EC.					

BUILDING BLOCK	SEASON	STRESS DURATION	SPP STRESS	INTEG STRESS	FLOW (m ³ /s)
Maintenance	Dry	35%	5.5	5.5	1.6
Maintenance	Wet	35%	2.5	2.5	2.76
AEC: FISH EC C/D (ECOSTATUS C/D)					
General: Decreased low flows (lower water levels) will lead to a loss in habitat diversity during these periods (reduction in riffle/rapid areas, decreased overhanging vegetation as cover as a result of decreased water level not reaching the edge of stream) with a resultant decrease in FROC for species preferring riffle/rapid/run (fast) habitats. Dry Season maintenance This stress level will maintain some FS (15% of cross-section) and FI (40% of cross section), but no more FD habitats will be available. It can be expected that this guild will be stressed more than presently and result in decreased abundance and overall FROC, with a resultant decreased EC. Wet Season maintenance At this fish stress level, fast habitats (FS, FI and FD) will be available at a much reduced quantity than present wet season, but it should still be adequate to maintain all life stages although reduced abundance and FROC can be expected, and a resultant decrease in EC may occur.					
BUILDING BLOCK	SEASON	STRESS DURATION	SPP STRESS	INTEG STRESS	FLOW (m ³ /s)
Maintenance	Dry	35%	7.5	8	0.845
Maintenance	Wet	35%	5.5	5.5	1.6

Table K8 Low flow requirements: LR guild

GENERAL					
INDICATOR: The large rheophilic species, <i>Varicorhinus nelspruitensis</i> (VNEL) is the most important indicator species regarding flows as it is the biggest species at the site having a requirement for continuous flows. Limited information is however available regarding the habitat requirements for different life stages (especially early life stages) of this species, and deficiencies were addressed by reference to fish species with similar behaviours and requirements of which information is available. VNEL is intolerant to no flow and requires flowing habitat (FI and FD) with substrate and water column as preferred cover for most of its life stage. They also require margins of FS, SS and SD with overhanging vegetation as nursery habitats. Flows should furthermore remain adequate to allow migration between reaches, thus depth in riffle and rapids should remain adequate, especially during the wet season.					
PES: FISH EC B/C (ECOSTATUS B/C)					
Dry Season maintenance At this fish stress level, adequate FI (43% of cross-section) and FD (10% of cross-section) will be maintained, the two most critical habitats for the survival of this species. This composition of FI and FD habitat should maintain the species in this ecological category. Dry Season drought At this stress level there will be no FD habitats available (based on cross-section), but adequate FI (35% of the cross-section) will be maintained for the survival of this species. The composition of habitats available at the site at this stress level should be adequate for this species to survive through drought period in the dry season and enable recovery once conditions improve. Wet Season maintenance This fish stress level will maintain adequate FI (23% on cross-section) and FD (43% on cross-section), the most important habitats required for most life stages and biological process requirements during the wet season (spawning, nursery habitats, and adequate habitats for juvenile and adult specimens) to maintain within current ecological category. Wet Season drought At fish stress level of 6 the preferred and most critical habitats of this species (FI and FD) will be limited (43% FI and 10% FD) but it should be adequate to allow spawning and maintain other life stages to recover after this stress period.					
BUILDING BLOCK	SEASON	STRESS DURATION	SPP STRESS	INTEG STRESS	FLOW (m ³ /s)
Drought	Dry	5%	8	8	0.845
Maintenance	Dry	35%	6	6	1.49
Drought	Wet	5%	6	6	1.49
Maintenance	Wet	35%	3.5	3.5	2.3

REC: FISH EC B (ECOSTATUS B)					
General Improvement of low flows to reflect natural hydrological regimes will ensure that flow dependant species and species that use this Ecotone from time to time will have more natural FROC within this area.					
Dry Season maintenance This stress level will maintain present day dry season conditions with good availability of preferred habitats (FI = 35%, FD = 20%). This species is presently in good condition at the site at these flows.					
Wet Season maintenance Improved FI and FD habitats (lower stress than presently) will result in improved habitat for especially spawning, and also increased nursery, abundance and thus improve to higher EC.					
BUILDING BLOCK	SEASON	STRESS DURATION	SPP STRESS	INTEG STRESS	FLOW (m ³ /s)
Maintenance	Dry	35%	5.5	5.5	1.6
Maintenance	Wet	35%	2	2	2.93
AEC: FISH EC C/D (ECOSTATUS C/D)					
General Decreased low flows (lower water levels) will lead to a loss in habitat diversity during these periods (reduction in riffle/rapid areas, decreased overhanging vegetation as cover as a result of decreased water level not reaching the edge of stream) with a resultant decrease in FROC for species preferring riffle/rapid/run (fast) habitats.					
Dry Season maintenance This is the maximum allowable stress level before FD habitats will be lost from site. It will maintain very limited FD (1% of cross-section) but adequate FI (46% of cross-section) at site. Reduced abundance can be expected at these reduced available habitats, which may result in decreased FROC, and thus overall EC.					
Wet Season maintenance Lower abundance than present will occur for the FI and FD habitats at this fish stress level, but it should still be adequate to maintain all life stages, albeit available in much reduced quantity, and therefore reduced abundance and FROC can be expected with a resultant decreased EC.					
BUILDING BLOCK	SEASON	STRESS DURATION	SPP STRESS	INTEG STRESS	FLOW (m ³ /s)
Maintenance	Dry	35%	6.5	6.5	1.26
Maintenance	Wet	35%	5	5.5	1.73

K2.2 LOW FLOW REQUIREMENTS IN TERMS OF STRESS FOR MACROINVERTEBRATES

The FDI low flow requirements are summarised in Table K9 below.

Table K9 Low flow requirements: FDI taxa

GENERAL
INDICATOR: Three flow dependent cobble dwelling macroinvertebrate taxa were used for this site. Perlidae prefer velocities > 0.6 m/s while Elmidae and Heptageniidae prefer velocities between 0.3 and 0.6 m/s although they can also survive at other velocity categories and live on other substrates. Perlidae and Heptageniidae are highly sensitive to water quality whereas Elmidae are moderately sensitive to water quality.
PES: MACROINVERTEBRATE EC: B/C (ECOSTATUS C)
Dry Season maintenance Suitable habitat (> 0.3 m/s over coarse substrate with some areas of 0.6 m/s over coarse substrate) is required to ensure that all the selected taxa can overwinter without significant detrimental impacts on the overall population. The average velocity of 0.43 m/s and maximum velocity of 1.31 (macroinvertebrate stress of 3) will ensure that this takes place. At this flow 26% FCS and 17% VFCS is available. The WP at this flow is 11.5 m.
Dry Season drought Suitable habitat (> 0.1 m/s over coarse substrate, with at least some areas of 0.3 m/s over coarse substrate) is required to ensure that a core of the selected taxa is able to survive a drought. The average velocity of 0.27 m/s and maximum velocity of 0.87 (macroinvertebrate stress of 5) will ensure that this takes place. At this flow 26% SCS, 21% FCS and 8% VFCS is available. The WP is 11.5.

Wet Season maintenance

During the wet season optimal habitats (> 0.6 m/s over coarse substrate) is required to ensure that a healthy population occurs during the summer. The average velocity of 0.4 m/s maximum velocity of 1.31 m/s (macroinvertebrate stress of 2) ensure that this takes place. At this flow 26% FCS and 17% VFCS is available. The WP is approx 11.6m.

Wet Season drought

During the wet season optimal habitats (> 0.3 m/s over coarse substrate with some areas of at least 0.6 m/s) is required to ensure that a healthy population occurs during the summer. The average velocity of 0.3 m/s and maximum velocity of 1.31 m/s (macroinvertebrate stress of 3) ensures that this takes place. At this flow 26% FCS and 17% VFCS are available.

BUILDING BLOCK	SEASON	STRESS DURATION	SPP STRESS	INTEG STRESS	FLOW (m ³ /s)
Drought	Dry	5%	5	9.4	0.396
Maintenance	Dry	35%	3	7.1	0.864
Drought	Wet	5%	3	7.1	0.864
Maintenance	Wet	35%	2	7.3	0.975

REC: MACROINVERTEBRATE EC B (ECOSTATUS B)**Dry Season maintenance**

Suitable habitat (> 0.3 m/s over coarse substrate with considerable areas of 0.6 m/s over coarse substrate) is required to ensure that all the selected taxa can overwinter without significant detrimental impacts on the overall population. The average velocity of 0.52 m/s and maximum velocity of 1.48 (macroinvertebrate stress of 2) will ensure that this takes place. At this flow 26% FCS and 17% VFCS is available. The WP is approx 11.5m.

Dry Season drought

Suitable habitat (> 0.1 m/s over coarse substrate, with at least some areas of 0.3 m/s over coarse substrate) is required to ensure that a core of the selected taxa is able to survive a drought. The average velocity of 0.27 m/s and maximum velocity of 0.87 (macroinvertebrate stress of 5) will ensure that this takes place. At this flow 26% SCS, 21% FCS and 8% VFCS is available. The WP is 11.5.

Wet Season maintenance

During the wet season optimal habitats (> 0.6 m/s over coarse substrate) is required to ensure that a healthy population occurs during the summer. The average velocity of 0.5m/s and maximum velocity of 1.5 m/s (macroinvertebrate stress of 1) ensure that this takes place. At this flow 23% FCS and 26% VFCS is available. The WP is approx 11.8m.

Wet Season drought

During the wet season, optimal habitats (> 0.3 m/s over coarse substrate with some areas of at least 0.6 m/s) are required to ensure that a healthy population occurs during the summer. The average velocity of 0.4 m/s and maximum velocity of 1.3 m/s (macroinvertebrate stress of 3) ensures that this takes place. At this flow 26% FCS and 17% VFCS are available. The WP is approx. 11.5m.

BUILDING BLOCK	SEASON	STRESS DURATION	SPP STRESS	INTEG ² STRESS	FLOW (m ³ /s)
Maintenance	Dry	35%	2	7.3	0.975
Maintenance	Wet	35%	1	6.2	1.398

AEC: MACROINVERTEBRATE EC C (ECOSTATUS C/D)**Dry Season maintenance**

Suitable habitat (> 0.3 m/s over coarse substrate with at least some areas of 0.6 m/s over coarse substrate) is required to ensure that all the selected taxa can overwinter without significant detrimental impacts on the overall population. The average velocity of 0.34 m/s and maximum velocity of 1.06 (macroinvertebrate stress of 4) will ensure that this takes place. At this flow 26% FCS and 9% VFCS is available. The WP is 11.9.

Dry Season drought

Suitable habitat (> 0.1 m/s over coarse substrate, with at least some areas of 0.3 m/s over coarse substrate) is required to ensure that a core of the selected taxa is able to survive a drought. The average velocity of 0.27 m/s and maximum velocity of 0.87 (macroinvertebrate stress of 5) will ensure that this takes place. At this flow 26% SCS, 21% FCS and 8% VFCS is available.

Wet Season maintenance

During the wet season optimal habitats (> 0.6 m/s over coarse substrate) is required to ensure that a healthy population occurs during the summer. The average velocity of 0.52 m/s maximum velocity of 1.48 m/s (macroinvertebrate stress of 2) ensure that this takes place. At this flow 23% FCS and 26% VFCS is available. The WP is 12.5.

Wet Season drought

During the wet season optimal habitats (> 0.3 m/s over coarse substrate with some areas of at least 0.6 m/s) is required

to ensure that a healthy population occurs during the summer. The average velocity of 0.3 m/s and maximum velocity of 1.31 m/s (macroinvertebrate stress of 3) ensures that this takes place. At this flow 26% FCS and 17% VFCS are available. The WP is 12.2.

BUILDING BLOCK	SEASON	STRESS DURATION	SPP STRESS	INTEG STRESS	FLOW (m ³ /s)
Maintenance	Dry	35%	4	8.9	0.678
Maintenance	Wet	35%	2	7.3	0.975

K2.3 LOW FLOW REQUIREMENTS IN TERMS OF RIPARIAN VEGETATION

The low flow requirements for riparian vegetation indicator species are summarised in Table K10.

Table K10 Low flow requirements: Riparian vegetation species

GENERAL					
INDICATOR: <i>Breonadia salicina</i> .					
PES: RIPARIAN VEGETATION EC C (ECOSTATUS C)					
Dry Season maintenance In order that the PES is maintained, population stress would not be expected to exceed 4 during dry season maintenance flows. At a stress of 4, leaf wilting/stress commences but is slight, and flower/fruit abortion commences (which is unlikely to occur in dry season). Dry Season drought Would not expect the average population to experience a stress of more than 6 during natural drought in the dry season. A stress of 6 equates to unseasonal thinning or partial mortality of above-ground parts (majority of the plant/s remain/s viable, but water stressed). A thinning of the population can be expected for reeds. Wet Season maintenance In order that the PES is maintained, population stress would not be expected to exceed 2 during wet (growing) season maintenance flows. At a stress of 2, leaf wilting/stress commences in adults, but is slight; the population is essentially unhampered in reproductive capacity. Wet Season drought Would not expect the average population to experience a stress of more than 5 during natural drought in the wet season. A stress of 5 equates to obvious leaf wilting or vegetative parts begin unseasonal discolouration; flower/fruit abortion is widespread.					
BUILDING BLOCK	SEASON	STRESS DURATION	SPP STRESS <i>Breonadia</i>	INTEG STRESS	FLOW (m ³ /s)
Drought	Dry	5%	6	9.5	0.331
Maintenance	Dry	35%	4	9	0.66
Drought	Wet	5%	5	9.5	0.331
Maintenance	Wet	35%	2	4	2
RIPARIAN VEGETATION EC B (ECOSTATUS B)					
Dry Season maintenance Similar to dry maintenance under PES, but with slightly less stress associated with slightly more flow. Wet Season maintenance In order that the REC is maintained, population stress would not be expected to exceed 1 or 1.5 during wet (growing) season maintenance flows. At a stress of 1, adults have full vigour and operate at maximum reproductive capacity; the population is essentially unstressed.					
BUILDING BLOCK	SEASON	STRESS DURATION	SPP STRESS <i>Breonadia</i>	INTEG STRESS	FLOW (m ³ /s)
Maintenance	Dry	35%	3	8.5	0.752
Maintenance	Wet	35%	1.5	2.5	2.76
RIPARIAN VEGETATION EC D (ECOSTATUS C/D)					
Dry Season maintenance					

Similar to PES dry season maintenance, but with reeds showing slightly more wilting stress as a result of reduced base flows.

Wet Season maintenance

In order that the AEC is maintained, population stress would not be expected to exceed 3 or 3.5 during wet (growing) season maintenance flows. At a stress of 3, leaf wilting/stress commences but is slight, and the population remains reproductively active.

BUILDING BLOCK	SEASON	STRESS DURATION	SPP STRESS <i>Breonadia</i>	INTEG STRESS	FLOW (m ³ /s)
Maintenance	Dry	35%	4.5	9.25	0.495
Maintenance	Wet	35%	3.5	9	0.66

K2.4 INSTREAM FLOOD FUNCTIONS

A description of the flood functions for biotic response is provided in Table K11.

Table K11 Functions for each Flood Class

Flood Class	Component	Function/Motivation
Class: I Range (m ³ /s): 9 - 12 Daily average: 10 Duration: 4	Fish	Class I floods are very important floods for fish and serves as migration cues and to maintain adequate longitudinal connectivity for migration. These floods will also flush fines and algae from substrates to ensure adequate conditions in substrates, a very important habitat for spawning of many of the species. It should furthermore inundate some vegetation for species spawning in flooded marginal vegetation and contributes to the creation of acceptable nursery areas. Some resetting of water quality will also take place, and the changes in water quality may also serve as stimulus to cue migratory activity and even gonad development. The frequency, extent and duration as recommended for the PES and AEC should be adequate to provide the functions as required to maintain the fish within the specific category.
	Macroinvertebrates	These freshets are recommended to stimulate hatching of eggs, flush organic flocculants and mobilise fines (1 - 2 mm sands) in order to improve biotope suitability they will also reset water quality. Four of these per year, Nov, Dec, Jan and Mar/Apr), are recommended for both the PES and the REC and 3 (Early wet season, middle of the wet season and end of the wet season) for the AEC.
Class: II Range (m ³ /s): 15 - 25 Daily average: 20 Duration: 5	Fish	Class II floods are similar in importance as Class I floods and have the same functionality as Class I floods. Their occurrence at lower frequency makes them only slightly less important for the fish assemblages than Class I. Secondary channels will be inundated by these floods which will create favourable spawning and refuge habitats for some species.
	Macroinvertebrates	These freshets are recommended to clear fines, scour substrate and inundate additional cobbles and fringing vegetation on the edge of the channel in order to create additional biotope, and reset water quality. One of these per year is recommended for all categories.
Class: III Range (m ³ /s): 35 - 55 Daily average: 50	Fish	Class III floods also provide similar functions as Class I, but due to its lower frequency it is not essential for the flood functions required by the indigenous fish species. These floods, and especially their receding limbs will however be utilised by many of the fish species for migration and even spawning if takes place within the summer season.
Class IV Range (m ³ /s): 70 + Daily average: 110	Fish	Class IV floods also provide similar functions as Class I, but due to its lower frequency of occurrence it is not essential for the flood functions required by the indigenous fish species. These floods, and especially their receding limbs will however be utilised by many of the fish species for migration and even spawning if takes place within the summer season.

K2.5 EWR RULE TABLES

EWR rule tables which provide the recommended EWR flows as a duration table, showing flows which should be provided when linked to a natural trigger (natural modelled hydrology in this case) are provided for the different EWR scenarios. EWR rules are supplied for total flows as well as for low flows only.

Table K12 EWR 2 assurance rules for PES: C

Desktop Version 2, Printed on 2008/07/30

Summary of IFR rule curves for: SB2 Natural Flows

Determination based on defined BBM Table with site specific assurance rules.

Regional Type: E. Escarp PES = C

Data are given in m³/s mean monthly flow

Month	% Points									
	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	1.747	1.743	1.732	1.708	1.661	1.576	1.432	1.220	0.964	0.772
Nov	2.777	2.768	2.744	2.695	2.601	2.433	2.158	1.759	1.286	0.932
Dec	2.919	2.908	2.881	2.828	2.726	2.547	2.255	1.837	1.345	0.978
Jan	3.716	3.530	3.361	3.191	2.997	2.669	2.364	1.936	1.438	1.070
Feb	6.314	5.869	5.475	5.109	4.727	4.080	3.586	2.878	2.044	1.423
Mar	4.165	3.983	3.813	3.642	3.441	3.094	2.750	2.252	1.661	1.220
Apr	2.792	2.787	2.767	2.726	2.646	2.500	2.254	1.891	1.454	1.125
May	2.527	2.524	2.509	2.475	2.408	2.281	2.063	1.736	1.335	1.031
Jun	2.417	2.415	2.401	2.371	2.309	2.191	1.987	1.677	1.294	1.002
Jul	2.115	2.115	2.104	2.080	2.030	1.933	1.761	1.493	1.155	0.896
Aug	1.910	1.908	1.898	1.874	1.827	1.737	1.581	1.344	1.050	0.827
Sep	1.826	1.824	1.813	1.790	1.744	1.658	1.510	1.287	1.013	0.806

Reserve flows without High Flows

Oct	1.747	1.743	1.732	1.708	1.661	1.576	1.432	1.220	0.964	0.772
Nov	1.942	1.936	1.922	1.893	1.837	1.737	1.573	1.336	1.054	0.843
Dec	2.110	2.104	2.087	2.053	1.990	1.877	1.694	1.431	1.122	0.892
Jan	2.400	2.390	2.368	2.327	2.249	2.115	1.900	1.598	1.247	0.987
Feb	3.026	3.016	2.991	2.941	2.847	2.680	2.408	2.017	1.558	1.216
Mar	2.849	2.841	2.819	2.773	2.686	2.530	2.275	1.904	1.465	1.137
Apr	2.792	2.787	2.767	2.726	2.646	2.500	2.254	1.891	1.454	1.125
May	2.527	2.524	2.509	2.475	2.408	2.281	2.063	1.736	1.335	1.031
Jun	2.417	2.415	2.401	2.371	2.309	2.191	1.987	1.677	1.294	1.002
Jul	2.115	2.115	2.104	2.080	2.030	1.933	1.761	1.493	1.155	0.896
Aug	1.910	1.908	1.898	1.874	1.827	1.737	1.581	1.344	1.050	0.827
Sep	1.826	1.824	1.813	1.790	1.744	1.658	1.510	1.287	1.013	0.806

Natural Duration curves

Oct	4.828	4.182	3.704	3.166	2.838	2.707	2.550	2.378	2.080	1.807
Nov	9.869	7.284	6.508	5.768	5.193	4.506	4.035	3.376	2.758	2.153
Dec	17.723	13.766	10.820	9.256	7.628	6.627	5.873	5.052	4.533	3.020
Jan	25.414	19.120	14.539	11.862	10.730	9.177	7.803	6.918	5.899	5.178
Feb	39.249	30.638	21.077	14.335	12.831	11.351	9.206	8.011	5.824	4.506
Mar	32.239	20.677	17.443	15.308	11.193	9.334	7.833	6.918	5.985	4.159
Apr	17.215	13.519	11.304	9.776	8.731	7.793	7.029	6.265	5.694	3.931
May	8.434	7.643	7.243	6.694	6.437	5.701	5.089	4.772	4.297	3.174
Jun	6.694	5.849	5.417	5.174	5.085	4.784	4.244	3.870	3.534	2.704
Jul	5.335	4.663	4.421	4.025	3.846	3.737	3.401	3.155	2.864	2.386
Aug	4.282	3.943	3.543	3.409	3.203	3.043	2.838	2.692	2.468	2.012
Sep	4.147	3.897	3.241	3.025	2.897	2.728	2.585	2.423	2.238	1.852

Table K13 EWR 2 assurance rules for REC: B

Desktop Version 2, Printed on 2008/07/30

Summary of IFR rule curves for: SB2 Natural Flows

Determination based on defined BBM Table with site specific assurance rules.

Regional Type: E. Escarp REC = B

Data are given in m³/s mean monthly flow

Month	% Points									
	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	1.910	1.907	1.893	1.866	1.811	1.711	1.544	1.297	1.000	0.776
Nov	3.041	3.031	3.004	2.948	2.841	2.650	2.336	1.881	1.342	0.939
Dec	3.447	3.434	3.400	3.332	3.204	2.977	2.608	2.079	1.455	0.991
Jan	4.657	4.465	4.281	4.084	3.840	3.424	2.980	2.355	1.630	1.093
Feb	9.243	8.598	8.022	7.476	6.892	5.900	5.092	3.933	2.567	1.550
Mar	5.638	5.449	5.261	5.052	4.777	4.300	3.741	2.933	1.973	1.256
Apr	4.134	4.124	4.089	4.017	3.874	3.612	3.173	2.526	1.746	1.159
May	3.617	3.612	3.585	3.528	3.413	3.196	2.824	2.265	1.579	1.059
Jun	3.314	3.311	3.289	3.239	3.139	2.949	2.619	2.117	1.497	1.025
Jul	2.717	2.717	2.701	2.666	2.592	2.449	2.193	1.796	1.296	0.912
Aug	2.267	2.265	2.251	2.221	2.158	2.039	1.833	1.519	1.131	0.836
Sep	2.023	2.020	2.008	1.980	1.926	1.823	1.647	1.382	1.057	0.811

Reserve flows without High Flows

Oct	1.910	1.907	1.893	1.866	1.811	1.711	1.544	1.297	1.000	0.776
Nov	2.276	2.269	2.250	2.212	2.140	2.010	1.798	1.490	1.124	0.851
Dec	2.706	2.696	2.672	2.622	2.528	2.362	2.091	1.704	1.247	0.907
Jan	3.341	3.324	3.289	3.220	3.092	2.870	2.516	2.018	1.438	1.010
Feb	4.505	4.487	4.442	4.353	4.183	3.882	3.394	2.693	1.867	1.253
Mar	4.322	4.307	4.266	4.183	4.023	3.736	3.266	2.585	1.777	1.173
Apr	4.134	4.124	4.089	4.017	3.874	3.612	3.173	2.526	1.746	1.159
May	3.617	3.612	3.585	3.528	3.413	3.196	2.824	2.265	1.579	1.059
Jun	3.314	3.311	3.289	3.239	3.139	2.949	2.619	2.117	1.497	1.025
Jul	2.717	2.717	2.701	2.666	2.592	2.449	2.193	1.796	1.296	0.912
Aug	2.267	2.265	2.251	2.221	2.158	2.039	1.833	1.519	1.131	0.836
Sep	2.023	2.020	2.008	1.980	1.926	1.823	1.647	1.382	1.057	0.811

Natural Duration curves

Oct	4.828	4.182	3.704	3.166	2.838	2.707	2.550	2.378	2.080	1.807
Nov	9.869	7.284	6.508	5.768	5.193	4.506	4.035	3.376	2.758	2.153
Dec	17.723	13.766	10.820	9.256	7.628	6.627	5.873	5.052	4.533	3.020
Jan	25.414	19.120	14.539	11.862	10.730	9.177	7.803	6.918	5.899	5.178
Feb	39.249	30.638	21.077	14.335	12.831	11.351	9.206	8.011	5.824	4.506
Mar	32.239	20.677	17.443	15.308	11.193	9.334	7.833	6.918	5.985	4.159
Apr	17.215	13.519	11.304	9.776	8.731	7.793	7.029	6.265	5.694	3.931
May	8.434	7.643	7.243	6.694	6.437	5.701	5.089	4.772	4.297	3.174
Jun	6.694	5.849	5.417	5.174	5.085	4.784	4.244	3.870	3.534	2.704
Jul	5.335	4.663	4.421	4.025	3.846	3.737	3.401	3.155	2.864	2.386
Aug	4.282	3.943	3.543	3.409	3.203	3.043	2.838	2.692	2.468	2.012
Sep	4.147	3.897	3.241	3.025	2.897	2.728	2.585	2.423	2.238	1.852

Table K14 EWR 2 assurance rules for AEC: C/D

Desktop Version 2, Printed on 2008/07/30

Summary of IFR rule curves for: SB2 Natural Flows

Determination based on defined BBM Table with site specific assurance rules.

Regional Type: E. Escarp AEC = C/D

Data are given in m³/s mean monthly flow

Month	% Points									
	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	1.400	1.398	1.390	1.375	1.344	1.288	1.195	1.056	0.889	0.764
Nov	2.442	2.435	2.415	2.375	2.298	2.160	1.933	1.604	1.215	0.924
Dec	1.594	1.590	1.580	1.561	1.523	1.457	1.350	1.196	1.014	0.879
Jan	3.066	2.885	2.725	2.574	2.415	2.147	1.939	1.646	1.306	1.054
Feb	5.423	4.983	4.601	4.259	3.922	3.356	2.992	2.471	1.858	1.401
Mar	3.307	3.129	2.970	2.821	2.662	2.391	2.172	1.855	1.479	1.198
Apr	1.976	1.973	1.963	1.942	1.900	1.823	1.695	1.505	1.277	1.105
May	1.818	1.817	1.808	1.790	1.754	1.685	1.569	1.393	1.177	1.013
Jun	1.775	1.774	1.766	1.750	1.715	1.649	1.535	1.362	1.148	0.985
Jul	1.598	1.598	1.591	1.577	1.548	1.491	1.390	1.233	1.034	0.882
Aug	1.487	1.486	1.480	1.465	1.436	1.380	1.283	1.136	0.954	0.816
Sep	1.459	1.458	1.451	1.436	1.406	1.350	1.254	1.109	0.931	0.796

Reserve flows without High Flows

Oct	1.400	1.398	1.390	1.375	1.344	1.288	1.195	1.056	0.889	0.764
Nov	1.520	1.517	1.508	1.490	1.455	1.392	1.289	1.141	0.964	0.833
Dec	1.594	1.590	1.580	1.561	1.523	1.457	1.350	1.196	1.014	0.879
Jan	1.751	1.745	1.733	1.710	1.667	1.593	1.475	1.308	1.115	0.971
Feb	2.136	2.130	2.117	2.091	2.042	1.955	1.814	1.611	1.372	1.194
Mar	1.991	1.987	1.975	1.952	1.908	1.828	1.697	1.508	1.283	1.115
Apr	1.976	1.973	1.963	1.942	1.900	1.823	1.695	1.505	1.277	1.105
May	1.818	1.817	1.808	1.790	1.754	1.685	1.569	1.393	1.177	1.013
Jun	1.775	1.774	1.766	1.750	1.715	1.649	1.535	1.362	1.148	0.985
Jul	1.598	1.598	1.591	1.577	1.548	1.491	1.390	1.233	1.034	0.882
Aug	1.487	1.486	1.480	1.465	1.436	1.380	1.283	1.136	0.954	0.816
Sep	1.459	1.458	1.451	1.436	1.406	1.350	1.254	1.109	0.931	0.796

Natural Duration curves

Oct	4.828	4.182	3.704	3.166	2.838	2.707	2.550	2.378	2.080	1.807
Nov	9.869	7.284	6.508	5.768	5.193	4.506	4.035	3.376	2.758	2.153
Dec	17.723	13.766	10.820	9.256	7.628	6.627	5.873	5.052	4.533	3.020
Jan	25.414	19.120	14.539	11.862	10.730	9.177	7.803	6.918	5.899	5.178
Feb	39.249	30.638	21.077	14.335	12.831	11.351	9.206	8.011	5.824	4.506
Mar	32.239	20.677	17.443	15.308	11.193	9.334	7.833	6.918	5.985	4.159
Apr	17.215	13.519	11.304	9.776	8.731	7.793	7.029	6.265	5.694	3.931
May	8.434	7.643	7.243	6.694	6.437	5.701	5.089	4.772	4.297	3.174
Jun	6.694	5.849	5.417	5.174	5.085	4.784	4.244	3.870	3.534	2.704
Jul	5.335	4.663	4.421	4.025	3.846	3.737	3.401	3.155	2.864	2.386
Aug	4.282	3.943	3.543	3.409	3.203	3.043	2.838	2.692	2.468	2.012
Sep	4.147	3.897	3.241	3.025	2.897	2.728	2.585	2.423	2.238	1.852

**APPENDIX L: SUPPORTING INFORMATION FOR THE DETERMINATION OF STRESS
INDICES AND EWR SCENARIOS OF EWR 3: KIDNEY**

L1 EWR 3: KIDNEY (SABIE RIVER) - DETERMINATION OF STRESS INDICES

Appendix L provides supporting information for the determination of stress indices and EWR scenarios of EWR 3: Kidney (Chapter 7 and 8 of the Sabie-Sand River System EWR Scenario Report: Volume 1).

L1.1 FISH INDICATOR SPECIES

Small rheophilic (SR) guild: *Chiloglanis anoterus* (CANO) and *Opsaridium peringueyi* (OPER) at the site are also good indicators for setting flows as a result of their high requirement for flowing water. These species all requires flowing water over substrates during all life stages, with some stages also preferring overhanging vegetation as cover.

Large semi rheophilic (LSR) guild: *Labeobarbus marequensis* (BMAR), *Hydrocynus vittatus* (HVIT) and *Labeo congoro* (LCON) are another important indicator guild present at this EWR site. These species utilises most habitats (SD, SS, FD, FI and FS) with substrate and water column as preferred cover.

The habitat requirements for the different life stages of the SR indicator fish species is summarised in Appendix K, Table K1 and for the LSR guild and in Table L1. Information in Bold type face indicates crucial habitat during the given life stage.

Table L1 Habitat requirements for different life stages of indicators species included in the LSR guild

Species	Spawning	Egg and embryo development	Larvae	Juveniles	Adults
BMAR	Flow habitat: FD, FI . Gravel beds in riffles and rapids. Spawning season: Oct – Apr. Cue: Rain-swollen rivers	Flow habitat: FD, FI . Gravel beds in riffles and rapids. Spawning season: Oct – Apr.	Nursery areas: >0.20 m. Flow habitat: Margins of SS, SD and backwaters. Cover: Overhanging vegetation.	Flow habitat: Mostly FS, SS (>0.20 m). Cover: Fringing vegetation ; moderately high flows of 0.5 - 0.8 m/s in rapid and shallow waters (20 - 30 cm) exposed bedrock substrate and riffles. Low flow refuge: SI, FS . Cover: Combined cover, especially over cobble - overhanging vegetation	Flow habitat: FD . Cover: Deep rocky bottom pools below rapids - Rocky runs, strong water current. Low flow refuge: FS, FD . Months: Jun – Sep. Cover: Deep reed-fringed pools. Combined cover - overhanging vegetation especially over cobble.
HVIT	Flow habitat: SD, FS/FI (>0.25 m deep), gravel/sand substrate. Spawning season: Oct – Jan. Cue: Increased flow. Temperature > 21°C.	Flow habitat: SD, sand and gravel substrate. Months: Oct – Jan. Incubation: 3 - 4 days. Temperature: >21°C.	Nursery areas: Backwaters formed by increased flow. Cover: Overhanging vegetation. Duration larval period: 2 months.	Flow habitat: Mostly SD . Cover: Marginal vegetation. Duration: 3 - 6 months. Low flow refuge months: Jun – Sep. SD . Cover: Overhanging vegetation, water column.	Flow habitat: SD . Cover: Water column. Duration: 3 - 6 months. Low flow refuge months: Jun – Sep. SD . Cover: Water column.
LCON	Flow habitat: FD, SD FS/FI (0.7 – 0.8 m/s). Substrate: Gravel/cobble. Cover: Water column. Spawning season: Oct – Jan. Cue: Increased flow.	Flow habitat: FD, FI, FS/FI (0.7 - 0.8 m/s). Substrate: Gravel. Months: Oct – Jan. Incubation: 3 - 4 days. Temperature: >24°C.	Nursery areas: >0.25 m deep. Flow habitat: Margins of FD, SD and backwaters. Cover: Rocks and cobbles. Duration larval period: 2 months.	Flow habitat: Mostly SD . Cover: Cobbles, rocks and water column. Duration: 3 - 6 months. Low flow refuge months: Jun – Sep. SD . Cover: Water column cobbles, rocks, undercut banks.	Flow habitat: FD, SD . Cover: Water column cobbles and rocks. Low flow refuge months: Jun – Sep. SD . Cover: Water column, rocks.

L1.2 FISH STRESS INDEX

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

Table L2 EWR 3: Habitat suitability for the SR and LSR guild

SR AND LSR GUILD																
Depth classes	Discharges (m ³ /s)															
	0.17	0.35	0.82	1.13	1.46	1.84	2.25	3.17	3.67	4.78	6.00	7.33	8.78	10.3	13.74	16.55
Slow (<0.3 m/s) Very Shallow (<0.1 m) (SVS)	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8
Slow (<0.3 m/s) Shallow (0.1 – 0.3 m) (SS)	2	2	2	2	4	4	6	6	6	6	6	6	6	8	8	8
Slow (<0.3 m/s) Deep (> 0.5 m) (SD)	8	8	8	8	8	6	6	8	8	8	8	8	8	8	8	8
Slow Shallow and Slow Deep	0	2	2	2	2	2	2	4	4	4	4	4	6	6	6	6
Fast (>0.3 m/s) Very Shallow (<0.1 m) (FVS)	10	10	8	8	8	8	8	8	8	8	8	8	8	8	8	8
Fast (>0.3 m/s) Shallow (0.1 – 0.3 m) (FS)	10	10	8	8	8	8	8	8	8	8	8	8	8	8	8	8
Fast (>0.3 m/s) Intermediate (0.2 – 0.3) (FI)	10	10	8	8	8	8	8	8	8	8	8	8	8	8	8	8
Fast (>0.3 m/s) Deep (> 0.3 m) (FD)	10	10	8	8	8	8	8	8	8	6	6	6	4	4	4	2
FAST TOTAL >0.1 m DEEP	10	10	8	8	8	8	8	6	6	6	6	4	4	4	2	2

The fish stress index is provided in Table L3

Table L3 Fish stress index

Habitat	Discharges (m ³ /s)															
	0.17	0.35	0.82	1.13	1.46	1.84	2.25	3.17	3.67	4.78	6.00	7.33	8.78	10.3	13.74	16.55
SMALL RHEOPHILIC (SR) GUILD																
Spawning habitat	0	0	0	0.5	1	1.5	2	2	2	2.5	2.5	3	3.5	4	4.5	5
Nursery habitat	0	0	0.5	0.5	0.5	1	1.5	2	2	2.5	3	3	3.5	4	4.5	5
Abundance	0	0	0.5	0.5	1	1.5	2	2	2.5	2.5	3	3	3.5	4	4.5	5
Cover	0	0	0.5	0.5	1	1.5	2	2	2.5	2.5	3	3	3.5	4	4.5	5
Connectivity (lateral & longitudinal)	0	0	0.5	1	2	2.5	3	3	3.5	3.5	4	4	4.5	4.5	5	5
Water Quality (esp. oxygen and temperature)	0	0	0.5	1	1.5	2	2.5	3	3.5	4	4	4	4.5	4.5	5	5
Species stress: CANO, OPER	10	10	9	9	8	7	6	5	5	4	4	3	2	2	1	0
LARGE SEMI RHEOPHILIC (LSR) GUILD																
Spawning habitat	0	0	0	0.5	0.5	1	1.5	1.5	2	2.5	3	3.5	4	4.5	4.5	5
Nursery habitat	0	0	0.5	1	1.5	2	2	2.5	3	3.5	3.5	4	4	4.5	5	5
Abundance	0	0	0.5	1	1	1.5	2	2.5	3	3.5	3.5	4	4	4.5	5	5
Cover	0	0	0.5	1	1	1.5	2	2.5	3	3.5	3.5	4	4	4.5	5	5
Connectivity (lateral & longitudinal)	0	0	0.5	1	1.5	2	2.5	3	3	3.5	3.5	4	4	4.5	5	5
Water Quality (esp. oxygen and temperature)	0	0	0.5	1	1.5	2	2.5	3	3.5	4	4	4	4.5	4.5	5	5
Species stress: BMAR, HVIT, LCON	10	10	9	8	8	7	6	5	4	3	3	2	2	1	0	0

L1.3 MACROINVERTEBRATE STRESS INDEX

The habitat flow index for flow dependent macroinvertebrate (FDI) taxa is provided in Table L4 and provides the % occurrence of various velocity and substrate classes under different flow conditions.

Table L4 Habitat suitability for FDI taxa

Habitat Flow Response Index	Habitat Response	Habitat Abundance and suitability													Flow (m ³ /s)
		VSCS ¹	SCS ²	FCS ³	VFCS ⁴	VSFS ⁵	SFS ⁶	FFS ⁷	VFFS ⁸	VBSR ⁹	SBR ¹⁰	FSR ¹¹	VFSR ¹²	Veg ¹³	
0	Habitats heterogeneous, plentiful and high quality. Diverse flow types. Very fast and fast velocities. Deep channel and wide wetted perimeter.	1	2	4	6	6	11	19	26	2	4	8	12	10	16.55
1	Habitats plentiful, high quality, very fast, fast and moderate, with wide wetted perimeter.	2	3	4	5	7	13	20	22	3	5	7	9	9	12.85
2	Critical habitats sufficient; quality slightly reduced: fast, wetted perimeter slightly reduced.	2	3	5	4	8	14	22	18	3	5	9	7	8	10.33
3	Reduced critical habitat reduced critical quality; moderate velocities, fairly deep. Wetted perimeter further reduced.	2	3	5	3	9	15	23	15	4	6	10	6	7	8.78
4	Critical habitats limited; moderate quality: Moderate velocity, deep areas in certain channels, wetted perimeter moderately reduced.	2	4	5	2	11	17	22	11	4	8	10	4	6	6.65
5	Critical habitat very reduced. Moderate quality; moderate velocity, few deep areas. Wetted perimeter moderately reduced.	5	5	2	1	23	24	11	3	10	10	4	2	5	4.78
6	Critical habitat residual and of low quality. Moderate to low velocities. Wetted perimeter markedly reduced. MV still inundated.	5	5	2	1	23	24	11	3	10	10	4	2	4	2.25
7	No critical flow habitats remain. Other habitats moderate quality. Little MV inundated. Slow, narrow wetted perimeter.	9	4	1	0	38	19	3	0	17	7	2	0	3	0.82
8	Moderate and fast-flowing habitats residual and of low quality. Very narrow wetted perimeter. Very little MV inundated.	11	2	0	0	49	10	0	0	24	4	0	0	2	0.35
9	Trickling flows through coarse and fine sediments. Marginal vegetation lost as a habitat.	14	0	0	0	59	0	0	0	27	0	0	0	1	0.17
10	No flow. Standing water habitats only, very poor quality.														0.00

1 Very Slow over Coarse Sediment

4 Very Fast over Coarse Sediment

7 Fast over Fine Sediment

10 Slow over Bedrock

13 Fringing vegetation

2 Slow over Coarse Sediment

5 Very Slow over Fine Sediment

8 Very Fast over Fine Sediment

11 Fast over Bedrock

3 Fast over Coarse Sediment

6 Slow over Fine Sediment

9 Very Slow over Bedrock

12 Very Fast over Bedrock

The stress index for FDI taxa is provided in Table L5 which rates the response of the species according to various biotic response metrics.

Table L5 Macroinvertebrate (FDI) stress index

Habitat characteristics					Biotic Response	Flow	Species Stress
Max depth (m)	Ave depth (m)	Max vel (m/s)	Ave vel (m/s)	WP (m)			
1.08	0.58	0.57	1.59	54.10	All indicator taxa very abundant and healthy.	12.85	0
1	0.53	0.51	1.5	51.5	Indicator taxa persist.	10.33	1
0.94	0.48	0.46	1.4	50.0	Perilidae, Heptageniidae and Elmidae persist, with slight reduction in abundances.	9.55	2
0.9	0.45	0.42	1.32	49.0	Most indicator taxa persist, but abundances reduced.	8.78	3
0.84	0.4	0.37	1.17	47.8	All life stages of all indicator taxa viable.	6.65	4
0.78	0.36	0.31	1.00	38.30	Perilidae decline in abundance and occupy remaining fast flowing areas. Heptageniidae and Elmidae persist at low abundances.	4.78	5
0.68	0.32	0.2	0.68	38.3	Perilidae rare, critical stages of sensitive indicator taxa non-viable, and at risk for less sensitive Heptageniidae and	2.25	6

Habitat characteristics					Biotic Response	Flow	Species Stress
Max depth (m)	Ave depth (m)	Max vel (m/s)	Ave vel (m/s)	WP (m)			
					Elmidae.		
0.6	0.28	0.09	0.34	32.6	Heptageniidae and Elmidae persist, but Perlids all but disappear, with all life-stages of sensitive indicator taxa at risk or non-viable.	1.54	7
0.56	0.26	0.05	0.17	30.0	Heptageniidae and Elmidae persist, but at very low numbers. All life stages of most indicator taxa at risk or non-viable.	0.82	8
0.54	0.26	0.02	0.09	28.5	Indicator taxa disappear.	0.35	9
							10

L1.4 RIPARIAN VEGETATION STRESS INDEX

A riparian vegetation stress index is provided in Table L6.

Table L6 Riparian vegetation stress index for indicator species

Biotic response					
Species Stress	Flow (m ³ /s)	<i>Breonadia salicina</i>	Flow (m ³ /s)	<i>Phragmites mauritanus</i>	
0	6	Adults with full vigour and at maximum reproductive capacity: Up to 75 cm rooting depth for upper limit. Lower limit at water level on average. Recruits at water level to 25 cm above.	8.8	Adults with full vigour and at maximum reproductive capacity. 30 - 50% population inundated (not more than 40 – 50 cm). Upper limit rooting depth up to 50 cm.	
1				Adults with full vigour and at maximum reproductive capacity.	
2		Leaf wilting/stress commences in adults, but is slight.		Leaf wilting/stress commences in adults, but is slight.	
3	2.2	Leaf wilting/stress commences, but is slight. Up to 90 cm on average substrate depth required for inundated soil moisture at upper limit. Recruits at 20 – 40 cm above water level.	5.3	Leaf wilting/stress commences, but is slight. Up to 60 cm rooting depth for upper limit. Lower limit 20 cm inundated on average.	
4		Flower/fruit abortion commences.		Flower/fruit abortion commences.	
5		Leaf wilting obvious, or vegetative parts begin unseasonal discolouration. Flower/fruit abortion widespread.		Leaf wilting obvious, or vegetative parts begin unseasonal discolouration. Flower/fruit abortion widespread.	
6	0.4	Unseasonal thinning or partial mortality of above-ground parts (majority of the plant/s remains viable, but water stressed). Up to 1 m rooting depth for sufficient substrate moisture (upper limit). Mortality may occur for lower zone individuals.	1.6	Unseasonal thinning or partial mortality of above-ground parts (majority of the plant/s remains viable, but water stressed). Up to 75 cm rooting depth for sufficient soil moisture. Water level at lower limit. Rhizomes at upper limits may begin thinning.	
7					
8	0	Unseasonal loss or mortality of above-ground parts (only minor portions of plants remain viable); rootstocks/rhizomes of some species remain viable. > 1 m rooting depth. Individuals at upper limit likely to begin senescence.	0	Unseasonal loss or mortality of above-ground parts (only minor portions of plants remain viable). Rootstocks/rhizomes of some species remain viable/dormant. More than 1 m rooting depth for sufficient soil moisture. Rhizome mortality commences.	
9		Complete mortality of small proportion of the population.		Complete mortality of small proportion of the population.	
10		Widespread and complete mortality of population.		Widespread and complete mortality of population.	

L2 EWR 3: KIDNEY (SABIE RIVER) – DETERMINATION OF EWR SCENARIOS

L2.1 LOW FLOW REQUIREMENTS IN TERMS OF STRESS FOR FISH

The fish low flow requirements for the EWR scenarios are summarised in Table L7 for the SR guild and Table L8 for LSR guild.

Table L7 Low flow requirements: SR guild

GENERAL					
INDICATOR: The small rheophilic species <i>Chiloglanis anoterus</i> (CANO) and <i>Opsaridium peringueyi</i> (OPER) at the site are good indicators for setting flows as a result of their high requirement for flowing water. These species all requires flowing water over substrates during all life stages, with some stages also preferring overhanging vegetation as cover. Optimal conditions for spawning of this guild consist of FD, FI, FS and SS with good quality substrate (clean cobbles and gravel), while the margins of the FS and SS are important for egg development and nursery areas for larvae, often with overhanging vegetation as cover. Juvenile and adult stages of this guild have a high preference for FS, FI and FD over substrates.					
PES: FISH EC B (ECOSTATUS A/B)					
Dry Season maintenance This stress level will result in conditions (FS=3%, FI=3% and FD=12%) only slightly better than is expected to prevail at present, but it is still highly stressed conditions for this fish guild and it may be difficult to maintain it within a B EC. It is thought that the reason for the maintenance of this fish guild within this stress level in a B EC is because of the highly reduced stress during wet seasons. Should the wet season stress levels increase in future, this dry season stress level may be inadequate to sustain this fish guild in a B EC at this EWR site.					
Dry Season drought At this fish stress level some FS (2%), FI (2%) and FD (5%) will be maintained. These are the critical habitats for the survival of this fish guild. At these proportions of habitats available at the site, this species should be able to survive through drought period in the dry season and enable recovery once conditions improve.					
Wet Season maintenance At this stress level will maintain adequate fast habitats (FS, FI and FD) the most important habitat required by all life stages and biological process requirements during the wet season (spawning, nursery habitats, and adequate habitats for juvenile and adult specimens) to maintain within current EC.					
Wet Season drought At fish stress level of 7 the preferred and most critical habitats of this species will be limited but should be adequate to allow at least some spawning to take place and also to maintain other life stages to recover after this stress period.					
BUILDING BLOCK	SEASON	STRESS DURATION	SPP STRESS	INTEG STRESS	FLOW (m ³ /s)
Drought	Dry	5%	8	8	1.46
Maintenance	Dry	35%	6	6	2.25
Drought	Wet	5%	7	7	2.8
Maintenance	Wet	35%	3	3.8	7.1
AEC: FISH EC C (ECOSTATUS B/C)					
General: Decreased low flows (increased abstraction, no reserves implemented) will affect especially rheophilic and semi rheophilic species, species with a preferences for FS and FD habitats and that are intolerant to no-flows conditions (BEUT, BMAR, CANO, CSWIE, LCYL and OPER). Deterioration of substrates (increased sediment) will further decrease FROC of species with high preference for this habitat (BMAR, CANO, and CPAR).					
Dry Season maintenance This stress level will maintain some habitats (FS (2%), FI (2%) and FD (5%) at the site but it will be available in reduced abundance than under present conditions. It can be expected that this guild will be stressed more than presently and result in decreased abundance and overall FROC, with a resultant decreased EC.					
Wet Season maintenance At this fish stress level, fast habitats (FS, FI and FD) will be available at a much reduced quantity than present wet					

season, but it should still be adequate to maintain all life stages although reduced abundance and FROC can be expected, and a resultant decrease in EC may occur.

BUILDING BLOCK	SEASON	STRESS DURATION	SPP STRESS	INTEG STRESS	FLOW (m ³ /s)
Drought	Dry	5%	8.9	8.9	0.95
Maintenance	Dry	35%	7.8	7.8	1.4
Maintenance	Wet	35%	4.5	4.9	4.9

Table L8 Low flow requirements: LSR guild

GENERAL					
INDICATOR: The large semi-rheophilic species (especially BMAR, HVIT, and LCON,) are another important indicator guild present at this EWR site. These species utilises most habitats (SD, SS, FD, FI and FS) with substrate and water column as preferred cover. They also require overhanging vegetation as nursery habitats. Flows should furthermore remain adequate to allow migration between reaches, thus depth in riffle and rapids should remain adequate, especially during the wet season.					
PES: FISH EC B (ECOSTATUS A/B)					
Dry Season maintenance Although this fish guild can survive in the dry season without flow (in SD) habitats, some flow is essential to maintain adequate water quality, food sources and to allow lateral and longitudinal movement of these species. At this fish stress level some fast habitats will be maintained in adequate abundance to provide the above mentioned functions and therefore maintain these species in this ecological category.					
Dry Season drought This is the maximum allowable stress level where some to ensure availability of adequate critical refuge areas (SD) with some flow between these habitats to ensure adequate water quality for survival through drought period in the dry season and enable recovery once conditions improve.					
Wet Season maintenance This fish stress level will maintain adequate fast habitats that are the most important habitat required for spawning and migration of this fish guild during the wet season (also ensure adequate habitats for juvenile and adult specimens) to maintain within current ecological category.					
Wet Season drought At fish stress level of 6 this fish guild will have much reduced spawning habitats, but it should be adequate to maintain some habitats to meet requirements of all life stages to ensure survival of these species and allow recovery after drought period.					
BUILDING BLOCK	SEASON	STRESS DURATION	SPP STRESS	INTEG STRESS	FLOW (m ³ /s)
Drought	Dry	5%	9	9.2	0.904
Maintenance	Dry	35%	7	7	1.84
Drought	Wet	5%	6	6	2.25
Maintenance	Wet	35%	2.5	3.8	7.076
AEC: FISH EC C (ECOSTATUS B/C)					
General: Decreased low flows (increased abstraction, no reserves implemented) will affect especially rheophilic and semi rheophilic species, species with a preferences for FS and FD habitats and that are intolerant to no-flows conditions (BEUT, BMAR, CANO, CSWI, LCYL and OPER). Deterioration of substrates (increased sediment) will further decrease FROC of species with high preference for this habitat (BMAR, CANO, and CPAR).					
Dry Season maintenance Although this fish guild can survive in the dry season without flow (in SD) habitats, some flow is essential to maintain adequate water quality, food sources and to allow lateral and longitudinal movement of these species. This stress level will maintain limited fast habitats at the site but it will be available in reduced abundance than under present conditions. It can be expected that this guild will be stressed more than presently and result in decreased abundance and overall FROC, with a resultant decreased EC.					
Wet Season maintenance At this fish stress level, fast habitats (FS, FI and FD) will be available at a much reduced quantity than present wet season, but it should still be adequate to maintain all life stages although reduced abundance and FROC can be expected, and a resultant decrease in EC may occur.					

BUILDING BLOCK	SEASON	STRESS DURATION	SPP STRESS	INTEG STRESS	FLOW (m ³ /s)
Maintenance	Dry	35%	8.5	9	1.13
Maintenance	Wet	35%	4	5.5	3.845

L2.2 LOW FLOW REQUIREMENTS IN TERMS OF STRESS FOR MACROINVERTEBRATES

The FDI low flow requirements are summarised in Table L9 below.

Table L9 Low flow requirements: FDI taxa

GENERAL					
INDICATOR: Three flow dependent cobble dwelling macroinvertebrate taxa were selected on the basis of their sensitivity to changes in velocity and water quality. Perlidae prefer velocities > 0.6 m/s over cobble habitats, and high quality water. Perlids will diminish in number or disappear altogether at velocities. Heptageniidae and Elmidae prefer velocities between 0.3 and 0.6 m/s over cobble habitats, but can survive in slightly lower velocity flows.					
PES: MACROINVERTEBRATE EC: B (ECOSTATUS A/B)					
Dry Season maintenance To maintain healthy breeding populations of the majority of FDIs over early to mid summer, flow velocities of 0.1 - > 0.3 m/s over cobble areas are required, at a minimum. Fastest flows are required over limited areas of critical habitat. The stress of 7 provides average velocities of 0.17 and maxima of 0.59 m/s, with average and maximum depths of 0.28 and 0.6m. This provides adequate FCS habitat for the FDI taxa. The areas of fast flow over coarse sediment (FCS) comprise approximately 2% of the habitat. Under these hydraulic habitat conditions the macroinvertebrate community should endure with little disruption.					
Dry Season drought Velocities of up to 0.15 m/s in limited areas of the anastomosing channel will maintain sufficient critical flow habitat to ensure there are adequate FDIs (of moderate sensitivity) to repopulate the system following the onset of flow. The stress of 8 equates to average velocities of 0.15 m/s, with maxima of 0.53 m/s, and average and maximum depths of 0.3 to 0.6 m. This flow/depth combination should result in adequate habitat to sustain an adequate portion of the rheophilic population through the drought.					
Wet Season maintenance For a B EC, ideal conditions are sought for the three FDIs in order to ensure a healthy population with no compromise to any life stage or to emergence. The requirement is for flow velocities of 0.3 - >0.6 m/s over critical habitat, with adequate areas of very fast flow. The stress of 4 provides for this, with average velocities of 0.3 m/s and maxima of 1 m/s.					
Wet Season drought To maintain healthy numbers of FDIs to ensure success in breeding, life-stage development and emergence, flows of 0.2 - > 0.6 are required. Fast flows are required over limited areas of critical habitat. The stress of 6 provides for this requirements, with average velocities of 0.2 m/s and maxima of 0.68 m/s.					
BUILDING BLOCK	SEASON	STRESS DURATION	SPP STRESS	INTEG STRESS	FLOW (m ³ /s)
Drought	Dry	5%	8	9.2	0.904
Maintenance	Dry	35%	7	7.9	1.498
Drought	Wet	5%	6	6	2.25
Maintenance	Wet	35%	4	4	6.65
AEC: MACROINVERTEBRATE EC C (ECOSTATUS B/C)					
Dry Season maintenance For a C EC, to maintain viable breeding populations of all FDIs over early to mid summer, flow velocities of >0.05 – 0.3 m/s over cobble areas are required. Fastest flows are required over limited areas of critical habitat. The stress of 7.5 approximates this condition, with average velocities of 0.07 m/s.					
Dry Season drought Velocities of up to 0.15 m/s in limited areas of the anastomosing channel will maintain sufficient critical flow habitat to ensure there are adequate FDIs (of moderate sensitivity) to repopulate the system following the onset of flow. The stress of 8 equates to average velocities of 0.15 m/s, with maxima of 0.53 m/s, and average and maximum depths of 0.3 to 0.6 m. This flow/depth combination should result in adequate habitat to sustain an adequate portion of the rheophilic population through the drought.					

Wet Season maintenance

For a C EC, requirements are to maintain healthy abundances of the three indicator taxa (at lower abundances than for the B). Flow velocities of 0.3 - >0.6 are desirable for all three. The species stress of 5 provides for these requirements, with average velocities of 0.3 and maxima of 0.68 m/s.

BUILDING BLOCK	SEASON	STRESS DURATION	SPP STRESS	INTEG STRESS	FLOW (m ³ /s)
Drought	Dry	5%	8	9.2	0.904
Maintenance	Dry	35%	7.5	9	1.13
Maintenance	Wet	35%	5	5	4.78

L2.3 LOW FLOW REQUIREMENTS IN TERMS OF RIPARIAN VEGETATION

The low flow requirements for riparian vegetation indicator species are summarised in Table L10.

Table L10 Low flow requirements: Riparian vegetation species

GENERAL							
INDICATOR: <i>Phragmites mauritianus</i> and <i>Breonadia salicina</i> .							
PES: RIPARIAN VEGETATION EC A/B (ECOSTATUS A/B)							
Dry Season maintenance In order that the PES is maintained, population stress would not be expected to exceed 4 or 5 during dry season maintenance flows. At a stress of 4, leaf wilting/stress commences but is slight, and flower/fruit abortion commences (which is unlikely to occur in dry season), but at 5 leaf wilting becomes obvious.							
Dry Season drought Would not expect the average population to experience a stress of more than 6 or 7 during natural drought in the dry season. A stress of 6 equates to unseasonal thinning or partial mortality of above-ground parts (majority of the plant/s remain/s viable, but water stressed) and a stress of 7 is more intense response of 6. A thinning of the population can be expected for reeds and juveniles of <i>B. salicina</i> may begin senescence.							
Wet Season maintenance In order that the PES is maintained, population stress would not be expected to exceed 2 during wet (growing) season maintenance flows. At a stress of 2, leaf wilting/stress commences in adults, but is slight; the population is essentially unhampered in reproductive capacity.							
Wet Season drought Would not expect the average population to experience a stress of more than 5 during natural drought in the wet season. A stress of 5 equates to obvious leaf wilting or vegetative parts begin unseasonal discolouration; flower/fruit abortion is widespread.							
BUILDING BLOCK	SEASON	STRESS DURATION	SPP STRESS <i>Phragmites</i>	INTEG STRESS	SPP STRESS <i>Breonadia</i>	INTEG STRESS	FLOW (m ³ /s)
Drought	Dry	5%	7	9.25	6	9.75	0.283
Maintenance	Dry	35%	5	5.75	4.5	8.5	1.295
Drought	Wet	5%	5	5.75	5	9.25	0.847
Maintenance	Wet	35%	2	4	2	5.5	3.515
AEC: RIPARIAN VEGETATION EC B/C (ECOSTATUS B/C)							
Dry Season maintenance Similar to PES dry season maintenance, but with reeds showing slightly more wilting stress as a result of reduced base flows.							
Wet Season maintenance In order that the AEC is maintained, population stress would not be expected to exceed 3 or 3.5 during wet (growing) season maintenance flows. At a stress of 3, leaf wilting/stress commences but is slight, and the population remains reproductively active.							
BUILDING BLOCK	SEASON	STRESS DURATION	SPP STRESS <i>Phragmites</i>	INTEG STRESS	SPP STRESS <i>Breonadia</i>	INTEG STRESS	FLOW (m ³ /s)

Maintenance	Dry	50%	6	7.5	5	9.25	0.847
Maintenance	Wet	50%	3	4.75	3	6	2.25

L2.4 INSTREAM FLOOD FUNCTIONS

A description of the flood functions for biotic response is provided in Table L11.

Table L11 Functions for each Flood Class

Flood Class	Component	Function/Motivation
Class: I Range (m ³ /s): 10 – 15 Daily average: 8 Duration: 3	Fish	Class I floods are very important floods for fish and serves as migration cues and to maintain adequate longitudinal connectivity for migration. These floods will also flush fines and algae from substrates to ensure adequate conditions in substrates, a very important habitat for spawning of many of the species. It should furthermore inundate some vegetation for species spawning in flooded marginal vegetation and contributes to the creation of acceptable nursery areas. Some resetting of water quality will also take place, and the changes in water quality may also serve as stimulus to cue migratory activity and even gonad development. The frequency, extent and duration as recommended for the PES, REC and AEC should be adequate to provide the functions as required to maintain the fish within the specific category.
	Macroinvertebrates	These freshettes are required in early to mid summer, to cleanse fines and algae off rock surfaces and undersides, thereby rejuvenating FDI habitat. Inundate additional areas of the anastomosing channel and marginal vegetation. Provide breeding and hatching cues; and reset water quality. Four were requested for the B EC and three for the C EC, in mid-summer months (October to February).
Class: II Range (m ³ /s): 15 - 30 Daily average: 20 Duration: 4	Fish	Class II floods are similar in importance as Class I floods and have the same functionality as Class I floods.
Class: III Range (m ³ /s): 45 – 55 Daily average: 40 Duration: 5	Fish	Class III floods also provide similar functions as Class I, but due to its lower frequency it is not essential for the flood functions required by the indigenous fish species. These floods, and especially their receding limbs will however be utilised by many of the fish species for migration and even spawning if it occurs within the spring/summer season.
Class IV Range (m ³ /s): 75 – 100 Daily average: 80	Fish	Class IV floods also provide similar functions as Class I, but due to its lower frequency of occurrence it is not essential for the flood functions required by the indigenous fish species. These floods, and especially their receding limbs will however be utilised by many of the fish species for migration and even spawning if it occurs within the summer season.
Range (m ³ /s): 150 +	Fish	Class V floods also provide similar functions as Class I, but due to its lower frequency it is not essential for the flood functions required by the indigenous fish species. The receding limbs will especially be utilised by many of the fish species for migration and even spawning if it occurs within the correct (spring/summer) season.
Range (m ³ /s): 250	Fish	Class VI floods also provide similar functions as Class I, but due to its lower frequency of occurrence it is not essential for the flood functions required by the indigenous fish species. The receding limbs will especially be utilised by many of the fish species for migration and even spawning if it occurs within the correct (spring/summer) season.

L2.5 EWR RULE TABLES

EWR rule tables which provide the recommended EWR flows as a duration table, showing flows which should be provided when linked to a natural trigger (natural modelled hydrology in this case) are provided for the different EWR scenarios. EWR rules are supplied for total flows as well as for low flows only.

Table L12 EWR 3 assurance rules for PES: A/B

Desktop Version 2, Printed on 2008/07/31

Summary of IFR rule curves for: SB3 Natural Flows

Determination based on defined BBM Table with site specific assurance rules.

Regional Type: E. Escarp PES = A/B

Data are given in m³/s mean monthly flow

Month	% Points									
	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	3.230	3.223	3.199	3.148	3.048	2.864	2.557	2.103	1.556	1.144
Nov	6.082	6.060	6.001	5.880	5.650	5.236	4.558	3.575	2.409	1.539
Dec	7.104	7.073	6.999	6.851	6.569	6.070	5.259	4.096	2.725	1.706
Jan	10.172	9.664	9.190	8.700	8.118	7.132	6.150	4.766	3.159	1.971
Feb	20.234	18.756	17.440	16.198	14.880	12.642	10.847	8.273	5.241	2.984
Mar	11.597	11.217	10.834	10.402	9.828	8.828	7.636	5.911	3.863	2.334
Apr	8.289	8.269	8.196	8.044	7.745	7.198	6.281	4.928	3.296	2.069
May	6.920	6.911	6.857	6.742	6.511	6.078	5.335	4.217	2.847	1.808
Jun	6.115	6.110	6.066	5.971	5.777	5.409	4.770	3.798	2.597	1.683
Jul	4.881	4.881	4.851	4.784	4.643	4.370	3.883	3.127	2.175	1.444
Aug	3.974	3.971	3.944	3.886	3.768	3.544	3.156	2.566	1.835	1.280
Sep	3.443	3.439	3.415	3.365	3.264	3.074	2.748	2.258	1.657	1.202

Reserve flows without High Flows

Oct	3.230	3.223	3.199	3.148	3.048	2.864	2.557	2.103	1.556	1.144
Nov	4.017	4.004	3.968	3.897	3.759	3.512	3.106	2.520	1.823	1.303
Dec	5.105	5.085	5.035	4.935	4.746	4.411	3.866	3.084	2.163	1.478
Jan	6.624	6.588	6.514	6.370	6.102	5.638	4.898	3.855	2.644	1.748
Feb	9.366	9.326	9.229	9.035	8.666	8.013	6.951	5.429	3.635	2.300
Mar	8.966	8.933	8.844	8.664	8.319	7.700	6.685	5.215	3.471	2.169
Apr	8.289	8.269	8.196	8.044	7.745	7.198	6.281	4.928	3.296	2.069
May	6.920	6.911	6.857	6.742	6.511	6.078	5.335	4.217	2.847	1.808
Jun	6.115	6.110	6.066	5.971	5.777	5.409	4.770	3.798	2.597	1.683
Jul	4.881	4.881	4.851	4.784	4.643	4.370	3.883	3.127	2.175	1.444
Aug	3.974	3.971	3.944	3.886	3.768	3.544	3.156	2.566	1.835	1.280
Sep	3.443	3.439	3.415	3.365	3.264	3.074	2.748	2.258	1.657	1.202

Natural Duration curves

Oct	8.860	7.624	6.814	5.761	5.111	4.723	4.488	4.178	3.711	3.088
Nov	18.808	14.742	11.802	10.093	9.086	8.221	7.272	5.760	4.911	3.746
Dec	33.923	25.989	21.229	16.726	13.922	12.291	10.275	9.491	7.706	5.066
Jan	55.880	37.817	26.202	23.749	19.710	17.111	13.702	11.645	10.447	8.180
Feb	82.507	64.559	41.460	31.754	23.177	20.747	16.923	13.368	10.074	7.647
Mar	66.439	45.318	34.009	28.054	20.968	16.599	14.501	11.787	10.122	6.776
Apr	32.280	25.035	20.359	17.535	14.271	13.499	12.222	11.084	9.630	6.227
May	15.170	13.355	12.444	11.391	10.783	9.849	8.703	8.180	7.396	5.115
Jun	11.682	10.073	9.525	9.136	8.600	8.194	7.353	6.632	6.030	4.568
Jul	9.580	8.162	7.646	7.042	6.735	6.452	6.022	5.451	5.052	4.036
Aug	7.553	7.105	6.254	6.000	5.679	5.417	5.010	4.749	4.238	3.435
Sep	7.612	7.060	5.741	5.409	5.235	4.842	4.552	4.209	3.866	3.140

Table L13 EWR 3 assurance rules for REC: B

Desktop Version 2, Printed on 2008/07/30

Summary of IFR rule curves for: SB2 Natural Flows

Determination based on defined BBM Table with site specific assurance rules.

Regional Type: E. Escarp REC = B

Data are given in m³/s mean monthly flow

Month	% Points									
	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	1.910	1.907	1.893	1.866	1.811	1.711	1.544	1.297	1.000	0.776
Nov	3.041	3.031	3.004	2.948	2.841	2.650	2.336	1.881	1.342	0.939
Dec	3.447	3.434	3.400	3.332	3.204	2.977	2.608	2.079	1.455	0.991
Jan	4.657	4.465	4.281	4.084	3.840	3.424	2.980	2.355	1.630	1.093
Feb	9.243	8.598	8.022	7.476	6.892	5.900	5.092	3.933	2.567	1.550
Mar	5.638	5.449	5.261	5.052	4.777	4.300	3.741	2.933	1.973	1.256
Apr	4.134	4.124	4.089	4.017	3.874	3.612	3.173	2.526	1.746	1.159
May	3.617	3.612	3.585	3.528	3.413	3.196	2.824	2.265	1.579	1.059
Jun	3.314	3.311	3.289	3.239	3.139	2.949	2.619	2.117	1.497	1.025
Jul	2.717	2.717	2.701	2.666	2.592	2.449	2.193	1.796	1.296	0.912
Aug	2.267	2.265	2.251	2.221	2.158	2.039	1.833	1.519	1.131	0.836
Sep	2.023	2.020	2.008	1.980	1.926	1.823	1.647	1.382	1.057	0.811

Reserve flows without High Flows

Oct	1.910	1.907	1.893	1.866	1.811	1.711	1.544	1.297	1.000	0.776
Nov	2.276	2.269	2.250	2.212	2.140	2.010	1.798	1.490	1.124	0.851
Dec	2.706	2.696	2.672	2.622	2.528	2.362	2.091	1.704	1.247	0.907
Jan	3.341	3.324	3.289	3.220	3.092	2.870	2.516	2.018	1.438	1.010
Feb	4.505	4.487	4.442	4.353	4.183	3.882	3.394	2.693	1.867	1.253
Mar	4.322	4.307	4.266	4.183	4.023	3.736	3.266	2.585	1.777	1.173
Apr	4.134	4.124	4.089	4.017	3.874	3.612	3.173	2.526	1.746	1.159
May	3.617	3.612	3.585	3.528	3.413	3.196	2.824	2.265	1.579	1.059
Jun	3.314	3.311	3.289	3.239	3.139	2.949	2.619	2.117	1.497	1.025
Jul	2.717	2.717	2.701	2.666	2.592	2.449	2.193	1.796	1.296	0.912
Aug	2.267	2.265	2.251	2.221	2.158	2.039	1.833	1.519	1.131	0.836
Sep	2.023	2.020	2.008	1.980	1.926	1.823	1.647	1.382	1.057	0.811

Natural Duration curves

Oct	4.828	4.182	3.704	3.166	2.838	2.707	2.550	2.378	2.080	1.807
Nov	9.869	7.284	6.508	5.768	5.193	4.506	4.035	3.376	2.758	2.153
Dec	17.723	13.766	10.820	9.256	7.628	6.627	5.873	5.052	4.533	3.020
Jan	25.414	19.120	14.539	11.862	10.730	9.177	7.803	6.918	5.899	5.178
Feb	39.249	30.638	21.077	14.335	12.831	11.351	9.206	8.011	5.824	4.506
Mar	32.239	20.677	17.443	15.308	11.193	9.334	7.833	6.918	5.985	4.159
Apr	17.215	13.519	11.304	9.776	8.731	7.793	7.029	6.265	5.694	3.931
May	8.434	7.643	7.243	6.694	6.437	5.701	5.089	4.772	4.297	3.174
Jun	6.694	5.849	5.417	5.174	5.085	4.784	4.244	3.870	3.534	2.704
Jul	5.335	4.663	4.421	4.025	3.846	3.737	3.401	3.155	2.864	2.386
Aug	4.282	3.943	3.543	3.409	3.203	3.043	2.838	2.692	2.468	2.012
Sep	4.147	3.897	3.241	3.025	2.897	2.728	2.585	2.423	2.238	1.852

Table L14 EWR 3 assurance rules for AEC: C/D

Desktop Version 2, Printed on 2008/07/30

Summary of IFR rule curves for: SB2 Natural Flows

Determination based on defined BBM Table with site specific assurance rules.

Regional Type: E. Escarp AEC = C/D

Data are given in m³/s mean monthly flow

Month	% Points									
	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	1.400	1.398	1.390	1.375	1.344	1.288	1.195	1.056	0.889	0.764
Nov	2.442	2.435	2.415	2.375	2.298	2.160	1.933	1.604	1.215	0.924
Dec	1.594	1.590	1.580	1.561	1.523	1.457	1.350	1.196	1.014	0.879
Jan	3.066	2.885	2.725	2.574	2.415	2.147	1.939	1.646	1.306	1.054
Feb	5.423	4.983	4.601	4.259	3.922	3.356	2.992	2.471	1.858	1.401
Mar	3.307	3.129	2.970	2.821	2.662	2.391	2.172	1.855	1.479	1.198
Apr	1.976	1.973	1.963	1.942	1.900	1.823	1.695	1.505	1.277	1.105
May	1.818	1.817	1.808	1.790	1.754	1.685	1.569	1.393	1.177	1.013
Jun	1.775	1.774	1.766	1.750	1.715	1.649	1.535	1.362	1.148	0.985
Jul	1.598	1.598	1.591	1.577	1.548	1.491	1.390	1.233	1.034	0.882
Aug	1.487	1.486	1.480	1.465	1.436	1.380	1.283	1.136	0.954	0.816
Sep	1.459	1.458	1.451	1.436	1.406	1.350	1.254	1.109	0.931	0.796

Reserve flows without High Flows

Oct	1.400	1.398	1.390	1.375	1.344	1.288	1.195	1.056	0.889	0.764
Nov	1.520	1.517	1.508	1.490	1.455	1.392	1.289	1.141	0.964	0.833
Dec	1.594	1.590	1.580	1.561	1.523	1.457	1.350	1.196	1.014	0.879
Jan	1.751	1.745	1.733	1.710	1.667	1.593	1.475	1.308	1.115	0.971
Feb	2.136	2.130	2.117	2.091	2.042	1.955	1.814	1.611	1.372	1.194
Mar	1.991	1.987	1.975	1.952	1.908	1.828	1.697	1.508	1.283	1.115
Apr	1.976	1.973	1.963	1.942	1.900	1.823	1.695	1.505	1.277	1.105
May	1.818	1.817	1.808	1.790	1.754	1.685	1.569	1.393	1.177	1.013
Jun	1.775	1.774	1.766	1.750	1.715	1.649	1.535	1.362	1.148	0.985
Jul	1.598	1.598	1.591	1.577	1.548	1.491	1.390	1.233	1.034	0.882
Aug	1.487	1.486	1.480	1.465	1.436	1.380	1.283	1.136	0.954	0.816
Sep	1.459	1.458	1.451	1.436	1.406	1.350	1.254	1.109	0.931	0.796

Natural Duration curves

Oct	4.828	4.182	3.704	3.166	2.838	2.707	2.550	2.378	2.080	1.807
Nov	9.869	7.284	6.508	5.768	5.193	4.506	4.035	3.376	2.758	2.153
Dec	17.723	13.766	10.820	9.256	7.628	6.627	5.873	5.052	4.533	3.020
Jan	25.414	19.120	14.539	11.862	10.730	9.177	7.803	6.918	5.899	5.178
Feb	39.249	30.638	21.077	14.335	12.831	11.351	9.206	8.011	5.824	4.506
Mar	32.239	20.677	17.443	15.308	11.193	9.334	7.833	6.918	5.985	4.159
Apr	17.215	13.519	11.304	9.776	8.731	7.793	7.029	6.265	5.694	3.931
May	8.434	7.643	7.243	6.694	6.437	5.701	5.089	4.772	4.297	3.174
Jun	6.694	5.849	5.417	5.174	5.085	4.784	4.244	3.870	3.534	2.704
Jul	5.335	4.663	4.421	4.025	3.846	3.737	3.401	3.155	2.864	2.386
Aug	4.282	3.943	3.543	3.409	3.203	3.043	2.838	2.692	2.468	2.012
Sep	4.147	3.897	3.241	3.025	2.897	2.728	2.585	2.423	2.238	1.852

**APPENDIX M: SUPPORTING INFORMATION FOR THE DETERMINATION OF STRESS
INDICES AND EWR SCENARIOS OF EWR 4: MAC MAC**

M1 EWR 4: MAC MAC (MAC MAC RIVER) - DETERMINATION OF STRESS INDICES

Appendix M provides supporting information for the determination of stress indices and EWR scenarios of EWR 4: Mac Mac (Chapter 9 and 10 of the Sabie-Sand River System EWR Scenario Report: Volume 1).

M1.1 FISH INDICATOR SPECIES

Large rheophilic (LR) guild: *Varicorhinus nelspruitensis* (VNEL) is the most important indicator species regarding the setting of flows as it is the biggest species at the site having a requirement for continuous flowing water for all of its life stages.

Small rheophilic (SR) guild: *Amphilius uranoscopus* (AURA), *Chiloglanis anoterus* (CANO) and *Opsaridium peringueyi* (OPER) at the site are also good indicators for setting flows as a result of their high requirement for flowing water. These species all requires flowing water over substrates during all life stages, with some stages also preferring overhanging vegetation as cover.

The habitat requirements for the different life stages of the LR indicator fish species is summarised in Appendix J, Table J1 in Table K1 for the SR guild.

M1.2 FISH STRESS INDEX

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

Table M1 EWR 4: Habitat suitability for the SR and LR guild

SR AND LR GUILD													
Depth classes	Discharges (m ³ /s)												
	0.06	0.09	0.31	0.44	0.51	0.60	0.70	1.10	1.26	1.44	1.64	1.86	2.37
Slow (<0.3 m/s) Very Shallow (<0.1 m) (SVS)	4	6	6	8	8	8	8	8	8	8	8	8	8
Slow (<0.3 m/s) Shallow (0.1 – 0.3 m) (SS)	4	4	4	4	4	4	4	6	6	6	6	6	6
Slow (<0.3 m/s) Deep (> 0.5 m) (SD)	10	10	10	10	10	10	10	8	8	8	8	8	8
Slow Shallow and Slow Deep	4	4	4	4	4	4	4	6	6	6	6	6	6
Fast (>0.3 m/s) Very Shallow (<0.1 m) (FVS)	8	8	8	8	8	8	8	8	8	8	8	8	8
Fast (>0.3 m/s) Shallow (0.1 – 0.3 m) (FS)	8	8	8	8	8	8	8	8	8	8	8	8	8
Fast (>0.3 m/s) Intermediate (0.2 – 0.3) (FI)	10	8	8	8	8	8	8	8	8	8	8	8	8
Fast (>0.3 m/s) Deep (> 0.3 m) (FD)	10	10	8	8	8	8	8	10	6	6	6	6	6
FAST TOTAL >0.1 m DEEP	10	8	8	8	8	8	6	6	6	6	6	4	4

The fish stress index is provided in Table M2.

Table M2 Fish stress index

Habitat	Discharges (m ³ /s)												
	0.06	0.09	0.31	0.44	0.51	0.60	0.70	1.10	1.26	1.44	1.64	1.86	2.37
SMALL RHEOPHILIC (SR) GUILD													
Spawning habitat	0	0	1.5	2.5	3	3	4	4.5	4.5	4.5	5	5	5
Nursery habitat	0.5	0.5	0.5	1.5	2	2.5	2.5	3.5	4	4.5	5	5	5
Abundance	0	0	1.5	2	2.5	3	3.5	4	4.5	4.5	5	5	5
Cover	0	0	1.5	2	2.5	3	3.5	4	4.5	4.5	5	5	5
Connectivity (lateral & longitudinal)	0.5	1	2.5	3.5	3.5	4	4	4.5	5	5	5	5	5
Water Quality (esp. oxygen and temperature)	0	0.5	1.5	2.5	2.5	3	3	4	4	4.5	4.5	4.5	5
Species stress: AURA, CANO, OPER	10	9	7	6	5	4	3	2	1	1	0	0	0
LARGE RHEOPHILIC (LR) GUILD													
Spawning habitat	0	0	0.5	1	1.5	2	3	3.5	3.5	4	4.5	5	5
Nursery habitat	0.5	0.5	0.5	1.5	2	2.5	2.5	3.5	4	4.5	5	5	5
Abundance	0	0	1	2	2	2	2.5	3.5	4	4	4.5	4.5	5
Cover	0	0	1	2	2	2	2.5	3.5	4	4	4.5	4.5	5
Connectivity (lateral & longitudinal)	0	0.5	1.5	3	3.5	3.5	4	4.5	4.5	5	5	5	5
Water Quality (esp. oxygen and temperature)	0	0.5	1.5	2.5	2.5	3	3	4	4	4.5	4.5	4.5	5
Species stress: VNEL	10	10	8	6	6	5	4	3	2	1	1	1	0

M1.3 MACROINVERTEBRATE STRESS INDEX

The habitat flow index for flow dependent macroinvertebrate (FDI) taxa is provided in Table M3 and provides the % occurrence of various velocity and substrate classes under different flow conditions.

Table M3 Habitat suitability for FDI taxa

Habitat Flow Response Index	Habitat Response	Habitat Abundance and suitability													Flow (m ³ /s)
		VSCS ¹	SCS ²	FCS ³	VFCS ⁴	VSFS ⁵	SFS ⁶	FFS ⁷	VFFS ⁸	VGBR ⁹	SBR ¹⁰	FBR ¹¹	VGBR ¹²	Veg ¹³	
0	Heterogeneous habitats in excess, high quality: very fast, deep, very wide wetted perimeter. Adequate inundated marginal vegetation. Few fines.	4	6	8	7	2	3	4	3	8	12	17	15	11	2.11
1	Diverse habitats, plentiful, high quality; fast, wide wetted perimeter.	5	7	9	5	2	3	4	2	10	15	19	10	9	1.26
2	Critical habitats sufficient; quality slightly reduced. Fast, wetted perimeter slightly reduced.	6	8	9	3	2	3	4	1	13	18	20	7	7	0.82
3	Reduced critical habitat slightly reduced critical quality. Moderate velocity.	8	11	8	2	3	4	3	1	15	21	15	4	5	0.51
4	Critical habitats reduced relative proportions of flow habitats very low; moderate quality. Moderate velocity. Some deep areas, wide WP moderately reduced.	9	12	6	2	3	4	2	1	18	24	12	4	2	0.31
5	Critical habitat very reduced; marginal vegetation lost moderate/ low quality. Moderate/slow velocity, few deep areas WP moderately reduced.	11	13	5	1	4	4	2	0	22	26	10	2	0	0.18
6	Critical habitat residual. Very fast flows disappear. Low quality; moderate/slow	12	14	4	0	4	5	1	0	24	28	8	0	0	0.09

Habitat Flow Response Index	Habitat Response	Habitat Abundance and suitability													Flow (m ³ /s)
		VSCS ¹	SCS ²	FCS ³	VFCS ⁴	VSFS ⁵	SFS ⁶	FFS ⁷	VFFS ⁸	VSBR ⁹	SBR ¹⁰	FBR ¹¹	VFBR ¹²	Veg ¹³	
	velocity.														
7	Loss of fast flow habitat, other habitats moderate quality. Slow, narrow WP.	16	12	2	0	5	4	1	0	32	24	4	0	0	0.03
8	Flowing water habitats residual and low quality: slow trickle, very narrow WP.	22	8	0	0	7	3	0	0	44	16	0	0	0	0.01
9	Trickling flow only. Largely slow flow, very slow flow or standing water habitats only. Quality significantly reduced.	24	6	0	0	8	2	0	0	48	12	0	0	0	0.01
10	No flow. Standing water habitats only. Low quality.	30	0	0	0	10	0	0	0	60	0	0	0	0	0.00

1 Very Slow over Coarse Sediment

4 Very Fast over Coarse Sediment

7 Fast over Fine Sediment

10 Slow over Bedrock

13 Fringing vegetation

2 Slow over Coarse Sediment

5 Very Slow over Fine Sediment

8 Very Fast over Fine Sediment

11 Fast over Bedrock

3 Fast over Coarse Sediment

6 Slow over Fine Sediment

9 Very Slow over Bedrock

12 Very Fast over Bedrock

The stress index for FDI taxa is provided in Table E4 which rates the response of the species according to various biotic response metrics.

Table M4 Macroinvertebrate (FDI) stress index

Biotic Response	Flow	Species Stress
Perlids and Heptageniids abundant and healthy.	2.12	0
Majority of Perlids and Heptageniids persist in a healthy state.	1.26	1
Perlids and Heptageniids persist at slightly lower abundances.	0.82	2
Abundances of Perlids particularly and Heptageniids reduced.	0.50	3
All life stages of Perlids and Heptageniids viable in limited areas, critical life stages of Perlids at risk.	0.31	4
Perlidae persist in low numbers. Heptageniidae persist. Critical life stages of Perlidae at risk.	0.18	5
Perlids rare, critical stages of sensitive indicator taxa non-viable, and at risk for Heptageniids (less sensitive taxa).	0.09	6
Heptageniidae persist, but most Perlids disappear. All life-stages of sensitive indicator taxa at risk or non-viable.	0.03	7
Heptageniidae persist at very low numbers. All life stages of most indicator taxa at risk or non-viable.	0.01	8
Heptageniids no longer present.	0.00	9
	0.00	10

M1.4 RIPARIAN VEGETATION STRESS INDEX

Table M5 Riparian vegetation stress index for indicator species

Biotic response		
Species Stress	Flow (m ³ /s)	<i>Breonadia salicina</i>
0	2.1	Adults with full vigour and at maximum reproductive capacity. Up to 50 cm rooting depth for upper limit. Lower limit at water level on average.
1		
2		
3	0.15	Leaf wilting/stress commences, but is slight. 30 - 80 cm substrate depth required for inundated soil moisture.
4		Flower/fruit abortion commences.
5		Leaf wilting obvious, or vegetative parts begin unseasonal discolouration. Flower/fruit abortion

Biotic response		
Species Stress	Flow (m ³ /s)	<i>Breonadia salicina</i>
		widespread.
6	0.006	Unseasonal thinning or partial mortality of above-ground parts (majority of the plant/s remains viable, but water stressed). 50 – 100 cm rooting depth for sufficient substrate moisture. Mortality may occur for lower zone individuals.
7		
8	0.001	Unseasonal loss or mortality of above-ground parts (only minor portions of plants remain viable). Rootstocks/rhizomes of some species remain viable. 60 cm to 1.1 m rooting depth. Individuals at upper limit likely to begin senescence.
9		Complete mortality of small proportion of the population.
10	0	Widespread and complete mortality of population.

M2 EWR 4: MAC MAC (MAC MAC RIVER) – DETERMINATION OF EWR SCENARIOS

M2.1 LOW FLOW REQUIREMENTS IN TERMS OF STRESS FOR FISH

The fish low flow requirements for the EWR scenarios are summarised in Table M6 for the SR guild and Table M7 for LR guild.

Table M6 Low flow requirements: SR guild

GENERAL					
INDICATOR: The small rheophilic species <i>Amphilius uranoscopus</i> (AURA), <i>Chiloglanis anoterus</i> (CANO) and <i>Opsaridium peringueyi</i> (OPER) at the site are also good indicators for setting flows as a result of their high requirement for flowing water. These species all requires flowing water over substrates during all life stages, with some stages also preferring overhanging vegetation as cover. Optimal conditions for spawning of this guild consist of FD, FI, FS and SS with good quality substrate (clean cobbles and gravel), while the margins of the FS and SS are important for egg development and nursery areas for larvae, often with overhanging vegetation as cover. Juvenile and adult stages of this guild have a high preference for FS, FI and FD over substrates.					
PES: FISH EC B/C (ECOSTATUS B)					
Dry Season maintenance At this fish stress level, adequate FS (8% on cross-section), FI (9% on cross-section) and some FD (5% on cross-section) will be maintained, the most critical habitats for the survival of species within this fish guild. This habitat composition should be adequate to maintain this fish guild in present EC					
Dry Season Drought At this fish stress level limited FS (7% on cross-section) and FI (6% on cross-section) will be maintained to ensure the survival of this fish guild (only 1% FD will be available on cross-section at this stress level). At these proportions of habitats available at the site, this fish guild should be able to survive through drought period in the dry season and enable recovery once conditions improve to remain within the PES.					
Wet Season maintenance This fish stress level will maintain adequate FS (11%) and FI (11%) and abundant FD (21%), the most important habitat required by all life stages to fulfil all required biological processes during the wet season (spawning, nursery habitats as well as adequate feeding and refuge habitats for juvenile and adult specimens) to maintain this fish guild within current EC.					
Wet Season drought At a fish stress level of 6 much reduced spawning habitats will be available for this fish guild (9% FS, 8% FI and 7% FD on cross-section), but it should be adequate to maintain some habitats to meet requirements of all life stages to ensure survival of these species during the wet season and allow recovery after drought period.					
BUILDING BLOCK	SEASON	STRESS DURATION	SPP STRESS	INTEG STRESS	FLOW (m ³ /s)
Drought	Dry	5%	8	8.8	0.186
Maintenance	Dry	35%	6.5	7.5	0.357
Drought	Wet	5%	6	6.9	0.414
Maintenance	Wet	35%	2.5	3.5	0.895
AEC: FISH EC C/D (ECOSTATUS C)					
General Decreased low flows will result in reduced fast habitats (riffles, rapids, runs) with a resultant loss or decreased frequency of occurrence (FROC) of rheophilic species. Embeddedness of cobbles and nutrient increases will reduce quality of habitat especially in riffles and rapids (interstitial spaces) with negative impact on above-mentioned species. Increased temperatures and resultant decreased oxygen will also affect FROC of above mentioned species.					
Dry Season maintenance This stress level will maintain some FS (6% of cross-section) and FI (8% of cross section), but very limited FD habitats (2% of cross-section) will be available. It can be expected that species in this fish guild will be stressed more than presently and result in decreased abundance and overall FROC, with a resultant decreased EC.					
Wet Season maintenance					

At this fish stress level, fast habitats (FS, FI and FD) will be available at a much reduced quantity than present wet season, but it should still be adequate to maintain all life stages although reduced abundance and FROC can be expected, and a resultant decrease in EC may occur.

BUILDING BLOCK	SEASON	STRESS DURATION	SPP STRESS	INTEG STRESS	FLOW (m ³ /s)
Maintenance	Dry	35%	7.5	8.3	0.263
Maintenance	Wet	35%	4.5	5.3	0.563

Table M7 Low flow requirements: LR guild

GENERAL					
INDICATOR: The large rheophilic species, <i>Varicorhinus nelspruitensis</i> (VNEL) is the most important indicator species regarding flows as it is the biggest species at the site having a requirement for continuous flows. Limited information is however available regarding the habitat requirements for different life stages (especially early life stages) of this species, and deficiencies were addressed by reference to fish species with similar behaviours and requirements of which information is available. VNEL is intolerant to no flow and requires flowing habitat (FI and FD) with substrate and water column as preferred cover for most of its life stage. They also require margins of FS, SS and SD with overhanging vegetation as nursery habitats. Flows should furthermore remain adequate to allow migration between reaches, thus depth in riffle and rapids should remain adequate, especially during the wet season.					
PES: FISH EC B/C (ECOSTATUS B)					
Dry Season maintenance At this fish stress level, adequate FI (8% of cross-section) and FD (7% of cross-section) will be maintained, the two most critical habitats for the survival of this species. This composition of FI and FD habitat should maintain the species in this EC.					
Dry Season drought At this fish stress level there will be very limited FD habitats available (2% on cross-section), but some FI (8% of the cross-section) will be maintained for the survival of this species. The composition of habitats available at the site at this stress level should be adequate for this species to survive through drought period in the dry season and enable recovery once conditions improve.					
Wet Season maintenance This fish stress level will maintain adequate FI (10% on cross-section) and FD (20% on cross-section), the most important habitats required for most life stages and biological process requirements during the wet season (spawning, nursery habitats, and adequate habitats for juvenile and adult specimens) to maintain within current EC.					
Wet Season drought: At fish stress level of 6 the preferred and most critical habitats of this species (FI and FD) will be limited (7% FI and 10% FD) but it should be adequate to allow some spawning and maintain other life stages to recover after this stress period.					
BUILDING BLOCK	SEASON	STRESS DURATION	SPP STRESS	INTEG STRESS	FLOW (m ³ /s)
Drought	Dry	5%	8.5	8.5	0.2
Maintenance	Dry	35%	6.5	6.5	0.45
Drought	Wet	5%	6	6	0.5
Maintenance	Wet	35%	3	3	1.09
AEC: FISH EC C/D (ECOSTATUS C)					
General Decreased low flows will result in reduced fast habitats (riffles, rapids, runs) with a resultant loss or decreased frequency of occurrence (FROC) of rheophilic species. Embeddedness of cobbles and nutrient increases will reduce quality of habitat especially in riffles and rapids (interstitial spaces) with negative impact on above-mentioned species. Increased temperatures and resultant decreased oxygen will also affect FROC of above mentioned species.					
Dry Season maintenance At this stress level some of the critical FI and FD habitats will be available. It will maintain some FD (5% of cross-section) and FI (9% of cross-section) at site. Reduced abundance can be expected at these lower than present day dry season flows, which may result in decreased FROC, and thus overall EC.					
Wet Season maintenance At this stress level some of the critical FI and FD habitats will be available. It will maintain some FD (11% of cross-section) and FI (7% of cross-section) at site. Flows should however still be adequate to maintain all life stages, albeit available in much reduced quantity, and therefore reduced abundance and FROC can be expected with a resultant decreased EC.					

BUILDING BLOCK	SEASON	STRESS DURATION	SPP STRESS	INTEG STRESS	FLOW (m ³ /s)
Maintenance	Dry	35%	7.5	7.5	0.35
Maintenance	Wet	35%	5	5	0.59

M2.2 LOW FLOW REQUIREMENTS IN TERMS OF STRESS FOR MACROINVERTEBRATES

The FDI low flow requirements are summarised in Table M8 below.

Table M8 Low flow requirements: FDI taxa

GENERAL					
INDICATOR: Two indicator taxa were selected for this site: Perlidae and Heptageniidae. Perlid stoneflies prefer velocities of > 0.6 m/s, but will persist at moderate velocities of 0.3 - 0.6 m/s and will even survive lower flows (in low abundances) if water quality is not compromised. Their preferred substrate is cobbles. It is necessary that this habitat is not covered with fines. Heptageniid mayflies prefer velocities of 0.3 - 0.6 m/s and cobble habitat. For both taxa, onset of early summer breeding requires maintenance of high quality water (low in organics and high clarity).					
PES: MACROINVERTEBRATE EC: A/B (ECOSTATUS B)					
Dry Season maintenance To maintain healthy breeding populations of Perlids, current speeds over critical habitat should exceed 0.6 m/s, and a depth of over 0.2 m should be common over these habitats. The stress of 4 provides velocities of 0.23 m/s (average) with a max of 0.74 m/s; and depths of 0.17 m (average) with a max of 0.42 m (max). These conditions cater for the requirements of Heptageniids.					
Dry Season drought The requirement is for maximum velocities approaching 0.6 m/s (in limited areas) which will enable small numbers of Perlidae to persist. A depth of greater than 10 cm is required (again in limited areas). The stress of 6 provides an average velocity of 0.16 m/s and a max of 0.55 m/s, and average depth of 0.12 m, thus satisfying requirements. These conditions will cater for the requirements of the Heptageniids.					
Wet Season maintenance Abundant Perlids and Heptageniids would be expected during wet season in an A/B. Over critical habitat, the requirement is for average flow velocities of > 0.3 m/s, and average depths of > 0.2 m. The stress of 2 provides for these conditions.					
Wet Season drought Viable populations of both indicators should be maintained through the wet season droughts. Velocities of 0.3 to > 0.6 are required, with depths of up to 0.2 over the critical habitat. The stress of 4 provides velocities of 0.23 m/s (average) to 0.74 m/s (max) and depths of 0.17 m (average) to 0.42 m (max).					
BUILDING BLOCK	SEASON	STRESS DURATION	SPP STRESS	INTEG STRESS	FLOW (m ³ /s)
Drought	Dry	5%	6	9.5	0.078
Maintenance	Dry	35%	4	8.1	0.294
Drought	Wet	5%	4	8.1	0.294
Maintenance	Wet	35%	2	3.9	0.739
AEC: MACROINVERTEBRATE EC B/C (ECOSTATUS C)					
Dry Season maintenance To maintain viable breeding populations of Perlids, maximum current speeds over critical habitat should be greater than 0.6 m/s, combined with a depth of 0.15 m over these habitats. The stress of 5 provides velocities of 0.19 m/s (average) with a max of 0.64 m/s; and depths of 0.14 m (average) with a max of 0.36 m (max). These conditions cater for the requirements of Heptageniids.					
Wet Season maintenance Perlids and Heptageniids should be present in somewhat lower abundances than in the A/B state. On average, flow velocities should approach 0.3 m/s, with maxima over 0.6 m/s, and average depths should approach 0.2 m. A stress of 3 provides for average velocities of 0.26 m/s and average depths of 0.19 m/s.					
BUILDING BLOCK	SEASON	STRESS DURATION	SPP STRESS	INTEG STRESS	FLOW (m ³ /s)
Maintenance	Dry	35%	5	9	0.155

Maintenance	Wet	35%	3	6	0.5
-------------	-----	-----	---	---	-----

M2.3 LOW FLOW REQUIREMENTS IN TERMS OF RIPARIAN VEGETATION

The low flow requirements for riparian vegetation indicator species are summarised in Table M9.

Table M9 Low flow requirements: Riparian vegetation species

GENERAL					
INDICATOR: <i>Breonadia salicina</i> .					
PES: RIPARIAN VEGETATION EC A/B (ECOSTATUS B)					
Dry Season maintenance In order that the PES is maintained, population stress would not be expected to exceed 4 during dry season maintenance flows. At a spp. stress of 4, leaf wilting/stress commences but is slight, and flower/fruit abortion commences (which is unlikely to occur in dry season). Dry Season drought Would not expect the average population to experience a stress of more than 6 during natural drought in the dry season. A spp. stress of 6 equates to unseasonal thinning or partial mortality of above-ground parts (majority of the plant/s remain/s viable, but water stressed). Juveniles of <i>B. salicina</i> may begin senescence. Wet Season maintenance In order that the PES is maintained, population stress would not be expected to exceed 2 during wet (growing) season maintenance flows. At a spp. stress of 2, leaf wilting/stress commences in adults, but is slight; the population is essentially unhampered in reproductive capacity. Wet Season drought Would not expect the average population to experience a spp. stress of more than 5 during natural drought in the wet season. A spp. stress of 5 equates to obvious leaf wilting or vegetative parts begin unseasonal discolouration; flower/fruit abortion is widespread. Especially near the upper limits of the species, but the majority of the population will survive in a single year drought.					
BUILDING BLOCK	SEASON	STRESS DURATION	SPP STRESS <i>Breonadia</i>	INTEG STRESS	FLOW (m ³ /s)
Drought	Dry	5%	6	10	0.001
Maintenance	Dry	35%	4	9.5	0.078
Drought	Wet	5%	5	9.75	0.039
Maintenance	Wet	35%	2	3.75	0.797
AEC: RIPARIAN VEGETATION EC B/C (ECOSTATUS C)					
This EWR scenario was not assessed as the AEC is related to alien vegetation.					

M2.4 INSTREAM FLOOD FUNCTIONS

A description of the flood functions for biotic response is provided in Table M11.

Table M10 Functions for each Flood Class

Flood Class	Component	Function/Motivation
Class: I Range (m ³ /s): 3 - 5 Daily average: 4 Duration: 3	Fish	Class I floods are very important floods for fish and serves as migration cues and to maintain adequate longitudinal connectivity for migration. These floods will also flush fines and algae from substrates to ensure adequate conditions in substrates, a very important habitat for spawning of many of the species. It should furthermore inundate some vegetation for species spawning in flooded marginal vegetation and contributes to the creation of acceptable nursery areas. Some resetting of water quality will also take place, and the changes in water quality may also serve as stimulus to cue migratory activity and even gonad development. The frequency, extent and duration as recommended for the PES and AEC should be adequate to provide the functions as required to maintain the fish within the specific category.
	Macroinvertebrates	These flushing flows are recommended to reset water quality, to clear the boulder / bedrock / cobble surfaces and undersides of fines, to provide breeding and hatching cues, and to inundate marginal areas and marginal vegetation. Four are required per year for the A/B class, and three for the B/C class.
Class: II Range (m ³ /s): 6 - 12 Daily average: 15 Duration: 4	Fish	Class II floods are similar in importance as Class I floods and have the same functionality as Class I floods. Their occurrence at lower frequency makes them only slightly less important for the fish assemblages than Class I. Secondary channels will be inundated by these floods which will create favourable spawning and refuge habitats for some species.
	Macroinvertebrates	These floods are recommended to move gravels, mobilise cobble habitat, and fulfil all the functions of the former class of floods. One is recommended per year for the A/B and for the B/C classes.
Class: III Range (m ³ /s): 25 - 35	Fish	Class III floods also provide similar functions as Class I, but due to its lower frequency it is not essential for the flood functions required by the indigenous fish species. These floods, and especially their receding limbs will however be utilised by many of the fish species for migration and even spawning if takes place within the summer season.
Class: IV Range (m ³ /s): 70 +	Fish	Class IV floods also provide similar functions as Class I, but due to its lower frequency of occurrence it is not essential for the flood functions required by the indigenous fish species. These floods, and especially their receding limbs will however be utilised by many of the fish species for migration and even spawning if takes place within the summer season.
Class: IV Range (m ³ /s):	Fish	Class V floods also provide similar functions as Class I, but due to its lower frequency of occurrence it is not essential for the flood functions required by the indigenous fish species. The receding limb will be utilised by many of the fish species for migration and even spawning if takes place within the summer season.

M2.5 EWR RULE TABLES

EWR rule tables which provide the recommended EWR flows as a duration table, showing flows which should be provided when linked to a natural trigger (natural modelled hydrology in this case) are provided for the different EWR scenarios. EWR rules are supplied for total flows as well as for low flows only.

Table M11 EWR 4 assurance rules for PES: B

Desktop Version 2, Printed on 2008/07/31

Summary of IFR rule curves for: SB4 Natural Flows

Determination based on defined BBM Table with site specific assurance rules.

Regional Type: E. Escarp PES = B

Data are given in m³/s mean monthly flow

Month	% Points									
	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	0.561	0.560	0.556	0.546	0.527	0.493	0.435	0.350	0.247	0.170
Nov	0.933	0.929	0.920	0.902	0.867	0.804	0.701	0.551	0.374	0.242
Dec	1.061	1.056	1.046	1.025	0.985	0.914	0.799	0.635	0.441	0.297
Jan	1.450	1.385	1.324	1.261	1.185	1.057	0.927	0.744	0.531	0.374
Feb	3.539	3.245	2.988	2.753	2.517	2.118	1.839	1.439	0.969	0.619
Mar	1.763	1.700	1.638	1.573	1.491	1.349	1.193	0.967	0.699	0.499
Apr	1.258	1.256	1.246	1.226	1.187	1.116	0.997	0.820	0.608	0.448
May	1.093	1.092	1.085	1.069	1.037	0.976	0.873	0.718	0.528	0.384
Jun	1.004	1.003	0.996	0.982	0.954	0.899	0.804	0.660	0.482	0.346
Jul	0.815	0.815	0.810	0.800	0.777	0.734	0.658	0.538	0.388	0.273
Aug	0.675	0.675	0.670	0.660	0.640	0.602	0.536	0.435	0.311	0.216
Sep	0.597	0.597	0.592	0.583	0.564	0.529	0.469	0.378	0.267	0.183

Reserve flows without High Flows

Oct	0.561	0.560	0.556	0.546	0.527	0.493	0.435	0.350	0.247	0.170
Nov	0.670	0.668	0.662	0.650	0.627	0.585	0.516	0.417	0.300	0.212
Dec	0.807	0.803	0.796	0.781	0.753	0.703	0.622	0.506	0.369	0.268
Jan	0.999	0.994	0.984	0.965	0.929	0.867	0.768	0.628	0.465	0.345
Feb	1.354	1.349	1.337	1.313	1.268	1.187	1.056	0.868	0.646	0.481
Mar	1.312	1.308	1.297	1.275	1.232	1.155	1.030	0.848	0.632	0.471
Apr	1.258	1.256	1.246	1.226	1.187	1.116	0.997	0.820	0.608	0.448
May	1.093	1.092	1.085	1.069	1.037	0.976	0.873	0.718	0.528	0.384
Jun	1.004	1.003	0.996	0.982	0.954	0.899	0.804	0.660	0.482	0.346
Jul	0.815	0.815	0.810	0.800	0.777	0.734	0.658	0.538	0.388	0.273
Aug	0.675	0.675	0.670	0.660	0.640	0.602	0.536	0.435	0.311	0.216
Sep	0.597	0.597	0.592	0.583	0.564	0.529	0.469	0.378	0.267	0.183

Natural Duration curves

Oct	1.198	1.038	0.896	0.773	0.691	0.665	0.624	0.594	0.508	0.437
Nov	2.373	1.790	1.601	1.431	1.273	1.111	1.003	0.845	0.671	0.525
Dec	4.379	3.465	2.696	2.300	1.983	1.777	1.449	1.269	1.120	0.769
Jan	6.168	4.869	3.674	3.035	2.740	2.304	2.001	1.732	1.538	1.307
Feb	10.342	7.358	5.250	3.869	3.204	2.931	2.323	2.046	1.509	1.145
Mar	8.255	5.399	4.260	3.999	2.707	2.389	1.956	1.788	1.553	1.079
Apr	4.433	3.422	2.917	2.442	2.184	1.960	1.833	1.597	1.447	1.003
May	2.053	1.889	1.822	1.706	1.632	1.445	1.322	1.213	1.109	0.806
Jun	1.628	1.478	1.370	1.319	1.277	1.204	1.069	0.984	0.887	0.694
Jul	1.284	1.157	1.068	1.004	0.960	0.933	0.833	0.788	0.709	0.601
Aug	1.072	0.974	0.889	0.851	0.795	0.750	0.706	0.657	0.605	0.493
Sep	1.038	0.949	0.795	0.756	0.710	0.675	0.629	0.590	0.544	0.448

Table M12 EWR 4 assurance rules for AEC: C

Desktop Version 2, Printed on 2008/07/31

Summary of IFR rule curves for: SB4 Natural Flows

Determination based on defined BBM Table with site specific assurance rules.

Regional Type: E. Escarp AEC = C

Data are given in m³/s mean monthly flow

Month	% Points									
	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	0.392	0.391	0.389	0.383	0.372	0.352	0.319	0.270	0.210	0.166
Nov	0.731	0.729	0.723	0.709	0.684	0.639	0.565	0.458	0.331	0.237
Dec	0.766	0.763	0.756	0.743	0.718	0.674	0.603	0.500	0.379	0.289
Jan	1.010	0.948	0.894	0.843	0.791	0.703	0.638	0.547	0.441	0.363
Feb	2.883	2.593	2.345	2.128	1.925	1.584	1.402	1.140	0.832	0.602
Mar	1.094	1.033	0.981	0.932	0.883	0.801	0.742	0.658	0.557	0.482
Apr	0.643	0.642	0.639	0.634	0.624	0.606	0.575	0.529	0.474	0.432
May	0.587	0.586	0.584	0.579	0.569	0.551	0.520	0.472	0.415	0.371
Jun	0.559	0.558	0.556	0.551	0.541	0.523	0.491	0.442	0.381	0.335
Jul	0.505	0.505	0.503	0.498	0.489	0.469	0.435	0.382	0.316	0.265
Aug	0.442	0.442	0.440	0.435	0.425	0.405	0.372	0.321	0.258	0.210
Sep	0.413	0.412	0.410	0.405	0.394	0.374	0.340	0.289	0.226	0.178

Reserve flows without High Flows

Oct	0.392	0.391	0.389	0.383	0.372	0.352	0.319	0.270	0.210	0.166
Nov	0.445	0.444	0.441	0.434	0.422	0.401	0.365	0.313	0.252	0.206
Dec	0.489	0.487	0.484	0.478	0.466	0.445	0.410	0.361	0.303	0.260
Jan	0.559	0.557	0.554	0.547	0.535	0.513	0.479	0.431	0.376	0.335
Feb	0.698	0.697	0.694	0.688	0.675	0.654	0.619	0.568	0.509	0.465
Mar	0.643	0.642	0.639	0.634	0.625	0.608	0.579	0.539	0.490	0.454
Apr	0.643	0.642	0.639	0.634	0.624	0.606	0.575	0.529	0.474	0.432
May	0.587	0.586	0.584	0.579	0.569	0.551	0.520	0.472	0.415	0.371
Jun	0.559	0.558	0.556	0.551	0.541	0.523	0.491	0.442	0.381	0.335
Jul	0.505	0.505	0.503	0.498	0.489	0.469	0.435	0.382	0.316	0.265
Aug	0.442	0.442	0.440	0.435	0.425	0.405	0.372	0.321	0.258	0.210
Sep	0.413	0.412	0.410	0.405	0.394	0.374	0.340	0.289	0.226	0.178

Natural Duration curves

Oct	1.198	1.038	0.896	0.773	0.691	0.665	0.624	0.594	0.508	0.437
Nov	2.373	1.790	1.601	1.431	1.273	1.111	1.003	0.845	0.671	0.525
Dec	4.379	3.465	2.696	2.300	1.983	1.777	1.449	1.269	1.120	0.769
Jan	6.168	4.869	3.674	3.035	2.740	2.304	2.001	1.732	1.538	1.307
Feb	10.342	7.358	5.250	3.869	3.204	2.931	2.323	2.046	1.509	1.145
Mar	8.255	5.399	4.260	3.999	2.707	2.389	1.956	1.788	1.553	1.079
Apr	4.433	3.422	2.917	2.442	2.184	1.960	1.833	1.597	1.447	1.003
May	2.053	1.889	1.822	1.706	1.632	1.445	1.322	1.213	1.109	0.806
Jun	1.628	1.478	1.370	1.319	1.277	1.204	1.069	0.984	0.887	0.694
Jul	1.284	1.157	1.068	1.004	0.960	0.933	0.833	0.788	0.709	0.601
Aug	1.072	0.974	0.889	0.851	0.795	0.750	0.706	0.657	0.605	0.493
Sep	1.038	0.949	0.795	0.756	0.710	0.675	0.629	0.590	0.544	0.448

**APPENDIX N: SUPPORTING INFORMATION FOR THE DETERMINATION OF STRESS
INDICES AND EWR SCENARIOS OF EWR 5: MARITE**

N1 EWR 5: MARITE (MARITE RIVER) - DETERMINATION OF STRESS INDICES

Appendix N provides supporting information for the determination of stress indices and EWR scenarios of EWR 5: Marite (Chapter 11 and 12 of the Sabie-Sand River System EWR Scenario Report: Volume 1).

N1.1 FISH INDICATOR SPECIES

Large rheophilic (LR) guild: *Varicorhinus nelspruitensis* (VNEL) is the most important indicator species regarding the setting of flows as it is the biggest species at the site having a requirement for continuous flowing water for all of its life stages.

Small rheophilic (SR) guild: *Amphilius uranoscopus* (AURA), *Chiloglanis anoterus* (CANO) and *Opsaridium peringueyi* (OPER) at the site are also good indicators for setting flows as a result of their high requirement for flowing water. These species all requires flowing water over substrates during all life stages, with some stages also preferring overhanging vegetation as cover.

The habitat requirements for the different life stages of the LR indicator fish species is summarised in Appendix J, Table J1 in Table K1 for the SR guild.

N1.2 FISH STRESS INDEX

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

Table N1 EWR 5: Habitat suitability for the SR and LR guild

SR AND LR GUILD																
Depth classes	Discharges (m ³ /s)															
	0.01	0.20	0.29	0.34	0.49	0.69	0.82	0.97	1.33	1.78	2.05	2.35	2.68	3.45	4.90	5.40
Slow (<0.3 m/s) Very Shallow (<0.1 m) (SVS)	0	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8
Slow (<0.3 m/s) Shallow (0.1 – 0.3 m) (SS)	10	0	2	2	2	2	4	4	6	8	8	8	8	8	8	8
Slow (<0.3 m/s) Deep (> 0.5 m) (SD)	10	10	10	10	10	10	8	8	8	8	8	8	8	8	8	8
Slow Shallow and Slow Deep	10	0	2	2	2	2	4	4	4	6	6	6	6	6	8	8
Fast (>0.3 m/s) Very Shallow (<0.1 m) (FVS)	10	10	8	8	8	8	8	8	8	8	8	8	8	8	8	8
Fast (>0.3 m/s) Shallow (0.1 – 0.3 m) (FS)	10	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8
Fast (>0.3 m/s) Intermediate (0.2 – 0.3) (FI)	10	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8
Fast (>0.3 m/s) Deep (> 0.3 m) (FD)	10	10	8	8	8	8	8	6	6	6	6	4	4	4	4	4
FAST TOTAL >0.1 m DEEP	10	8	8	8	8	8	10	6	6	6	4	4	4	4	2	2

The fish stress index is provided in Table N2

Table N2 Fish stress index

Habitat	Discharges (m ³ /s)															
	0.01	0.20	0.29	0.34	0.49	0.69	0.82	0.97	1.33	1.78	2.05	2.35	2.68	3.45	4.90	5.40
SMALL RHEOPHILIC (SR) GUILD																
Spawning habitat	0	0	0.5	0.5	1	1.5	2	2.5	2.5	3	3.5	3.5	4	4.5	5	5
Nursery habitat	0	0.5	1	1.5	2	3	3	3	4	4.5	4.5	5	5	5	5	5
Abundance	0	0.5	1	1	1.5	1.5	2	2.5	2.5	3	3.5	3.5	4	4.5	5	5
Cover	0	0.5	1	1	1.5	1.5	2	2.5	2.5	3	3.5	3.5	4	4.5	5	5
Connectivity (lateral & longitudinal)	0	0.5	1	2	2.5	2.5	3	4	4.5	5	5	5	5	5	5	5
Water Quality (esp. oxygen and temperature)	0	0.5	1.5	2	2	2.5	3	3	4	4.5	4.5	4.5	5	5	5	5
Species stress: AURA, CANO; OPER	10	9	8	7	7	6	5	4	3	2	2	2	1	1	0	0
LARGE SEMI RHEOPHILIC (LR) GUILD																
Spawning habitat	0	0	0	0	0.5	1	1.5	2	2.5	3	3	3.5	4	4.5	5	5
Nursery habitat	0	0.5	1	1.5	2	3	3	3	4	4.5	4.5	5	5	5	5	5
Abundance	0	0.5	0.5	0.5	1	1.5	2	2.5	3	3	3.5	4	4	4.5	5	5
Cover	0	0.5	0.5	0.5	1	1.5	2	2.5	3	3	3.5	4	4	4.5	5	5
Connectivity (lateral & longitudinal)	0	0.5	1	1.5	2	2.5	3	3.5	4	4.5	5	5	5	5	5	5
Water Quality (esp. oxygen and temperature)	0	0.5	1.5	2	2	2.5	3	3	4	4.5	4.5	4.5	5	5	5	5
Species stress: VNEL	10	9	9	8	7	6	5	5	3	3	2	1	1	1	0	0

N1.3 MACROINVERTEBRATE STRESS INDEX

The habitat flow index for flow dependent macroinvertebrate (FDI) taxa is provided in Table N3. These tables provide the % occurrence of various velocity and substrate classes under different flow conditions.

Table N3 Habitat suitability for FDI taxa

Habitat Flow Response Index	Habitat Response	Habitat Abundance and suitability													Flow (m ³ /s)
		VSCS ¹	SCS ²	FCS ³	VFCS ⁴	VSFS ⁵	SFS ⁶	FFS ⁷	VFFS ⁸	VSBR ⁸	SBR ¹⁰	FBR ¹¹	VFBR ¹²	Veg ¹³	
0	All habitats in excess, very high quality. Very fast, very deep, very wide WP.	3	6	11	25	1	2	4	8	1	2	4	8	25	4.900
1	All plentiful, high quality. Fast, wide WP.	4	8	13	21	1	3	4	7	1	3	4	7	24	3.890
2	Critical habitats sufficient. Quality slightly reduced, fast, WP slightly reduced.	6	10	16	15	2	3	5	5	2	3	5	5	22	2.680
3	Reduced critical habitat and critical quality. Moderate velocity, fairly deep.	12	16	16	6	4	5	5	2	4	5	5	2	17	1.330
4	Critical habitats limited and of moderate quality. Moderate velocity, some deep areas. Wide WP moderately reduced.	19	21	10	3	6	7	3	1	6	7	3	1	13	0.690
5	Critical habitat very reduced, moderate/low quality. Moderate/slow velocity, few deep areas WP moderately/very reduced.	23	23	8	2	8	8	3	1	7	7	2	1	7	0.440
6	Critical habitat residual. Low quality, moderate/slow velocity.	27	24	7	1	9	8	2	0	9	8	2	0	2	0.290
7	No critical habitat, other habitats moderate quality. Slow, narrow WP.	36	21	4	0	12	7	1	0	11	7	1	0	0	0.110

Habitat Flow Response Index	Habitat Response	Habitat Abundance and suitability													Flow (m ³ /s)
		VSCS ¹	SCS ²	FCS ³	VFCS ⁴	VSFS ⁵	SFS ⁶	FFS ⁷	VFFS ⁸	VSBR ⁹	SBR ¹⁰	FSR ¹¹	VFSR ¹²	Veg ¹³	
8	Flowing water habitats residual and of low quality. Slow trickle, very narrow WP.	44	16	1	0	15	5	0	0	14	5	0	0	0	0.050
9	Standing water habitats only, very low quality, no flow.	53	7	0	0	18	2	0	0	18	2	0	0	0	0.011
10	Only hyporheic refugia, no surface water.	60	0	0	0	20	0	0	0	20	0	0	0	0	0.000

1 Very Slow over Coarse Sediment

4 Very Fast over Coarse Sediment

7 Fast over Fine Sediment

10 Slow over Bedrock

13 Fringing vegetation

2 Slow over Coarse Sediment

5 Very Slow over Fine Sediment

8 Very Fast over Fine Sediment

11 Fast over Bedrock

3 Fast over Coarse Sediment

6 Slow over Fine Sediment

9 Very Slow over Bedrock

12 Very Fast over Bedrock

The stress index for FDI taxa (Table N5) rates the response of the species according to various biotic response metrics.

Table N4 Macroinvertebrate (FDI) stress index

Habitat characteristics					Biotic Response	Flow	Species Stress
Max depth (m)	Ave depth (m)	Max vel (m/s)	Ave vel (m/s)	WP (m)			
0.76	0.45	0.7	1.84	17.1	All indicator taxa very abundant and healthy.	3.89	0
0.72	0.44	0.61	1.71	16.2	90% indicator taxa persist.	3.30	1
0.66	0.4	0.48	1.46	15.3	Most indicator taxa persist, but slight (80%) reduction.	2.68	2
0.56	0.34	0.31	1.04	13.6	Most indicator taxa persist, but abundances reduced.	1.33	3
0.48	0.31	0.21	0.72	11.6	All life stages viable in limited areas, critical life stages of some sensitive indicator taxa at risk.	1.01	4
0.4	0.27	0.17	0.61	10.2	Critical life-stages of sensitive indicator taxa at risk or non-viable.	0.69	5
0.34	0.23	0.15	0.51	9.3	Sensitive indicator taxa rare, critical stages of sensitive indicator taxa non-viable and at risk for some less sensitive taxa.	0.44	6
0.22	0.15	0.1	0.36	7.4	Some indicator taxa persist, but most disappear. All life-stages of sensitive indicator taxa at risk or non-viable.	0.29	7
0.16	0.09	0.07	0.25	7.1	Some indicator taxa persist, but at very low numbers. All life stages of most indicator taxa at risk or non-viable.	0.11	8
0.1	0.04	0.04	0.15	5.8	Indicator taxa no longer present.	0.05	9
0.02	0.01	0.01	0.05	0.4	No surface flow	0.00	10

N1.4 RIPARIAN VEGETATION STRESS INDEX

The riparian vegetation stress index is provided in Table N5.

Table N5 Riparian vegetation stress index for indicator species

Biotic response				
Species Stress	Flow (m ³ /s)	<i>Breonadia salicina</i>	Flow (m ³ /s)	<i>Phragmites mauritianus</i>
0	3.45	Adults with full vigour and at maximum reproductive capacity. Up to 50 – 60 cm rooting depth for upper limit. Lower limit at water level on average.	4.9	Adults with full vigour and at maximum reproductive capacity. 30 - 50% population inundated (not more than 40 – 50 cm). Upper limit rooting depth up to 50 cm.
1				Adults with full vigour and at maximum reproductive capacity.
2				Leaf wilting/stress commences in adults, but is slight.
3	0.82	Leaf wilting/stress commences, but is slight. 60 - 90 cm substrate depth required for inundated soil moisture.	1.14	Leaf wilting/stress commences, but is slight. Up to 80 cm rooting depth for upper limit. Lower limit 20 cm inundated on average.
4		Flower/fruit abortion commences.		Flower/fruit abortion commences.
5		Leaf wilting obvious, or vegetative parts begin unseasonal discolouration. Flower/fruit abortion widespread.		Leaf wilting obvious, or vegetative parts begin unseasonal discolouration. Flower/fruit abortion widespread.
6	0.34	Unseasonal thinning or partial mortality of above-ground parts (majority of the plant/s remains viable, but water stressed). 80 - 1100 cm rooting depth for sufficient substrate moisture. Mortality may occur for lower zone individuals.	0.38	Unseasonal thinning or partial mortality of above-ground parts (majority of the plant/s remains viable, but water stressed). Up to 100 cm rooting depth for sufficient soil moisture. Water level at lower limit. Rhizomes at upper limits may begin thinning.
7				
8	0.06	Unseasonal loss or mortality of above-ground parts (only minor portions of plants remain viable). Rootstocks/rhizomes of some species remain viable. > 1 m rooting depth. Individuals at upper limit likely to begin senescence.	0.14	Unseasonal loss or mortality of above-ground parts (only minor portions of plants remain viable). Rootstocks/rhizomes of some species remain viable/dormant. More than 1 m rooting depth for sufficient soil moisture. Rhizome mortality commences.
9		Complete mortality of small proportion of the population.		Complete mortality of small proportion of the population.
10	0	Widespread and complete mortality of population.	0	Widespread and complete mortality of population.

N2 EWR 5: MARITE (MARITE RIVER) - DETERMINATION OF EWR SCENARIOS

N2.1 LOW FLOW REQUIREMENTS IN TERMS OF STRESS FOR FISH

The fish low flow requirements for the EWR scenarios are summarised in Table N6 for the SR guild and Table N7 for LR guild.

Table N6 Low flow requirements: SR guild

GENERAL					
INDICATOR: The small rheophilic species <i>Amphilius uranoscopus</i> (AURA), <i>Chiloglanis anoterus</i> (CANO) and <i>Opsaridium peringueyi</i> (OPER) at the site are also good indicators for setting flows as a result of their high requirement for flowing water. These species all requires flowing water over substrates during all life stages, with some stages also preferring overhanging vegetation as cover. Optimal conditions for spawning of this guild consist of FD, FI, FS and SS with good quality substrate (clean cobbles and gravel), while the margins of the FS and SS are important for egg development and nursery areas for larvae, often with overhanging vegetation as cover. Juvenile and adult stages of this guild have a high preference for FS, FI and FD over substrates.					
PES: FISH EC B/C (ECOSTATUS B/C)					
Dry Season maintenance At this fish stress level, some FS (3% on cross-section), FI (2% on cross-section) and adequate FD (13% on cross-section) will be maintained, the most critical habitats for the survival of the species within this guild. This habitat composition should maintain this fish guild in present EC.					
Dry Season drought At this fish stress level limited FS (4% on cross-section) and FI (7% on cross-section) will be maintained to ensure the survival of this fish guild (no FD will be available on cross-section at this stress level). At these proportions of habitats available at the site, this fish guild should be able to survive through drought period in the dry season and enable recovery once conditions improve to remain within the PES.					
Wet Season maintenance This fish stress level will maintain adequate FS (4%) and FI (7%) and abundant FD (26%), the most important habitat required by all life stages to fulfil all required biological processes during the wet season (spawning, nursery habitats as well as adequate feeding and refuge habitats for juvenile and adult specimens) to maintain this fish guild within current EC.					
Wet Season drought At a fish stress level of 7.5 much reduced spawning habitats will be available for this fish guild (3% FS, 2% FI and 13% FD on cross-section), but it should be adequate to maintain some habitats to meet requirements of all life stages to ensure survival of these species during the wet season and allow recovery after drought period.					
BUILDING BLOCK	SEASON	STRESS DURATION	SPP STRESS	INTEG STRESS	FLOW (m ³ /s)
Drought	Dry	5%	9	9.3	0.203
Maintenance	Dry	35%	7	7	1.78
Drought	Wet	5%	7.5	7.5	0.425
Maintenance	Wet	35%	3	4.1	1.335
REC: FISH EC B (ECOSTATUS B)					
General Improved flow regime (close to natural regime) will improve habitat diversity and abundance, with a resultant improved FROC of most species.					
Dry Season maintenance At this recommended stress level, the abundance of fast habitats (FS = 4.5%, FI = 1% and FD = 17.5% of cross-section) will be improved from present conditions, which should result in improved abundance of this fish guild and therefore improved FROC.					
Wet Season maintenance At this stress level FS – FI - FD habitats will be available as 9% - 5% - 34% of the cross-section, respectively. This					

improvement from the present condition can be expected to improved habitat for especially spawning, and also increased nursery, abundance and thus improvement to a higher EC.

BUILDING BLOCK	SEASON	STRESS DURATION	SPP STRESS	INTEG STRESS	FLOW (m ³ /s)
Maintenance	Dry	35%	5.5	5.8	0.746
Maintenance	Wet	35%	2.5	2.8	1.964

AEC: FISH EC C/D (ECOSTATUS C/D)

General

No releases for EWR will result in loss of habitat diversity, reflected by reduced FROC of most expected species. It will also affect the migratory cues, impacting negatively species migrating between reaches. Increased sediment will reduce the quality of substrate as habitat through embeddedness, impacting on species with high preference for substrates.

Dry Season maintenance

This stress level will maintain some FS (1% of cross-section), FI (8% of cross-section) and FD (3% of cross-section). It can be expected that this guild will be stressed more than presently and result in decreased abundance and overall FROC, with a resultant decreased EC.

Wet Season maintenance

At this fish stress level, fast habitats (FS = 4%, FI = 3% and FD = 20% of cross section) will be available at a much reduced quantity than present wet conditions, but it should still be adequate to maintain all life stages although reduced abundance and FROC can be expected, and a resultant decrease in EC may occur.

BUILDING BLOCK	SEASON	STRESS DURATION	SPP STRESS	INTEG STRESS	FLOW (m ³ /s)
Maintenance	Dry	35%	8	9	0.29
Maintenance	Wet	35%	4.5	5.4	0.808

Table N7 Low flow requirements: LR guild

GENERAL					
INDICATOR: The large rheophilic species, <i>Varicorhinus nelspruitensis</i> (VNEL) is the most important indicator species regarding flows as it is the biggest species at the site having a requirement for continuous flows. Limited information is however available regarding the habitat requirements for different life stages (especially early life stages) of this species, and deficiencies were addressed by reference to fish species with similar behaviours and requirements of which information is available. VNEL is intolerant to no flow and requires flowing habitat (FI and FD) with substrate and water column as preferred cover for most of its life stage. They also require margins of FS, SS and SD with overhanging vegetation as nursery habitats. Flows should furthermore remain adequate to allow migration between reaches, thus depth in riffle and rapids should remain adequate, especially during the wet season.					
PES: FISH EC B/C (ECOSTATUS B/C)					
Dry Season maintenance Present day stress according to available information (flow duration graph) is expected to be too high for maintenance within the PES and therefore slightly lower stress (7.5) is recommended to ensure at least some of the critical habitats (FD,FI,) for this species will be maintained during the dry season. At this fish stress level, some FI (3% of cross-section) and FD (11% of cross-section) will be maintained, the two most critical habitats for the survival of this species. This composition of FI and FD habitat should maintain the species in this EC.					
Dry Season drought Limited critical habitats (FI and FD) will be maintained to ensure the survival of this fish guild and allow recovery after stressed drought period.					
Wet Season maintenance This fish stress level will maintain adequate FI (5% on cross-section) and FD (34% on cross-section), the most important habitats required for most life stages and biological process requirements during the wet season (spawning, nursery habitats, and adequate habitats for juvenile and adult specimens) to maintain within current EC.					
Wet Season drought This is the maximum allowable fish stress level where this fish species will still have adequate habitat to maintain some level of spawning. At fish stress level of 6.5 the preferred and most critical habitats of this species will be greatly reduced (1% FI and 16% FD).					
BUILDING BLOCK	SEASON	STRESS DURATION	SPP STRESS	INTEG STRESS	FLOW (m ³ /s)
Drought	Dry	5%	8.5	8.5	0.32
Maintenance	Dry	35%	7.5	7.5	0.595

Drought	Wet	5%	6.5	6.5	0.6
Maintenance	Wet	35%	3	3	1.78
REC: FISH EC B (ECOSTATUS B)					
General Improved flow regime (close to natural regime) will improve habitat diversity and abundance, with a resultant improved FROC of species such as VNEL. Dry Season maintenance This stress level will reduce present day dry season stress somewhat by providing more preferred habitats (FI = 1% and FD = 16% of cross-section). Improved abundance and overall FROC can be expected which should improve the overall EC of this site. Wet Season maintenance Improved FI and FD habitats will result in improved habitat for especially spawning, and also increased nursery, abundance and thus an improvement to a higher EC.					
BUILDING BLOCK	SEASON	STRESS DURATION	SPP STRESS	INTEG STRESS	FLOW (m ³ /s)
Maintenance	Dry	35%	6.5	6.5	0.6
Maintenance	Wet	35%	2	2.8	1.9
AEC: FISH EC C/D (ECOSTATUS C/D)					
General No releases for EWR will result in loss of habitat diversity, reflected by reduced FROC of most expected species. It will also affect the migratory cues, impacting negatively species migrating between reaches (esp. BMAR, CGAR, TSPAR, and VNEL). Dry Season maintenance At this stress level limited critical FI (6% of cross-section) and FD (5% of cross-section) habitats will be available. Reduced abundance can be expected at these lower than present day dry season flows, which may result in decreased FROC, and thus overall EC. Wet Season maintenance At this stress level some of the critical FI and FD habitats will be available. It will maintain some FI (5% of cross-section) and FD (24% of cross-section) at site. Flows should however still be adequate to maintain all life stages, albeit available in much reduced quantity, and therefore reduced abundance and FROC can be expected with a resultant decreased EC.					
BUILDING BLOCK	SEASON	STRESS DURATION	SPP STRESS	INTEG STRESS	FLOW (m ³ /s)
Maintenance	Dry	35%	8	8	0.35
Maintenance	Wet	35%	4.5	4.5	1.2

N2.2 LOW FLOW REQUIREMENTS IN TERMS OF STRESS FOR MACROINVERTEBRATES

The FDI low flow requirements are summarised in Table N8.

Table N8 Low flow requirements: FDI taxa

GENERAL
INDICATOR: Three flow dependent cobble dwelling macroinvertebrate taxa were used for this site. Perlidae prefer velocities >0.6 m/s while Elmidae and Heptageniidae prefer velocities between 0.3 and 0.6 m/s although they can also survive at other velocity categories and live on other substrates. Perlidae and Heptageniidae are highly sensitive to water quality whereas Elmidae are moderately sensitive to water quality.
PES: MACROINVERTEBRATE EC: C (ECOSTATUS C)
Dry Season maintenance Suitable habitat (>0.3 m/s over coarse substrate with some areas of 0.6 m/s over coarse substrate) is required to ensure that all the selected taxa can overwinter without significant detrimental impacts on the overall population. The average velocity of 0.17 m/s and maximum velocity of 0.61 (macroinvertebrate stress of 6) will ensure that this takes place. At this flow 8% FCS, 2% FBR and 2% VFCS; 1% VFBR is available. The WP at this flow is 10.2m.
Dry Season drought

Suitable habitat (>0.1 m/s over coarse substrate, with at least some areas of 0.3 m/s over coarse substrate) is required to ensure that a core of the selected taxa are able to survive a drought. The average velocity of 0.1 m/s and maximum velocity of 0.36 m/s (macroinvertebrate stress of 8) will ensure that this takes place. At this flow 21% SCS, 7% SBR, 4% FCS and 1% FBR is available. The WP is 7.4.

Wet Season maintenance

During the wet season optimal habitats (>0.6 m/s over coarse substrate) is required to ensure that a healthy population occurs during the summer. The average velocity of 0.26 m/s maximum velocity of 0.87 m/s (macroinvertebrate stress of 4) ensure that this takes place. At this flow 13% FCS, 5%FBR and 4%VFCS, 2% VFBR is available. The WP is 12.8.

Wet Season drought

During the wet season optimal habitats (>0.3 m/s over coarse substrate with some areas of at least 0.6 m/s) is required to ensure that a healthy population occurs during the summer. The average velocity of 0.17 m/s and maximum velocity of 0.61 m/s (macroinvertebrate stress of 6) ensures that this takes place. At this flow 8% FCS, 2% FBR and 2% VFCS, 1% VFBR are available. The WP at this flow is 10.2 m.

BUILDING BLOCK	SEASON	STRESS DURATION	SPP STRESS	INTEG STRESS	FLOW (m ³ /s)
Drought	Dry	5%	8	9.8	0.345
Maintenance	Dry	35%	5	9.4	1.338
Drought	Wet	5%	6	9.5	1.007
Maintenance	Wet	35%	4	9.2	1.669

REC: MACROINVERTEBRATE EC B (ECOSTATUS B)

Dry Season maintenance

Suitable habitat (>0.3 m/s over coarse substrate with considerable areas of 0.6 m/s over coarse substrate) is required to ensure that all the selected taxa can overwinter without significant detrimental impacts on the overall population. The average velocity of 0.21 m/s and maximum velocity of 0.72 m/s (macroinvertebrate stress of 5) will ensure that this takes place. At this flow 10% FCS, 3% FBR and 3% VFCS and 1% VFBR is available. The wetted perimeter is 11.6.

Wet Season maintenance

During the wet season optimal habitats (>0.6 m/s over coarse substrate) is required to ensure that a healthy population occurs during the summer. The average velocity of 0.31 m/s maximum velocity of 1.04 m/s (macroinvertebrate stress of 3) ensure that this takes place. At this flow 16% FCS, 5% FBR and 6% VFCS, 2% VFBR is available. The wetted perimeter is 13.6.

BUILDING BLOCK	SEASON	STRESS DURATION	SPP STRESS	INTEG STRESS	FLOW (m ³ /s)
Maintenance	Dry	35	3	9	2.1
Maintenance	Wet	35	2	7	4.66

AEC: MACROINVERTEBRATE EC D (ECOSTATUS D)

Dry Season maintenance

Suitable habitat (>0.3 m/s over coarse substrate) is required to ensure that all the selected taxa can overwinter without significant detrimental impacts on the overall population. The average velocity of 0.15 m/s and maximum velocity of 0.51 m/s (macroinvertebrate stress of 7) will ensure that this takes place. At this flow 24% SCS, 8% SBR; 7% FCS, 2% FBR and 1% VFCS is available. The wetted perimeter is 9.3.

Wet Season maintenance

During the wet season optimal habitats (>0.6 m/s over coarse substrate) is required to ensure that a healthy population occurs during the summer. The average velocity of 0.21 m/s maximum velocity of 0.72 m/s (macroinvertebrate stress of 5) ensure that this takes place. At this flow 10% FCS, 3% FBR and 3% VFCS, 1% VFBR is available. The wetted perimeter is 11.6m.

BUILDING BLOCK	SEASON	STRESS DURATION	SPP STRESS	INTEG STRESS	FLOW (m ³ /s)
Maintenance	Dry	35%	7	9.7	0.676
Maintenance	Wet	35%	5	9.4	1.338

N2.3 LOW FLOW REQUIREMENTS IN TERMS OF RIPARIAN VEGETATION

The low flow requirements for riparian vegetation indicator species are summarised in Table N9.

Table N9 Low flow requirements: Riparian vegetation species

GENERAL							
INDICATOR: <i>Breonadia salicina</i> and <i>Phragmites mauritanus</i> .							
PES: RIPARIAN VEGETATION EC B/C (ECOSTATUS B/C)							
Dry Season maintenance In order that the PES is maintained, population stress would not be expected to exceed 4 or 5 during dry season maintenance flows. At a spp. stress of 4, leaf wilting/stress commences but is slight, and flower/fruit abortion commences (which is unlikely to occur in dry season), but at 5 leaf wilting becomes obvious. Dry Season drought Would not expect the average population to experience a spp. stress of more than 6 or 7 during natural drought in the dry season. A stress of 6 equates to unseasonal thinning or partial mortality of above-ground parts (majority of the plant/s remain/s viable, but water stressed) and a spp. stress of 7 is more intense response of 6. A thinning of the population can be expected for reeds and juveniles of <i>B. salicina</i> may begin senescence. Wet Season maintenance Would not expect the average population to experience a stress of more than 5 during natural drought in the wet season. A spp. stress of 5 equates to obvious leaf wilting or vegetative parts begin unseasonal discolouration; flower/fruit abortion is widespread. Wet Season drought In order that the PES is maintained, population stress would not be expected to exceed 2 during wet (growing) season maintenance flows. At a spp. stress of 2, leaf wilting/stress commences in adults, but is slight; the population is essentially unhampered in reproductive capacity.							
BUILDING BLOCK	SEASON	STRESS DURATION	SPP STRESS <i>Phragmites</i>	INTEG STRESS	SPP STRESS <i>Breonadia</i>	INTEG STRESS	FLOW (m ³ /s)
Drought	Dry	5%	7	9.25	6	8.5	0.32
Maintenance	Dry	50%	5	6.5	4.5	6.5	0.6
Drought	Wet	5%	5	6.5	5	7	0.5
Maintenance	Wet	50%	2	2.5	2	3	1.78
REC: RIPARIAN VEGETATION EC B (ECOSTATUS B)							
This EWR scenario was not assessed as the REC is based on non flow related improvements.							
REC: RIPARIAN VEGETATION EC C/D (ECOSTATUS C/D)							
This EWR scenario was not assessed as the AEC is related to non flow related impacts.							

N2.4 INSTREAM FLOOD FUNCTIONS

A description of the flood functions for biotic response is provided in Table N10.

Table N10 Functions for each Flood Class

Flood Class	Component	Function/Motivation
Class: I Range (m ³ /s): 4 - 6 Daily average: 4 Duration: 3	Fish	Class I floods are very important floods for fish and serves as migration cues and to maintain adequate longitudinal connectivity for migration. These floods will also flush fines and algae from substrates to ensure adequate conditions in substrates, a very important habitat for spawning of many of the species. It should furthermore inundate some vegetation for species spawning in flooded marginal vegetation and contributes to the creation of acceptable nursery areas. Some resetting of water quality will also take place, and the changes in water quality may also serve as stimulus to cue migratory activity and even gonad development. The frequency, extent and duration as recommended for the PES and AEC should be adequate to provide the functions as required to maintain the fish within the specific category.
	Macroinvertebrates	These freshets are recommended to stimulate hatching of eggs, flush organic flocculants and mobilise fines (1 - 2 mm sands) in order to improve biotope suitability they will also reset water quality. Another function is to inundate the grasses and reeds to provide extra habitat for vegetation

Flood Class	Component	Function/Motivation
		dwelling macroinvertebrates. Five of these per year, (Oct, Nov, Dec, Jan and Mar/Apr) are recommended for the REC. Four (Nov, Dec, Jan, Mar/Apr) for the PES and three (Nov, Jan, Mar/Apr) for the AEC.
Class: II Range (m ³ /s): 8 - 18 Daily average: 8 Duration: 4	Fish	Class II floods are similar in importance as Class I floods and have the same functionality as Class I floods. Their occurrence at lower frequency makes them only slightly less important for the fish assemblages than Class I. Secondary channels will be inundated by these floods which will create favourable spawning and refuge habitats for some species.
	Macroinvertebrates	These freshets are recommended to clear fines, scour substrate and inundate reeds, grasses and <i>Ludwichia</i> and activate the secondary channel in order to create additional biotopes, and reset water quality. Two of these per year are recommended for the REC and PES and one for the AEC in the middle of the wet Season.
Class: III Range (m ³ /s): 28 - 42 Daily average: 25 Duration: 5	Fish	Class III floods also provide similar functions as Class I, but due to its lower frequency it is not essential for the flood functions required by the indigenous fish species. These floods, and especially their receding limbs will however be utilised by many of the fish species for migration and even spawning if takes place within the summer season. Important secondary channels will be inundated during these floods to create favourable habitat for some species.
CLASS : IV Range (m ³ /s): 80 +	Fish	Class IV floods also provide similar functions as Class I, but due to its lower frequency of occurrence it is not essential for the flood functions required by the indigenous fish species. These floods, and especially their receding limbs will however be utilised by many of the fish species for migration and even spawning if takes place within the summer season. Important secondary channels will be inundated during these floods to create favourable habitat for some species.
CLASS : V Range (m ³ /s): 250 +	Fish	Class V floods also provide similar functions as Class I, but due to its lower frequency of occurrence it is not essential for the flood functions required by the indigenous fish species. The receding limb will be utilised by many of the fish species for migration and even spawning if takes place within the summer season.

N2.5 EWR RULE TABLES

EWR rule tables which provide the recommended EWR flows as a duration table, showing flows which should be provided when linked to a natural trigger (natural modelled hydrology in this case) are provided for the different EWR scenarios. EWR rules are supplied for total flows as well as for low flows only.

Table N11 EWR 5 assurance rules for PES: B/C

Desktop Version 2, Printed on 2008/07/31

Summary of IFR rule curves for: SB5 Natural Flows

Determination based on defined BBM Table with site specific assurance rules.

Regional Type: E. Escarp PES = B/C

Data are given in m³/s mean monthly flow

Month	% Points									
	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	0.612	0.611	0.607	0.599	0.583	0.554	0.506	0.435	0.350	0.285
Nov	1.078	1.074	1.065	1.046	1.010	0.944	0.837	0.681	0.497	0.359
Dec	1.996	1.987	1.966	1.925	1.846	1.706	1.478	1.152	0.768	0.482
Jan	2.604	2.456	2.321	2.187	2.034	1.776	1.539	1.206	0.819	0.533
Feb	6.912	6.293	5.752	5.262	4.772	3.945	3.383	2.576	1.626	0.919
Mar	2.669	2.602	2.530	2.444	2.323	2.110	1.837	1.443	0.974	0.625
Apr	1.932	1.928	1.911	1.878	1.811	1.689	1.485	1.184	0.820	0.547
May	1.447	1.445	1.435	1.413	1.367	1.283	1.138	0.919	0.651	0.448
Jun	1.207	1.206	1.198	1.181	1.146	1.080	0.965	0.789	0.572	0.407
Jul	0.936	0.936	0.931	0.920	0.896	0.849	0.766	0.636	0.474	0.349
Aug	0.757	0.757	0.752	0.743	0.723	0.686	0.623	0.525	0.405	0.314
Sep	0.649	0.648	0.645	0.637	0.621	0.591	0.541	0.464	0.370	0.299

Reserve flows without High Flows

Oct	0.612	0.611	0.607	0.599	0.583	0.554	0.506	0.435	0.350	0.285
Nov	0.809	0.807	0.801	0.788	0.764	0.720	0.648	0.544	0.421	0.329
Dec	1.125	1.121	1.111	1.091	1.052	0.983	0.872	0.713	0.525	0.385
Jan	1.552	1.544	1.527	1.495	1.436	1.332	1.168	0.936	0.666	0.467
Feb	2.300	2.291	2.268	2.222	2.135	1.980	1.729	1.369	0.945	0.629
Mar	2.218	2.211	2.189	2.146	2.064	1.916	1.674	1.323	0.907	0.596
Apr	1.932	1.928	1.911	1.878	1.811	1.689	1.485	1.184	0.820	0.547
May	1.447	1.445	1.435	1.413	1.367	1.283	1.138	0.919	0.651	0.448
Jun	1.207	1.206	1.198	1.181	1.146	1.080	0.965	0.789	0.572	0.407
Jul	0.936	0.936	0.931	0.920	0.896	0.849	0.766	0.636	0.474	0.349
Aug	0.757	0.757	0.752	0.743	0.723	0.686	0.623	0.525	0.405	0.314
Sep	0.649	0.648	0.645	0.637	0.621	0.591	0.541	0.464	0.370	0.299

Natural Duration curves

Oct	2.427	2.057	1.732	1.568	1.251	1.165	1.064	0.993	0.904	0.698
Nov	6.273	4.853	3.781	2.924	2.384	2.215	1.728	1.335	1.161	0.887
Dec	11.880	8.804	6.366	5.458	4.182	3.607	2.733	2.333	1.863	1.236
Jan	22.357	14.804	9.371	7.874	6.269	4.734	3.913	3.536	2.543	1.829
Feb	30.853	22.830	14.339	9.809	7.626	6.453	4.803	3.542	2.650	1.521
Mar	23.174	16.114	11.649	9.293	6.459	4.663	4.010	3.192	2.599	1.546
Apr	10.729	8.183	6.709	4.776	4.001	3.650	3.202	2.805	2.446	1.412
May	4.043	3.454	3.185	3.032	2.726	2.543	2.337	1.983	1.800	1.131
Jun	2.924	2.704	2.442	2.280	2.149	1.952	1.813	1.624	1.481	1.154
Jul	2.363	2.109	1.927	1.815	1.650	1.576	1.434	1.340	1.247	0.978
Aug	2.035	1.688	1.583	1.493	1.363	1.303	1.221	1.139	1.049	0.825
Sep	2.072	1.674	1.424	1.308	1.235	1.161	1.069	1.011	0.922	0.725

Table N12 EWR 5 assurance rules for REC: B

Desktop Version 2, Printed on 2008/07/31

Summary of IFR rule curves for: SB5 Natural Flows

Determination based on defined BBM Table with site specific assurance rules.

Regional Type: E. Escarp REC = B

Data are given in m³/s mean monthly flow

Month	% Points									
	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	0.987	0.985	0.976	0.959	0.926	0.865	0.763	0.613	0.431	0.295
Nov	1.493	1.487	1.473	1.443	1.386	1.284	1.116	0.873	0.585	0.370
Dec	2.446	2.436	2.409	2.355	2.253	2.072	1.779	1.358	0.862	0.493
Jan	3.611	3.398	3.203	3.008	2.786	2.409	2.060	1.569	0.998	0.575
Feb	7.627	7.003	6.453	5.944	5.417	4.526	3.859	2.902	1.776	0.937
Mar	3.342	3.271	3.191	3.087	2.933	2.660	2.289	1.753	1.117	0.642
Apr	2.559	2.552	2.529	2.480	2.384	2.209	1.914	1.480	0.957	0.563
May	1.976	1.973	1.957	1.924	1.855	1.727	1.507	1.176	0.770	0.462
Jun	1.701	1.699	1.686	1.659	1.603	1.496	1.312	1.031	0.684	0.420
Jul	1.372	1.372	1.363	1.344	1.302	1.222	1.079	0.856	0.576	0.360
Aug	1.159	1.158	1.149	1.131	1.095	1.026	0.905	0.722	0.496	0.324
Sep	1.040	1.039	1.031	1.015	0.982	0.920	0.814	0.654	0.458	0.309

Reserve flows without High Flows

Oct	0.987	0.985	0.976	0.959	0.926	0.865	0.763	0.613	0.431	0.295
Nov	1.230	1.226	1.214	1.191	1.146	1.064	0.931	0.739	0.510	0.340
Dec	1.595	1.589	1.572	1.539	1.477	1.366	1.186	0.927	0.623	0.396
Jan	2.100	2.088	2.064	2.016	1.927	1.773	1.527	1.180	0.778	0.481
Feb	3.015	3.001	2.969	2.904	2.780	2.561	2.206	1.695	1.094	0.647
Mar	2.890	2.880	2.850	2.789	2.674	2.467	2.126	1.634	1.050	0.613
Apr	2.559	2.552	2.529	2.480	2.384	2.209	1.914	1.480	0.957	0.563
May	1.976	1.973	1.957	1.924	1.855	1.727	1.507	1.176	0.770	0.462
Jun	1.701	1.699	1.686	1.659	1.603	1.496	1.312	1.031	0.684	0.420
Jul	1.372	1.372	1.363	1.344	1.302	1.222	1.079	0.856	0.576	0.360
Aug	1.159	1.158	1.149	1.131	1.095	1.026	0.905	0.722	0.496	0.324
Sep	1.040	1.039	1.031	1.015	0.982	0.920	0.814	0.654	0.458	0.309

Natural Duration curves

Oct	2.427	2.057	1.732	1.568	1.251	1.165	1.064	0.993	0.904	0.698
Nov	6.273	4.853	3.781	2.924	2.384	2.215	1.728	1.335	1.161	0.887
Dec	11.880	8.804	6.366	5.458	4.182	3.607	2.733	2.333	1.863	1.236
Jan	22.357	14.804	9.371	7.874	6.269	4.734	3.913	3.536	2.543	1.829
Feb	30.853	22.830	14.339	9.809	7.626	6.453	4.803	3.542	2.650	1.521
Mar	23.174	16.114	11.649	9.293	6.459	4.663	4.010	3.192	2.599	1.546
Apr	10.729	8.183	6.709	4.776	4.001	3.650	3.202	2.805	2.446	1.412
May	4.043	3.454	3.185	3.032	2.726	2.543	2.337	1.983	1.800	1.131
Jun	2.924	2.704	2.442	2.280	2.149	1.952	1.813	1.624	1.481	1.154
Jul	2.363	2.109	1.927	1.815	1.650	1.576	1.434	1.340	1.247	0.978
Aug	2.035	1.688	1.583	1.493	1.363	1.303	1.221	1.139	1.049	0.825
Sep	2.072	1.674	1.424	1.308	1.235	1.161	1.069	1.011	0.922	0.725

Table N13 EWR 5 assurance rules for AEC: C/D

Desktop Version 2, Printed on 2008/07/31

Summary of IFR rule curves for: SB5 Natural Flows

Determination based on defined BBM Table with site specific assurance rules.

Regional Type: E. Escarp AEC = C/D

Data are given in m³/s mean monthly flow

Month	% Points									
	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	0.425	0.424	0.423	0.419	0.412	0.400	0.378	0.347	0.309	0.281
Nov	0.854	0.852	0.845	0.832	0.807	0.761	0.686	0.578	0.450	0.354
Dec	1.017	1.013	1.005	0.988	0.956	0.899	0.807	0.676	0.520	0.405
Jan	2.000	1.856	1.730	1.613	1.492	1.290	1.144	0.937	0.696	0.518
Feb	5.483	4.934	4.463	4.046	3.647	2.977	2.584	2.021	1.358	0.865
Mar	1.770	1.706	1.646	1.583	1.506	1.373	1.232	1.027	0.784	0.602
Apr	1.161	1.159	1.151	1.136	1.105	1.050	0.956	0.818	0.652	0.527
May	0.890	0.889	0.884	0.874	0.853	0.815	0.748	0.649	0.527	0.434
Jun	0.758	0.758	0.754	0.746	0.731	0.700	0.648	0.569	0.470	0.396
Jul	0.605	0.605	0.603	0.598	0.587	0.566	0.528	0.470	0.397	0.340
Aug	0.505	0.505	0.503	0.499	0.490	0.474	0.445	0.402	0.348	0.307
Sep	0.448	0.448	0.446	0.442	0.436	0.422	0.400	0.367	0.325	0.294

Reserve flows without High Flows

Oct	0.425	0.424	0.423	0.419	0.412	0.400	0.378	0.347	0.309	0.281
Nov	0.538	0.537	0.534	0.529	0.518	0.498	0.466	0.419	0.364	0.323
Dec	0.711	0.709	0.704	0.695	0.677	0.646	0.596	0.523	0.438	0.375
Jan	0.947	0.944	0.936	0.921	0.894	0.847	0.772	0.666	0.543	0.452
Feb	1.373	1.369	1.358	1.337	1.297	1.226	1.111	0.946	0.751	0.606
Mar	1.318	1.315	1.305	1.285	1.248	1.180	1.069	0.908	0.717	0.574
Apr	1.161	1.159	1.151	1.136	1.105	1.050	0.956	0.818	0.652	0.527
May	0.890	0.889	0.884	0.874	0.853	0.815	0.748	0.649	0.527	0.434
Jun	0.758	0.758	0.754	0.746	0.731	0.700	0.648	0.569	0.470	0.396
Jul	0.605	0.605	0.603	0.598	0.587	0.566	0.528	0.470	0.397	0.340
Aug	0.505	0.505	0.503	0.499	0.490	0.474	0.445	0.402	0.348	0.307
Sep	0.448	0.448	0.446	0.442	0.436	0.422	0.400	0.367	0.325	0.294

Natural Duration curves

Oct	2.427	2.057	1.732	1.568	1.251	1.165	1.064	0.993	0.904	0.698
Nov	6.273	4.853	3.781	2.924	2.384	2.215	1.728	1.335	1.161	0.887
Dec	11.880	8.804	6.366	5.458	4.182	3.607	2.733	2.333	1.863	1.236
Jan	22.357	14.804	9.371	7.874	6.269	4.734	3.913	3.536	2.543	1.829
Feb	30.853	22.830	14.339	9.809	7.626	6.453	4.803	3.542	2.650	1.521
Mar	23.174	16.114	11.649	9.293	6.459	4.663	4.010	3.192	2.599	1.546
Apr	10.729	8.183	6.709	4.776	4.001	3.650	3.202	2.805	2.446	1.412
May	4.043	3.454	3.185	3.032	2.726	2.543	2.337	1.983	1.800	1.131
Jun	2.924	2.704	2.442	2.280	2.149	1.952	1.813	1.624	1.481	1.154
Jul	2.363	2.109	1.927	1.815	1.650	1.576	1.434	1.340	1.247	0.978
Aug	2.035	1.688	1.583	1.493	1.363	1.303	1.221	1.139	1.049	0.825
Sep	2.072	1.674	1.424	1.308	1.235	1.161	1.069	1.011	0.922	0.725

**APPENDIX O: SUPPORTING INFORMATION FOR THE DETERMINATION OF STRESS
INDICES AND EWR SCENARIOS OF EWR 6: MUTLUMUVI**

O1 EWR 6: MUTLUMUVI (MUTLUMUVI RIVER) - DETERMINATION OF STRESS INDICES

Appendix O provides supporting information for the determination of stress indices and EWR scenarios of EWR 6: Mutlumuvi (Chapter 13 and 14 of the Sabie-Sand River System EWR Scenario Report: Volume 1).

O1.1 FISH INDICATOR SPECIES

Small rheophilic (SR) guild: *Chiloglanis anoterus* (CANO) are good indicators for setting flows as a result of their high requirement for flowing water. These species all requires flowing water over substrates during all life stages, with some stages also preferring overhanging vegetation as cover.

Large semi rheophilic (LSR) guild: *Labeobarbus marequensis* (BMAR), *Labeo cylindricus* (LCYL) and *Labeo molybdinus* (LMOL) are another important indicator guild present at this EWR site. This species utilises most habitats (SD, SS, FD, FI and FS) with substrate and water column as preferred cover.

The habitat requirements for the different life stages of the LSR indicator fish species is summarised in Appendix L, Table L1 and in Appendix K, Table K1 for the SR guild.

O1.2 FISH STRESS INDEX

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

Table O1 EWR 6: Habitat suitability for the SR and LSR guild

SR AND LSR GUILD													
Depth classes	Discharges (m ³ /s)												
	0.01	0.05	0.10	0.16	0.23	0.30	0.38	0.46	0.55	0.64	0.73	0.83	1.14
Slow (<0.3 m/s) Very Shallow (<0.1 m) (SVS)	8	8	8	8	8	8	6	6	6	6	8	8	8
Slow (<0.3 m/s) Shallow (0.1 – 0.3 m) (SS)	0	0	0	0	0	0	2	2	2	2	4	4	4
Slow (<0.3 m/s) Deep (> 0.5 m) (SD)	10	10	10	10	8	8	8	8	8	8	8	8	6
Slow Shallow and Slow Deep	0	0	0	0	0	0	2	2	2	2	2	2	2
Fast (>0.3 m/s) Very Shallow (<0.1 m) (FVS)	10	10	10	10	10	10	10	8	8	8	8	8	8
Fast (>0.3 m/s) Shallow (0.1 – 0.3 m) (FS)	10	10	10	10	10	10	10	10	10	8	8	8	8
Fast (>0.3 m/s) Intermediate (0.2 – 0.3) (FI)	10	10	10	10	10	10	10	8	8	8	8	8	8
Fast (>0.3 m/s) Deep (> 0.3 m) (FD)	10	10	10	10	10	10	10	8	8	8	8	8	8
FAST TOTAL >0.1 m DEEP	10	10	10	10	10	10	10	8	8	8	8	8	8

The fish stress index is provided in Table O2

Table O2 Fish stress index

Habitat	Discharges (m ³ /s)												
	0.01	0.05	0.10	0.16	0.23	0.30	0.38	0.46	0.55	0.64	0.73	0.83	1.14
SMALL RHEOPHILIC (SR) GUILD													
Spawning habitat	0	0	0	0	0	0	0	0.5	1	2.5	3	4	5
Nursery habitat	0	0	0	0	0.5	0.5	0.5	1	1.5	2.5	3	4	5
Abundance	0.5	0.5	0.5	0.5	1	1	1	1.5	2	2.5	3	4	5
Cover	0.5	0.5	0.5	0.5	1	1	1	1.5	2	2.5	3	4	5
Connectivity (lateral & longitudinal)	0.5	1	1.5	2	2	2.5	2.5	3	3	3.5	4	4.5	5
Water Quality (esp. oxygen and temperature)	0.5	1	1	1	1.5	1.5	2	3	4	4.5	4.5	5	5
Species stress: CANO	9	9	9	9	8	8	8	7	6	4	3	2	0
LARGE SEMI RHEOPHILIC (LSR) GUILD													
Spawning habitat	0	0	0	0	0	0	0	0.5	1.5	2	2.5	4	5
Nursery habitat	0.5	0.5	1	1.5	2	2.5	2.5	3	3.5	4	4.5	4.5	5
Abundance	0.5	0.5	1	1	1.5	2	2.5	2.5	3	3	4	4.5	5
Cover	0.5	0.5	1	1	1.5	2	2.5	2.5	3	3	4	4.5	5
Connectivity (lateral & longitudinal)	0.5	0.5	1	1.5	2	2	2.5	2.5	3	3	4	4.5	5
Water Quality (esp. oxygen and temperature)	0.5	0.5	1	1	1.5	1.5	2	3	4	4.5	4.5	5	5
Species stress: BMAR	9	9	8	8	7	7	6	5	4	4	2	1	0

O1.3 MACROINVERTEBRATE STRESS INDEX

The habitat flow index for flow dependent macroinvertebrate (FDI) taxa is provided in Table O3 and provides the % occurrence of various velocity and substrate classes under different flow conditions.

Table O3 Habitat suitability for FDI taxa

Habitat Flow Response Index	Habitat Response	Habitat Abundance and suitability													Flow (m ³ /s)
		VSCS ¹	SCS ²	FCS ³	VFCS ⁴	VSFS ⁵	SFS ⁶	FFS ⁷	VFFS ⁸	VSBR ⁹	SBR ¹⁰	FBR ¹¹	VFBR ¹²	Veg ¹³	
0	All habitat in excess, very high quality. Very fast, very deep, very wide WP.	5	4	1	0	16	11	3	0	30	24	6	0	1	1.140
1	All plentiful, high quality. Fast, wide WP.	6	3	1	0	18	10	2	0	36	18	6	0	0	1.040
2	Critical habitats sufficient; quality slightly reduced. Fast, WP slightly reduced.	6	3	1	0	17	10	3	0	36	18	6	0	0	0.930
3	Reduced critical habitat, reduced critical quality. Moderate velocity, fairly deep.	5	4	1	0	16	11	3	0	30	24	6	0	0	0.830
4	Critical habitats limited; moderate quality; Moderate velocity, Some deep areas. Wide WP moderately reduced.	5	4	1	0	16	11	3	0	30	24	6	0	0	0.730
5	Critical habitat very reduced; moderate/ low quality. Moderate/slow velocity, few deep areas WP moderately/very reduced.	6	3	1	0	18	10	2	0	36	18	6	0	0	0.640
6	Critical habitat residual. Low quality; Moderate/slow velocity.	7	3	0	0	20	9	1	0	42	18	0	0	0	0.460
7	No critical habitat, other habitats moderate quality. Slow, narrow WP	8	2	0	0	23	7	0	0	48	12	0	0	0	0.300
8	Flowing water habitats residual low quality; slow trickle, very narrow WP.	8	2	0	0	24	6	0	0	48	12	0	0	0	0.230
9		10	0	0	0	30	0	0	0	60	0	0	0	0	0.052

10	Standing water habitats only, very low quality. No flow.	10	0	0	0	30	0	0	0	60	0	0	0	0	0.000
1	Very Slow over Coarse Sediment	2	Slow over Coarse Sediment	3	Fast over Coarse Sediment										
4	Very Fast over Coarse Sediment	5	Very Slow over Fine Sediment	6	Slow over Fine Sediment										
7	Fast over Fine Sediment	8	Very Fast over Fine Sediment	9	Very Slow over Bedrock										
10	Slow over Bedrock	11	Fast over Bedrock	12	Very Fast over Bedrock										
13	Fringing vegetation														

The stress index for FDI taxa is provided in Table O4 which rates the response of the species according to various biotic response metrics.

Table O4 Macroinvertebrate (FDI) stress index

Habitat characteristics					Biotic Response	Flow	Species Stress
Max depth (m)	Ave depth (m)	Max vel (m/s)	Ave vel (m/s)	WP (m)			
0.72	0.33	0.13	0.45	28.3	All indicator taxa abundant.	1.14	0
0.7	0.32	0.12	0.44	27.0	All indicator taxa present. Heptageniidae less abundant.	1.04	1
0.68	0.31	0.12	0.42	25.7	All indicator taxa present, but the Hydropsychidae and Heptageniidae are less abundant.	0.93	2
0.66	0.31	0.11	0.41	24.9	All indicator taxa present, but the Heptageniidae and Hydropsychidae are much less abundant.	0.83	3
0.64	0.3	0.11	0.38	24.2	All life stages of Heptageniidae and Hydropsychidae are viable in limited areas, critical life stages of some sensitive rheophilic species at risk.	0.78	4
0.62	0.29	0.1	0.36	23.4	Critical life-stages of sensitive indicator taxa at risk or non-viable.	0.73	5
0.58	0.27	0.08	0.29	22.0	Heptageniidae and Hydropsychidae occur in very low numbers, critical stages of sensitive rheophilic species non-viable, and at risk for some less sensitive species.	0.64	6
0.54	0.27	0.06	0.23	18.9	Heptageniidae and Hydropsychidae persist but at very low numbers. All life stages of most rheophilic taxa at risk or non-viable.	0.3	7
0.52	0.26	0.05	0.19	18.0	Heptageniidae and Hydropsychidae persist but at extremely low numbers. All life stages of most rheophilic taxa non-viable.	0.05	8
0.48	0.23	0.03	0.1	16.2	Indicator taxa no longer present.	0.01	9
0.44	0.21	0	0.01	16.2		0.00	10

O1.4 RIPARIAN VEGETATION STRESS INDEX

Table O5 Riparian vegetation stress index for indicator species

Biotic response				
Species Stress	Flow (m ³ /s)	<i>Breonadia salicina</i>	Flow (m ³ /s)	<i>Phragmites mauritanus</i>
0	1.04	Adults with full vigour and at maximum reproductive capacity. Up to 75 cm rooting depth for upper limit, lower limit at water level on average, recruits at water level to 25 cm above.	1.6	Adults with full vigour and at maximum reproductive capacity. 30 - 50% population inundated (not more than 40 - 50 cm). Upper limit rooting depth up to 50 cm.
1				Adults with full vigour and at maximum reproductive capacity.
2				Leaf wilting/stress commences in adults, but is slight.
3	0.46	Leaf wilting/stress commences, but is slight. Up to 90 cm on average substrate depth required for inundated soil moisture at upper limit, recruits at 20 - 40 cm above water level.	0.55	Leaf wilting/stress commences, but is slight. Up to 60 cm rooting depth for upper limit, lower limit 20 cm inundated on average.
4		Flower/fruit abortion commences.		Flower/fruit abortion commences.
5		Leaf wilting obvious, or vegetative parts begin unseasonal discolouration. Flower/fruit abortion widespread.		Leaf wilting obvious, or vegetative parts begin unseasonal discolouration. Flower/fruit abortion widespread.
6	0.1	Unseasonal thinning or partial mortality of above-	0.16	Unseasonal thinning or partial mortality of above-

Biotic response				
Species Stress	Flow (m ³ /s)	<i>Breonadia salicina</i>	Flow (m ³ /s)	<i>Phragmites mauritianus</i>
		ground parts (majority of the plant/s remains viable, but water stressed). Up to 1 m rooting depth for sufficient substrate moisture (upper limit), mortality may occur for lower zone individuals, recruits at 30 – 50 cm above water level and mortality is likely.		ground parts (majority of the plant/s remains viable, but water stressed). Up to 75 cm rooting depth for sufficient soil moisture, water level at lower limit, rhizomes at upper limits may begin thinning.
7				
8	0.012	Unseasonal loss or mortality of above-ground parts (only minor portions of plants remain viable). Rootstocks/rhizomes of some species remain viable. >1 m rooting depth, individuals at upper limit likely to begin senescence.	0	Unseasonal loss or mortality of above-ground parts (only minor portions of plants remain viable). Rootstocks/rhizomes of some species remain viable/dormant. More than 1 m rooting depth for sufficient soil moisture, rhizome mortality commences.
9		Complete mortality of small proportion of the population.		Complete mortality of small proportion of the population.
10	0	Widespread and complete mortality of population.		Widespread and complete mortality of population.

O2 EWR 6: MUTLUMUVI (MUTLUMUVI RIVER) – DETERMINATION OF EWR SCENARIOS

O2.1 LOW FLOW REQUIREMENTS IN TERMS OF STRESS FOR FISH

The fish low flow requirements for the EWR scenarios are summarised in Table O6 for the SR guild and Table O7 for LSR guild.

Table O6 Low flow requirements: SR guild

GENERAL					
INDICATOR: The small rheophilic species <i>Chiloglanis anoterus</i> (CANO) at the site is a good indicator for setting flows as a result of its high requirement for flowing water. This species generally requires flowing water over substrates during all life stages. Optimal conditions for spawning of this guild consist of FD, FI with good quality substrate (clean cobbles and gravel), while the margins of the FS and SS are important for egg development and nursery areas for larvae. Juvenile and adult stages of this guild have a high preference for FS, FI and FD over substrates.					
PES: FISH EC C (ECOSTATUS C)					
Dry Season maintenance At this fish stress level, no fast habitats will be available at the site according to the hydraulic information of the cross-section. It was however indicated that the cross-section is an underestimation of the fast habitats available at the site due to it running through a predominant deeper area, including more slow habitats. The fact that this indicator guild was also sampled at very low flows at this site indicates their ability to occur at the site under relatively low flows. It is therefore estimated that at a stress level of 9, adequate habitats will be available for this fish guild to survive and maintain itself within the PES.					
Dry Season drought Since the present hydrology indicate that there is currently prolonged period of zero flow at this site, it is assumed that this fish guild is surviving with these occurrences taking place. It is assumed that they may be surviving these periods in areas where adequate trickles occur, or potentially further upstream where perennial flow may be present during these conditions. This area is then recolonised once conditions improve. It is therefore estimated that drought conditions of zero flows will still maintain the current PES as long as adequate wet season flows are ensured, and overall good catchment management is implemented to ensure refuge areas (such as upstream of the site) that can be utilised by these species during the drought periods. It will therefore be crucial to ensure connectivity and therefore migration barriers in the system should be limited or mitigated to enable recolonisation to this reach after periods of zero flows.					
Wet Season maintenance This fish stress level will maintain some fast habitats (1% FS, 1% FI and 3.5% FD on cross-section), the most important habitats required for most life stages and biological process requirements during the wet season (spawning, nursery habitats, and adequate habitats for juvenile and adult specimens) to maintain within present ecological category.					
Wet Season drought At fish stress level of 8 the preferred and most critical habitats of this species will be greatly reduced and very limited fast habitats will be available at the site. If this habitat is not adequate to allow spawning and other life stages, this species will probably seek more suitable habitats further downstream of in tributaries to complete these life stages, and then re-colonise this site after the drought period.					
BUILDING BLOCK	SEASON	STRESS DURATION	SPP STRESS	INTEG STRESS	FLOW (m ³ /s)
Drought	Dry	5%	10	10	0.001
Maintenance	Dry	60%	9	9	0.163
Drought	Wet	5%	8	8	0.38
Maintenance	Wet	60%	3.5	5.5	0.685
REC: FISH EC B (ECOSTATUS B)					
General Improved flow management (release of EWR, increased low flows, decreased zero flows) will improve FROC of at least some species with preference of FS and FD, as well as species intolerant to no flow. Improved substrate condition (reduced sedimentation) will further improve the habitat quality of species with a requirement for this habitat type.					
Dry Season drought					

Since the present hydrology indicate that there is currently prolonged period of zero flow at this site, it is assumed that this fish guild is surviving with these occurrences taking place. It is assumed that they may be surviving these periods in areas where adequate trickles occur, or potentially further upstream where perennial flow may be present during these conditions. This area is then recolonised once conditions improve. Improved flows to prevent any zero flows at the site will therefore have a notable improvement in conditions for the rheophilic fish species, and an improvement in the EC can therefore be expected.

Dry Season maintenance

Even slightly improvement in fast habitats can be expected to result in the survival of higher abundance of this species during the dry season, which is the most stressed period for this small rheophilic species. This may result in an overall improved FROC of this species with a resultant improvement in EC.

Wet Season maintenance

Improved abundance and availability of fast habitats (1% FS, 1% FI and 5% FD on cross-section) should result in improved habitat for especially spawning, and also increased nursery, abundance and thus an improvement to a higher EC.

BUILDING BLOCK	SEASON	STRESS DURATION	SPP STRESS	INTEG STRESS	FLOW (m ³ /s)
Drought	Dry	5%	9.5	9.5	0.082
Maintenance	Dry	60%	8.5	8.5	0.272
Maintenance	Wet	60%	2	3	0.83

AEC: FISH EC D (ECOSTATUS C/D)

General

Deteriorated flow management (no release of EWR, decreased water levels during low flow periods, increased zero flows) will decrease the FROC of at least some species with preference of FS and FD, as well as species intolerant to no flow. Flow intolerant species may even be lost under such conditions, although they may re-colonise from downstream section during favourable conditions. Deteriorated substrate condition (increased sedimentation and excessive algal growth) will further contribute to the loss or decreased FROC of the above mentioned species.

Dry Season maintenance

At this fish stress level, no fast habitats will be available at the site according to the hydraulic information of the cross-section. As mentioned above it was however indicated that the cross-section is an underestimation of the fast habitats available at the site due to it running through a predominant deeper area, therefore reflecting more slow habitats. The fact that this indicator guild was also sampled at very low flows at this site indicates their ability to occur at the site under relatively low flows. It is therefore estimated that at a stress level exceeding 9, adequate habitats may be available for this fish guild to survive these conditions. At this stress level it however thought that this fish guild will be highly stressed and may even be eradicated from this area during the dry season, and may only re-colonise the area once conditions improve in the wet season.

Wet Season maintenance

At this fish stress level some fast habitats will be available, but reduced from present conditions, it can be expected that reduced abundance and FROC will occur with a resultant decreased EC.

BUILDING BLOCK	SEASON	STRESS DURATION	SPP STRESS	INTEG STRESS	FLOW (m ³ /s)
Maintenance	Dry	60%	9.5	9.5	0.082
Maintenance	Wet	60%	5	6.2	0.604

Table O7 Low flow requirements: LSR guild

GENERAL					
INDICATOR: The large semi-rheophilic species (especially BMAR, LCYL, and LMOL) are another important indicator guild present at this EWR site. Valuable information regarding the habitat requirements for different life stages is available for BMAR and should be adequate to support the requirements of other species within this guild. This species was therefore used as indicators for the large semi-rheophilic guild. This species utilises most habitats (SD, SS, FD, FI and FS) with substrate and water column as preferred cover. They also require overhanging vegetation as nursery habitats. Flows should furthermore remain adequate to allow migration between reaches, thus depth in riffle and rapids should remain adequate, especially during the wet season.					
PES: FISH EC C (ECOSTATUS C)					
Dry Season maintenance Although this fish guild can survive in the dry season without flow (in SD) habitats, some flow is essential to maintain adequate water quality, food sources and to allow lateral and longitudinal movement of these species. At this fish stress level some flow will be maintained in adequate abundance to provide the above mentioned functions and therefore maintain these species in this ecological category.					
Dry Season drought This fish guild should be able to survive zero flow conditions for short periods as long as pools are maintained for refuge to enable recovery once conditions improve.					
Wet Season maintenance This fish stress level will maintain adequate fast habitats (1% FS, 1% FI and 3.5% FD on cross-section) that are the most important habitat required for spawning and migration of this fish guild during the wet season (also ensure adequate habitats for juvenile and adult specimens) to maintain within current ecological category.					
Wet Season drought At fish stress level of 7 this fish guild will have much reduced spawning habitats, but it should be adequate to maintain some habitats to meet requirements of all life stages to ensure survival of these species and allow recovery after drought period. If this habitat is not adequate to allow spawning and other life stages, this species will probably seek more suitable habitats further downstream of in tributaries to complete these life stages, and then re-colonise this site after the drought period.					
BUILDING BLOCK	SEASON	STRESS DURATION	SPP STRESS	INTEG STRESS	FLOW (m ³ /s)
Drought	Dry	5%	10	10	0.001
Maintenance	Dry	60%	8	9	0.163
Drought	Wet	5%	7	8.5	0.272
Maintenance	Wet	60%	3	5.5	0.685
REC: FISH EC B (ECOSTATUS B)					
General: Improved flow management (release of EWR, increased low flows, decreased zero flows) will improve FROC of at least some species with preference of FS and FD. Improved substrate condition (reduced sedimentation) will further improve the habitat quality of species with a requirement for this habitat type.					
Dry season drought Since the present hydrology indicate that there is currently prolonged period of zero flow at this site, and indications are that this fish guild is surviving with these occurrences taking place. Should zero flows be prevented during drought conditions in future, it can be expected that the conditions in the pools that serve as refuge areas for this guild during droughts, will show adequate improvement (especially in terms of water quality) to result in an overall improvement of the EC of this fish guild.					
Dry Season maintenance Even slightly improvement in fast habitats can be expected to result in the survival of higher abundance of this species during the dry season. At this recommended stress level, increased abundance of fast and slow habitats will be available, which would result in improved abundance of this fish guild and therefore improved FROC.					
Wet Season maintenance At this stress level FS – FI – FD habitats will be available as 1% - 1% - 4% of the cross-section, respectively. This improvement from the present condition can be expected to improved habitat for especially spawning, and also increased nursery, abundance and thus improvement to a higher EC.					
BUILDING BLOCK	SEASON	STRESS DURATION	SPP STRESS	INTEG STRESS	FLOW (m ³ /s)

Drought	Dry	5%	9.9	9.9	0.082
Maintenance	Dry	60%	7	8.5	0.272
Maintenance	Wet	60%	2	5	0.73
AEC: FISH EC D (ECOSTATUS C/D)					
General: Deteriorated flow management (no release of EWR, decreased water levels during low flow periods, increased zero flows) will decrease the FROC of at least some species with preference of FS and FD. Deteriorated substrate condition (increased sedimentation and excessive algal growth) will further contribute to the loss or decreased FROC of some species. Dry Season maintenance Although this fish guild can survive in the dry season without flow (in SD) habitats, some flow is essential to maintain adequate water quality, food sources and to allow lateral and longitudinal movement of these species. This stress level will maintain limited fast habitats at the site but it will be available in reduced abundance than under present conditions. It can be expected that this guild will be stressed more than presently and result in decreased abundance and overall FROC, with a resultant decreased EC. Wet Season maintenance At this fish stress level very limited fast habitats (0% FS, 1% FI and 1% FD on cross-section) will be available at a much reduced quantity than present wet season, but it should still be adequate to maintain all life stages although reduced abundance and FROC can be expected, and a resultant decrease in EC may occur.					
BUILDING BLOCK	SEASON	STRESS DURATION	SPP STRESS	INTEG STRESS	FLOW (m³/s)
Maintenance	Dry	60%	8.5	9.5	0.082
Maintenance	Wet	60%	5	7	0.46

O2.2 LOW FLOW REQUIREMENTS IN TERMS OF STRESS FOR MACROINVERTEBRATES

The FDI low flow requirements are summarised in Table O8 below.

Table O8 Low flow requirements: FDI taxa

GENERAL
INDICATOR: Two flow dependent cobble dwelling macroinvertebrate taxa were used for this site. Heptageniidae and Hydropsychidae prefer velocities between 0.3 and 0.6 m/s although they can also survive at other velocity categories and live on other substrates. Heptageniidae are highly sensitive to water quality whereas Hydropsychidae are moderately sensitive to water quality.
PES: MACROINVERTEBRATE EC: B/C (ECOSTATUS C)
Dry Season maintenance Suitable habitat is required to ensure that populations of sensitive rheophilic taxa are sustained during the dry season. The maximum velocity of 0.06 m/s associated with the flow of 0.066 m³/s (as per the hydraulic data) will not achieve this – however it must be noted that the cross-section on which the hydraulic information is based did not go through the critical section of the riffle. The modelled velocities are likely to be approximately half the value of the actual velocities (Birkhead <i>pers.comm.</i>). There will thus be small areas with flow >0.1 m/s which may maintain a core of rheophilic taxa. Dry Season drought Suitable habitat is required to sustain a small number of rheophilic taxa. Again, the maximum velocity of 0.01 m/s associated with the flow of 0.017 m³/s (as per the hydraulic data) will not achieve this. The same argument as for dry season Maintenance applies here, and at least small numbers of rheophiles may survive the drought, depending on its duration. Wet Season maintenance During the wet season optimal habitats (> 0.6 m/s over coarse substrate) is required to ensure healthy population of FDIs during the summer. The maximum velocity of 0.36 m/s (macroinvertebrate stress of 6) will not suffice, however the argument provided for the dry season flows applies here. According to Birkhead (<i>pers.comm.</i>), actual velocities are likely to be about double the modelled velocities. It is therefore likely that the maximum velocity will be in the order of 0.7 m/s which will enable the survival of indicator taxa over the wet season. Wet Season drought

During the wet season optimal habitats (> 0.3 m/s over coarse substrate with some areas of at least 0.6 m/s) is required to ensure that a healthy population occurs during the summer. The maximum velocity of 0.06 m/s will not achieve this, however the former argument applies, and a small number of rheophiles are likely to survive the drought, depending on its duration.

BUILDING BLOCK	SEASON	STRESS DURATION	SPP STRESS	INTEG STRESS	FLOW (m ³ /s)
Drought	Dry	5%	9	9.9	0.017
Maintenance	Dry	60%	8	9.6	0.066
Drought	Wet	5%	8	9.6	0.066
Maintenance	Wet	60%	6	6	0.6

REC: MACROINVERTEBRATE EC B (ECOSTATUS B)

Dry Season maintenance

Suitable habitat (small areas of velocities >0.3- >0.6 m/s), is required to sustain rheophilic taxa over the summer. The modelled hydraulics provides a maximum velocity of 0.14 m/s for the flow of 0.163 m³/s (macroinvertebrate stress of 7.5), however – as already discussed, the actual value is likely to be approximately double the modelled value (i.e. 0.28 m/s). This is the lower limit of the range of velocities required, but may be adequate to ensure that FDI persist through the dry season to provide a suitable breeding population.

Wet Season maintenance

During the wet season optimal habitats (> 0.6 m/s over coarse substrate) is required to ensure that a healthy population occurs during the summer. The modelled maximum velocity of 0.38 m/s (macroinvertebrate stress of 5), as discussed, suggests an actual maximum velocity of approx 0.76 m/s, which will be more than adequate to sustain FDI populations and juveniles through the wet season.

BUILDING BLOCK	SEASON	STRESS DURATION	SPP STRESS	INTEG STRESS	FLOW (m ³ /s)
Maintenance	Dry	60%	7.5	9	0.163
Maintenance	Wet	60%	5	5	0.73

AEC: MACROINVERTEBRATE EC C/D (ECOSTATUS C/D)

Dry Season maintenance

Suitable hydraulic habitat is required to ensure that at least some rheophilic taxa persist. The modelled maximum velocity of 0.04 m/s (macroinvertebrate stress of 8.5) relates to an actual velocity of 0.08m/s (as discussed). Small areas of this velocity flow will provide suitable conditions for certain of the less-sensitive rheophiles.

Wet Season maintenance

During the wet season, areas of optimal hydraulic habitat (> 0.6 m/s over coarse substrate) are required to ensure that a small portion of the FDI population is catered for during the wet season. The modelled maximum velocity of 0.23 m/s (macroinvertebrate stress of 7) relates to an actual velocity of approx. 0.46m/s. This is within the range of fast flows (0.3 - 0.6 m/s), and is likely to cater for both indicator taxa over the wet season.

BUILDING BLOCK	SEASON	STRESS DURATION	SPP STRESS	INTEG STRESS	FLOW (m ³ /s)
Maintenance	Dry	60%	8.5	9.75	0.042
Maintenance	Wet	60%	7	8.4	0.293

02.3 LOW FLOW REQUIREMENTS IN TERMS OF RIPARIAN VEGETATION

The low flow requirements for riparian vegetation indicator species are summarised in Table O9.

Table O9 Low flow requirements: Riparian vegetation species

GENERAL							
INDICATOR: <i>Phragmites mauritianus</i> and <i>Breonadia salicina</i> .							
PES: RIPARIAN VEGETATION EC C (ECOSTATUS C)							
Dry Season maintenance In order that the PES is maintained, population stress would not be expected to exceed 5 or 6 during dry season maintenance flows. At a species stress of 5, leaf wilting becomes obvious and 6 as above. Dry Season drought Would not expect the average population to experience a spp. stress of more than 6 or 7 during natural drought in the dry season. A species stress of 6 equates to unseasonal thinning or partial mortality of above-ground parts (majority of the plant/s remain/s viable, but water stressed) and a stress of 7 is more intense response of 6. A thinning of the population can be expected for reeds and juveniles of <i>B. salicina</i> may begin senescence. Wet Season maintenance In order that the PES is maintained, population stress would not be expected to exceed 2 during wet (growing) season maintenance flows. At a species stress of 2, leaf wilting/stress commences in adults, but is slight. The population is essentially unhampered in reproductive capacity. Wet Season drought Would not expect the average population to experience a spp. stress of more than 5 during natural drought in the wet season. A species stress of 5 equates to obvious leaf wilting or vegetative parts begin unseasonal discolouration; flower/fruit abortion is widespread.							
BUILDING BLOCK	SEASON	STRESS DURATION	SPP STRESS <i>Phragmites</i>	INTEG STRESS	SPP STRESS <i>Breonadia</i>	INTEG STRESS	FLOW (m ³ /s)
Drought	Dry	5%	7	9.5	6	9.5	0.082
Maintenance	Dry	60%	5.5	8.75	5	8.75	0.217
Drought	Wet	5%	5.5	8.75	5	8.75	0.217
Maintenance	Wet	60%	2.5	4.75	2	6	0.64
REC: RIPARIAN VEGETATION EC B (ECOSTATUS B)							
This EWR scenario was not assessed as the REC is based on non flow related improvements.							
AEC: RIPARIAN VEGETATION EC D (ECOSTATUS C/D)							
Dry Season maintenance <i>P. mauritianus</i>: Stress will increase in dry season since low flow abstraction is increased. Unseasonal thinning or partial mortality of above-ground parts (majority of the plant/s remains viable, but water stressed); up to 75 cm rooting depth for sufficient soil moisture, water level at lower limit, rhizomes at upper limits may begin thinning i.e. reedsbeds will begin to reduce in the upper limits. <i>B. salicina</i>: Unseasonal thinning or partial mortality of above-ground parts (majority of the plant/s remains viable, but water stressed). Up to 1 m rooting depth for sufficient substrate moisture (upper limit), mortality may occur for lower zone individuals, recruits at 30 – 50 cm above water level and mortality is likely. Wet Season maintenance <i>P. mauritianus</i>: Leaf wilting/stress commences, but is slight; up to 70 cm rooting depth for upper limit, lower limit 20 cm inundated on average. Stress remains low enough to facilitate complete vegetative growth at the lower limit which will enable reeds to expand into additional habitat. <i>B. salicina</i>: Leaf wilting/stress commences, but is slight. Up to 90 cm on average substrate depth required for inundated soil moisture at upper limit, recruits at 20 - 40 cm above water level, fruit/flower abortion commences but is slight.							
BUILDING BLOCK	SEASON	STRESS DURATION	SPP STRESS <i>Phragmites</i>	INTEG STRESS	SPP STRESS <i>Breonadia</i>	INTEG STRESS	FLOW (m ³ /s)
Maintenance	Dry	60%	6.5	9.25	6	9.5	0.123
Maintenance	Wet	60%	3.5	7	3.5	7.5	0.46

02.4 INSTREAM FLOOD FUNCTIONS

A description of the flood functions for biotic response is provided in Table O10.

Table O10 Functions for each Flood Class

Flood Class	Component	Function/Motivation
Class: 1 Range (m ³ /s): 1.6 – 2.5 Daily average: 1.6 Duration: 3	Fish	Class I floods are very important floods for fish and serves as migration cues and to maintain adequate longitudinal connectivity for migration. These floods will also flush fines and algae from substrates to ensure adequate conditions in substrates, a very important habitat for spawning of many of the species. It will furthermore inundate some vegetation (especially in new activated channels) for species spawning in flooded marginal vegetation and contributes to the creation of acceptable nursery areas (increased flooded vegetation). Some resetting of water quality will also take place, and the changes in water quality may also serve as stimulus to cue migratory activity and even gonad development. The frequency, extent and duration as recommended for the PES, REC and AEC should be adequate to provide the functions as required to maintain the fish within the specific category.
	Macroinvertebrates	These freshets are recommended to stimulate hatching of eggs, flush organic flocculants and mobilise fines (1 - 2 mm sands) in order to improve biotope suitability they will also reset water quality. Another function is to inundate the reedbeds and sedges to provide extra habitat for vegetation dwelling macroinvertebrates. Four of these per year, (Oct / Nov, Dec, Jan and Mar/Apr) are recommended for the REC and the PES and three (Oct / Nov, Jan, Mar/Apr) for the AEC.
Class: II Range (m ³ /s): 10 - 12 Daily average: 10 Duration: 4	Fish	Class II floods also provide similar flood functions for fish as Class I floods.
	Macroinvertebrates	These freshets are recommended to clear fines, scour substrate and inundate a large proportion of reeds and sedges and activate the seasonal channels in order to create additional biotopes, and reset water quality. One of these per year is recommended for all categories in the middle of the wet Season.
Class: III Range (m ³ /s): 16 - 30	Fish	Class III floods also provide similar functions as Class I, but due to its lower frequency of occurrence it is not essential for the flood functions required by the indigenous fish species. These floods, and especially their receding limbs will however be utilised by many of the fish species for migration and even spawning if it occurs within the spring/summer season.
Class: IV Range (m ³ /s): 50 + Duration: (30 ave)	Fish	Class IV floods also provide similar functions as Class I, but due to its lower frequency of occurrence it is not essential for the flood functions required by the indigenous fish species. These floods, and especially their receding limbs will however be utilised by many of the fish species for migration and even spawning if it occurs within the spring/summer season.
Class: V Range (m ³ /s): 190 +	Fish	Class V floods also provide similar functions as Class I, but due to its lower frequency it is not essential for the flood functions required by the indigenous fish species. The receding limbs will especially be utilised by many of the fish species for migration and even spawning if it occurs within the correct (spring/summer) season.

O2.5 EWR RULE TABLES

EWR rule tables which provide the recommended EWR flows as a duration table, showing flows which should be provided when linked to a natural trigger (natural modelled hydrology in this case) are provided for the different EWR scenarios. EWR rules are supplied for total flows as well as for low flows only.

Table O11 EWR 6 assurance rules for PES: C

Desktop Version 2, Printed on 2009/07/02

Summary of IFR rule curves for: SB6 Natural Flows

Determination based on defined BBM Table with site specific assurance rules.

Regional Type: E. Escarp PES = C

Data are given in m³/s mean monthly flow

Month	% Points									
	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	0.195	0.195	0.193	0.189	0.182	0.169	0.146	0.113	0.074	0.044
Nov	0.365	0.364	0.360	0.353	0.339	0.314	0.272	0.212	0.140	0.087
Dec	0.473	0.471	0.467	0.457	0.439	0.407	0.355	0.281	0.193	0.128
Jan	0.696	0.670	0.644	0.616	0.581	0.522	0.457	0.365	0.259	0.180
Feb	2.182	1.986	1.817	1.664	1.513	1.259	1.092	0.854	0.572	0.363
Mar	0.878	0.852	0.826	0.798	0.761	0.697	0.623	0.515	0.387	0.292
Apr	0.628	0.626	0.622	0.613	0.595	0.561	0.506	0.423	0.324	0.250
May	0.516	0.515	0.512	0.504	0.490	0.462	0.414	0.343	0.255	0.189
Jun	0.460	0.460	0.457	0.451	0.438	0.414	0.371	0.307	0.228	0.168
Jul	0.390	0.390	0.388	0.383	0.372	0.351	0.314	0.256	0.183	0.127
Aug	0.335	0.334	0.332	0.327	0.317	0.298	0.265	0.215	0.153	0.106
Sep	0.251	0.251	0.249	0.245	0.237	0.222	0.196	0.158	0.110	0.075

Reserve flows without High Flows

Oct	0.195	0.195	0.193	0.189	0.182	0.169	0.146	0.113	0.074	0.044
Nov	0.251	0.250	0.248	0.243	0.234	0.218	0.192	0.154	0.108	0.075
Dec	0.362	0.361	0.358	0.351	0.338	0.315	0.278	0.225	0.163	0.116
Jan	0.516	0.513	0.508	0.498	0.479	0.446	0.393	0.319	0.232	0.169
Feb	0.725	0.723	0.716	0.704	0.680	0.638	0.570	0.472	0.357	0.272
Mar	0.697	0.695	0.690	0.679	0.658	0.620	0.558	0.467	0.360	0.281
Apr	0.628	0.626	0.622	0.613	0.595	0.561	0.506	0.423	0.324	0.250
May	0.516	0.515	0.512	0.504	0.490	0.462	0.414	0.343	0.255	0.189
Jun	0.460	0.460	0.457	0.451	0.438	0.414	0.371	0.307	0.228	0.168
Jul	0.390	0.390	0.388	0.383	0.372	0.351	0.314	0.256	0.183	0.127
Aug	0.335	0.334	0.332	0.327	0.317	0.298	0.265	0.215	0.153	0.106
Sep	0.251	0.251	0.249	0.245	0.237	0.222	0.196	0.158	0.110	0.075

Natural Duration curves

Oct	0.653	0.579	0.511	0.470	0.399	0.381	0.362	0.351	0.299	0.202
Nov	1.269	0.984	0.795	0.664	0.594	0.552	0.471	0.382	0.324	0.212
Dec	2.856	1.919	1.449	1.157	0.870	0.717	0.609	0.564	0.429	0.280
Jan	5.638	3.663	2.188	1.520	1.262	1.064	0.904	0.747	0.605	0.381
Feb	11.615	5.824	3.125	1.914	1.554	1.343	1.112	0.889	0.744	0.372
Mar	7.389	4.338	3.342	2.091	1.396	1.184	1.008	0.825	0.706	0.321
Apr	3.985	2.658	1.551	1.389	1.161	1.011	0.914	0.799	0.710	0.370
May	1.359	1.191	1.086	0.997	0.851	0.806	0.717	0.687	0.586	0.310
Jun	1.042	0.934	0.880	0.810	0.706	0.675	0.606	0.583	0.505	0.285
Jul	0.818	0.728	0.683	0.642	0.605	0.553	0.515	0.467	0.429	0.269
Aug	0.709	0.642	0.579	0.549	0.523	0.474	0.437	0.418	0.366	0.243
Sep	0.644	0.583	0.532	0.486	0.448	0.428	0.394	0.370	0.328	0.224

Table O12 EWR 6 assurance rules for REC: B

Desktop Version 2, Printed on 2009/07/02

Summary of IFR rule curves for: SB6 Natural Flows

Determination based on defined BBM Table with site specific assurance rules.

Regional Type: E. Escarp REC = B

Data are given in m³/s mean monthly flow

Month	% Points									
	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	0.323	0.322	0.320	0.316	0.308	0.293	0.268	0.232	0.188	0.154
Nov	0.464	0.462	0.459	0.451	0.436	0.410	0.368	0.305	0.232	0.177
Dec	0.437	0.435	0.432	0.425	0.412	0.389	0.351	0.297	0.233	0.186
Jan	0.790	0.763	0.736	0.707	0.668	0.603	0.528	0.423	0.302	0.212
Feb	2.341	2.145	1.973	1.816	1.554	1.343	1.112	0.889	0.615	0.372
Mar	1.056	1.030	1.002	0.969	0.923	0.843	0.743	0.598	0.426	0.297
Apr	0.789	0.787	0.781	0.768	0.742	0.695	0.617	0.501	0.362	0.257
May	0.621	0.620	0.616	0.606	0.587	0.551	0.489	0.397	0.283	0.196
Jun	0.550	0.549	0.546	0.538	0.522	0.491	0.439	0.359	0.260	0.185
Jul	0.502	0.502	0.499	0.493	0.480	0.454	0.408	0.337	0.247	0.179
Aug	0.418	0.418	0.416	0.410	0.399	0.378	0.342	0.287	0.219	0.167
Sep	0.359	0.358	0.356	0.352	0.342	0.325	0.296	0.251	0.197	0.155

Reserve flows without High Flows

Oct	0.323	0.322	0.320	0.316	0.308	0.293	0.268	0.232	0.188	0.154
Nov	0.359	0.358	0.355	0.350	0.340	0.323	0.294	0.252	0.202	0.165
Dec	0.335	0.334	0.332	0.327	0.319	0.304	0.280	0.245	0.204	0.174
Jan	0.609	0.606	0.600	0.588	0.566	0.527	0.465	0.377	0.275	0.200
Feb	0.884	0.881	0.873	0.856	0.825	0.770	0.680	0.551	0.400	0.287
Mar	0.876	0.873	0.865	0.850	0.820	0.766	0.678	0.550	0.399	0.286
Apr	0.789	0.787	0.781	0.768	0.742	0.695	0.617	0.501	0.362	0.257
May	0.621	0.620	0.616	0.606	0.587	0.551	0.489	0.397	0.283	0.196
Jun	0.550	0.549	0.546	0.538	0.522	0.491	0.439	0.359	0.260	0.185
Jul	0.502	0.502	0.499	0.493	0.480	0.454	0.408	0.337	0.247	0.179
Aug	0.418	0.418	0.416	0.410	0.399	0.378	0.342	0.287	0.219	0.167
Sep	0.359	0.358	0.356	0.352	0.342	0.325	0.296	0.251	0.197	0.155

Natural Duration curves

Oct	0.653	0.579	0.511	0.470	0.399	0.381	0.362	0.351	0.299	0.202
Nov	1.269	0.984	0.795	0.664	0.594	0.552	0.471	0.382	0.324	0.212
Dec	2.856	1.919	1.449	1.157	0.870	0.717	0.609	0.564	0.429	0.280
Jan	5.638	3.663	2.188	1.520	1.262	1.064	0.904	0.747	0.605	0.381
Feb	11.615	5.824	3.125	1.914	1.554	1.343	1.112	0.889	0.744	0.372
Mar	7.389	4.338	3.342	2.091	1.396	1.184	1.008	0.825	0.706	0.321
Apr	3.985	2.658	1.551	1.389	1.161	1.011	0.914	0.799	0.710	0.370
May	1.359	1.191	1.086	0.997	0.851	0.806	0.717	0.687	0.586	0.310
Jun	1.042	0.934	0.880	0.810	0.706	0.675	0.606	0.583	0.505	0.285
Jul	0.818	0.728	0.683	0.642	0.605	0.553	0.515	0.467	0.429	0.269
Aug	0.709	0.642	0.579	0.549	0.523	0.474	0.437	0.418	0.366	0.243
Sep	0.644	0.583	0.532	0.486	0.448	0.428	0.394	0.370	0.328	0.224

Table O13 EWR 6 assurance rules for AEC: C/D

Desktop Version 2, Printed on 2009/07/02

Summary of IFR rule curves for: SB6 Natural Flows

Determination based on defined BBM Table with site specific assurance rules.

Regional Type: E. Escarp AEC = C/D

Data are given in m³/s mean monthly flow

Month	% Points									
	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	0.107	0.107	0.106	0.104	0.101	0.095	0.086	0.072	0.055	0.042
Nov	0.258	0.257	0.255	0.250	0.242	0.226	0.200	0.162	0.117	0.084
Dec	0.320	0.319	0.316	0.311	0.300	0.282	0.253	0.211	0.161	0.124
Jan	0.395	0.393	0.389	0.383	0.370	0.348	0.314	0.265	0.208	0.166
Feb	2.065	1.870	1.702	1.553	1.407	1.164	1.014	0.800	0.548	0.360
Mar	0.772	0.747	0.723	0.697	0.666	0.611	0.552	0.466	0.365	0.289
Apr	0.526	0.525	0.522	0.515	0.502	0.477	0.436	0.375	0.302	0.247
May	0.427	0.427	0.424	0.419	0.408	0.388	0.353	0.300	0.235	0.186
Jun	0.345	0.345	0.343	0.339	0.332	0.317	0.291	0.251	0.202	0.165
Jul	0.263	0.263	0.262	0.259	0.253	0.242	0.223	0.192	0.153	0.124
Aug	0.197	0.197	0.196	0.194	0.190	0.182	0.169	0.148	0.122	0.103
Sep	0.132	0.132	0.131	0.130	0.127	0.122	0.113	0.100	0.084	0.072

Reserve flows without High Flows

Oct	0.107	0.107	0.106	0.104	0.101	0.095	0.086	0.072	0.055	0.042
Nov	0.132	0.131	0.131	0.129	0.126	0.120	0.111	0.098	0.083	0.072
Dec	0.197	0.197	0.196	0.193	0.189	0.181	0.168	0.150	0.128	0.112
Jan	0.395	0.393	0.389	0.383	0.370	0.348	0.314	0.265	0.208	0.166
Feb	0.608	0.606	0.602	0.592	0.575	0.543	0.492	0.419	0.333	0.269
Mar	0.592	0.590	0.586	0.578	0.562	0.534	0.487	0.419	0.338	0.278
Apr	0.526	0.525	0.522	0.515	0.502	0.477	0.436	0.375	0.302	0.247
May	0.427	0.427	0.424	0.419	0.408	0.388	0.353	0.300	0.235	0.186
Jun	0.345	0.345	0.343	0.339	0.332	0.317	0.291	0.251	0.202	0.165
Jul	0.263	0.263	0.262	0.259	0.253	0.242	0.223	0.192	0.153	0.124
Aug	0.197	0.197	0.196	0.194	0.190	0.182	0.169	0.148	0.122	0.103
Sep	0.132	0.132	0.131	0.130	0.127	0.122	0.113	0.100	0.084	0.072

Natural Duration curves

Oct	0.653	0.579	0.511	0.470	0.399	0.381	0.362	0.351	0.299	0.202
Nov	1.269	0.984	0.795	0.664	0.594	0.552	0.471	0.382	0.324	0.212
Dec	2.856	1.919	1.449	1.157	0.870	0.717	0.609	0.564	0.429	0.280
Jan	5.638	3.663	2.188	1.520	1.262	1.064	0.904	0.747	0.605	0.381
Feb	11.615	5.824	3.125	1.914	1.554	1.343	1.112	0.889	0.744	0.372
Mar	7.389	4.338	3.342	2.091	1.396	1.184	1.008	0.825	0.706	0.321
Apr	3.985	2.658	1.551	1.389	1.161	1.011	0.914	0.799	0.710	0.370
May	1.359	1.191	1.086	0.997	0.851	0.806	0.717	0.687	0.586	0.310
Jun	1.042	0.934	0.880	0.810	0.706	0.675	0.606	0.583	0.505	0.285
Jul	0.818	0.728	0.683	0.642	0.605	0.553	0.515	0.467	0.429	0.269
Aug	0.709	0.642	0.579	0.549	0.523	0.474	0.437	0.418	0.366	0.243
Sep	0.644	0.583	0.532	0.486	0.448	0.428	0.394	0.370	0.328	0.224

**APPENDIX P: SUPPORTING INFORMATION FOR THE DETERMINATION OF STRESS
INDICES AND EWR SCENARIOS OF EWR 7: THULANDZITEKA**

P1 EWR 7: TLULANDZITEKA (TLULANDZITEKA RIVER) - DETERMINATION OF STRESS INDICES

Appendix P provides supporting information for the determination of stress indices and EWR scenarios of EWR 7: Tlulandziteka (Chapter 15 and 16 of the Sabie-Sand River System EWR Scenario Report: Volume 1).

P1.1 FISH INDICATOR SPECIES

Small rheophilic (SR) guild: *Chiloglanis anoterus* (CANO) are good indicators for setting flows as a result of their high requirement for flowing water. These species all requires flowing water over substrates during all life stages, with some stages also preferring overhanging vegetation as cover.

Large semi rheophilic (LSR) guild: *Labeobarbus marequensis* (BMAR), *Labeo cylindricus* (LCYL) and *Labeo molybdinus* (LMOL) are another important indicator guild present at this EWR site. This species utilises most habitats (SD, SS, FD, FI and FS) with substrate and water column as preferred cover.

The habitat requirements for the different life stages of the LSR indicator fish species is summarised in Appendix L, Table L1 and in Appendix K, Table K1 for the SR guild.

P1.2 FISH STRESS INDEX

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

Table P1 EWR 7: Habitat suitability for the SR and LSR guild

SR AND LSR GUILD										
Depth classes	Discharges (m ³ /s)									
	0.04	0.07	0.11	0.15	0.19	0.24	0.36	0.43	0.50	0.68
Slow (<0.3 m/s) Very Shallow (<0.1 m) (SVS)	6	6	8	8	8	8	8	8	8	8
Slow (<0.3 m/s) Shallow (0.1 – 0.3 m) (SS)	8	8	6	8	8	8	8	8	8	8
Slow (<0.3 m/s) Deep (> 0.5 m) (SD)	10	10	10	10	10	10	10	10	10	10
Slow Shallow and Slow Deep	8	8	6	8	8	8	8	8	8	8
Fast (>0.3 m/s) Very Shallow (<0.1 m) (FVS)	6	6	6	6	6	6	6	6	6	6
Fast (>0.3 m/s) Shallow (0.1 – 0.3 m) (FS)	8	6	6	6	6	6	8	8	8	8
Fast (>0.3 m/s) Intermediate (0.2 – 0.3) (FI)	10	10	10	8	8	8	6	6	8	8
Fast (>0.3 m/s) Deep (> 0.3 m) (FD)	10	10	10	10	10	10	10	8	8	8
FAST TOTAL >0.1 m DEEP	10	10	10	8	8	8	6	6	6	6

The fish stress index is provided in Table P2

Table P2 Fish stress index

Habitat	Discharges (m ³ /s)									
	0.04	0.07	0.11	0.15	0.19	0.24	0.36	0.43	0.50	0.68
SMALL RHEOPHILIC (SR) GUILD										
Spawning habitat	0	0	0	0.5	1	2	3	3.5	4	5
Nursery habitat	0.5	0.5	1	2	3	3.5	4	4	4.5	5
Abundance	0.5	0.5	1	1.5	2	2.5	3	3.5	4	5
Cover	0.5	0.5	1	1.5	2	2.5	3	3.5	4	5
Connectivity (lateral & longitudinal)	0.5	1	1.5	2	3	3.5	4	4.5	5	5
Water Quality (esp. oxygen and temperature)	2	2	2.5	2.5	3	3	3.5	4	4.5	5
Species stress: CANO	9	9	8	7	5	4	3	2	1	0
LARGE SEMI RHEOPHILIC (LSR) GUILD										
Spawning habitat	0	0	0	0	0.5	1	2	3	4	5
Nursery habitat	0.5	1	1.5	2	2.5	3	3.5	4	4.5	5
Abundance	0.5	1	1.5	2	2.5	3	4	4	4.5	5
Cover	0.5	1	1.5	2	2.5	3	4	4	4.5	5
Connectivity (lateral & longitudinal)	0.5	0.5	1	1.5	2	2	2.5	4	4.5	5
Water Quality (esp. oxygen and temperature)	2	2	2.5	2.5	3	3	3.5	4	4.5	5
Species stress: BMAR	9	8	7	7	6	5	4	2	1	0

P1.3 MACROINVERTEBRATE STRESS INDEX

The habitat flow index for flow dependent macroinvertebrate (FDI) taxa is provided in Table P3 and provides the % occurrence of various velocity and substrate classes under different flow conditions.

Table P3 Habitat suitability for FDI taxa

Habitat Flow Response Index	Habitat Response	Habitat Abundance and suitability													Flow (m ³ /s)
		VSCS ¹	SCS ²	FCS ³	VFCs ⁴	VSFS ⁵	SFS ⁶	FFS ⁷	VFFS ⁸	VSBR ⁹	SBR ¹⁰	FSR ¹¹	VFSR ¹²	Veg ¹³	
0	All habitat in excess, very high quality. Very fast, very deep, very wide WP.	3	6	10	18	3	7	13	24	0	0	0	0	16	0.680
1	All plentiful, high quality. Fast, wide WP.	3	7	13	22	3	7	12	22	0	0	0	0	11	0.500
2	Critical habitats sufficient; quality slightly reduced. Fast, WP slightly reduced.	4	9	16	27	3	6	11	18	0	0	0	0	6	0.360
3	Reduced critical habitat, reduced critical quality. Moderate velocity, fairly deep.	6	12	22	28	3	6	10	12	0	0	0	0	1	0.240
4	Critical habitats limited; moderate quality: Moderate velocity. Some deep areas. Wide WP moderately reduced.	8	16	28	22	3	6	10	7	0	0	0	0	0	0.150
5	Critical habitat very reduced; moderate/ low quality. Moderate/slow velocity, few deep areas WP moderately/very reduced.	11	21	32	15	3	6	8	4	0	0	0	0	0	0.083
6	Critical habitat residual. Low quality; Moderate/slow velocity.	13	26	33	9	3	6	8	2	0	0	0	0	0	0.044
7	No critical habitat, other habitats moderate quality. Slow, narrow WP	21	40	17	2	5	10	4	1	0	0	0	0	0	0.013

Habitat Flow Response Index	Habitat Response	Habitat Abundance and suitability													Flow (m ³ /s)
		VSCS ¹	SCS ²	FCS ³	VFCS ⁴	VSFS ⁵	SFS ⁶	FFS ⁷	VFFS ⁸	VSBR ⁹	SBR ¹⁰	FSR ¹¹	VFSR ¹²	Veg ¹³	
8	Flowing water habitats residual low quality: slow trickle, very narrow WP.	28	43	8	1	7	11	2	0	0	0	0	0	0	0.006
9		36	40	4	0	9	10	1	0	0	0	0	0	0	0.002
10	Standing water habitats only, very low quality, no flow	60	20	0	0	15	5	0	0	0	0	0	0	0	0.000

1 Very Slow over Coarse Sediment

4 Very Fast over Coarse Sediment

7 Fast over Fine Sediment

10 Slow over Bedrock

13 Fringing vegetation

2 Slow over Coarse Sediment

5 Very Slow over Fine Sediment

8 Very Fast over Fine Sediment

11 Fast over Bedrock

3 Fast over Coarse Sediment

6 Slow over Fine Sediment

9 Very Slow over Bedrock

12 Very Fast over Bedrock

The stress index for FDI taxa is provided in Table P4 which rates the response of the species according to various biotic response metrics.

Table P4 Macroinvertebrate (FDI) stress index

Habitat characteristics					Biotic Response	Flow	Species Stress
Max depth (m)	Ave depth (m)	Max vel (m/s)	Ave vel (m/s)	WP (m)			
0.36	0.16	0.65	1.67	7.1	All indicator taxa very abundant and healthy.	0.5	0
0.32	0.14	0.62	1.62	6.1	All indicator taxa present, but the Perlidae are less abundant.	0.36	1
0.28	0.13	0.59	1.54	5.0	All indicator taxa present, but the Perlidae and Heptageniidae are less abundant	0.29	2
0.24	0.13	0.54	1.45	3.7	All indicator taxa present, but the Perlidae, Heptageniidae and Elmidae are less abundant	0.24	3
0.2	0.11	0.47	1.28	3.1	All life stages of Perlidae, Elmidae and Heptageniidae are viable in limited areas, critical life stages of some sensitive rheophilic species at risk.	0.15	4
0.16	0.1	0.39	1.12	2.3	Critical life-stages of sensitive indicator taxa at risk or non-viable.	0.083	5
0.12	0.07	0.34	0.95	2.0	Perlidae, Heptageniidae and Elmidae occur at low numbers, critical stages of sensitive rheophilic species non-viable, and at risk for some less sensitive species.	0.044	6
0.08	0.04	0.21	0.64	1.6	Perlidae, Elmidae and Heptageniidae persist but at very low numbers. All life stages of most rheophilic taxa at risk or non-viable.	0.013	7
0.06	0.03	0.16	0.5	1.2	Heptageniidae and Elmidae persist but at extremely low numbers. All life stages of most rheophilic taxa at risk or non-viable.	0.006	8
0.04	0.02	0.13	0.39	0.7	Indicator taxa no longer present.	0.002	9
0.02	0.01	0.07	0.23	0.4		0.00	10

P1.4 RIPARIAN VEGETATION STRESS INDEX

Table P5 Riparian vegetation stress index for indicator species

Biotic response		
Species Stress	Flow (m ³ /s)	<i>Phragmites mauritianus</i>
0	0.7	Adults with full vigour and at maximum reproductive capacity. 30 - 50% population inundated, upper limit rooting depth at 60 cm.
1		
2		
3	0.17	Leaf wilting/stress commences, but is slight. Up to 80 cm rooting depth for upper limit, lower limit at water level on average.
4		Flower/fruit abortion commences.

Biotic response		
Species Stress	Flow (m ³ /s)	<i>Phragmites mauritianus</i>
5		Leaf wilting obvious, or vegetative parts begin unseasonal discolouration. Flower/fruit abortion widespread.
6	0.03	Unseasonal thinning or partial mortality of above-ground parts (majority of the plant/s remains viable, but water stressed). Up to 90 cm rooting depth for sufficient soil moisture, water level at lower limit, rhizomes at upper limits may begin thinning.
7		
8	0	Unseasonal loss or mortality of above-ground parts (only minor portions of plants remain viable). Rootstocks/rhizomes of some species remain viable/dormant. More than 1 m rooting depth for sufficient soil moisture, rhizome mortality commences.
9		Complete mortality of small proportion of the population.
10		Widespread and complete mortality of population.

P2 EWR 7: TLULANDZITEKA (TLULANDZITEKA RIVER) - DETERMINATION OF EWR SCENARIOS

P2.1 LOW FLOW REQUIREMENTS IN TERMS OF STRESS FOR FISH

The fish low flow requirements for the EWR scenarios are summarised in Table P6 for the SR guild and Table P7 for LSR guild.

Table P6 Low flow requirements: SR guild

GENERAL					
INDICATOR: The small rheophilic species <i>Chiloglanis anoterus</i> (CANO) at the site is a good indicator for setting flows as a result of its high requirement for flowing water. This species generally requires flowing water over substrates during all life stages. Optimal conditions for spawning of this guild consist of FD, FI with good quality substrate (clean cobbles and gravel), while the margins of the FS and SS are important for egg development and nursery areas for larvae. Juvenile and adult stages of this guild have a high preference for FS, FI and FD over substrates.					
PES and REC: FISH EC C (ECOSTATUS C)					
Dry Season maintenance At this fish stress level, some FS (34% on cross-section) will be available but no FI and FD habitats will be available (on cross-section). This habitat composition should be just adequate to provide the most critical habitats for the survival of species within this fish guild during the dry season. This habitat composition should be adequate to maintain this fish guild in present ecological category.					
Dry Season drought Since the present hydrology indicate that there is currently prolonged period of zero flow at this site, it is assumed that this fish guild is surviving with these occurrences taking place. It is assumed that they may be surviving these periods in areas where adequate trickles occur, or potentially further upstream where perennial flow may be present during these conditions. This area is then recolonised once conditions improve. It is therefore estimated that drought conditions of zero flows will still maintain the current PES as long as adequate wet season flows are ensured, and overall good catchment management is implemented to ensure refuge areas (such as upstream of the site) that can be utilised by these species during the drought periods. It will therefore be crucial to ensure connectivity and therefore migration barriers in the system should be limited or mitigated to enable recolonisation to this reach after periods of zero flows.					
Wet Season maintenance This fish stress level will maintain adequate FS (20% of cross-section) and FI (20% of cross section) while no FD will be available on cross section. The habitat composition should however be adequate for all life stages to fulfil all required biological processes during the wet season (spawning, nursery habitats as well as adequate feeding and refuge habitats for juvenile and adult specimens) to maintain this fish guild within current EC.					
Wet Season drought At a fish stress level of 7 much reduced spawning habitats will be available for this fish guild (39% FS, 1% FI and 0% FD on cross-section), but it should be adequate to maintain some habitats to meet requirements of all life stages to ensure survival of these species during the wet season and allow recovery after drought period.					
BUILDING BLOCK	SEASON	STRESS DURATION	SPP STRESS	INTEG STRESS	FLOW (m ³ /s)
Drought	Dry	5%	10	10	0.001
Maintenance	Dry	60%	8.5	8.5	0.09
Drought	Wet	5%	7	7	0.15
Maintenance	Wet	60%	3.5	4.5	0.3
AEC up: FISH EC B (ECOSTATUS B)					
General Improved flows will result in more FD and FS habitats, improving the current FROC of species with preference for fast habitats.					
Dry Season maintenance Even slightly improvement in fast habitats can be expected to result in the survival of higher abundance of this species during the dry season, which is the most stressed period for this small rheophilic species. At this fish stress level of 5 some FS (33% of cross-section) and FI (9% of cross section) will be available. This improvement from present condition may result in an overall improved FROC of this species with a resultant improvement in EC.					

Dry season drought

At this fish stress level, some FS (34% on cross-section) will be available but no FI and FD habitats will be available (on cross-section). This habitat composition should be just adequate to provide the most critical habitats for the survival of species within this fish guild during the dry season droughts, and allow for recovery after these highly stressed conditions.

Wet Season maintenance

Improved abundance and availability of fast habitats should result in improved habitat for especially spawning, and also increased nursery, abundance and thus an improvement to a higher EC.

BUILDING BLOCK	SEASON	STRESS DURATION	SPP STRESS	INTEG STRESS	FLOW (m ³ /s)
Drought	Dry	5%	8.5	8.5	0.09
Maintenance	Dry	60%	5	6	0.19
Maintenance	Wet	60%	2.5	3.2	0.388

AEC down: FISH EC D (ECOSTATUS D)**General**

Reduced flows and increased zero flows will reduce FS and FD habitats and also lead to loss of flow intolerant and moderately flow intolerant species. Reduced water quality will put further pressure on the water quality intolerant species. Deterioration in substrates as a result of sedimentation and benthic algae will lead to decreased FROC of this indicator guild.

Dry Season maintenance

At this fish stress level, limited very fast habitats will be available at the site according to the hydraulic information of the cross-section (39%FVS and no FS, FI and FD). It is therefore estimated that at this stress level very little suitable habitats will be available for this fish guild to survive these conditions, and that this fish guild will be stressed to a level where reduced abundance and FROC will occur which will be reflected by a decrease in EC.

Wet Season maintenance

At this fish stress level some fast habitats will be available, but at this reduced from present conditions, it can be expected that reduced abundance and FROC will occur with a resultant decreased EC.

BUILDING BLOCK	SEASON	STRESS DURATION	SPP STRESS	INTEG STRESS	FLOW (m ³ /s)
Drought	Dry	5%	10	10	0.001
Maintenance	Dry	60%	9.2	9.2	0.07
Maintenance	Wet	60%	5.5	6.2	0.182

Table P7 Low flow requirements: LSR guild

GENERAL
INDICATOR: The large semi-rheophilic species (especially BMAR, LCYL, and LMOL) are another important indicator guild present at this EWR site. Valuable information regarding the habitat requirements for different life stages is available for BMAR and should be adequate to support the requirements of other species within this guild. This species was therefore used as indicators for the large semi-rheophilic guild. This species utilises most habitats (SD, SS, FD, FI and FS) with substrate and water column as preferred cover. They also require overhanging vegetation as nursery habitats. Flows should furthermore remain adequate to allow migration between reaches, thus depth in riffle and rapids should remain adequate, especially during the wet season.
PES and REC: FISH EC C (ECOSTATUS C)
Dry Season maintenance Although this fish guild can survive in the dry season without flow (in SD) habitats, some flow is essential to maintain adequate water quality, food sources and to allow lateral and longitudinal movement of these species. At this fish stress level some fast habitats (only 1% FI on cross-section) will be maintained to at least provide the above mentioned functions and therefore maintain these species in this ecological category.
Dry Season drought This fish stress level will ensure availability of adequate critical refuge areas (SD) for survival through drought period in the dry season and enable recovery once conditions improve.
Wet Season maintenance This fish stress level will maintain adequate fast habitats (15% FS, 23% FI and 0%FD on cross-section) that are the most important habitat required for spawning and migration of this fish guild during the wet season (also ensure adequate habitats for juvenile and adult specimens) to maintain within current ecological category.

Wet Season drought

At fish stress level of 6 this fish guild will have much reduced spawning habitats (33%FS and 9%FI), but it should be adequate to maintain some habitats to meet requirements of all life stages to ensure survival of these species and allow recovery after drought period. If this habitat is not adequate to allow spawning and other life stages, this species will probably seek more suitable habitats further downstream of in tributaries to complete these life stages, and then re-colonise this site after the drought period.

BUILDING BLOCK	SEASON	STRESS DURATION	SPP STRESS	INTEG STRESS	FLOW (m ³ /s)
Drought	Dry	5%	10	10	0.001
Maintenance	Dry	60%	7	7	0.15
Drought	Wet	5%	6	6	0.19
Maintenance	Wet	60%	4	4	0.36

AEC up: FISH EC B (ECOSTATUS B)**General**

Improved flows will result in more FD and FS habitats, improving the current FROC of species with preference for fast habitats during some life stages.

Dry Season maintenance

Even slightly improvement in fast habitats can be expected to result in the survival of higher abundance of this species during the dry season. At this recommended stress level, more than present fast and slow habitats will be available, which would result in improved abundance of this fish guild and therefore improved FROC.

Dry Season drought

At this fish stress level, some FS (34% on cross-section) will be available but no FI and FD habitats will be available (on cross-section). This habitat composition should be just adequate to provide the most critical habitats for the survival of species within this fish guild during the dry season and maintain this fish guild in a B EC.

Wet Season maintenance

At this stress level FS – FI - FD habitats will be available as 16% - 24.5% - 0.5% of the cross-section, respectively. This improvement from the present condition can be expected to improved habitat for especially spawning, and also increased nursery, abundance and thus improvement to a higher EC.

BUILDING BLOCK	SEASON	STRESS DURATION	SPP STRESS	INTEG STRESS	FLOW (m ³ /s)
Drought	Dry	5%	8.5	9.3	0.049
Maintenance	Dry	60%	6	6	0.19
Maintenance	Wet	60%	3	3	0.395

AEC down: FISH EC D (ECOSTATUS D)**General**

Reduced flows and increased zero flows will reduce FS and FD habitats and also lead to loss of flow intolerant and moderately flow intolerant species. Reduced water quality will put further pressure on the water quality intolerant species. Deterioration in substrates as a result of sedimentation and benthic algae will lead to decreased FROC of some species.

Dry Season maintenance

Although this fish guild can survive in the dry season without flow (in SD) habitats, some flow is essential to maintain adequate water quality, food sources and to allow lateral and longitudinal movement of these species. This stress level will maintain limited FS habitats at the site (no FI and FD), available in reduced abundance than under present conditions. It can be expected that this guild will be stressed more than presently and result in decreased abundance and overall FROC, with a resultant decreased EC.

Wet Season maintenance

At this fish stress level very limited fast habitats (25%FS, 16%FI and 0%FD on cross-section) will be available at a much reduced quantity than present wet season, but it should still be adequate to maintain all life stages although reduced abundance and FROC can be expected, and a resultant decrease in EC may occur.

BUILDING BLOCK	SEASON	STRESS DURATION	SPP STRESS	INTEG STRESS	FLOW (m ³ /s)
Drought	Dry	5%	10	10	0.001
Maintenance	Dry	60%	8.5	9.3	0.0493
Maintenance	Wet	60%	5	5	0.24

P2.2 LOW FLOW REQUIREMENTS IN TERMS OF STRESS FOR MACROINVERTEBRATES

The FDI low flow requirements are summarised in Table P8 below.

Table P8 Low flow requirements: FDI taxa

GENERAL					
INDICATOR: Three flow dependent cobble dwelling macroinvertebrate taxa were used for this site. Perlidae prefer velocities > 0.6 m/s while Elmidae and Heptageniidae prefer velocities between 0.3 and 0.6 m/s although they can also survive at other velocity categories and live on other substrates. Perlidae and Heptageniidae are highly sensitive to water quality whereas Elmidae are moderately sensitive to water quality.					
PES and REC: MACROINVERTEBRATE EC:B/C (ECOSTATUS C)					
Dry Season maintenance Suitable habitat (> 0.3 m/s over coarse substrate with some areas of 0.6 m/s over coarse substrate) is required to ensure that all the selected taxa can overwinter without significant detrimental impacts on the overall population. The average velocity of 0.39 m/s and maximum velocity of 1.12 (macroinvertebrate stress of 5) will ensure that this takes place. At this flow 32% FCS and 15% VFCS is available. The wetted perimeter at this flow is 2.3 m.					
Dry Season drought Suitable habitat (> 0.3 m/s over coarse substrate, with at least some areas of 0.6 m/s over coarse substrate) is required to ensure that a core of the selected taxa is able to survive a drought. The average velocity of 0.21 m/s and maximum velocity of 0.64 (macroinvertebrate stress of 7) will ensure that this takes place. At this flow 17% FCS and 2% VFCS is available. The WP is 1.6 m.					
Wet Season maintenance During the wet season optimal habitats (> 0.6 m/s over coarse substrate) is required to ensure that a healthy population occurs during the summer. The average velocity of 0.54 m/s maximum velocity of 1.45 m/s (macroinvertebrate stress of 3) ensure that this takes place. At this flow 22% FCS, and 27% VFCS is available. The WP is 3.7 m.					
Wet Season drought During the wet season optimal habitats (> 0.3 m/s over coarse substrate with some areas of at least 0.6 m/s) is required to ensure that a healthy population occurs during the summer. The average velocity of 0.34 m/s and maximum velocity of 0.95 m/s (macroinvertebrate stress of 6) ensures that this takes place. At this flow 32% FCS and 9% VFCS are available. The WP at this flow is 2 m.					
BUILDING BLOCK	SEASON	STRESS DURATION	SPP STRESS	INTEG STRESS	FLOW (m ³ /s)
Drought	Dry	5%	7 ¹	10	0.001
Maintenance	Dry	60%	5	8.5	0.09
Drought	Wet	5%	6	9.2	0.0562
Maintenance	Wet	60%	3	5	0.24
AEC up: MACROINVERTEBRATE EC B (ECOSTATUS B)					
Dry Season maintenance Suitable habitat (> 0.3 m/s over coarse substrate with some areas of 0.6 m/s over coarse substrate) is required to ensure that all the selected taxa can overwinter without significant detrimental impacts on the overall population. The average velocity of 0.34 m/s and maximum velocity of 0.95 m/s (macroinvertebrate stress of 6) will ensure that this takes place. At this flow 32% FCS and 9% VFCS is available. The WP at this flow is 2 m.					
Dry Season drought Suitable habitat (> 0.3 m/s over coarse substrate, with at least some areas of 0.6 m/s over coarse substrate) is required to ensure that a core of the selected taxa is able to survive a drought. The average velocity of 0.34 m/s and maximum velocity of 0.95 (macroinvertebrate stress of 7) will ensure that this takes place. At this flow 32% FCS and 9% VFCS are available. The WP at this flow is 2 m.					
Wet Season maintenance During the wet season optimal habitats (> 0.6 m/s over coarse substrate) is required to ensure that a healthy population occurs during the summer. The average velocity of 0.57 m/s maximum velocity of 1.50 m/s (macroinvertebrate stress of 2) ensure that this takes place. At this flow 20% FCS, and 27% VFCS is available. The WP is 3.9 m.					
BUILDING BLOCK	SEASON	STRESS DURATION	SPP STRESS	INTEG STRESS	FLOW (m ³ /s)

Drought	Dry	5%	6	9.2	0.056
Maintenance	Dry	60%	4	7	0.15
Maintenance	Wet	60%	2	4.5	0.3
AEC down: MACROINVERTEBRATE EC C (ECOSTATUS D)					
Dry Season maintenance Suitable habitat (> 0.3 m/s over coarse substrate with some areas of 0.6 m/s over coarse substrate) is required to ensure that all the selected taxa can overwinter without significant detrimental impacts on the overall population. The average velocity of 0.39 m/s and maximum velocity of 1.12 (macroinvertebrate stress of 6) will ensure that this takes place. At this flow 32% FCS and 15% VFCS is available. The WP this flow is 2.3 m.					
Wet Season maintenance During the wet season optimal habitats (> 0.6 m/s over coarse substrate) is required to ensure that a healthy population occurs during the summer. The average velocity of 0.47 m/s maximum velocity of 1.28 m/s (macroinvertebrate stress of 4) ensure that this takes place. At this flow 28% FCS, and 22% VFCS is available. The WP is 3.1 m.					
BUILDING BLOCK	SEASON	STRESS DURATION	SPP STRESS	INTEG STRESS	FLOW (m ³ /s)
Drought	Dry	5%	7	10	0.001
Maintenance	Dry	60%	6	9.2	0.056
Maintenance	Wet	60%	4	7	0.15

1 The species stress changed to 10 during refinement when the drought for the AEC up was identified as being different than for the PES.

P2.3 LOW FLOW REQUIREMENTS IN TERMS OF RIPARIAN VEGETATION

The low flow requirements for riparian vegetation indicator species are summarised in Table P9.

Table P9 Low flow requirements: Riparian vegetation species

GENERAL					
INDICATOR: <i>Phragmites mauritianus</i> .					
PES and REC: RIPARIAN VEGETATION EC: C (ECOSTATUS C)					
Dry Season maintenance In order that the PES is maintained, population stress would not be expected to exceed 4 or 5 during dry season maintenance flows. At a spp. stress of 4, leaf wilting/stress commences but is slight, and flower/fruit abortion commences (which is unlikely to occur in dry season), but at 5 leaf wilting becomes obvious.					
Dry Season drought Would not expect the average population to experience a spp. stress of more than 6 or 7 during natural drought in the dry season. A stress of 6 equates to unseasonal thinning or partial mortality of above-ground parts (majority of the plant/s remain/s viable, but water stressed) and a spp. stress of 7 is more intense response of 6. A thinning of the population can be expected for reeds and juveniles of <i>B. salicina</i> may begin senescence.					
Wet Season maintenance In order that the PES is maintained, population spp. stress would not be expected to exceed 2 during wet (growing) season maintenance flows. At a spp. stress of 2, leaf wilting/stress commences in adults, but is slight; the population is essentially unhampered in reproductive capacity.					
Wet Season drought Would not expect the average population to experience a spp. stress of more than 5 during natural drought in the wet season. A spp. stress of 5 equates to obvious leaf wilting or vegetative parts begin unseasonal discolouration; flower/fruit abortion is widespread.					
BUILDING BLOCK	SEASON	STRESS DURATION	SPP STRESS <i>Phragmites</i>	INTEG STRESS	FLOW (m ³ /s)
Drought	Dry	5%	7	9.75	0.018
Maintenance	Dry	60%	5	8.75	0.08
Drought	Wet	5%	5	8.75	0.08

Maintenance	Wet	60%	2	4.25	0.33
AEC up: RIPARIAN VEGETATION EC: B (ECOSTATUS B)					
This EWR scenario was not assessed as the REC is based on non flow related improvements.					
AEC down: RIPARIAN VEGETATION EC: D (ECOSTATUS D)					
Dry Season maintenance Reeds stress will increase in dry season since low flow abstraction is increased. Unseasonal thinning or partial mortality of above-ground parts (majority of the plant/s remains viable, but water stressed). Up to 90 cm rooting depth for sufficient soil moisture, water level at lower limit, rhizomes at upper limits may begin thinning i.e. reedsbeds will begin to reduce in the upper limits, (but will expand towards receding water levels at lower limits during growing season – see below). Wet Season maintenance Small proportion of reeds remain inundated and upper limit rooting depth is at about 70 cm. Spp. stress remains low enough to facilitate complete vegetative growth at the lower limit which will enable reeds to expand into additional habitat.					
BUILDING BLOCK	SEASON	STRESS DURATION	SPP STRESS <i>Phragmites</i>	INTEG STRESS	FLOW (m ³ /s)
Maintenance	Dry	60%	6	9.5	0.035
Maintenance	Wet	60%	2.5	4.75	0.27

P2.4 INSTREAM FLOOD FUNCTIONS

Table P10 Functions for each Flood Class

Flood Class	Component	Function / Motivation
Class I Range (m ³ /s): 1.6 – 2.5 Daily average: 1.5 Duration: 3	Fish	Class I floods are very important floods for fish and serves as migration cues and to maintain adequate longitudinal connectivity for migration. These floods will also flush fines and algae from substrates to ensure adequate conditions in substrates, a very important habitat for spawning of many of the species. It will furthermore inundate some vegetation (especially in new activated channels) for species spawning in flooded marginal vegetation and contributes to the creation of acceptable nursery areas (increased flooded vegetation). Some resetting of water quality will also take place, and the changes in water quality may also serve as stimulus to cue migratory activity and even gonad development. The frequency, extent and duration as recommended for the PES, REC and AEC should be adequate to provide the functions as required to maintain the fish within the specific EC.
	Macroinvertebrates	These freshets are recommended to stimulate hatching of eggs, flush organic flocculants, mobilise fines (1 - 2 mm sands) and scour the substrates in order to improve biotope suitability they will also reset water quality. Another function is to inundate the grasses and reeds to provide extra habitat for vegetation dwelling macroinvertebrates. Four of these per year, are recommended for the REC and the PES and three for the AEC.
Class: II Range (m ³ /s): 4 – 9 Daily average: 4 Duration: 3	Fish	Class II floods also provide similar flood functions for fish as Class I floods.
	Macroinvertebrates	These freshets are recommended to flush organic flocculants, mobilise fines (1 - 2 mm sands) and scour the substrates in order to improve biotope suitability they will also reset water quality. Another function is to inundate the grasses and reeds to provide extra habitat for vegetation dwelling macroinvertebrates. Three of these per year, are recommended for the REC, two for the PES and one for the AEC.
Class: III Range (m ³ /s): 15 Ave Daily average: 9 Duration: 4	Fish	Class III floods also provide similar functions as Class I, but due to its lower frequency of occurrence it is not essential for the flood functions required by the indigenous fish species.
	Macroinvertebrates	Activate and turn over gravels, and scouring. These freshets are recommended to scour the substrates in order to improve biotope suitability. One of these per year, is recommended for the REC and the PES and one every second year for the AEC.
Class: IV Range (m ³ /s):	Fish	Class IV floods also provide similar functions as Class I, but due to its lower frequency of occurrence it is not essential for the flood functions required by

Flood Class	Component	Function / Motivation
28 Ave		the indigenous fish species. These floods, and especially their receding limbs will however be utilised by many of the fish species for migration and even spawning if it occurs within the spring/summer season.
Class: V Range (m ³ /s): 68 + (60 ave)	Fish	Class V floods also provide similar functions as Class I, but due to its lower frequency it is not essential for the flood functions required by the indigenous fish species. The receding limbs will especially be utilised by many of the fish species for migration and even spawning if it occurs within the correct (spring/summer) season.

P2.5 EWR RULE TABLES

EWR rule tables which provide the recommended EWR flows as a duration table, showing flows which should be provided when linked to a natural trigger (natural modelled hydrology in this case) are provided for the different EWR scenarios. EWR rules are supplied for total flows as well as for low flows only.

Table P11 EWR 7 assurance rules for PES: C

Desktop Version 2, Printed on 2009/07/02

Summary of IFR rule curves for: SB7 Natural Flows

Determination based on defined BBM Table with site specific assurance rules.

Regional Type: E. Escarp PES = C

Data are given in m³/s mean monthly flow

Month	% Points									
	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	0.097	0.097	0.096	0.094	0.089	0.081	0.067	0.046	0.021	0.002
Nov	0.205	0.204	0.201	0.196	0.187	0.169	0.141	0.099	0.050	0.014
Dec	0.271	0.270	0.267	0.261	0.251	0.231	0.200	0.156	0.103	0.064
Jan	0.899	0.815	0.743	0.677	0.613	0.505	0.436	0.339	0.227	0.143
Feb	1.674	1.499	1.349	1.217	1.000	0.860	0.719	0.575	0.380	0.228
Mar	0.546	0.522	0.501	0.479	0.454	0.410	0.367	0.305	0.231	0.176
Apr	0.349	0.348	0.345	0.340	0.329	0.309	0.277	0.228	0.170	0.126
May	0.279	0.278	0.277	0.272	0.264	0.249	0.222	0.182	0.132	0.095
Jun	0.251	0.251	0.249	0.245	0.237	0.221	0.194	0.154	0.103	0.065
Jul	0.209	0.209	0.207	0.204	0.198	0.184	0.161	0.125	0.079	0.044
Aug	0.139	0.139	0.138	0.135	0.130	0.121	0.104	0.079	0.047	0.023
Sep	0.111	0.111	0.110	0.108	0.103	0.093	0.078	0.054	0.025	0.003

Reserve flows without High Flows

Oct	0.097	0.097	0.096	0.094	0.089	0.081	0.067	0.046	0.021	0.002
Nov	0.097	0.097	0.096	0.093	0.088	0.080	0.066	0.045	0.021	0.002
Dec	0.167	0.167	0.165	0.162	0.156	0.145	0.128	0.104	0.075	0.053
Jan	0.279	0.278	0.275	0.270	0.260	0.244	0.217	0.180	0.136	0.104
Feb	0.363	0.361	0.358	0.352	0.341	0.321	0.288	0.242	0.187	0.146
Mar	0.377	0.376	0.373	0.367	0.357	0.337	0.306	0.260	0.206	0.165
Apr	0.349	0.348	0.345	0.340	0.329	0.309	0.277	0.228	0.170	0.126
May	0.279	0.278	0.277	0.272	0.264	0.249	0.222	0.182	0.132	0.095
Jun	0.251	0.251	0.249	0.245	0.237	0.221	0.194	0.154	0.103	0.065
Jul	0.209	0.209	0.207	0.204	0.198	0.184	0.161	0.125	0.079	0.044
Aug	0.139	0.139	0.138	0.135	0.130	0.121	0.104	0.079	0.047	0.023
Sep	0.111	0.111	0.110	0.108	0.103	0.093	0.078	0.054	0.025	0.003

Natural Duration curves

Oct	0.418	0.370	0.325	0.302	0.258	0.246	0.235	0.220	0.194	0.131
Nov	0.822	0.625	0.502	0.421	0.378	0.355	0.301	0.247	0.208	0.135
Dec	1.856	1.232	0.933	0.739	0.553	0.459	0.388	0.358	0.276	0.175
Jan	3.786	2.333	1.523	0.982	0.821	0.687	0.590	0.478	0.381	0.246
Feb	7.374	3.592	2.001	1.232	1.000	0.860	0.719	0.575	0.471	0.236
Mar	4.831	2.916	2.136	1.296	0.889	0.754	0.653	0.526	0.455	0.213
Apr	2.515	1.690	0.988	0.876	0.752	0.644	0.586	0.517	0.459	0.243
May	0.889	0.777	0.694	0.624	0.556	0.515	0.463	0.444	0.377	0.202
Jun	0.667	0.602	0.556	0.521	0.455	0.440	0.394	0.370	0.324	0.193
Jul	0.523	0.467	0.437	0.414	0.388	0.358	0.336	0.306	0.280	0.179
Aug	0.455	0.411	0.370	0.351	0.336	0.302	0.284	0.269	0.235	0.153
Sep	0.409	0.374	0.340	0.313	0.289	0.270	0.251	0.243	0.208	0.143

Table P12 EWR 7 assurance rules for REC: B

Desktop Version 2, Printed on 2009/07/02

Summary of IFR rule curves for: SB7 Natural Flows

Determination based on defined BBM Table with site specific assurance rules.

Regional Type: E. Escarp REC = B

Data are given in m³/s mean monthly flow

Month	% Points									
	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	0.167	0.167	0.165	0.162	0.156	0.145	0.127	0.100	0.068	0.043
Nov	0.302	0.300	0.297	0.291	0.280	0.259	0.225	0.176	0.118	0.075
Dec	0.600	0.598	0.591	0.578	0.553	0.459	0.388	0.335	0.214	0.124
Jan	0.931	0.847	0.774	0.708	0.642	0.532	0.460	0.359	0.241	0.154
Feb	1.741	1.566	1.415	1.232	1.000	0.860	0.719	0.575	0.402	0.236
Mar	0.588	0.564	0.542	0.519	0.491	0.444	0.395	0.324	0.240	0.177
Apr	0.394	0.394	0.391	0.385	0.374	0.353	0.318	0.266	0.203	0.156
May	0.335	0.334	0.332	0.327	0.318	0.300	0.270	0.224	0.168	0.126
Jun	0.287	0.287	0.285	0.281	0.274	0.259	0.235	0.197	0.150	0.115
Jul	0.263	0.263	0.262	0.258	0.252	0.239	0.217	0.182	0.138	0.104
Aug	0.239	0.239	0.237	0.234	0.227	0.214	0.192	0.158	0.116	0.084
Sep	0.191	0.191	0.190	0.187	0.182	0.172	0.155	0.129	0.097	0.073

Reserve flows without High Flows

Oct	0.167	0.167	0.165	0.162	0.156	0.145	0.127	0.100	0.068	0.043
Nov	0.203	0.202	0.201	0.197	0.190	0.177	0.156	0.126	0.090	0.064
Dec	0.251	0.250	0.248	0.243	0.234	0.219	0.194	0.158	0.116	0.084
Jan	0.311	0.309	0.306	0.301	0.290	0.271	0.241	0.200	0.151	0.115
Feb	0.430	0.429	0.425	0.417	0.403	0.378	0.337	0.278	0.209	0.157
Mar	0.418	0.417	0.414	0.407	0.394	0.371	0.334	0.279	0.215	0.166
Apr	0.394	0.394	0.391	0.385	0.374	0.353	0.318	0.266	0.203	0.156
May	0.335	0.334	0.332	0.327	0.318	0.300	0.270	0.224	0.168	0.126
Jun	0.287	0.287	0.285	0.281	0.274	0.259	0.235	0.197	0.150	0.115
Jul	0.263	0.263	0.262	0.258	0.252	0.239	0.217	0.182	0.138	0.104
Aug	0.239	0.239	0.237	0.234	0.227	0.214	0.192	0.158	0.116	0.084
Sep	0.191	0.191	0.190	0.187	0.182	0.172	0.155	0.129	0.097	0.073

Natural Duration curves

Oct	0.418	0.370	0.325	0.302	0.258	0.246	0.235	0.220	0.194	0.131
Nov	0.822	0.625	0.502	0.421	0.378	0.355	0.301	0.247	0.208	0.135
Dec	1.856	1.232	0.933	0.739	0.553	0.459	0.388	0.358	0.276	0.175
Jan	3.786	2.333	1.523	0.982	0.821	0.687	0.590	0.478	0.381	0.246
Feb	7.374	3.592	2.001	1.232	1.000	0.860	0.719	0.575	0.471	0.236
Mar	4.831	2.916	2.136	1.296	0.889	0.754	0.653	0.526	0.455	0.213
Apr	2.515	1.690	0.988	0.876	0.752	0.644	0.586	0.517	0.459	0.243
May	0.889	0.777	0.694	0.624	0.556	0.515	0.463	0.444	0.377	0.202
Jun	0.667	0.602	0.556	0.521	0.455	0.440	0.394	0.370	0.324	0.193
Jul	0.523	0.467	0.437	0.414	0.388	0.358	0.336	0.306	0.280	0.179
Aug	0.455	0.411	0.370	0.351	0.336	0.302	0.284	0.269	0.235	0.153
Sep	0.409	0.374	0.340	0.313	0.289	0.270	0.251	0.243	0.208	0.143

Table P13 EWR 7 assurance rules for AEC: D

Desktop Version 2, Printed on 2009/07/02

Summary of IFR rule curves for: SB7 Natural Flows

Determination based on defined BBM Table with site specific assurance rules.

Regional Type: E. Escarp AEC = D

Data are given in m³/s mean monthly flow

Month	% Points									
	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	0.060	0.059	0.059	0.057	0.055	0.049	0.041	0.028	0.013	0.002
Nov	0.234	0.233	0.230	0.224	0.213	0.193	0.160	0.113	0.057	0.015
Dec	0.269	0.268	0.265	0.260	0.249	0.230	0.199	0.155	0.103	0.064
Jan	0.670	0.609	0.557	0.509	0.463	0.386	0.337	0.269	0.190	0.131
Feb	1.590	1.416	1.267	1.137	1.000	0.812	0.703	0.547	0.363	0.226
Mar	0.448	0.426	0.405	0.386	0.365	0.330	0.301	0.260	0.210	0.174
Apr	0.239	0.239	0.238	0.235	0.229	0.219	0.202	0.176	0.146	0.123
May	0.199	0.199	0.198	0.196	0.191	0.182	0.166	0.143	0.114	0.093
Jun	0.179	0.179	0.178	0.175	0.170	0.161	0.144	0.119	0.087	0.063
Jul	0.159	0.159	0.158	0.156	0.151	0.142	0.126	0.100	0.068	0.043
Aug	0.119	0.119	0.118	0.116	0.112	0.104	0.090	0.069	0.043	0.023
Sep	0.099	0.099	0.098	0.096	0.092	0.083	0.069	0.048	0.022	0.003

Reserve flows without High Flows

Oct	0.060	0.059	0.059	0.057	0.055	0.049	0.041	0.028	0.013	0.002
Nov	0.099	0.099	0.098	0.095	0.090	0.081	0.067	0.046	0.021	0.002
Dec	0.139	0.139	0.138	0.135	0.131	0.123	0.110	0.091	0.069	0.052
Jan	0.219	0.218	0.217	0.213	0.207	0.196	0.178	0.153	0.124	0.103
Feb	0.279	0.278	0.276	0.273	0.266	0.253	0.233	0.204	0.169	0.143
Mar	0.279	0.279	0.277	0.274	0.268	0.258	0.240	0.215	0.185	0.163
Apr	0.239	0.239	0.238	0.235	0.229	0.219	0.202	0.176	0.146	0.123
May	0.199	0.199	0.198	0.196	0.191	0.182	0.166	0.143	0.114	0.093
Jun	0.179	0.179	0.178	0.175	0.170	0.161	0.144	0.119	0.087	0.063
Jul	0.159	0.159	0.158	0.156	0.151	0.142	0.126	0.100	0.068	0.043
Aug	0.119	0.119	0.118	0.116	0.112	0.104	0.090	0.069	0.043	0.023
Sep	0.099	0.099	0.098	0.096	0.092	0.083	0.069	0.048	0.022	0.003

Natural Duration curves

Oct	0.418	0.370	0.325	0.302	0.258	0.246	0.235	0.220	0.194	0.131
Nov	0.822	0.625	0.502	0.421	0.378	0.355	0.301	0.247	0.208	0.135
Dec	1.856	1.232	0.933	0.739	0.553	0.459	0.388	0.358	0.276	0.175
Jan	3.786	2.333	1.523	0.982	0.821	0.687	0.590	0.478	0.381	0.246
Feb	7.374	3.592	2.001	1.232	1.000	0.860	0.719	0.575	0.471	0.236
Mar	4.831	2.916	2.136	1.296	0.889	0.754	0.653	0.526	0.455	0.213
Apr	2.515	1.690	0.988	0.876	0.752	0.644	0.586	0.517	0.459	0.243
May	0.889	0.777	0.694	0.624	0.556	0.515	0.463	0.444	0.377	0.202
Jun	0.667	0.602	0.556	0.521	0.455	0.440	0.394	0.370	0.324	0.193
Jul	0.523	0.467	0.437	0.414	0.388	0.358	0.336	0.306	0.280	0.179
Aug	0.455	0.411	0.370	0.351	0.336	0.302	0.284	0.269	0.235	0.153
Sep	0.409	0.374	0.340	0.313	0.289	0.270	0.251	0.243	0.208	0.143

**APPENDIX Q: SUPPORTING INFORMATION FOR THE DETERMINATION OF STRESS
INDICES AND EWR SCENARIOS OF EWR 8: SAND**

Q1 EWR 8: LOWER SAND (SAND RIVER) - DETERMINATION OF STRESS INDICES

Appendix Q provides supporting information for the determination of stress indices and EWR scenarios of EWR 8: Lower Sand (Chapter 17 and 18 of the Sabie-Sand River System EWR Scenario Report: Volume 1).

Q1.1 FISH INDICATOR SPECIES

Small rheophilic (SR) guild: *Chiloglanis anoterus* (CANO) are good indicators for setting flows as a result of their high requirement for flowing water. These species all requires flowing water over substrates during all life stages, with some stages also preferring overhanging vegetation as cover.

Large semi rheophilic (LSR) guild: *Labeobarbus marequensis* (BMAR), *Labeo cylindricus* (LCYL) and *Labeo molybdinus* (LMOL) are another important indicator guild present at this EWR site. This species utilises most habitats (SD, SS, FD, FI and FS) with substrate and water column as preferred cover.

The habitat requirements for the different life stages of the LSR indicator fish species is summarised in Appendix L, Table L1 and in Appendix K, Table K1 for the SR guild.

Q1.2 FISH STRESS INDEX

The abundance of fish velocity-depth classes are provided in Table Q1.

Table Q1 EWR 8: Habitat suitability for the SR and LSR guild

SR AND LSR GUILD															
Depth classes	Discharges (m ³ /s)														
	0.03	0.06	0.10	0.15	0.21	0.51	0.59	1.04	1.24	1.34	1.63	2.33	3.12	4.71	5.23
Slow (<0.3 m/s) Very Shallow (<0.1 m) (SVS)	0	2	2	4	8	8	8	8	8	8	8	8	8	8	8
Slow (<0.3 m/s) Shallow (0.1 – 0.3 m) (SS)	10	8	8	8	6	6	6	6	6	6	6	6	6	8	6
Slow (<0.3 m/s) Deep (> 0.5 m) (SD)	10	10	10	10	10	10	10	10	10	10	10	8	8	8	8
Slow Shallow and Slow Deep	10	8	8	8	6	6	6	6	6	6	6	6	6	6	6
Fast (>0.3 m/s) Very Shallow (<0.1 m) (FVS)	8	8	6	6	8	8	8	8	6	6	6	6	8	8	8
Fast (>0.3 m/s) Shallow (0.1 – 0.3 m) (FS)	10	8	8	8	6	4	6	8	8	8	8	8	6	8	8
Fast (>0.3 m/s) Intermediate (0.2 – 0.3) (FI)	10	10	10	10	10	8	6	6	8	8	8	8	8	8	8
Fast (>0.3 m/s) Deep (> 0.3 m) (FD)	10	10	10	10	10	10	10	8	6	6	8	8	8	6	6
FAST TOTAL >0.1 m DEEP	10	10	10	10	10	8	6	4	6	6	6	6	6	6	6

The fish stress index is provided in Table Q2.

Table Q2 Fish stress index

Habitat	Discharges (m ³ /s)														
	0.03	0.06	0.10	0.15	0.21	0.51	0.59	1.04	1.24	1.34	1.63	2.33	3.12	4.71	5.23
SMALL RHEOPHILIC (SR) GUILD															
Spawning habitat	0	0	0	0	0.5	1	1.5	2	2	2.5	3	3.5	4	5	5
Nursery habitat	0.5	0.5	0.5	0.5	1	2	2.5	2.5	2.5	3	3	4	4.5	5	5
Abundance	0	0	0	0	0.5	0.5	1	2	2	2.5	3	3.5	4.5	5	5
Cover	0	0	0	0	0.5	0.5	1	2	2	2.5	3	3.5	4.5	5	5
Connectivity (lateral & longitudinal)	0	0	0	0	0.5	0.5	1	2	2.5	3	3	4.5	4.5	5	5
Water Quality (esp. oxygen and temperature)	0	0	0	0	0.5	1	2	2.5	2.5	3	3.5	4	4.5	5	5
Species stress: CANO	10	10	10	10	9	8	7	6	6	5	4	2	1	0	0
LARGE SEMI RHEOPHILIC (LSR) GUILD															
Spawning habitat	0	0	0	0	0	0	0.5	1	1.5	2	2.5	3	4	5	
Nursery habitat	0	0.5	0.5	0.5	1	2	2	2.5	2.5	3	3.5	4	4.5	5	
Abundance	0	0	0.5	0.5	0.5	1	1	1.5	1.5	2	3	3.5	4	5	
Cover	0	0	0.5	0.5	0.5	1	1	1.5	1.5	2	3	3.5	4	5	
Connectivity (lateral & longitudinal)	0	0.5	0.5	0.5	0.5	1	2	2.5	2.5	3	3	3.5	4	5	
Water Quality (esp. oxygen and temperature)	0	0.5	0.5	0.5	1	1.5	2	2.5	2.5	3	3.5	4	4.5	5	
Species stress: BMAR	10	10	9	9	9	8	7	6	6	5	4	3	2	0	

Q1.3 MACROINVERTEBRATE STRESS INDEX

The habitat flow index for flow dependent (FDI) and marginal vegetation macroinvertebrate (MVI) taxa is provided in Table Q3 and provides the % occurrence of various velocity and substrate classes under different flow conditions.

Table Q3 Habitat suitability for FDI and MVI taxa

Habitat Flow Response Index	Habitat Response	Habitat Abundance and suitability													Flow (m ³ /s)
		VSCS ¹	SCS ²	FCS ³	VFCS ⁴	VSFS ⁵	SFS ⁶	FFS ⁷	VFFS ⁸	VSBR ⁸	SBR ¹⁰	FBR ¹¹	VFBR ¹²	Veg ¹³	
0	All habitat (coarse sands and MV) in excess, very high quality, flow very fast over part of the channel, very deep, very wide WP.	0	0	0	0	5	17	30	10	0	0	0	0	38	5.2
1	All plentiful, high quality; fast, wide wetted perimeter. Increase in inundated MV (grass and reeds).	0	0	0	0	3	11	19	8	0	0	0	0	59	3.73
2	Critical habitats sufficient; plentiful inundated vegetation, quality slightly reduced. High velocities, WP reduced.	0	0	0	0	4	12	21	8	0	0	0	0	55	2.33
3	Reduced fast flow habitat, plentiful inundated vegetation, reduced water quality. Moderate velocities, moderately deep, WP further reduced.	0	0	0	0	4	14	22	7	0	0	0	0	53	1.85
4	Critical habitats (MV in fast current) limited. Moderate quality, moderate velocities, some deep areas, WP moderately reduced.	0	0	0	0	5	17	25	5	0	0	0	0	48	1.41
5	Fast and moderately fast flow habitat reduced, moderate quality. Moderate velocities, few deep areas, WP further	0	0	0	0	3	11	21	10	0	0	0	0	55	1.24

Habitat Flow Response Index	Habitat Response	Habitat Abundance and suitability													Flow (m ³ /s)
		VSCS ¹	SCS ²	FCS ³	VFCS ⁴	VSFS ⁵	SFS ⁶	FFS ⁷	VFFS ⁸	VSBR ⁹	SBR ¹⁰	FBR ¹¹	VFBR ¹²	Veg ¹³	
	reduced.														
6	Critical habitat residual. Low quality, moderate/slow velocities. Reduced depth.	0	0	0	0	4	15	29	12	0	0	0	0	40	0.77
7	No critical habitats (very fast flow), other habitats moderate quality. Moderate velocities, narrow WP, shallow.	0	0	0	0	12	43	23	0	0	0	0	0	22	0.1
8	Flowing water habitats residual and low quality. Slow trickle over sand and, in few places over bedrock. Very narrow wetted perimeter. Marginal vegetation out of flow persists on channel periphery.	0	0	0	0	52	33	1	0	0	0	0	0	14	0.006
9	Standing water habitats only, no connectivity, very low quality, no flow. Marginal vegetation forms a habitat on the periphery of small pools. Very narrow WP.	0	0	0	0	40	41	1	0	0	0	0	0	18	0.002
10	No flow. Only surface water. Marginal vegetation persists at pool margins.	0	0	0	0	80	20	0	0	0	0	0	0	0	0.0

1 Very Slow over Coarse Sediment

4 Very Fast over Coarse Sediment

7 Fast over Fine Sediment

10 Slow over Bedrock

13 Fringing vegetation

2 Slow over Coarse Sediment

5 Very Slow over Fine Sediment

8 Very Fast over Fine Sediment

11 Fast over Bedrock

3 Fast over Coarse Sediment

6 Slow over Fine Sediment

9 Very Slow over Bedrock

12 Very Fast over Bedrock

The stress index for FDI taxa is provided in Table Q4 which rates the response of the species according to various biotic response metrics.

Table Q4 Macroinvertebrate (FDI) stress index

Habitat characteristics					Biotic Response	Flow	Species Stress
Max depth (m)	Ave depth (m)	Max vel (m/s)	Ave vel (m/s)	WP (m)			
0.28	0.87	0.42	45.8	0.28	Heptageniids and other FDIs abundant and healthy.	5.2	0
0.25	0.85	0.41	37.1	0.25	Heptageniidae persist in a healthy condition.	3.73	1
0.22	0.82	0.39	28.3	0.22	Heptageniidae and more sensitive FDI persist.	2.33	2
0.2	0.78	0.38	25.6	0.2	Heptageniids persist at lower abundances, FDI abundances somewhat reduced.	1.85	3
0.17	0.73	0.35	23.4	0.17	Heptageniidae present at lower abundances. More flow sensitive taxa present at lower abundances. All life stages viable in limited areas.	1.24	4
0.22	0.86	0.42	14.1	0.22	Heptageniidae present in low abundances. Critical life-stages of more sensitive FDIs taxa at risk or non-viable.	0.77	5
0.19	0.84	0.42	9.8	0.19		0.1	6
0.07	0.48	0.24	6.7	0.07	Heptageniids persist, but more sensitive FDIs present only in low numbers. All life-stages of sensitive indicator taxa at risk or non-viable.	0.006	7
0.02	0.21	0.09	4.6	0.02	Heptageniids present in very low numbers, other sensitive FDI absent due to loss of fast flow. Likely that critical life stages of Heptageniids are threatened.	0.002	8
0.01	0.17	0.07	0.4	0.01	Heptageniids and all FDIs absent.	0.000	9
0.01	0.17	0.07	0.4	0.01			

The stress index for MVI taxa is provided in Table Q5 which rates the response of the species according to various biotic response metrics.

Table Q5 Macroinvertebrate (MVI) stress index

Habitat characteristics					Biotic Response	Flow	Species Stress
Max depth (m)	Ave depth (m)	Max vel (m/s)	Ave vel (m/s)	WP (m)			
0.28	0.87	0.42	45.8	0.28	All indicator taxa very abundant and healthy.	5.2	0
0.25	0.85	0.41	37.1	0.25	Atyidae persist in a healthy state.	3.73	1
0.22	0.82	0.39	28.3	0.22	Atyidae present and abundant.	2.33	2
0.2	0.78	0.38	25.6	0.2	Atyidae persist with reduced abundances.	1.85	3
0.17	0.73	0.35	23.4	0.17	Atyidae present and abundant. All life stages viable in limited areas, critical life stages of some sensitive indicator taxa (with a preference for MVIC) at risk.	1.24	4
0.22	0.86	0.42	14.1	0.22	Atyidae present, abundances reduced. Critical life-stages of sensitive indicator taxa at risk or non-viable.	0.77	5
0.19	0.84	0.42	9.8	0.19	Atyidae present, more sensitive MVIC rare, critical stages of sensitive indicator taxa non-viable, and at risk for some less sensitive taxa.	0.1	6
0.07	0.48	0.24	6.7	0.07	Atyidae persist in low numbers. Some life-stages at risk or non-viable.	0.006	7
0.02	0.21	0.09	4.6	0.02	Atyidae persist at very low numbers. All life stages of most MVI taxa at risk or non-viable.	0.002	8
0.01	0.17	0.07	0.4	0.01	Atyidae absent.	0.000	9
0.01	0.17	0.07	0.4	0.01	Indicator taxa have disappeared.		10

Q1.4 RIPARIAN VEGETATION STRESS INDEX**Table Q6 Riparian vegetation stress index for indicator species**

Biotic response				
Species Stress	Flow (m ³ /s)	<i>Phragmites mauritanus</i>	Flow (m ³ /s)	<i>Breonadia salicina</i>
0	2.9	Adults with full vigour and at maximum reproductive capacity. 30 - 50% population inundated, inundation stress not yet present (max of 50 cm inundation).	2.8	Adults with full vigour and at maximum reproductive capacity. Up to 50 – 60 cm rooting depth for upper limit, lower limit at water level or slightly inundated on average.
1				
2				
3	1.7	Leaf wilting/stress commences, but is slight. Up to 80 cm rooting depth for upper limit, lower limit at water level on average.	1.14	Leaf wilting/stress commences, but is slight. 60 - 90 cm substrate depth required for inundated soil moisture.
4		Flower/fruit abortion commences.		Flower/fruit abortion commences.
5		Leaf wilting obvious, or vegetative parts begin unseasonal discolouration. Flower/fruit abortion widespread.		Leaf wilting obvious, or vegetative parts begin unseasonal discolouration. Flower/fruit abortion widespread.
6	0.7	Unseasonal thinning or partial mortality of above-ground parts (majority of the plant/s remains viable, but water stressed). Up to 90 cm rooting depth for sufficient soil moisture, water level at lower limit, rhizomes at upper limits may begin thinning.	0.15	Unseasonal thinning or partial mortality of above-ground parts (majority of the plant/s remains viable, but water stressed). 80 - 1100 cm rooting depth for sufficient substrate moisture, mortality may occur for lower zone individuals.
7				
8	0.03	Unseasonal loss or mortality of above-ground parts (only minor portions of plants remain viable). Rootstocks/rhizomes of some species remain viable/dormant. More than 1 m rooting depth for sufficient soil moisture, rhizome mortality commences.	0.03	Unseasonal loss or mortality of above-ground parts (only minor portions of plants remain viable). Rootstocks/rhizomes of some species remain viable. > 1 m rooting depth, individuals at upper limit likely to begin senescence.
9		Complete mortality of small proportion of the population.		Complete mortality of small proportion of the population.
10	0	Widespread and complete mortality of population.	0	Widespread and complete mortality of population.

Q2 EWR 8: LOWER SAND (SAND RIVER) - DETERMINATION OF EWR SCENARIOS

Q2.1 LOW FLOW REQUIREMENTS IN TERMS OF STRESS FOR FISH

The fish low flow requirements for the EWR scenarios are summarised in Table Q7 for the SR guild and Table Q8 for LSR guild.

Table Q7 Low flow requirements: SR guild

GENERAL					
INDICATOR: Small rheophilic (CANO).					
PES: FISH EC B (ECOSTATUS B)					
Dry Season maintenance At this fish stress level, some FS (44% on cross-section) and very limited FI (3% on cross-section) will be present while no FD habitats will be available (on cross-section). This habitat composition should be adequate to provide the most critical habitats for the survival of species within this fish guild during the dry season. This habitat composition should be adequate to maintain this fish guild in the present EC. Dry Season drought At this fish stress level adequate FS (23% of cross-section) will be maintained, but FI and FD will be absent. The available FS habitats should be adequate to ensure the survival of this fish guild. At these proportions of habitats available at the site, this fish guild should be able to survive through drought period in the dry season and enable recovery once conditions improve to remain within the PES. Wet Season maintenance This fish stress level will maintain adequate FS (12% of cross-section), FI (5% of cross section) and FD (19% on cross-section) will be available. The habitat composition should be adequate for all life stages to fulfil all required biological processes during the wet season (spawning, nursery habitats as well as adequate feeding and refuge habitats for juvenile and adult specimens) to maintain this fish guild within current EC. Wet Season drought At a fish stress level of 9 much reduced spawning habitats will be available for this fish guild (30% FS, 0% FI and 0% FD on cross-section), but it should be adequate to maintain some habitats to meet requirements of all life stages to ensure survival of these species during the wet season and allow recovery after drought period. If this habitat is not adequate to allow spawning and other life stages, this species will probably seek more suitable habitats further downstream (in Sabie River) to complete these life stages, and then re-colonise this site after the drought period.					
BUILDING BLOCK	SEASON	STRESS DURATION	SPP STRESS	INTEG STRESS	FLOW (m ³ /s)
Drought	Dry	5%	9.75	9.75	0.001
Maintenance	Dry	60%	8.5	8.5	0.36
Drought	Wet	5%	9	9	0.21
Maintenance	Wet	60%	3	3.5	1.98
AEC: FISH EC C (ECOSTATUS C)					
General Decreased low flows (lower water levels for longer periods) and increased period of no flow will result in decreased FROC of species with preference for FS and FD habitats and a complete loss in species intolerant to no flow conditions. Dry Season maintenance At this fish stress level, limited fast habitats will be available at the site according to the hydraulic information of the cross-section (35%FS and 0%FI and 0%FD on cross-section). It is therefore estimated that at this stress level adequate habitats may be available for this fish guild to survive these conditions. At this stress level it is however thought that this fish guild will be stressed, reduced abundance and FROC will occur which will be reflected by a decrease in EC. Wet Season maintenance At this fish stress level some fast habitats will be available, but reduced from present conditions, it can be expected that reduced abundance and FROC will occur with a resultant decreased EC.					

BUILDING BLOCK	SEASON	STRESS DURATION	SPP STRESS	INTEG STRESS	FLOW (m ³ /s)
Maintenance	Dry	60%	9.5	9.5	0.106
Maintenance	Wet	60%	5	5	1.34

Table Q8 Low flow requirements: LSR guild

GENERAL					
INDICATOR: The large semi-rheophilic species (especially BMAR, LCYL, and LMOL) are another important indicator guild present at this EWR site. Valuable information regarding the habitat requirements for different life stages is available for BMAR and should be adequate to support the requirements of other species within this guild. This species was therefore used as indicators for the large semi-rheophilic guild. This species utilises most habitats (SD, SS, FD, FI and FS) with substrate and water column as preferred cover. They also require overhanging vegetation as nursery habitats. Flows should furthermore remain adequate to allow migration between reaches, thus depth in riffle and rapids should remain adequate, especially during the wet season.					
PES: FISH EC B (ECOSTATUS B)					
Dry Season maintenance Although this fish guild can survive in the dry season without flow (in SD) habitats, some flow is essential to maintain adequate water quality, food sources and to allow lateral and longitudinal movement of these species. At this fish stress level some fast habitats (43% FS and only 2% FI on cross-section) will be maintained to at least provide the above mentioned functions and therefore maintain these species in this EC. Dry Season drought This fish stress level will ensure availability of adequate critical refuge areas (SD) with some flow between these habitats to ensure acceptable water quality for survival through drought period in the dry season and enable recovery once conditions improve. Should conditions become unacceptable, these fish species may disappear from this site and re-colonise from the downstream section (Sabie River) during the wet season. Wet Season maintenance This fish stress level will maintain adequate fast habitats (17% FS, 7% FI and 18% FD on cross-section) that are the most important habitat required for spawning and migration of this fish guild during the wet season (also ensure adequate habitats for juvenile and adult specimens) to maintain within current EC. Wet Season drought At fish stress level of 9 this fish guild will have much reduced fast habitats (31% FS and no FI and FD). This habitat may not be adequate to allow spawning (also related to natural absence of suitable spawning substrates) and other life stages, this species will probably seek more suitable habitats further downstream of in tributaries to complete these life stages, and then re-colonise this site after the drought period.					
BUILDING BLOCK	SEASON	STRESS DURATION	SPP STRESS	INTEG STRESS	FLOW (m ³ /s)
Drought	Dry	5%	9.75	9.75	0.001
Maintenance	Dry	60%	8.5	8.5	0.36
Drought	Wet	5%	9	9	0.21
Maintenance	Wet	60%	3	3	2.33
AEC: FISH EC C (ECOSTATUS C)					
General Decreased low flows (lower water levels for longer periods) and increased period of no flow will result in decreased FROC of species with preference for FS and FD habitats. Dry Season maintenance Although this fish guild can survive in the dry season without flow (in SD) habitats, some flow is essential to maintain adequate water quality, food sources and to allow lateral and longitudinal movement of these species. This stress level will maintain very limited FS habitats (3% of cross-section) at the site (no FI and FD), available in reduced abundance than compared to present conditions. It can be expected that this guild will be stressed more than presently and result in decreased abundance and overall FROC, with a resultant decreased EC. Wet Season maintenance At this fish stress level limited fast habitats (9% FS, 6% FI and 30% FD on cross-section) will be available at a much reduced quantity than present wet season, but it should still be adequate to maintain all life stages although reduced abundance and FROC can be expected, and a resultant decrease in EC may occur. If this habitat is not suitable to allow spawning (also related to natural absence of suitable spawning substrates) and other life stages, this species will probably seek more suitable habitats further downstream of in tributaries to complete these life stages, and then re-					

colonise this site after the drought period.

BUILDING BLOCK	SEASON	STRESS DURATION	SPP STRESS	INTEG STRESS	FLOW (m ³ /s)
Maintenance	Dry	60%	9.5	9.5	0.106
Maintenance	Wet	60%	5	5	1.34

Q2.2 LOW FLOW REQUIREMENTS IN TERMS OF STRESS FOR MACROINVERTEBRATES

The low flow requirements for FDIs are summarised in Table Q9 and in Table Q10 for the MVIs.

Table Q9 Low flow requirements: FDI taxa

GENERAL					
INDICATOR: The only flow dependent taxon occurring commonly at the site at the time of sampling was Heptageniidae, preferring velocities between 0.3 and 0.6 m/s, and high quality water.					
PES: MACROINVERTEBRATE EC: C (ECOSTATUS B)					
Dry Season maintenance Velocities in the range of 0.3 - 0.6 m/s are required to support reduced abundances of FDIs through the dry season. The stress of 6 provides average velocities of 0.24 m/s and max velocities of 0.48 m/s. Dry Season drought It is likely that during these periods there will be only trickling surface flow, discontinuous surface water (pools) and the FDIs will disappear. These conditions equate to a species stress of 10. Wet Season maintenance Velocities in the range of 0.3 - 0.6 m/s over limited critical flow areas will ensure a viable community of FDIs, which would be anticipated in a C category. A stress of 2 fulfils this requirement, providing average and maximum velocities of 0.22 and 0.82 m/s respectively. Wet Season drought In order to maintain sufficient FDIs to repopulate the river once flow recommences, small areas of flow velocities between 0.3 and 0.6 m/s are optimum, although Heptageniids and less sensitive FDIs will survive in flows of 0.1 - 0.3 m/s for limited periods. A stress of 6 approximates this requirement, with average velocities of 0.24 m/s and maxima of 0.48 m/s.					
BUILDING BLOCK	SEASON	STRESS DURATION	SPP STRESS	INTEG STRESS	FLOW (m ³ /s)
Drought	Dry	5%	10	10	0.001
Maintenance	Dry	60%	6	9.4	0.1
Drought	Wet	5%	6	9.4	0.1
Maintenance	Wet	60%	2	3	2.33
REC: MACROINVERTEBRATE EC B (ECOSTATUS B)					
Dry Season maintenance Velocities of 0.3 - 0.6 m/s with maxima of >0.6 m/s are required support a viable community of FDIs. The stress of 5 provides for this requirement, with average velocities of 0.42 m/s and max velocities of 0.84 m/s. Dry Season drought It is likely that during these periods there will be only trickling surface flow, discontinuous surface water (pools) and the FDIs will disappear. These conditions equate to a stress of 9 (discharge = 0.002). Wet Season maintenance Velocities of > 0.6 m/s over limited critical habitat areas, and 0.3 - 0.6 m/s on average will ensure an abundant community of FDIs, which would be anticipated in a B EC. A stress of 2 fulfils this requirement, providing average velocities of 0.39 m/s and maximum velocities of 0.82 m/s. Wet Season drought In order to maintain sufficient FDIs to repopulate the river under flow conditions, limited areas of flow velocities between 0.3 and 0.6 m/s are required. Less sensitive FDIs will survive in flows of 0.1 - 0.3 m/s for limited periods. A stress of 6 approximates this requirement, with average velocities of 0.24 m/s and maxima of 0.48 m/s.					

BUILDING BLOCK	SEASON	STRESS DURATION	SPP STRESS	INTEG STRESS	FLOW (m ³ /s)
Drought	Dry	5%	10	10	0.001
Maintenance	Dry	60%	5	7	0.59
Drought	Wet	5%	6	9.4	0.1
Maintenance	Wet	60%	2	3	2.33
AEC: MACROINVERTEBRATE EC C/D (ECOSTATUS C)					
Dry Season maintenance Velocities of 0.3 - 0.6 m/s and > 0.6 m/s are required to support a community of FDIs. The species stress of 6 approximates this condition, with average velocities of 0.24 m/s and max velocities of 0.48 m/s.					
Wet Season maintenance Velocities of 0.3 - 0.6 m/s on average over limited critical flow areas will ensure low abundances of FD macroinvertebrates, which would be anticipated in a C/D class. A stress of 4 fulfils this requirement, providing average velocities of 0.35 m/s.					
BUILDING BLOCK	SEASON	STRESS DURATION	SPP STRESS	INTEG STRESS	FLOW (m ³ /s)
Maintenance	Dry	60%	6	9.4	0.126
Maintenance	Wet	60%	4	6	1.24

Table Q10 Low flow requirements: MVI taxa

GENERAL					
INDICATOR One macroinvertebrate taxon, Atyidae, was selected on the basis of its preference for the marginal vegetation (in or out of flow) habitat, and its sensitivity to the disappearance thereof.					
PES: MACROINVERTEBRATE EC: C (ECOSTATUS B)					
Dry Season maintenance Indicator taxa will persist at low abundances in the marginal vegetation and water column. The requirement is for depths of >10 cm in limited areas, for vegetation inundation. This equates to a stress of 7 (max depth 0.14 m, average depth 0.07 m).					
Dry Season drought Despite no surface flow during these periods, pools will persist in the channel, and these will be fringed with marginal vegetation (MV). Atyidae will persist in this habitat, in very low abundances. The conditions associated with a stress of 8 match these requirements.					
Wet Season maintenance A healthy population of MVIs are expected in the water column and the vegetation. An average depth of 0.15 to 0.2 m and a high proportion of vegetation will facilitate this. A stress of 4 fulfils these conditions (average depth 0.17 m, 48% vegetation).					
Wet Season drought MVIs will survive in the water column and MV. Depths of approximately 0.1 - 0.15 m are required to inundate grasses, and provide adequate depth in limited parts of the channel. A stress of 7 provides average depths of 0.07 m and maximum depths of 0.14 m.					
BUILDING BLOCK	SEASON	STRESS DURATION	SPP STRESS	INTEG STRESS	FLOW (m ³ /s)
Drought	Dry	5%	8	10	0.001
Maintenance	Dry	60%	7	10	0.001
Drought	Wet	5%	7	10	0.001
Maintenance	Wet	60%	4	6	1.24
REC: MACROINVERTEBRATE EC B (ECOSTATUS B)					
Dry Season maintenance MVI indicators should be in reasonable abundances in the B EC. An average depth of >0.1 m, and a high proportion of MV will provide conducive conditions. These requirements equate to a species stress of 6.					
Dry Season drought					

Despite no surface flow during these periods, pools will persist in the channel, and these will be fringed with MV. Atyidae will persist in this habitat, in very low abundances. The conditions associated with a species stress of 8 match these requirements.

Wet Season maintenance

Plentiful MVIs expected in the water column and the vegetation. An average depth of >0.2 m and a high proportion of vegetation will facilitate this. A species stress of 3 equates to these conditions (average depth 0.2 m, 53% vegetation).

Wet Season drought

MVIs will survive in the water column and MV. Depths of approximately 0.1 - 0.15 m are required to inundate grasses, and provide adequate depth in limited parts of the channel. A species stress of 7 provides average depths of 0.07 m and maximum depths of 0.14 m.

BUILDING BLOCK	SEASON	STRESS DURATION	SPP STRESS	INTEG STRESS	FLOW (m ³ /s)
Drought	Dry	5%	8	10	0.001
Maintenance	Dry	60%	6	9.4	0.1
Drought	Wet	5%	7	10	0.001
Maintenance	Wet	60%	3	3.8	1.85

AEC: MACROINVERTEBRATE EC C/D (ECOSTATUS C)

Dry Season maintenance

Indicator taxa will persist at low abundances in the marginal vegetation and water column. The requirement is for depths of >10 cm in limited areas, for vegetation inundation. This equates to a species stress of 7 (max depth 0.14 m, average depth 0.07 m).

Wet Season maintenance

MVIs will be present, but in lower abundances than for either B or C EC. Depths should be greater than 0.2 m in areas, and vegetation should comprise a significant proportion of the habitat. A species stress of 5 adequately fulfils these conditions, with average depth 0.17 m, max depth 0.48 m, and vegetation modelled as 40% of total flow habitat.

BUILDING BLOCK	SEASON	STRESS DURATION	SPP STRESS	INTEG STRESS	FLOW (m ³ /s)
Maintenance	Dry	60%	7	10	0.001
Maintenance	Wet	60%	5	7	0.77

Q2.3 LOW FLOW REQUIREMENTS IN TERMS OF RIPARIAN VEGETATION

The low flow requirements for riparian vegetation indicator species are summarised in Table Q11.

Table Q11 Low flow requirements: Riparian vegetation species

GENERAL
INDICATOR: <i>Phragmites mauritianus</i> .
PES: RIPARIAN VEGETATION EC B (ECOSTATUS B)
Dry Season maintenance In order that the PES is maintained, population stress would not be expected to exceed 6 during dry season maintenance flows. At a species stress of 6, unseasonal thinning or partial mortality of above-ground parts (majority of the plant/s remains viable, but water stressed). Reeds have up to 90 cm rooting depth for sufficient soil moisture, water level at lower limit, rhizomes at upper limits may begin thinning. Dry Season drought Would not expect the average population to experience a stress of more than 8 during natural drought in the dry season. A species stress of 8 equates to unseasonal loss or mortality of above-ground parts (only minor portions of plants remain viable); rootstocks/rhizomes of some species remain viable/dormant. Reeds have more than 1m rooting depth for sufficient soil moisture, rhizome mortality commences. A thinning of the population can be expected for reeds. Wet Season Maintenance In order that the PES is maintained, population stress would not be expected to exceed 2 during wet (growing) season maintenance flows. At a species stress of 2, leaf wilting/stress commences in adults, but is slight; the population is essentially unhampered in reproductive capacity. Reeds up to 80 cm rooting depth for upper limit, lower limit at water level on average.

Wet Season drought

Would not expect the average population to experience a stress of more than 6 during natural drought in the wet season. At a species stress of 6, unseasonal thinning or partial mortality of above-ground parts (majority of the plant/s remains viable, but water stressed). Reeds have up to 90 cm rooting depth for sufficient soil moisture, water level at lower limit, rhizomes at upper limits may begin thinning. Flower and fruit abortion is also prevalent.

BUILDING BLOCK	SEASON	STRESS DURATION	SPP STRESS <i>Phragmites</i>	INTEG STRESS	FLOW (m ³ /s)
Drought	Dry	5%	8.5	10	0.001
Maintenance	Dry	60%	6	7	0.59
Drought	Wet	5%	6.5	8	0.51
Maintenance	Wet	60%	2.5	3.75	1.805

AEC: RIPARIAN VEGETATION EC B/C (ECOSTATUS C)**Dry Season maintenance**

Reeds stress will increase in dry season since low flow abstraction is increased. Unseasonal thinning or partial mortality of above-ground parts (majority of the plant/s remains viable, but water stressed). Up to 90 cm rooting depth for sufficient soil moisture, water level at lower limit, rhizomes at upper limits may begin thinning i.e. reedsbeds will begin to reduce in the upper limits, (but will expand towards receding water levels at lower limits during growing season – see below).

Wet Season maintenance

Small proportion of reeds remain inundated and upper limit rooting depth is at about 70 cm. Species stress remains low enough to facilitate complete vegetative growth at the lower limit which will enable reeds to expand into additional habitat.

BUILDING BLOCK	SEASON	STRESS DURATION	SPP STRESS <i>Phragmites</i>	INTEG STRESS	FLOW (m ³ /s)
Maintenance	Dry	60%	6.5	8	1.34
Maintenance	Wet	60%	3.75	5	0.51

Q2.4 INSTREAM FLOOD FUNCTIONS**Table Q12 Functions for each Flood Class**

Flood Class	Component	Function/Motivation
Class: I Range (m ³ /s): 4 – 7 Daily average: 5 Duration: 4	Fish	Class I floods are very important floods for fish and serves as migration cues and to maintain adequate longitudinal connectivity for migration. These floods will also flush fines and algae from substrates to ensure adequate conditions in substrates, a very important habitat for spawning of many of the species. It will furthermore inundate some vegetation (especially in new activated channels) for species spawning in flooded marginal vegetation and contributes to the creation of acceptable nursery areas (increased flooded vegetation). Some resetting of water quality will also take place, and the changes in water quality may also serve as stimulus to cue migratory activity and even gonad development. The frequency, extent and duration as recommended for the PES, REC and AEC should be adequate to provide the functions as required to maintain the fish within the specific EC.
	Macroinvertebrates	These flushing flows are recommended to reset water quality, to clear the boulder / bedrock/cobble surfaces and undersides of fines, to provide breeding and hatching cues, and to inundate marginal areas and marginal vegetation. Four are required per year for the B EC, and three for the C EC.
Class: II Range (m ³ /s): 30 – 65 Daily average: 30 Duration: 5	Fish	Class II floods also provide similar flood functions for fish as Class I floods.
	Macroinvertebrates	These floods are recommended to move and clean sands and gravels, refresh vegetation as a habitat, and fulfil all the functions of the former class of floods. One is recommended per year for all ECs.
Class: III Range (m ³ /s)	Fish	Class III floods also provide similar functions as Class I, but due to its lower frequency of occurrence it is not essential for the flood functions required by the indigenous fish species.
Class IV Range (m ³ /s)	Fish	Class IV floods also provide similar functions as Class I, but due to its lower frequency of occurrence it is not essential for the flood functions required by

Flood Class	Component	Function/Motivation
		the indigenous fish species. These floods, and especially their receding limbs will however be utilised by many of the fish species for migration and even spawning if it occurs within the spring/summer season.
Class: V Range (m ³ /s): 150 + (160 ave)	Fish	Class V floods also provide similar functions as Class I, but due to its lower frequency it is not essential for the flood functions required by the indigenous fish species. The receding limbs will especially be utilised by many of the fish species for migration and even spawning if it occurs within the correct (spring/summer) season. These floods will be especially important to clear substrates of fines and benthic algae and maintain adequate substrate quality.

Q2.5 EWR RULE TABLES

EWR rule tables which provide the recommended EWR flows as a duration table, showing flows which should be provided when linked to a natural trigger (natural modelled hydrology in this case) are provided for the different EWR scenarios. EWR rules are supplied for total flows as well as for low flows only.

Table Q13 EWR 8 assurance rules for REC: B

Desktop Version 2, Printed on 2009/06/22

Summary of IFR rule curves for: SB8 Natural Flows

Determination based on defined BBM Table with site specific assurance rules.

Regional Type: E. Escarp REC = B

Data are given in m³/s mean monthly flow

Month	% Points									
	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	0.362	0.359	0.354	0.343	0.324	0.290	0.237	0.161	0.074	0.009
Nov	0.891	0.885	0.873	0.850	0.807	0.732	0.613	0.444	0.249	0.105
Dec	1.184	1.174	1.152	1.108	1.026	0.891	0.699	0.470	0.263	0.150
Jan	1.963	1.845	1.734	1.616	1.402	1.231	0.982	0.682	0.406	0.255
Feb	7.673	6.839	6.131	4.551	3.509	3.038	2.381	2.030	1.129	0.622
Mar	2.902	2.785	2.665	2.525	2.260	1.995	1.593	1.094	0.626	0.369
Apr	1.629	1.620	1.594	1.540	1.438	1.264	1.011	0.706	0.425	0.271
May	1.003	0.996	0.979	0.945	0.883	0.779	0.632	0.457	0.299	0.212
Jun	0.863	0.857	0.842	0.812	0.757	0.665	0.534	0.379	0.238	0.161
Jul	0.696	0.692	0.683	0.666	0.634	0.579	0.490	0.366	0.221	0.115
Aug	0.543	0.539	0.532	0.518	0.491	0.446	0.373	0.270	0.150	0.062
Sep	0.417	0.415	0.409	0.397	0.376	0.339	0.280	0.197	0.101	0.030

Reserve flows without High Flows

Oct	0.362	0.359	0.354	0.343	0.324	0.290	0.237	0.161	0.074	0.009
Nov	0.473	0.470	0.464	0.452	0.429	0.390	0.327	0.239	0.136	0.060
Dec	0.780	0.773	0.759	0.731	0.678	0.590	0.466	0.318	0.184	0.110
Jan	1.253	1.246	1.227	1.185	1.107	0.975	0.781	0.548	0.334	0.216
Feb	2.351	2.343	2.311	2.240	2.100	1.852	1.476	1.010	0.573	0.332
Mar	2.192	2.185	2.155	2.090	1.961	1.732	1.385	0.955	0.552	0.330
Apr	1.629	1.620	1.594	1.540	1.438	1.264	1.011	0.706	0.425	0.271
May	1.003	0.996	0.979	0.945	0.883	0.779	0.632	0.457	0.299	0.212
Jun	0.863	0.857	0.842	0.812	0.757	0.665	0.534	0.379	0.238	0.161
Jul	0.696	0.692	0.683	0.666	0.634	0.579	0.490	0.366	0.221	0.115
Aug	0.543	0.539	0.532	0.518	0.491	0.446	0.373	0.270	0.150	0.062
Sep	0.417	0.415	0.409	0.397	0.376	0.339	0.280	0.197	0.101	0.030

Natural Duration curves

Oct	1.620	1.456	1.299	1.180	1.012	0.915	0.866	0.818	0.694	0.459
Nov	3.549	2.859	1.971	1.686	1.447	1.289	1.165	0.930	0.806	0.521
Dec	10.450	5.462	3.573	2.655	2.363	1.695	1.441	1.310	0.967	0.635
Jan	18.089	9.558	5.395	3.655	3.300	2.729	2.173	1.770	1.370	0.829
Feb	38.538	16.286	9.077	4.551	3.509	3.038	2.381	2.030	1.674	0.798
Mar	26.430	10.570	7.486	4.958	2.987	2.714	2.195	1.792	1.512	0.691
Apr	9.267	5.127	3.573	2.998	2.500	2.215	1.941	1.779	1.535	0.795
May	3.177	2.815	2.520	2.184	1.923	1.729	1.602	1.497	1.262	0.683
Jun	2.442	2.230	2.091	1.806	1.663	1.505	1.381	1.292	1.111	0.648
Jul	2.046	1.807	1.676	1.520	1.404	1.296	1.180	1.079	0.978	0.609
Aug	1.759	1.557	1.411	1.333	1.213	1.113	1.045	0.960	0.833	0.538
Sep	1.601	1.489	1.350	1.223	1.115	1.026	0.941	0.876	0.772	0.494

Table Q14 EWR 8 assurance rules for AEC: C

Desktop Version 2, Printed on 2008/08/01

Summary of IFR rule curves for: SB8 Natural Flows

Determination based on defined BBM Table with site specific assurance rules.

Regional Type: E. Escarp AEC = C

Data are given in m³/s mean monthly flow

Month	% Points									
	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	0.555	0.551	0.543	0.527	0.497	0.445	0.363	0.247	0.113	0.014
Nov	0.617	0.613	0.605	0.588	0.558	0.505	0.421	0.303	0.165	0.064
Dec	1.159	1.149	1.128	1.085	1.005	0.873	0.685	0.462	0.260	0.150
Jan	1.651	1.534	1.430	1.324	1.133	1.001	0.810	0.579	0.367	0.250
Feb	6.807	5.977	5.282	4.551	3.509	3.038	2.381	1.751	1.014	0.609
Mar	2.083	1.969	1.862	1.750	1.541	1.375	1.123	0.810	0.517	0.356
Apr	1.122	1.116	1.100	1.066	1.001	0.892	0.731	0.538	0.361	0.264
May	0.831	0.825	0.812	0.785	0.736	0.655	0.539	0.402	0.278	0.210
Jun	0.778	0.772	0.759	0.732	0.683	0.603	0.488	0.351	0.227	0.160
Jul	0.705	0.701	0.692	0.674	0.642	0.586	0.496	0.370	0.223	0.115
Aug	0.638	0.634	0.625	0.608	0.577	0.522	0.435	0.312	0.170	0.064
Sep	0.596	0.592	0.584	0.567	0.536	0.483	0.397	0.277	0.137	0.034

Reserve flows without High Flows

Oct	0.555	0.551	0.543	0.527	0.497	0.445	0.363	0.247	0.113	0.014
Nov	0.617	0.613	0.605	0.588	0.558	0.505	0.421	0.303	0.165	0.064
Dec	0.728	0.722	0.709	0.683	0.634	0.553	0.438	0.301	0.177	0.110
Jan	0.941	0.936	0.922	0.893	0.838	0.745	0.609	0.445	0.294	0.211
Feb	1.485	1.480	1.462	1.421	1.340	1.197	0.980	0.710	0.458	0.319
Mar	1.373	1.369	1.352	1.315	1.242	1.112	0.916	0.672	0.443	0.317
Apr	1.122	1.116	1.100	1.066	1.001	0.892	0.731	0.538	0.361	0.264
May	0.831	0.825	0.812	0.785	0.736	0.655	0.539	0.402	0.278	0.210
Jun	0.778	0.772	0.759	0.732	0.683	0.603	0.488	0.351	0.227	0.160
Jul	0.705	0.701	0.692	0.674	0.642	0.586	0.496	0.370	0.223	0.115
Aug	0.638	0.634	0.625	0.608	0.577	0.522	0.435	0.312	0.170	0.064
Sep	0.596	0.592	0.584	0.567	0.536	0.483	0.397	0.277	0.137	0.034

Natural Duration curves

Oct	1.620	1.456	1.299	1.180	1.012	0.915	0.866	0.818	0.694	0.459
Nov	3.549	2.859	1.971	1.686	1.447	1.289	1.165	0.930	0.806	0.521
Dec	10.450	5.462	3.573	2.655	2.363	1.695	1.441	1.310	0.967	0.635
Jan	18.089	9.558	5.395	3.655	3.300	2.729	2.173	1.770	1.370	0.829
Feb	38.538	16.286	9.077	4.551	3.509	3.038	2.381	2.030	1.674	0.798
Mar	26.430	10.570	7.486	4.958	2.987	2.714	2.195	1.792	1.512	0.691
Apr	9.267	5.127	3.573	2.998	2.500	2.215	1.941	1.779	1.535	0.795
May	3.177	2.815	2.520	2.184	1.923	1.729	1.602	1.497	1.262	0.683
Jun	2.442	2.230	2.091	1.806	1.663	1.505	1.381	1.292	1.111	0.648
Jul	2.046	1.807	1.676	1.520	1.404	1.296	1.180	1.079	0.978	0.609
Aug	1.759	1.557	1.411	1.333	1.213	1.113	1.045	0.960	0.833	0.538
Sep	1.601	1.489	1.350	1.223	1.115	1.026	0.941	0.876	0.772	0.494