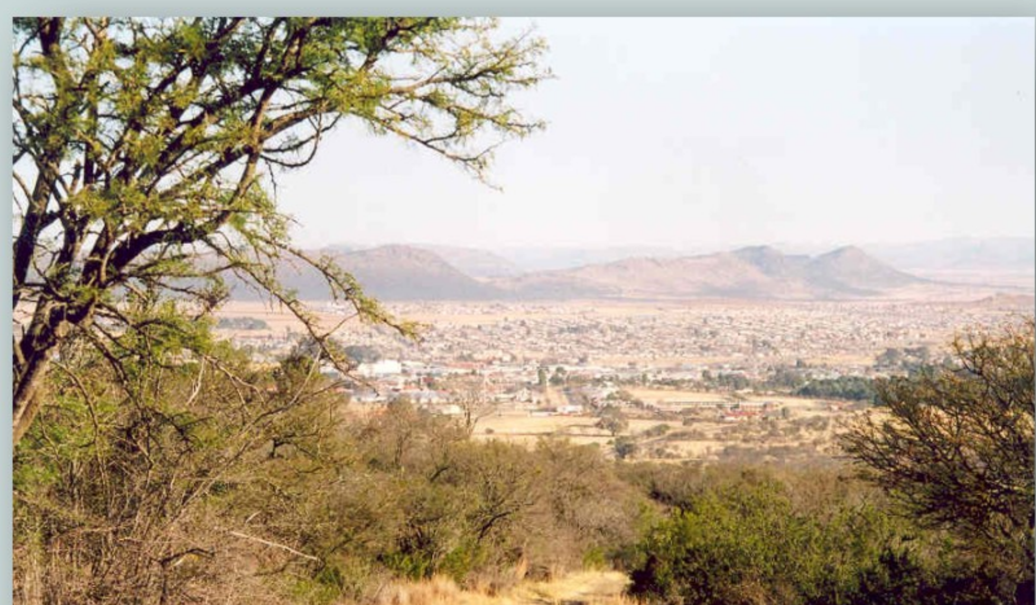
REPORT NO: P WMA 12/S00/3108

DEPARTMENT OF WATER AFFAIRS AND FORESTRY
DIRECTORATE OF OPTIONS ANALYSIS

LUKANJI REGIONAL WATER SUPPLY FEASIBILITY STUDY

APPENDIX 2: ECOLOGICAL RESERVE (QUANTITY) ON THE KEI RIVER



FINAL

IWR

January 2006

DEPARTMENT OF WATER AFFAIRS AND FORESTRY

DIRECTORATE OF OPTIONS ANALYSIS

LUKANJI REGIONAL WATER SUPPLY FEASIBILITY STUDY

APPENDIX 2

ECOLOGICAL RESERVE (QUANTITY) ON THE KEI RIVER

PREPARED BY

IWR Source-to-Sea
P O Box 122
Persequor Park
0020

Tel : 012 - 349 2991
Fax : 012 - 349 2991
e-mail : iwre@icon.co.za

FINAL

January 2006

Title	**:**	**Appendix 2 : Ecological Reserve (Quantity) on the Kei River**
Authors	**:**	**S Koekemoer and D Louw**
Project Name	**:**	**Lukanji Regional Water Supply Feasibility Study**
DWAF Report No.	**:**	**P WMA 12/S00/3108**
Ninham Shand Report No.	**:**	**10676/3842**
Status of Report	**:**	**Final**
First Issue	**:**	**February 2004**
Final Issue	**:**	**January 2006**

Approved for the Study Team :

……………………………………

M J SHAND
Ninham Shand (Pty) Ltd

DEPARTMENT OF WATER AFFAIRS AND FORESTRY

Directorate : Options Analysis

Approved for the Department of Water Affairs and Forestry by :

……………………………………

A D BROWN
Chief Engineer : Options Analysis (South)
(Project Manager)

……………………………………

L S MABUDA
Director

ACKNOWLEDGEMENTS

The following specialist contributed to and participated in the Kei Reserve Specialist meeting:

Drew Birkhead	Hydraulics	Streamflow Solutions
Anton Bok	Fish	Anton Bok & Associates
Denis Hughes	Hydrology	IWR Rhodes
Nigel Kemper	Riparian Vegetation	Integrated Environmental Assessments
Neels Kleynhans	Fish	DWAF, RQS
Delana Louw	Process specialist	IWR Source-to-Sea
Jay O'Keeffe	Facilitator	IWR Rhodes
Nico Rossouw	Water quality	Ninham Shand Consulting Services
Christa Thirion	Invertebrates	DWAF, RQS
Mandy Uys	Invertebrates	Laughing Waters
Roy Wadeson	Geomorphology	Private

DWAF (Resource Directed Measures Office) and Ninham Shand for their participation and contribution:

Rod Blackhurst	Ninham Shand
Alan Brown	DWAF
Thokozani Mbele	RDM Office
Retha Stassen	RDM Office

Program design and presentation of graphs and integration of specialist documents:

Delana Louw	IWR Source-to-Sea
Shael Koekemoer	IWR Source-to-Sea

Report Editing

Shael Koekemoer and Delana Louw IWR Source-to-Sea

The following specialist contributed to and participated in the Kei Reserve Specialist Report:

Chapter 1: Introduction and Background
Delana Louw

Chapter 2: Approach: Determination of stress indices
Delana Louw
Neels Kleynhans

Chapter 3: Approach: Ecological classification
Delana Louw
Neels Kleynhans

Chapter 4: Approach: Determination of IFR scenarios
Delana Louw
Neels Kleynhans

Chapter 5 – 16
Shael Koekemoer

Chapter 17:
Delana Louw
Neels Kleynhans
Christa Thirion

EXECUTIVE SUMMARY

BACKGROUND

The National Water Act (No. 36 of 1998) is based on the central guiding principles of sustainability and equity. Sustainability of resource use is to be ensured by the implementation of resource protection measures, including the application of the Ecological Reserve (the quality, quantity and reliability of water required to maintain the ecological functioning of aquatic ecosystems).

IWR Source-to-Sea was requested by Ninham Shand to undertake an Ecological Reserve Determination for the Quantity component on the Kei System at an Intermediate level for the major section of the study area using the Intermediate Ecological Reserve Methodology (IERM).

This report documents the proceedings of a specialist meeting during which the Ecological Water Requirement (quantity) Scenarios were determined.

STUDY AREA AND IFR SITES

The study area for the IERM included the Black Kei upstream of its confluence with the White Kei and downstream of its confluence with the Klaas Smits River, the White Kei River below Xonxa dam, Oxkraal River below the Oxkraal Dam, Klipplaat River below Waterdown Dam.

- IFR 1: Klipplaat River below Waterdown Dam.
- IFR 2: On the upper Black Kei River downstream of the Klaas Smits River confluence.
- IFR 3: On the lower Black Kei River above the White River confluence.
- IFR 4: On the White Kei River below the Xonxa Dam and below the Indwe River confluence.

ECOLOGICAL CLASSIFICATION

The process according to the current RDM specifications was applied. This process is under review. Very broadly the process consists of an assessment of reference conditions, the Present Ecological State (PES) (i.e. how far has the system moved from reference conditions and why), the Ecological Importance and Sensitivity (EIS) and the range of ECs which will then be addressed is specified. The results are provided below:

IFR sites	PES	EIS	REC	Alternative scenario	Alternative scenario
IFR 1	C	Moderate	C	B/C	D
IFR 2	D	Moderate	D	-	C
IFR 3	C/D	Moderate	C/D	B/C	D
IFR 4	C	Moderate	C/D	B/C	D

IFR SCENARIO RECOMMENDATIONS

IFRs represent the flow component of the Ecological Reserve. The method used during this study is a combination of the FS-R method (low flows), the Building Block Methodology and DRIFT (high flows). The FS-R indicates where natural stress has been decreased to the detriment of the natural ecosystem balance under present conditions.

The results are summarised in the following table as a % of the MAR.

IFR site	REC	IFR as % of present MAR	Alternative scenario (up)	IFR as % of present MAR	Alternative scenario (down)	IFR as % of present MAR
IFR 1	C	24.8	B/C	29.2	D	17.5
IFR 2	D	9.2	C	14.7	-	-
IFR 3	C/D	11.2	B/C	20.1	D	7.8
IFR 4	C/D	20.7	B/C	30.4	D	16

The confidence specialists have in their data and their recommendations in general varied from medium-low to medium-high.

ECOLOGICAL CONSEQUENCES OF OPERATIONAL FLOW SCENARIOS

The objective of this phase of the study was to determine the ecological (or more correctly biophysical) consequences of different flow scenarios at each IFR site.

During this assessment, consideration is given on whether the IFRs are available, can be managed or supplied as well as the impact on existing users. Various alterations of the IFR to achieve the same objective or EC are considered with the objective to recommend an optimised scenario (if available).

Flow scenarios were developed and tested whether the REC is met (see table below).

Y = yes; N = no

	PES	REC	SC1	SC2	SC3	SC4	SC5	NO IFR
IFR 1	C	C	Y	Y	Y	Y	Y	N (?)
IFR 2	D	D	Y	Y	Y	Y	Y	N
IFR 3	C/D	C/D	Y	Y	Y	Y	Y (?)	N (?)
IFR 4	C/D	C/D	N	Y	Y	Y(?)	N	N
Number of IFR sites where ecological objectives are achieved			3Y 1N	4Y	4Y	4Y(?)	3Y 1N	4N

Scenario 4, 5 and No IFR are the only practical scenarios to assess as they consider existing constraints. Of these scenarios, Scenario 4 has the least ecological impact as it meets the ecological objectives at all the IFR sites. The 'No IFR' scenario is not an acceptable scenario from an ecological point of view as it does not meet the REC at any site.

The Scenario 5 has the least impact on yield but cannot meet the REC at IFR 4 on the White Kei. For the Black Kei and Klipplaat River, Scenario 5 would be acceptable. A decision must be made comparing the socio-economic value and importance of the White Kei system compared to the Ecological Importance. Other factors such as the present use of Goods and Services as part of Resource Economics and the potential impact on this if the river is allowed to degrade, as well as the confidence in the IFR 4 assessment and the ecological consequences assessments should be considered to aid in the decision

LUKANJI REGIONAL WATER SUPPLY FEASIBILITY STUDY

KEI RIVER WATER QUALITY RESERVE DETERMIANTION

CONTENTS

1 INTRODUCTION AND BACKGROUND 1-1
1.1 Background...... 1-1
1.2 Study area 1-1
1.3 Purpose of this report...... 1-1
1.4 Outline of the report 1-2

2 APPROACH: DETERMINATION OF STRESS INDICES *(CHAPTER 5)* 2-1
2.1 Introduction 2-1
2.2 Fish (CJ Kleynhans) *(Chapter 5.1)*...... 2-1
2.2.1 Hydraulics input (A L Birkhead) 2-5
2.3 Invertebrates (M Uys & C Thirion) *(Chapter 5.2)* 2-6
2.4 Riparian Vegetation (N Kemper) 2-7
2.5 Natural and present day stress profiles...... 2-8

3 APPROACH: ECOLOGICAL CLASSIFICATION *(CHAPTER 6)* 3-1
3.1 General approach...... 3-1
3.2 Reference conditions *(Chapter 6.1)*...... 3-6
3.3 Present Ecologial State (PES) *(Chapter 6.2)* 3-6
3.3.1 Habitat Driver Status *(Chapter 6.2.1)* 3-6
3.3.2 Biological responses PES *(Chapter 6.2.2)* 3-8
3.3.3 Trajectory of change *(Chapter 6.2.3)* 3-11
3.3.4 PES Ecostatus *(Chapter 6.2.4)* 3-11
3.4 EIS *(Chapter 6.3)* 3-11
3.5 Range of ECS (*Chapter 6.4)* 3-11
3.6 Defining ecS (*Chapter 6.5)* 3-12

4 APPROACH: DETERMINATION OF IFR SCENARIOS *(CHAPTER 7)* 4-1
4.1 Low flow requirements *(Chapter 7.1)* 4-1
4.1.1 Component Integrated / System stress *(Chapter 7.1.1)*...... 4-1
4.1.2 Generating stress requirements *(Chapter 7.1.2)*...... 4-2
4.1.3 Provision of motivations for determining stress requirements...... 4-5
4.2 Approach to High Flows *(Chapter 7.2)* 4-7
4.3 Final results *(Chapter 7.3)* 4-10
4.4 Confidence evaluations of the results *(Chapter 7.4)* 4-10

5 IFR 1 – KLIPPLAAT RIVER: STRESS INDICES 5-1
5.1 Fish stress index 5-1
5.2 Aquatic invertebrates stress index 5-3
5.3 Riparian vegetation stress index 5-4

6 IFR 1 – KLIPPLAAT RIVER: ECOLOGICAL CLASSIFICATION 6-1
6.1 Reference conditions 6-1
6.2 PES 6-2
6.2.1 Habitat Driver Status...... 6-2
6.2.2 Biological Response PES 6-3
6.2.3 Trajectory of change 6-4
6.2.4 Ecostatus 6-4
6.3 EIS 6-4
6.4 Range of ECs...... 6-5
6.5 Defining ECs 6-5

7 IFR 1 – KLIPPLAAT RIVER: DETERMINATION OF IFR SCENARIOS 7-1
7.1 Low flow requirements 7-1
7.1.1 Component and integrated stress curves 7-1
7.1.2 Generating stress requirements 7-1
7.2 High flow requirements 7-3
7.3 Final Results 7-6
7.3.1 IFR table for recommended scenario: C REC 7-6
7.3.2 IFR table for alternative scenario: D EC 7-6
7.3.3 IFR table for alternative scenario: B/C EC 7-7
7.3.4 IFR rule table for recommended scenario: C REC 7-8
7.3.5 IFR rule table for alternative scenario: D EC 7-8
7.3.6 IFR rule table for alternative scenario: B/C EC 7-9
7.4 Confidence 7-9

8 IFR 2 – UPPER BLACK KEI RIVER: STRESS INDICES 8-1
8.1 Fish stress index 8-1
8.2 Aquatic invertebrates stress index 8-3

9 IFR 2 – UPPER BLACK KEI RIVER: ECOLOGICAL CLASSIFICATION 9-1
9.1 Reference conditions 9-1
9.2 PES 9-2
9.2.1 Habitat Driver Status 9-2
9.2.2 Biological Response PES 9-3
9.2.3 Trajectory of change 9-4
9.2.4 Ecostatus 9-4
9.3 EIS 9-4
9.4 Range of ECs 9-4
9.5 Defining ECs 9-5

10 IFR 2 – UPPER BLACK KEI RIVER: DETERMINATION OF IFR SCENARIOS 10-1
10.1.1 Component and integrated stress curves 10-1
10.1.2 Generating stress requirements 10-1
10.2 High flow requirements 10-3
10.3 Final Results 10-5
10.3.1 IFR table for recommended scenario: D REC 10-5
10.3.2 IFR table for alternative scenario: C EC 10-5
10.3.3 IFR rules for recommended scenario: D REC 10-6
10.3.4 IFR rules for alternative scenario: C EC 10-6
10.4 Confidence 10-7

11 IFR 3 – LOWER BLACK KEI RIVER: STRESS INDICES 11-1
11.1 Fish stress index 11-1
11.2 Aquatic invertebrates stress index 11-2

12 IFR 3 – LOWER BLACK KEI RIVER: ECOLOGICAL CLASSIFICATION 12-1
12.1 Reference conditions 12-1
12.2 PES 12-2
12.2.1 Habitat Driver Status 12-2
12.2.2 Biological Response PES 12-3
12.2.3 Trajectory of change 12-4
12.2.4 Ecostatus 12-4
12.3 EIS 12-4
12.4 Range of ECs 12-4
12.5 Defining ECs 12-5

13 IFR 3 – LOWER BLACK KEI RIVER: IFRS 13-1

13.1 Low flow requirements 13-1
13.1.1 Component and integrated stress curves 13-1
13.1.2 Generating stress requirements 13-1
13.2 High flow requirements 13-3
13.3 Final Results 13-6
13.3.1 IFR table for recommended scenario: C/D REC 13-6
13.3.2 IFR table for alternative scenario: D EC 13-6
13.3.3 IFR table for alternative scenario: B/C EC 13-7
13.3.4 IFR rule table for recommended scenario: C/D REC 13-8
13.3.5 IFR rule table for alternative scenario: D EC 13-8
13.3.6 IFR rule table for alternative scenario: B/C EC 13-9
13.4 Confidence 13-9

14 IFR 4 – WHITE KEI RIVER: STRESS INDICES 14-1
14.1 Fish stress index 14-1
14.2 Aquatic invertebrates stress index 14-2

15 IFR 4 – WHITE KEI RIVER: ECOLOGICAL CLASSIFICATION 15-1
15.1 Reference conditions 15-1
15.2 PES 15-2
15.2.1 Habitat Driver Status 15-2
15.2.2 Biological Response PES 15-3
15.2.3 Trajectory of change 15-4
15.2.4 Ecostatus 15-4
15.3 EIS 15-4
15.4 Range of ECs 15-4
15.5 Defining ECs 15-5

16 IFR 4 – WHITE KEI RIVER: IFRS 16-1
16.1 Low flow requirements 16-1
16.1.1 Component and integrated stress curves 16-1
16.1.2 Generating stress requirements 16-1
16.2 High flow requirements 16-3
16.3 Final Results 16-5
16.3.1 IFR table for recommended scenario: C/D REC 16-5
16.3.2 IFR table for alternative scenario: D EC 16-5
16.3.3 IFR table for alternative scenario: B/C EC 16-6
16.3.4 IFR rule table for recommended scenario: C/D REC 16-7
16.3.5 IFR rule table for alternative scenario: D EC 16-7
16.3.6 IFR rule table for alternative scenario: B/C EC 16-8
16.4 Confidence 16-8

17 ECOLOGICAL CONSEQUENCES OF OPERATIONAL FLOW SCENARIOS 17-1
17.1 Objectives 17-1
17.2 Evaluate impact of the IFRs on the yield of the system 17-1
17.3 Design of additional flow scenarios 17-1
17.4 Scenario 4 17-1
17.5 Scenario 5 17-2
17.6 Ecological evaluation of different flow scenarios 17-2
17.7 Ecological consequences: results 17-3
17.8 Conclusions 17-9

18 REFERENCES 18-1

LIST OF TABLES

Table 2.1 Illustration of a completed Flow-Depth class table 2-2
Table 2.2 Habitat suitability and the derived fish stress 2-3
Table 2.3 Fish stress index table 2-5
Table 2.4 Example of the matrix of discharge against habitat abundance using IFR Site 3 on the Little Thukela River 2-6
Table 2.5 Illustration of a completed Flow-Depth class's table 2-6
Table 2.6 Marginal Invertebrate Stress table 2-6
Table 2.7 Generic riparian vegetation stress table 2-7
Table 2.8 An example of a vegetation stress index for *Juncus* adults 2-8
Table 3.1 The sequence of actions required for providing technical information on the EC. The left hand column shows the question that the action in the right hand column is answering 3-1
Table 3.2 Guidelines for the range of ECs to be addressed *(under modification)* 3-2
Table 3.3 Driver Habitat State questions 3-7
Table 3.4 Fuzzy Fish Index (FFI) 3-9
Table 3.5 Aquatic invertebrate PES 3-10
Table 3.6 Riparian vegetation PES 3-10
Table 3.7 Fuzzy Fish Index used in a predictive manner 3-13
Table 3.8 Aquatic invertebrate table 3-13
Table 4.1 A summary of the flood class ranges, and the recommended high flow events for each scenario. 4-8
Table 4.2 High flows - Functions and associated critical hydraulic parameters 4-9
Table 4.3 The recommended high flow events for each scenario. 4-10
Table 4.4 Confidence table 4-11
Table 5.1 Stress table – Eurytopic fish species 5-1
Table 5.2 Stress table – Limnophilic fish species 5-2
Table 5.3 Stress table – Flow Dependent invertebrate's species 5-3
Table 5.4 Stress table – Riparian vegetation - Restionaceae 5-4
Table 6.1 Fuzzy Fish Index – IFR 1: PES 6-3
Table 6.2 Invert communities observed – IFR 1: PES 6-4
Table 6.3 Fuzzy Fish Index – IFR 1: Alternative ECs 6-6
Table 7.1 Flood Class ranges for IFR 1 7-4
Table 7.2 The number of high flow events required for each EC – IFR 1 7-5
Table 7.3 Confidence table – IFR 1 7-9
Table 8.1 Stress table – Eurytopic fish species 8-1
Table 8.2 Stress table – Limnophilic fish species 8-2
Table 8.3 Stress table – Marginal vegetation invertebrate species 8-3
Table 9.1 Fuzzy Fish Index – IFR 2: PES 9-3
Table 9.2 Invert communities observed during winter – IFR 2: PES 9-4
Table 9.3 Fuzzy Fish Index – IFR 2: Alternative EC 9-6
Table 10.1 Flood Class ranges for IFR 2 10-3
Table 10.2 Number of high flow events for each EC - IFR 2 10-4
Table 10.3 Confidence table – IFR 2 10-7
Table 11.1 Stress table – Limnophilic and Eurytopic fish species 11-1
Table 11.2 Stress table – Flow Dependent invertebrates species 11-2
Table 12.1 Fuzzy Fish Index – IFR 3: PES 12-3
Table 12.2 Invert communities observed – IFR 3: PES 12-4
Table 12.3 Fuzzy Fish Index – IFR 3: Alternative ECs 12-6
Table 13.1 Flood Class ranges for IFR 3 13-4
Table 13.2 Number of high flow events required for each EC – IFR 3 13-5
Table 13.3 Confidence table – IFR 3 13-9
Table 14.1 Stress table – Limnophilic and Eurytopic fish species 14-1
Table 14.2 Stress table – Flow Dependent invertebrate species 14-2
Table 15.1 Fuzzy Fish Index – IFR 4: PES D 15-3
Table 15.2 Invert communities observed – IFR 4: PES C/D 15-4

Table 15.3 Fuzzy Fish Index for Alternative ECs 15-6
Table 16.1 Flood Class ranges for IFR 4 16-3
Table 16.2 High flow events required for each EC – IFR 4 16-4
Table 16.3 Confidence table – IFR 4 16-8
Table 17-1 Fish and aquatic invertebrate categories for low flows 17-4
Table 17-2 Instream Ecostatus for each flow scenario at each IFR site 17-5
Table 17-3 Summary of the number of IFR sites where the REC can be met 17-9

LIST OF FIGURES

Figure 1-1 Study area 1-1
Figure 3-1 Illustration of the distribution of Ecological Categories on a continuum and the relationship with Management Classes 3-2
Figure 3-2 Flow diagram illustrating the information generated to determine the EC 3-3
Figure 3-3 Flow diagram illustrating the information generated to determine the EC 3-6
Figure 3-4 EC figure 3-12
Figure 4-1 Component and integrated/stress curves 4-1
Figure 4-2 Conversion from component stress to integrated stress 4-2
Figure 4-3 A comparison between flow duration and stress duration graphs 4-3
Figure 4-4 Sequence of steps followed during the determination of stress requirement (This graph is not related to any specific river and serves as an example) 4-5
Figure 4-5 The hand-drawn line representing a band of flow/stress requirements from the individual specialists 4-7
Figure 4-6 The final curve 4-7
Figure 5-1 IFR 1: 15 July 2003, 0.24m^3/s 5-1
Figure 6-1 IFR 1 – Ecological categories 6-5
Figure 7-1 Component and integrated stress curves 7-1
Figure 7-2 IFR 1 – Stress duration curve for a recommended scenario of a C REC 7-2
Figure 7-3 IFR 1 – Stress duration curve for an alternative scenario of a D EC 7-2
Figure 7-4 IFR 1 – Stress duration curve for an alternative scenario of a B/C EC 7-3
Figure 7-5 IFR 1 – Final curve 7-3
Figure 8-1 IFR 2: 15 July 2003, 0.36m^3/s 8-1
Figure 9-1 IFR 2 – Ecological categories 9-5
Figure 10-1 Component and integrated stress curves 10-1
Figure 10-2 IFR 2 – Stress duration curve for a recommended scenario of a D REC 10-2
Figure 10-3 IFR 2 – Stress duration curve for a alternative scenario of a C EC 10-2
Figure 10-4 IFR 2 – Final curve 10-3
Figure 11-1 IFR 3, 14 July 2003, 0.16m^3/s 11-1
Figure 12-1 IFR 3 – Ecological categories 12-5
Figure 13-1 Component and integrated stress curves 13-1
Figure 13-2 IFR 3 – Stress duration curve for a recommended scenario of a C/D REC 13-2
Figure 13-3 IFR 3 – Stress duration curve for an alternative scenario of a D EC 13-2
Figure 13-4 IFR 3 – Stress duration curve for an alternative scenario of a B/C EC 13-3
Figure 13-5 IFR 3 – Final curve 13-3
Figure 14-1 IFR 4: 15 July 2003, 1.07m^3/s. 14-1
Figure 15-1 IFR 4 – Ecological categories 15-5
Figure 16-1 Component and integrated stress curves 16-1
Figure 16-2 IFR 4 – Stress duration curve for a recommended scenario of a C/D REC 16-1
Figure 16-3 IFR 4 – Stress duration curve for an alternative scenario of a D EC 16-1
Figure 16-4 IFR 4 – Stress duration curve for an alternative scenario of a B/C EC 16-2
Figure 16-5 IFR 4 – Final curve 16-2
Figure 17-1 Ecological consequences of various flow scenarios at IFR 1 17-7
Figure 17-2 Ecological consequences of various flow scenarios at IFR 2 17-7
Figure 17-3 Ecological consequences of various flow scenarios at IFR 3 17-8
Figure 17-4 Ecological consequences of various flow scenarios at IFR 4 17-8

LIST OF APPENDICES

APPENDIX A:	IFR site selection and IFR sites
APPENDIX B:	Kei River delineation report
APPENDIX C:	Geomorphological classification
APPENDIX D:	Geomorphological aerial photographic analysis of the Kei Reserve study
APPENDIX E:	An assessment of the Intermediate Habitat Integrity for the Kei River system
APPENDIX F:	Fish
APPENDIX G:	Ecological Importance and Sensitivity
APPENDIX H:	Low flow requirements and flood classes
APPENDIX I:	River hydraulics
APPENDIX J:	Ecological consequences of Flow scenarios
APPENDIX K:	Operation of the Upper Kei Water Supply System

LIST OF TERMS AND ACRONYMS

ASPT	Average Score Per Taxon
BBM	Building Block Methodology
DRIFT	Downstream Response to Imposed Flow Transformations
DWAF	Department: Water Affairs and Forestry
EC	Ecological Category
EIS	Ecological Importance and Sensitivity
ERC	Ecological Reserve Category
EWR	Ecological Water Requirement
FFI	Fuzzy Fish index
FS-R	Flow Stressor Response
HSI	Habitat Suitability Index
IERM	Intermediate Ecological Reserve Methodology
IFR	Instream Flow Requirement
Imp	Importance
MAR	Mean Annual Runoff
PES	Present Ecological State
RDM	Resource Directed Measures
REC	Recommended Ecological Category
RU	Resource Units
SASS	South African Scoring System
SI	Socio-cultural Importance
Traj	Trajectory

1 INTRODUCTION AND BACKGROUND

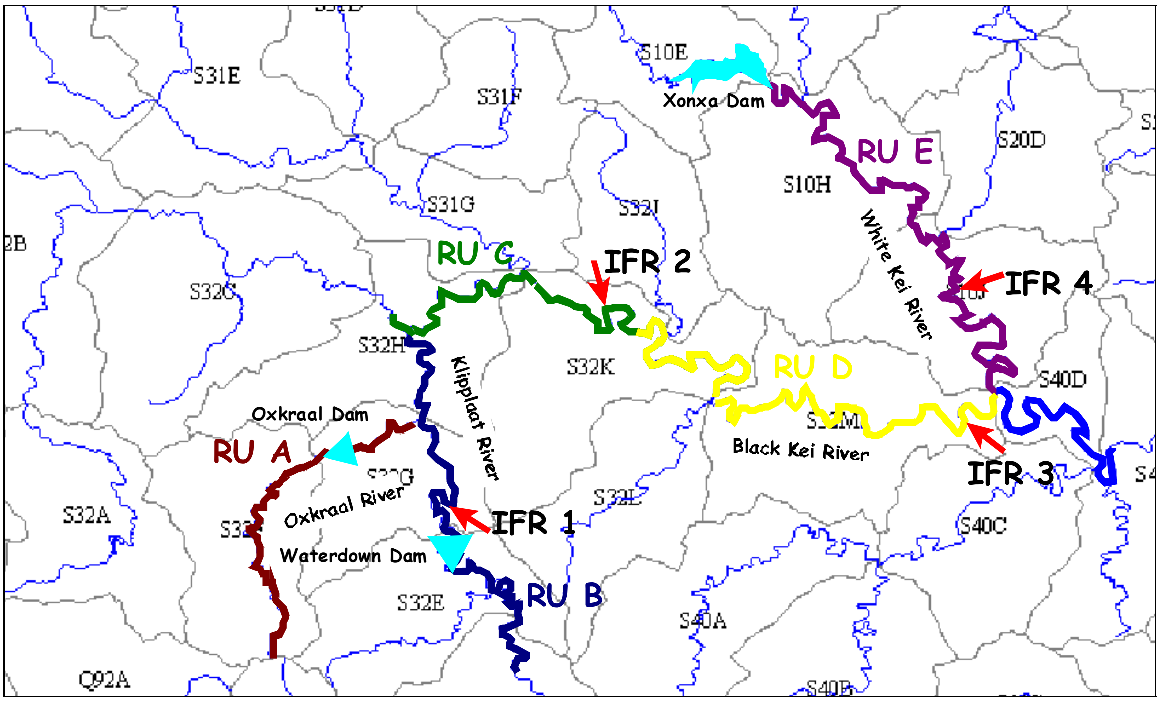
1.1 BACKGROUND

IWR Source-to-Sea was requested by Ninham Shand to undertake an Ecological Reserve determination for the Quantity component on the Kei System at an Intermediate level for the major section of the study area using the Intermediate Ecological Reserve Methodology (IERM). This study forms part of the Lukhanji Regional Water Supply Study.

1.2 STUDY AREA

The study area for the IERM (Figure 1-1) included the Black Kei upstream of its confluence with the White Kei and downstream of its confluence with the Klaas Smits River, the White Kei River below the Xonxa dam, the Oxkraal River below the Oxkraal Dam and the Klipplaat River below the Waterdown Dam. The system operation of the study area is described in ref (DWAF, 2005).

Figure 1-1 Study area



Note: The RUs are discussed in Appendix B.

1.3 PURPOSE OF THIS REPORT

This report serves as the documentation of the results of a specialist meeting held during 29 September to 3 October 2003 to recommend the Ecological Category and associated Instream Flow Requirements (IFRs). The quantity component only was addressed. Input from the quality specialist was provided to determine ecological status. The quality component is however addressed separately (DWAF, 2005, Appendix 3).

The purpose of the report is to

- Document the approach followed.
- Provide the sequential actions undertaken during the specialist meetings to produce the results and to provide a detailed explanation of format of the report chapters for each IFR site in which the results are provided.
- Provide all the results for each IFR site.

1.4 OUTLINE OF THE REPORT

The report is outlined as follows:

Chapter 1: Introduction and Background
This chapter

Chapter 2: Approach: Determination of stress indices
This chapter provides an explanation of the approach followed during the determination of stress indices for all the components at the four IFR sites. The chapters providing the results are used as an example and on explanation for each chapter section is provided.

Chapter 3: Approach: Ecological classification
This chapter covers the general approach to the sequential steps followed in the Ecological Classification. The approach to defining the reference conditions, PES, trajectory of change and Ecological Category for each biological component is provided.

Chapter 4: Approach: Determination of IFR scenarios
This chapter provides the general approach to the determination of different IFR scenarios with respect to low and high flows. Aspects covered in this chapter are component and integrated stress curves, generating stress requirements, general approach to high flows, final results and confidence in the final results.

Chapter 5 – 16
The results, of the process described in chapters 2 to 4, are provided for each IFR site.

Chapter 17: Ecological consequences of operational flow scenarios
The ecological evaluation of different flow scenarios for each site is discussed as well as the ecological consequences results.

Chapter 18: References

---

2 APPROACH: DETERMINATION OF STRESS INDICES *(CHAPTER 5)*

This chapter, as well as Chapter 3 and 4, provide an explanation of the overall approach followed to provide the quantity component (Instream Flow Requirements (IFRs)) of the Ecological Water Requirements Scenarios (EWRs) for the Lukhanji Regional Water Supply Study. The Flow-Stress Response method (FS-R) (O'Keeffe *et al*, 2002) was used to provide the low flows, and a method adjusted from the standard Building Block Methodology (BBM; King & Louw, 1998) and Downstream Response to Imposed Flow Transformation (DRIFT; Brown, C & King, J., 2001) approach was followed to set high flows. It is not the function of this report to provide the in-depth scientific rationales for these methods (which are available in scientific journals, as referenced).

The step-by-step method followed to provide the final flow recommendations for each IFR site is documented only in this chapter. The results for each site are then recorded on a chapter-by-chapter basis. The approach followed in producing the results is explained section-by-section. Chapter 5, 6 and 7 are used as an example and the relevant section numbers are in brackets.

2.1 INTRODUCTION

A site-specific index of zero (no stress or optimum habitat) to 10 (maximum stress or no habitat) was designed for fish, invertebrates and, in some cases, riparian vegetation. The approach for the instream biota is to scale the habitats (type and abundance) according to a flow-depth scale (zero to 10). The biotic response to these habitat conditions is then calculated and then the associated stress.

The tools used to determine the stress indices were the following:

- Hydraulics.
- Photos and videos of various flow conditions.
- Habitat modelling.
- Geomorphological information.
- Fish survey results and historical information.
- Aquatic invertebrate survey results and historical information.
- Vegetation surveys on profile and habitat modelling cross-sections.

The stress indices for each site are provided in the spreadsheets (Appendix H). The general approaches followed for the instream components are described in the following sections.

2.2 FISH (CJ KLEYNHANS) *(CHAPTER 5.1)*

The interpretation is based on a number of assumptions and principles:

- That flow is directly related to the processes (geomorphological) that provide the habitat that fish require during various stages of their life cycle (spawning, larvae, ova, sub-adults, adults). Flows are interpreted in broad categories in terms of flow (velocities) and depth:
  Slow (<0.3m/s), Deep (>0.5m)
  Slow (<0.3m/s), Shallow (<0.3m)
  Fast (>0.3m/s), Deep (>0.5m)
  Fast (>0.3m/s), Shallow (<0.3m)
- Habitat also involves the cover that fish species require. Cover (shelter) are indirectly or directly related to flow and are assessed as follows:
  Overhanging vegetation
  Undercut banks and root wads
  Substrate
  Water column
  Aquatic macrophytes

The responses of flow-depth classes can be generalised by the following Excel tables. The explanations of the tables are provided in the blocks surrounding the table:

Table 2.1 Illustration of a completed Flow-Depth class table

FAST-DEEP: DEPTH > 0.3m; VELOCITY >0.3 m/s

FAST-SHALLOW: DEPTH <0.3 m; VELOCITY >0.3 m/s

SLOW-DEEP: DEPTH >0.5 m; VELOCITY <0.3 m/s

SLOW-SHALLOW: DEPTH <0.5 m; VELOCITY <0.3m/s

0=Absent;
1=Rare (<5%);
2=Sparse (5-25%);
3=Moderate (25-75%);
4= Abundant (75-90%);
5=Very abundant (>90%)
(modified from Rankin 1995)

Depending on the size of the river, a site with a low percentage of a particular depth-flow class can still actually cover a substantial area at a site. A low rating would be unrealistic in such a situation. This is compensated for by judging the qualitative value of depth-flow classes for fish. Percentage of area covered was mainly used, therefore, as a guideline in this estimation.

(1) Overhanging vegetation - thick vegetation overhanging water by approximately 0.3 m and not more than 0.1 m above the water surface (Wang et al. 1996).

Undercut banks and root wads - banks overhanging water by approximately 0.3 m and not more than 0.1 m above the water surface (Wang et al. 1996).

Stream substrate - the degree to which various substrate components (rocks, boulders, cobbles, gravel, sand, fine sediment and woody debris ("snags")) provide cover for fish are judged qualitatively. No detail assessment of the stream substrate and estimation of the contribution of individual components are attempted.

Related to the water depth and dependant on the species (and its size).

Aquatic macrophytes - submerged and emergent plants were included and a qualitative estimate made of the cover value for fish.

These features are considered to provide fish with the necessary cover (e.g. refuge from high flow velocity, predators, high temperatures, etc.) to utilise a particular flow and depth class.

RIVER: Black Kei SITE: IFR 2 DATE: 19-08-03

FLOW (m^3/s)	RELATIVE FLOW-DEPTH							
	FAST DEEP	1	FAST	1	SLOW DEEP	4	SLOW	3
17	COVER TYPES ASSOCIATED WITH EACH FLOW-DEPTH CLASS							
	Overhanging	1	Overhanging	3	Overhanging	3	Overhanging	2
	Undercut banks	1	Undercut banks	2	Undercut banks	2	Undercut banks	2
	Substrate:	3	Substrate:	3	Substrate:	1	Substrate:	3
	Water Column:	0	Water Column:	0	Water Column:	2	Water Column:	0
	Aquatic macrophytes:	1	Aquatic macrophytes:	3	Aquatic macrophytes:	1	Aquatic macrophytes:	3
	Remarks:		Remarks:		Remarks:		Remarks:	
	Approx Width classes: 1-2m=1; 2-4m=2; 4-8m=3; 8-10m=4; 10-15m=5; >15m=6	3	Approx Width classes: 1-2m=1; 2-4m=2; 4-8m=3; 8-10m=4; 10-15m=5; >15m=6	3	Approx Width classes: 1-2m=1; 2-4m=2; 4-8m=3; 8-10m=4; 10-15m=5; >15m=6	5	Approx Width classes: 1-2m=1; 2-4m=2; 4-8m=3; 8-10m=4; 10-15m=5; >15m=6	3

Table 2.2 Habitat suitability and the derived fish stress

Species requering fast flow during certain phases of the life-cycle, I.e. to breed in particular habitats and to make nursery areas with suitable cover available. Generally, increased habitat suitability and availability resulting from increased flow, can be expected to benefit such species. Flow will stimulate breeding activities and stimulate migration.

With some species, breeding can take place without any increase in flow. Some species may require some increase in level of SD or SS habitat to make overhanging vegetation/aquatic macrophytes effective and available as breeding and nursery areas.

Suitability rating for different requirements
None =0;
Poor=1;
Low=2;
Moderate=3;
High=4;
Very High=5

Species requiring fast flow during all phases of the

IFR 2 **19-08-03**

FISH SPECIES RESPONSES: HABITAT SUITABILITY FOR DIFFERENT LIFE-STAGE REQUIREMENTS

Rheophilic spp =		Semi-rheophilic spp	B aeneus	Non-rheophilic spp	B. anoplus
Breeding and early life-stages=		Breeding and early life-stages=	1	Breeding and early life-stages=	2
Survival /Abundance =		Survival /Abundance =	2	Survival /Abundance =	3
Cover =		Cover =	2	Cover =	4
Health and condition=		Health and condition=	3	Health and condition=	4
Water quality=		Water quality=	4	Water quality=	4
Habitat flow stress response with breeding requirements	10	**Habitat flow stress response with breeding requirements**	5.2	**Habitat flow stress response with breeding requirements**	3.2
Habitat flow stress response without breeding requirements	10	**Habitat flow stress response without breeding requirements**	4.5	**Habitat flow stress response without breeding requirements**	2.5

Fast flow will stimulate breeding activities in suitable substrate. Slower flowing patches within fast areas (also edges) important as nursery areas for larvae.

Fast flowing habitats with suitable cover (often substrate related) is required for survival and abundance. Connectivity between fast flowing habitats is also essential (e.g. sufficient depth, cover and velocity).

Cover is often related to abundance of suitable substrate in fast flowing habitat. Increased flows will generally enhance cover over suitable substrate.

Increased flows can be expected to enhance feeding conditions and prevent high population concentrations which will limited spreading of diseases and parasites. High base flows will generally be associated with lowered physiological stress conditions.

Flow related water quality: mainly related to flow-depth, temperature and oxygen concentrations. Based on the premise that lower base flows will tend to lead to increased water temperatures and lowered oxygen concentrations.

Fast flow will stimulate breeding activities in suitable substrate. Slower flowing habitats (also patches and edges within fast flowing areas) important as nursery areas for larvae.

Flow related water quality: mainly related to flow-depth, temperature and oxygen concentrations. Based on the premise that lower base flows will tend to lead to increased water temperatures and lowered oxygen concentrations.

Increased flows can be expected to enhance feeding conditions and prevent high population concentrations which will limited spreading of diseases and parasites. High base flows will generally be associated with lowered physiological stress conditions.

With some species, breeding can take place without any increase in flow. Some species may require some increase in level of SD or SS habitat to make overhanging vegetation/aquatic macrophytes effective and available as breeding and nursery areas.

Slow flowing habitats with suitable cover (often overhanging vegetation, aquatic macrophtyes and water column) enhances survival and abundance. Connectivity between slow flowing habitats will enhance surivival and abundance (e.g. escape routes).

Cover is related to overhanging vegetation, undercut banks, water column and macrophytes in slow flowing habitat. Increased flows (and water levels) will generally enhance these cover types.

Increased flows can be expected to enhance feeding conditions and prevent high population concentrations which will limited spreading of diseases and parasites. High base flows will generally be associated with lowered physiological stress conditions.

Flow related water quality: mainly related to flow-depth, temperature and oxygen concentrations. Based on the premise that lower base flows will tend to lead to increased water temperatures and lowered oxygen concentrations.

Fast flowing and slow flowing habitats with suitable cover (often substrate or water column) is required for survival and abundance. Connectivity between fast flowing and slow flowing habitats may also be important (e.g. depending on the species, sufficient depth, cover and velocity).

Depending on the species, cover is related to abundance of suitable substrate in fast flowing habitat or overhanging vegetation, undercut banks, water column and macrophytes in slow flowing habitat. Increased flows (and water levels) will generally enhance these cover types.

In Table 2.1 the habitats are rated as well as the cover for a specific flow. In Table 2.2 the suitability rating for different requirements are rated and a stress calculated. The stress is calculated using the following approach:

Habitat suitabilities for a particular species (i.e. with reference to the preferences and requirements of the "target" species during different life-stages) were rated on the basis of expert knowledge, based on a simplified habitat suitability index (HSI) calculated as proposed by Stuber, Gebhart and Maughan (1982). This method makes use of the suitability of various habitat characteristics to fulfil the life-stage requirements of the "target" species. The suitability of the habitat (flow-depth class and cover) under various flow conditions was scored for each of the following:

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

Suitability scoring followed the following guidelines:

Very high = 5; High = 4; Moderate = 3; Low = 2; Poor = 1; None = 0

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

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

Where assessment needs to be done outside the breeding season (dry season), the HSI can be calculated by excluding suitability for breeding requirements:

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

The average HSI score is expressed as a proportion of 10 and then transformed (reversed) to relate a high score out of 10 to a low suitability, and vice versa, e.g. 0 would indicate completely suitable conditions while 10 would indicate completely unsuitable conditions.

The tables are used in the following sequential way:

- During every site visit the above tables are completed. Note that the completion of these tables is only of any use if the flow is known during the site visit.
- This then provides a habitat rating and associated fish stress at one or more flows which provides a calibration for the rest of the information.
- During the specialist meeting, these tables are completed for other flows. The first priority would be to rate those flows for which photographs and known flows are available.
- During the specialist meeting, these flows and habitat scores are verified by the hydraulician. I.e., the habitat abundances are estimated by the fish specialist according to what they visualise, and secondly by what they experience if they are undertaking a fish survey. The hydraulician has more quantitative means at his disposal and can therefore check the rating.
- To complete the rest of the table, input from the hydraulician is required (see section below). The hydraulics specialist provides flows which would result in the range of flow depth classes required to complete the 0 - 10 flow depth scale. An interactive process follows, and once agreement on the flow for a specific flow depth scale is reached, the above tables are completed for those flows and the stresses derived.

The final stress index is provided in the following format.

Table 2.3 Fish stress index table

Flow-Depth Response index	Habitat abundance and suitability				Limnophilic and Eurytopic combined		
	FD	FS	SD	SS	Response: Abundance	Species stress	Flow (m^3/s)
0	5	5	5	5	All very abundant	0	
1	4	5	5	5	All very abundant	0	
2	4	4	5	5	All very abundant	0	
3	3	4	5	5	All very abundant	0	
4	2	3	5	5	All very abundant	2	1
5	2	2	4	5	Abundant	3	0.36
6	1	2	3	4	Moderate	4	0.17
7	0	2	2	3	Low	6	0.1
8	0	1	1	2	Low	7	0.05
9	0	0	0	1	Rare	9	0
10	0	0	0	0	None	10	0

2.2.1 Hydraulics input (A L Birkhead)

The approach followed to assess the habitat-flow-response of fish to various low flows during the dry season (i.e. outside the breeding season) and during the wet season (breeding season) is explained here. It attempts to relate the stress response of fish species to altered flows, based on:

- The habitat and cover preferences of fish species. This is based on available literature, as well as expert knowledge.
- The responses of various broadly defined fish habitat attributes to different base-flows. This assessment is based on interpretation of hydraulic characteristics of the habitats at the site being investigated. This was done with the assistance and guidance of a hydraulician.
- Where habitat modelling is available, this information is used in conjunction with the hydraulics as an additional source of information that can lead to a more reliable interpretation of fish habitat conditions.

A matrix of discharge against habitat abundance (based on modelled depth and velocity) was developed (e.g. Table 2.4, an example from IFR Site 3 on the Little Thukela River). The depth and velocity threshold values corresponding to discharge values of 11.0, 3.1, 0.37 and 0.1m^3/s are shaded in Table 2.4. Note that the average velocity in the rapid unit is estimated to be half the maximum value. It is for this reason that the average velocity of 0.15 m/s (Q = 0.10 m^3/s) in the rapid is shaded - since this corresponds to the flow below which all fast flowing (> 0.3m/s) habitat disappears.

For each of these flows, abundance ratings are estimated for the site for all four flow-depth categories. The slow-velocity categories are expected to disappear at high discharges, and the fast-velocity categories at low discharges. It is therefore expected that discharge-habitat type matrices (when given in the format of Table 2.4) will have higher abundance values on the diagonal. Other pertinent discharge values (corresponding to, for example, linear interpolations in flow depth or velocity) between these "threshold values" (e.g. 1.0 and 9.0 m^3/s, and including the cessation of flow condition) are also included in the matrix and habitat abundance ratings estimated based on available hydraulic information.

Table 2.4 Example of the matrix of discharge against habitat abundance using IFR Site 3 on the Little Thukela River

Discharge Q (m^3/s)	Rapid			Pool			Habitat type abundance			
	y	y_{av}	v	y	y_{av}	v	FD	FS	SD	SS
11.0	0.79	0.48	1.60	2.50	1.62	0.30	5	2	0	1
9.0	0.75	0.44	1.45	2.42	1.56	0.26	4	2	1	1
3.1	0.66	0.36	1.04	2.23	1.41	0.16	3	3	3	2
1.0	0.43	0.22	0.47	1.91	1.18	0.04	2	3	4	2
0.37	0.43	0.18	0.29	1.80	1.10	0.02	1	2	4	3
0.10	0.34	0.11	0.15	1.72	1.05	0.01	0	1	3	3
0.00	0.24	0.00	0.00	1.61	0.96	0.00	0	0	2	3

y = flow depth (m) y_{av} = average flow depth (m) v = average velocity (m/s)

2.3 INVERTEBRATES (M UYS & C THIRION) *(CHAPTER 5.2)*

The process for invertebrates has not yet been developed in the same way as for the fish. During this study, a first attempt was made to follow a habitat-response approach. Further development, refinement and testing will still be required.

Table 2.5 was developed for use during the site visit to rate a specific condition (in this case a flow of 0.17m^3/s). During the specialist meeting the rest of the flow-depth responses, shown in Table 2.6, are completed with the aid of the cross-sections, photos, habitat models and the hydraulician.

Table 2.5 Illustration of a completed Flow-Depth class's table

Flow-Depth Response	Habitat abundance and suitability					Modifier	Flow (m^3/s)	Habitat response**
	SIC	SOC	MVIC	MVOC	GS pool			
Observation*	3	4	2	2	3			
	2	3	2	1	3	Boulders embedded, filamentous algae, vegetation stems only (out of current).	0.17	SIC habitat reduced by embeddedness. SOC habitat reduced due to algal covering over cobbles and some boulders. MV only roots and base of stems. SIC average depth 0.13m. If flow reduced by depth of 5-20cm, will alter SIC to SOC. Flow removed from the exposed surfaces of boulders will remove SIC altogether. For MVIC: A reduction in depth of 15cm will expose stems (in the MVIC area). For MVOC, only root zone submerged at present.

* Estimate of the site
** Findings after calibration

Table 2.6 Marginal Invertebrate Stress table

Flow-Depth Response index	Habitat abundance and suitability					Flow (m^3/s)	Depth (m)	Velocity (m/s)	Habitat response (specific to site)	Biotic response	Species stress
	SIC	SOC	MVIC	MVOC	GS pool					MV Inverts (Based on Kleynhans, 1999)	
0	5	5	5	5	5	2	0.75	0.46	All habitats in excess, very high quality.	MVIs Abundant 1	1
1	5	5	4	4	4	1.5	0.7	0.39	All habitats plentiful, very high quality.		
2	4	4	4	3	3				SIC and VIC sufficient, quality slightly reduced.	Slight reduction for MVIs: Abundant 2	
3	3	4	3	3	3	0.35	0.51	0.17	Reduced SIC and VIC, Reduced quality.	Further reduction for MVI species: Moderate 4	4
4	3	4	3	2	3				SIC and VIC limited, of moderate quality.		
5	2	3	2	2	3	0.17	0.44	0.12	SIC and VIC very reduced, of moderate quality.	Sensitive MVI species: Low 6	6

Flow-Depth Response index	Habitat abundance and suitability					Flow (m^3/s)	Depth (m)	Velocity (m/s)	Habitat response (specific to site)	Biotic response	Species stress
	SIC	SOC	MVIC	MVOC	GS pool					MV Inverts (Based on Kleynhans, 1999)	
6	2	3	1	1	2				SIC and VIC residual and of low quality		
7	1	2	0	1	2				No VIC, Some VOC, little SIC.	All MVI species: Rare 7	
8	1	2	0	0	2	0.02	0.28	0.05	Flowing water present, little SIC, no VIC.	Only pool dwellers: MVIs absent: None 9	9
9	0	1	0	0	1	0	0.2	0.03	No surface flow.		
10	0	0	0	0	0	0			No surface water.	None	10

2.4 RIPARIAN VEGETATION (N KEMPER)

The critical vegetation components were selected based on their life history characteristics dependence on water and location relative to the river and available riparian habitats. J*uncus* is the dominant species at all sites and, depending on its location and extent at each site, it was used as an indicator species if possible.

Juncus usually occurs in riparian areas in large vegetative mats. Its reproductive success is mainly achieved by vegetative growth achieved by the extension of the rhizome into viable marginal and instream habitats. This strategy affords *Juncus* the ability to optimise its contact with the river as well as to locate itself in areas less disturbed by higher flows. *Juncus* also reproduces by seeds which are produced on extended inflorescences mainly during the summer months. The seeds are probably water borne.

The stress levels of the critical components of *Juncus* were investigated in relation to a range of river flows and associated water levels and available habitats.

Generic vegetation stress tables (Table 2.7) were compiled for stress levels from 0 (no stress) to 10 (maximum stress).

Table 2.7 Generic riparian vegetation stress table

Stress	Life history stages / characteristics	
	Adults	Juveniles
0	Complete health and reproductive vigour.	Germination and establishment of seedlings.
1		
2		
3	First signs of water stress.	Growth reduced or terminated.
4	Flower/fruit abortion.	Moderate wilting.
5	Leaf wilting.	
6	Thinning or partial death of above-ground biomass.	Severe wilting.
7	Complete loss or death of above-ground biomass, but rootstock remains viable.	
8	Complete death including rootstocks.	Desiccation/death.
9		
10	Stress levels of 10 were identified to occur when water levels fell below the maximum rooting depth of individuals. This would most likely occur during low flows in summer months when individuals are active and growing. Stress is less likely to occur during winter months, as the individuals are dormant.	

Stress response tables were constructed for the critical components for various levels of stress corresponding with different river flows.

The generic vegetation index was applied for *Juncus* adults occurring in the marginal zone and on islands within the active channel, also in a site-specific manner. An example of the stress index is shown in Table 2.8.

Table 2.8 An example of a vegetation stress index for *Juncus* adults

Flow (m^3/s)	Depth (m)	Response	Motivation	Stress
1	0.4	Complete health and reproductive vigour	A stress of 0 would occur if water reached the base of the above- ground biomass. Most of roots located in saturated ground.	0
0.8	0.38	Good health and reproductive vigour	Water levels well within rooting depth of individuals.	1
0.5	0.34	First signs of water stress	Large percentage of roots not in contact with water.	3
0.35	0.32	Leaf wilting or loss	Most of roots are exposed except for root tips.	5
0	0.1	Death of both above ground and below ground biomass.	Maximum stress levels occur when water levels are reduced below the maximum root depth of the adults would result in stress levels of 8 - 10. Roots no longer have contact with water.	8

2.5 NATURAL AND PRESENT DAY STRESS PROFILES

The modelled natural flow (either monthly or daily pending data availability) and observed/historical present day is converted to stress using the different stress indices as provided above. If observed/historical present day data is not available, then modelled present day data is used. (Note: The available hydrology to use for the present day situation, whether modelled or observed, must be assessed to determine what is most likely to represent the conditions which the biota have been, and could still be, reacting to).

The wet and dry season profiles are printed out and provided to specialists. Specialists then determine whether these represent the expected stress conditions under natural flow conditions. This, in essence, represents a hydrological check of the stress indices.

3 APPROACH: ECOLOGICAL CLASSIFICATION *(CHAPTER 6)*

3.1 GENERAL APPROACH

This process has been developed through consulting projects only such as the Olifants and Thukela Reserve Studies. Problems with these applications have been indicated and a dedicated development (referred to as the Ecostatus project) to address these problems is now taking place as a DWAF, RQS study managed by Dr Kleynhans in association with IWR S2S. Where new processes have been available, they have been used within the Kei Study. As the two studies were running parallel with the Ecostatus project ending later than the Kei Study, some components of the Ecostatus project still had to be developed. In these cases, the process reverted to the old methods.

The general process and principles of the method have however remained unchanged and are presented below:

The objective of the Ecological classification is to create an understanding of the Present Ecological State and ecological functioning of the river and estuary and, based on this, to set realistic ecological aims/objectives. This information is necessary as a scenario approach is followed and suites of ecological aims or ecological states therefore have to be described. For each of these, a flow scenario must be described.

Ecological classification must not be confused with the Classification System to determine Management Classes. It forms a component of the Classification System which considers a much wider suit of components than just ecological.

The sequential steps followed in Ecological Classification are shown in Table 3.1

Table 3.1 The sequence of actions required for providing technical information on the EC. The left hand column shows the question that the action in the right hand column is answering

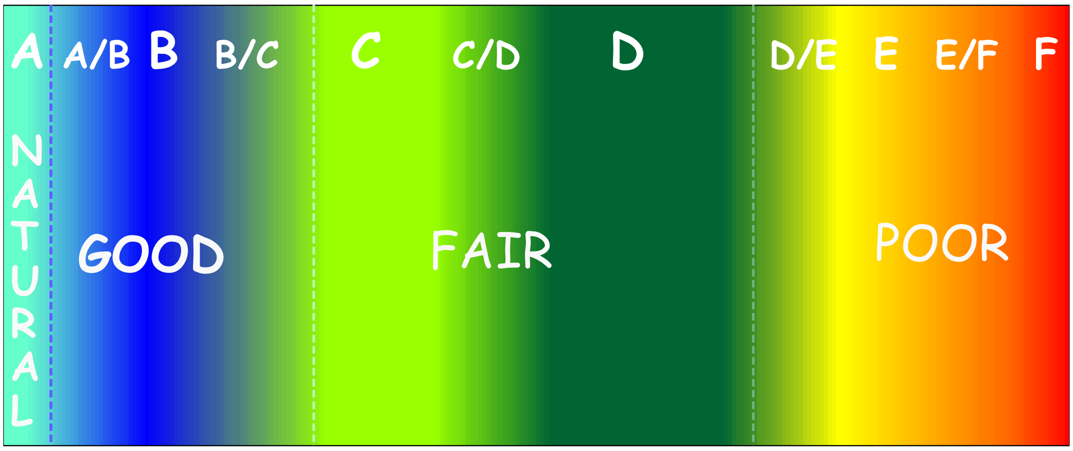
QUESTION	ACTION
What was the river like before human impact?	1. DETERMINE REFERENCE CONDITIONS.
Compared to what the river used to look like, what does it look like now?	2. DETERMINE PES. (Category A - F).
Is the river changing, and if so, how severely? how fast?	3. DETERMINE TRAJECTORY OF CHANGE IF THE STATUS QUO IS MAINTAINED.
What is the main cause for the change?	4. DETERMINE CRITICAL CAUSE FOR THE PES AND/OR THE TRAJECTORY OF CHANGE.
What is the source of the causes?	AND GIVE THE SOURCE OF THE CAUSE.
How ecologically and socially important is the river?	5. DETERMINE IMPORTANCE AND SENSITIVITY CATEGORIES (Low, Moderate, High, Very High) as well as Socio-Cultural Importance.
What would the ecological aims be for the river?	6. CONSIDERING THE IMPORTANCE AND THE PRESENT ECOLOGICAL STATE SHOULD THE PES BE IMPROVED (if so, by how much) OR MAINTAINED? (NOTE: Maintaining the PES could still require restoration management depending on the trajectory of change). (Category A - D).
Can the main cause realistically be addressed to achieve the ecological aims?	7. DETERMINE WHAT WOULD BE REQUIRED TO ADDRESS THE CAUSES. 8. DETERMINE HOW DIFFICULT IT WOULD BE TO ADDRESS THE SOURCE. (RESTORATION/REVERSIBILITY POTENTIAL). (Easy, reasonable, difficult, very difficult). PROVIDE REASONS.
What should the Ecological category be for the river?	9. CONSIDERING THE ECOLOGICAL AIMS, AND THE DIFFICULTY OF ACHIEVING THE AIMS, DETERMINE THE RECOMMENDED EC AND THE RANGE OF ECs TO BE ADDRESSED.

The results of the process, i.e. the PES and EC are provided as different river categories ranging from A (near natural) to F (completely modified). These will be converted to a descriptive terminology when applied to Management Classes which are the output of the Classification System procedures (as referred to in the Act (1998) and which must still be devised).

The interface between ECs and Management Classes are provided in Figure 3-1.

The so-called 'half categories', e.g. B/C, are also used in cases where there are uncertainties regarding whether the category is, for example, a B or a C. Categories represent bands or a range within a continuum, and the B/C therefore represents a condition close to the B band. An illustration of these concepts is provided in Figure 3-1.

Figure 3-1 Illustration of the distribution of Ecological Categories on a continuum and the relationship with Management Classes



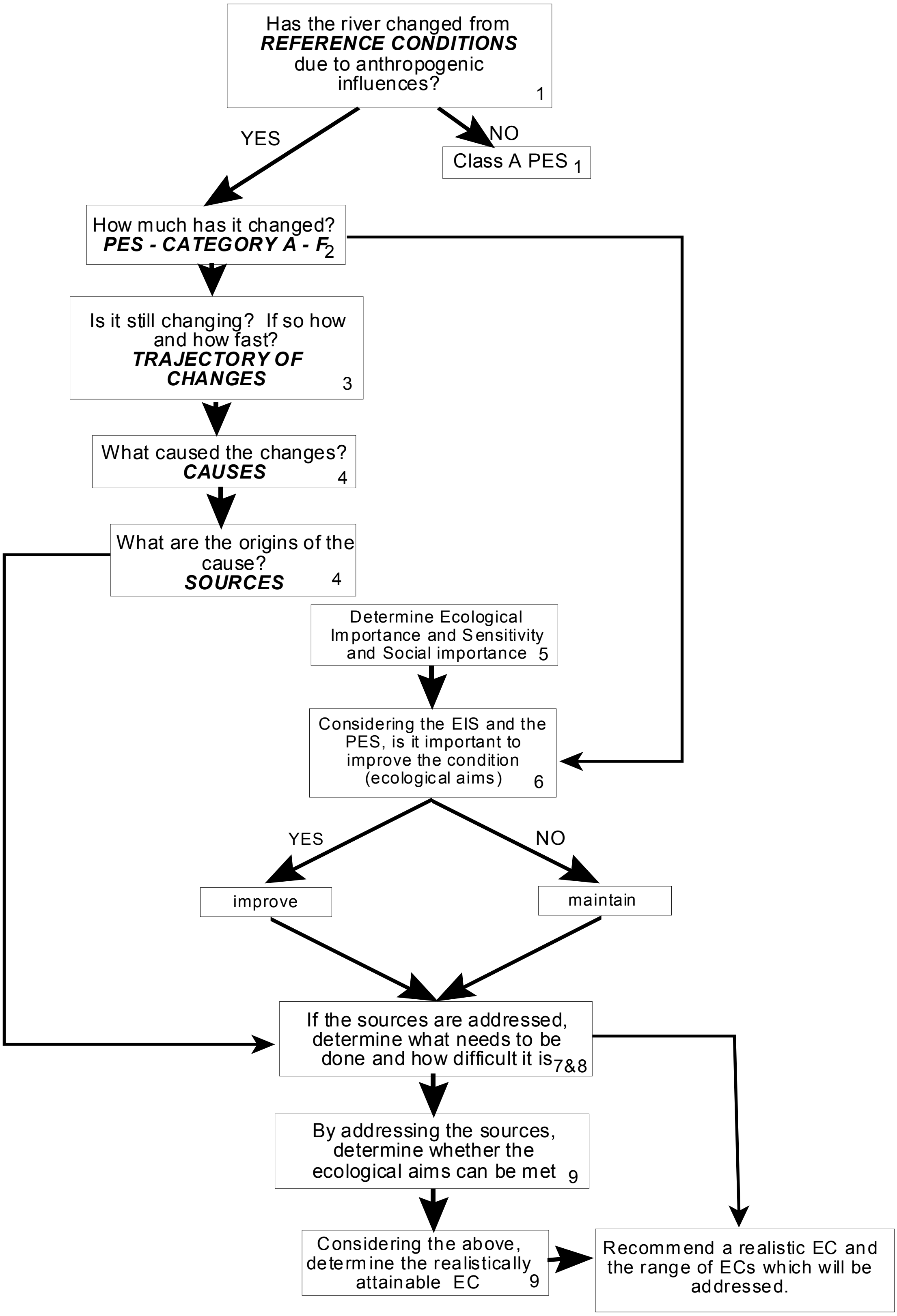
The range of Ecological Categories (ECs) for which flow scenarios must be supplied are guided by the rules as shown in Table 3.2. These must be seen as guidelines to determine a *realistic* range of ECs which can be addressed within the scenario approach.

Table 3.2 Guidelines for the range of ECs to be addressed *(under modification)*

PES	Range of ECs
A	A
A/B	A/B, B/C
B	B, C
B/C	B, B/C, C/D
C	B, C, D
C/D	B/C, C/D, D
D	C, D
D/E, E, E/F, F	D

The flow diagram below illustrates the process and the blocks are discussed below according to the numbers in the flow diagram (Figure 3-2).

Figure 3-2 Flow diagram illustrating the information generated to determine the EC



1. Has the river changed from reference conditions due to anthropogenic changes?
Reference condition describes the natural condition prior to anthropogenic change and is described for each specialist component using the information below:

- Search for the least impacted sites, either in the same or in comparable river zones.
- Use the results of historical surveys before major human impacts.
- Use aerial photographs.
- Use expert judgement.

Historical information and data, and/or data from reference sites (minimally impacted sites) are used to describe the reference conditions for the channel, hydrology, biota and the water quality. Due to data limitations and/or the absence of any existing category A resource units, the reference condition may not represent a natural river state, but rather the best estimate of a minimally impaired baseline state. If the river has not changed, then the present ecological state can be described as in an A category condition, and the resource is in a natural, near to pristine, or minimally impacted state. For such a resource, the present state equals the reference condition. If the river has changed, it leads to the next step.

2. How much has it changed (Categories B - F)?
The Present Ecological State (PES) is derived from, or described as a change for the worse from a described reference condition, which ideally relates to an A category condition - the historically natural condition. The PES of the river is expressed in the components: habitat (habitat integrity), biophysical (fish, riparian vegetation, aquatic invertebrates and geomorphology) and water quality (chemistry) integrity. Each component is assigned ***(this process is under review and development)*** a category level (A-F), where categories A-D are judged to be ecologically sustainable, and categories E and F indicate a current state that is ecologically unsustainable. The PES is compared with the reference conditions using:

- Surveys during the project.
- Results of historical surveys/databases.
- Aerial photographs.
- Expert judgement.

No integration of the different PES components into a single category is required, as this would detract from the specific details provided. However an overall 'Ecostatus' is provided which consists of a subjective evaluation of all the information provided into an overall category for the river. The Ecostatus evaluation is also important for the determination of an EC for the river, as an EC is determined for each of the different components, as well as for an overall (i.e. Ecostatus) EC for the river. The factors, which contribute to an overall classification of the ecological status of a resource unit, are complex and interactive. The best information that the specialists have, are the motivations for the individual components, as these are data based and individually argued and motivated. The links between indices and Ecostatus throughout the process is described in Figure 3-3. ***(The process to determine the Ecostatus is under development)***

3. Is it still changing, if so, how, and how fast? (Trajectory of Change)
The Trajectory of Change is addressed to determine whether the biota have at this point in time already adjusted to any catchment changes, or whether they are still adjusting. Therefore, if a PES for a specific component has been assessed, is this PES likely to change in future if nothing else different happens in the catchment. The trajectory of changes can be ascribed to the causes and sources described in 4. The trajectory can be stable, negative or positive. The trajectory is described for each of the components for which a PES is determined, and from this information it is therefore possible to derive whether the PES evaluation reflects a stable state, or whether it is still changing under present conditions. The Trajectory of Change evaluation is provided as '0' for stable, '+' for improving, and '-' for degrading. The rate of change is illustrated by providing the resulting category the component would be in 5 years and in 20 years. ***(This process is under review)***

4. What caused the changes and what are the sources of the causes?

The impacts on the river are listed and separated into flow-related and non-flow related activities and are referred to as causes. Proximal causes observed in the system due to changes in water quality, flow and external factors are for example higher salinity, sedimentation, loss of indigenous riparian plants, flow reduction, low abundance of indigenous fish, etc.

Certain causes may be related to changes in flow, for example a decrease in fish population. Loss of indigenous riparian vegetation could, however, be caused by catchment related activities such as deforestation for purposes of collecting firewood. The determination of whether the causes are flow or non-flow related is important as this influences the decision of whether mitigation solely by flow manipulation is possible and appropriate, or whether source-directed measures are necessary. For example: Flow reduction due to abstraction for irrigation could be mitigated by flow measures; loss of indigenous riparian vegetation due to overgrazing could not be mitigated by flow manipulation; water quality problems due to sewage treatment works could be mitigated by increasing flows for dilution, but it would not be appropriate to recommend Reserve flows for this purpose.

Best judgement of the activities which have been responsible for the changes from the reference state to the PES, such as: overgrazing, irrigation, mining effluent, sewage treatment works, etc is used. ***(This process of assessing the causes and using the information within the process is under review)***

5. Determine the Ecological Importance and Sensitivity (EIS) and Socio-cultural Importance (SI)

EIS: The Ecological Importance of a river is an expression of its importance to the maintenance of ecological diversity and functioning on local and wider scales. Ecological sensitivity (or fragility) refers to the system's ability to resist disturbance and its capability to recover from disturbance once it has occurred (resilience). Both abiotic and biotic components of the system are taken into consideration in the assessment of Ecological Importance and Sensitivity (EIS).

SI: This process is not part of an IERM.

6. Considering the EIS, SI and PES, determine the ecological aims for the river.

If the Ecological Importance or Social-cultural Importance is high or very high, the ecological aims should be to improve the river. However, the PES should also be considered to determine whether improvement is realistic. If the EIS and SI evaluation is moderate or low, the ecological aims should be to maintain the river in its PES.

7. If the sources are addressed, what needs to be done to achieve the aim?

The recommended EC must be attainable and it must therefore be considered whether the problems in the catchment can be addressed to ensure that the ecological aims are achieved. The specialists decide to the best of their ability what would have to be done to address the causes of degradation, how effective such remedial actions might be, and how difficult they might be to achieve (for example, if a major supply dam had to be demolished to improve the river, this would be classed as 'very difficult') (O'Keeffe & Louw, 1999). It is acknowledged that this process is subjective and that ecological specialists undertake evaluations on technical possibilities.

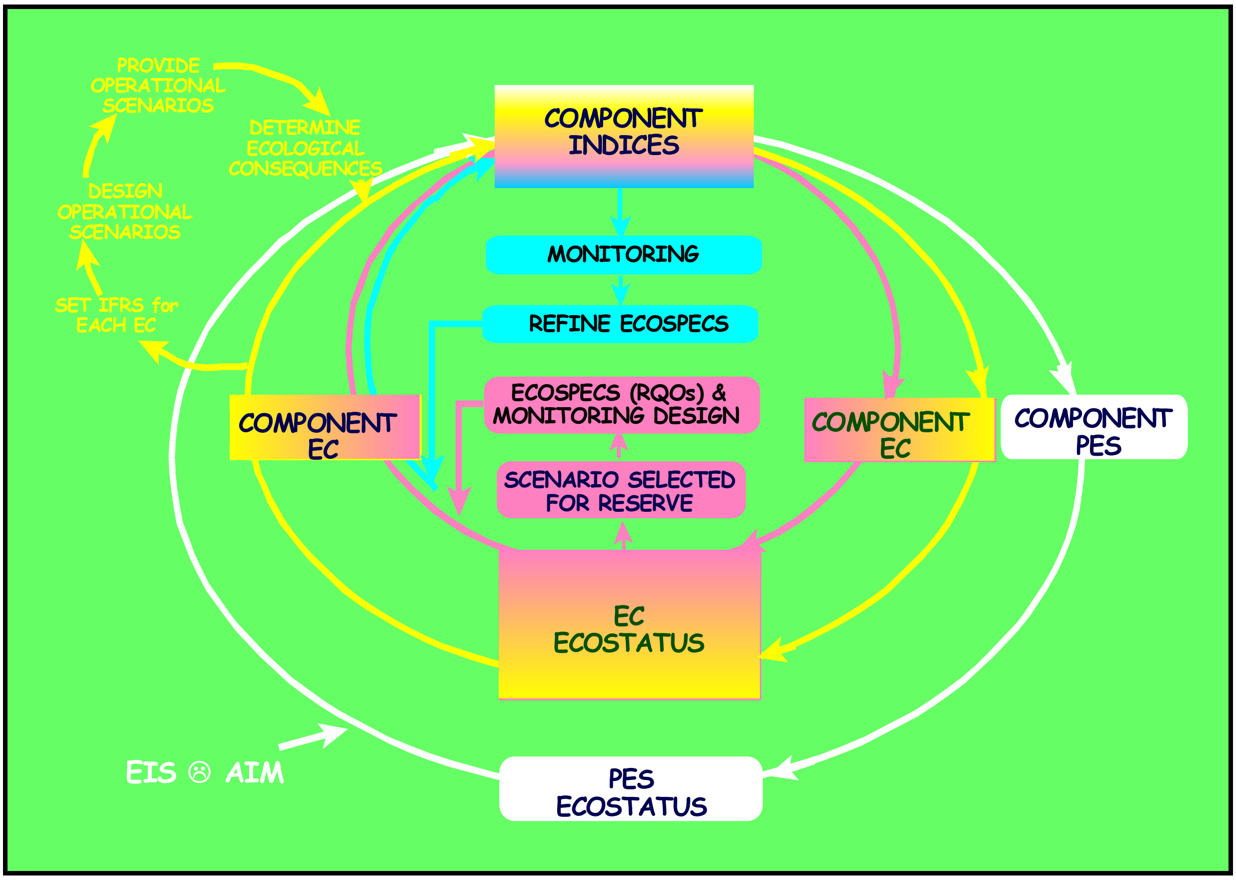
8. Considering the difficulty of addressing the source of critical causes.

In general it can be accepted that if the PES is in a C or D category or lower and the importance is High or Very High, more effort would be required to attain an EC which is an improvement on the PES. However, the kind of change(s) that resulted in a particular PES may vary in terms of the possibility of reducing their impact in order to achieve restoration of the system. It follows that each of the attributes will have to be assessed in terms of the perceived possibility of restoring them to a condition where such an improvement will lead to an improvement of the PES. Some changes may be practically irreversible within the limits of time and effort (including financial resources) required to achieve this. While five years is a commonly used time frame for many institutions and is considered a realistic period for attempting to estimate future conditions (Gonzalez, 1996), it is difficult to put limits to what can be regarded as realistic efforts.

9. Recommend attainable EC.
Based on the above, the specialists recommend a motivated EC. This is referred to as the Recommended EC (REC). Based on the REC, a range of ECs to be addressed are identified and defined. ***(The process to define the range is being refined.)***

The PES and the difficulty of addressing the sources are assessed. As the EC must be realistic and attainable, even if only in the long term, an assessment must now be made whether the aims (i.e. improvement or maintenance) can be met (see 6 above). For each component, an EC is set on this basis and then the component ECs are integrated into one value, i.e. the Ecostatus EC and if necessary, a long term EC. The integration process is the same as followed when determining the PES for the Ecostatus.

Figure 3-3 Flow diagram illustrating the information generated to determine the EC



3.2 REFERENCE CONDITIONS *(CHAPTER 6.1)*

Reference conditions are described for fish, invertebrates, riparian vegetation and geomorphology in a qualitative manner. Note that water quality reference conditions are provided in a separate report (DWAF, 2005, Appendix 3).

3.3 PRESENT ECOLOGIAL STATE (PES) *(CHAPTER 6.2)*

3.3.1 Habitat Driver Status *(Chapter 6.2.1)*
A rule-based model that has been developed and is in the process of being tested was used to provide an integrated present category for the drivers (in relation to the biotic response it could result in) as well as an estimate of what proportion of the problems are flow and non-flow related. This model (written in Delphi code) is used in providing specific categories for geomorphology, water quality and hydrology.

The list of questions that have to be addressed and illustrative scores are shown in the Table 3.3 below. The output of the model is the individual scoring of each question, a Habitat Driver Category and the proportion as a % of the problems that are flow-related. In the report the questions, the scoring as well as the reasoning for each score has been provided and is illustrated in Table 3.3.

Table 3.3 Driver Habitat State questions

Question	Score	Reasoning
Geomorphology		
To what extent is the channel structure artificial?	1	No change.
To what extent has event (high flows) hydrology changed?	3	Intermediate flows probably altered by the presence of Waterdown Dam 8km upstream.
To what extent has sediment input changed?	4	Reduced sediment coming down the channel due to the dam and due to improved catchment condition.
To what extent has riparian vegetation changed?	3	Thicker riparian zone and encroachment onto bars and banks.
To what extent has in-channel sediment storage changed?	4	Large change due to clean water releases (erosion of bed) also reduced width and increased depth causing an increased velocity.
Water Quality (Wq)		
Modified 30 Sept 03, assessment based on in-lake water quality and assessment of impacts release water at the IFR site.		
To what extent has the 95%tile of the natural Wq changed? pH	1	PES = largely natural.
To what extent are these changes related to water quantity changes.	1	PH not related to flow although the release depth may affect the pH of the released water.
To what extent has the 95%tile of the natural Wq changed? Salts	1	Salts PES = largely natural.
To what extent are these changes related to water quantity changes.	1	Salts at the IFR not related to flow. In-lake concentrations vary very little over time.
To what extent has the 95%tile of the natural Wq changed? Nutrients	2	Nutrients PES = Good to fair (C/D)
To what extent are these changes related to water quantity changes.	1	Nutrients at the IFR site are hardly related to flow, but is more affected by the abstraction depth.
To what extent has the 95%tile of the natural Wq changed? Temp	4	Temperature PES = large change from natural if released from bottom layers.
To what extent are these changes related to water quantity changes.	3	Temperature is moderately related to flow because it affects the water retention time and recovery distance. Temperature is more affected by the abstraction depth.
To what extent has the 95%tile of the natural Wq changed? Turbidity	2	Turbidity PES at the IFR site is probably moderately modified because the dam acts as a sediment trap. Although the surface layer may have low turbidity, the bottom layers may still be turbid with fine suspended sediments.
To what extent are these changes related to water quantity changes.	2	Turbidity is slightly related to flow at the IFR site. The fine suspended sediment load at the IFR site comes from the bottom releases from the dam and is probably not generated by scouring between the dam and the IFR site.
To what extent has the 95%tile of the natural Wq changed? Oxygen	2	The dissolved oxygen concentrations at the IFR site is probably slightly modified from natural due to the bottom releases (low DO) and re-aeration (add DO) downstream of the dam.
To what extent are these changes related to water quantity changes.	3	DO is moderately related to flow because the release rate would affect the recovery distance downstream of the dam (the re-aeration rate and turbulent mixing).
Hydrology		
To what extent has low flows (70%ile) changed?	3	Changes in flow duration graph.
To what extent has the duration of zero flows changed?	3	Changes in flow duration graph.
To what extent has the seasonality changed?	1	Changes in flow duration graph.
To what extent have moderate events been reduced?	4	Changes in flow duration graph.

Geomorphology: 15% Flow related   Water quality: 49% Flow related
Overall: 53% Flow related   Category: C/D

3.3.2 Biological responses PES *(Chapter 6.2.2)*

The first step during the biological responses section is for the ecologists to verify the % flow and non-flow related problems, in terms of their components natural and present stress profiles. These were provided to them during the previous phase of the events (see Chapter 2). For example, the following is the sort of issue that should be considered:

- If the present stress duration line lies close to the natural line, the biotic component is either not sensitive to flow changes, or the problems are mostly non-flow related. If however this is not supported by the results of the Habitat Driver Status, a review is required.

Fish (Kleynhans)

Below follows an example of the Fuzzy Fish Index (FFI) (Table 3.4) which is completed by the fish specialist. This is undertaken during the site visit/s and verified during the specialist meeting. Surveys and the collation of any historical information must be targeted to enable the specialist to complete these forms. The process is in development and the rule-based models might still be adjusted.

Table 3.4 Fuzzy Fish Index (FFI)

PES RATINGS PER RESOURCE UNIT (KEI)	
Resource unit	**IFR 1**
Native species richness	5
Presence of native intolerant species	5
Abundance of native species	2
Frequency of occurrence of native	4
Health/condition of native and introduced species	3
Presence of introduced fish species	2
In-stream habitat modification	2
TOTAL SCORE	**23**
%	65.7
FISH ASSEMBLAGE CATEGORY	**C**

Native species richness:
Number of species expected: number of species currently present (most recent). Score according to:
None of expected present=0
Only few of expected present=1-2
Majority of expected species present=3-4
All/almost all of expected present=5

Presence of native intolerant species:
No intolerant species present=0
Few intolerant species =1-2
Majority of intolerant species present =3-4
All/almost all intolerant species present (OR no intolerants naturally present)=5

Abundance of native species:
No fish=0
Only few individuals=1-2
Moderate abundance=3-4
Abundance as expected for natural conditions=5

Frequency of occurrence of native:
Fish absent at all sites=0
Fish present at only very few sites=1-2
Fish present at most sites=3-4
Fish present at all sites=5

Health/condition of native and introduced species:
All fish seriously affected/fish absent=0
Most fish affected=1-2
Most fish unaffected=3-4
Only single/few individuals affected=5

Presence of introduced fish species:
Predaceous species and/or habitat modifiying species with a critical impact on native species=0
Predaceous species and/or habitat modifiying species with a serious impact on native species=1-2
Predaceous species and/or habitat modifiying species with a moderate impact on native species=3-4
Predaceous species and/or habitat modifiying species no impact on native species=5

In-stream habitat modification:
Water quality/Flow/Stream bed substrate, critically modified, no suitable conditions for expected species=0
Water quality/Flow/Stream bed substrate, seriously modified, little suitable conditions for expected species=1-2
Water quality/Flow/Stream bed substrate, moderately modified, moderately suitable conditions for expected species=3-4
Water quality/Flow/Stream bed substrate, little/no modification, abundant suitable conditions for expected species=5.

Fish assemblage category:
TAKING INTO ACCOUNT THE ABOVE INFORMATION: RATE FISH ASSEMBLAGE INTEGRITY CATEGORY A – F BASED ON GENERAL SCORING GUIDELINES:

Category	% of total expected score
A:	90 – 100
B:	80 – 90
C:	60 – 80
D:	40 – 60
E:	20 – 40
F:	0 – 20

Aquatic invertebrates (Thirion & Uys)
As no method for deriving PES for invertebrates is available as yet, the specialists derived their PES on the basis of extrapolation from Thirion's Table of 'SASS4 and ASPT values per Ecoregion as an indication of biotic condition' (from *Draft report for RHP Mpumalanga Pilot Study)*. As Eastern Cape rivers are not yet covered in this system specialist experience of invertebrate data collection and analysis in Eastern Cape river systems over several years was utilised.

The information was provided in a table, illustrated in Table 3.5.

Table 3.5 Aquatic invertebrate PES

Bio	PES	Invert Communities Observed Winter
SIC	SASS: 93 Taxa: 16 ASPT: 5.8	Porifera, Turbellaria, Oligochaetes, Baetidae (>2 spp), Caenidae, Heptageniidae, Leptophlebiidae, Tricorythidae, Aeshnidae, Hydropsychidae, Chironomidae, Simuliidae, Tabanidae, Ancylidae, Sphaeriidae, Unionidae.
MV	SASS: 72 Taxa: 13 ASPT: 5.5	Porifera, Hydracarina, Baetidae (>2 spp), Corduliidae, Corixidae, Hydropsychidae, Leptoceridae, Gyrinidae, Ceratopogonidae, Chironomidae, Simuliidae, Ancylidae, Planorbidae.
TOT	SASS: 147 Taxa: 25 ASPT: 5.9	Porifera, Turbellaria, Oligochaetes, Hydracarina, Baetidae (>2 spp), Caenidae, Leptophlebiidae, Tricorythidae, Aeshnidae, Corduliidae, Gomphidae, Libellulidae, Corixidae, Hydropsychidae, Leptoceridae, Gyrinidae, Ceratopogonidae, Chironomidae, Simuliidae, Tabanidae, Ancylidae, Planorbidae, Sphaeriidae, Unionidae

Vegetation (Kemper)
No rule-based method is yet available to assess vegetation. A qualitative description and reasoning is provided and the following qualitative index (Table 3.6) is used as a guide.

Table 3.6 Riparian vegetation PES

Riparian vegetation PES index	Description
A	Unmodified, natural.
B	Largely natural with few modifications. Small change in vegetation state is evident as a result of anthropogenic pressure.
C	Moderately modified. A moderate change in vegetation state is evident either as a slight change in more than one component simultaneously or as a larger change in a single component only. Changes are visible but the vegetation zone maintains a natural character and remains more natural than impacted / artificial.
D	Largely modified. Large changes in vegetation state are visible for more than one component simultaneously. Changes are obvious and the vegetation appears to be more impacted / artificial than natural. The extent of riparian zone degradation is visible either in definite patches or generally throughout.
E	Seriously modified. The change in vegetation state is extensive in most or all of the components simultaneously. The vegetation is seriously impacted or replaced throughout. The riparian zone is highly degraded throughout and natural recovery is unlikely in the short to medium term.
F	Critically modified. Little to no natural vegetation remains and changes are likely to be irreversible. The riparian zone is critically degraded and no natural recovery is likely even in the long term.

Note: Vegetation state comprises four components, *viz.* species composition, structure, cover and distribution.

Species composition:
Describes the species compositional make-up of the vegetation present. The removal of one or more species and/or the introduction of others (such as exotic species) will result in a shift in species composition.
Structure:
Describes the physical structure and size/age class of vegetation present. The death or removal of specific size classes of trees will lead to a corresponding shift in structure.
Cover:
Describes the extent of vegetational cover. The removal of vegetation either due to utilisation or erosion will result in corresponding changes in the abundance and extent of vegetation cover.
Distribution:
Describes the location of vegetation within the riparian zone. Removal of vegetation in specific areas will lead to corresponding changes in the distribution of remaining vegetation.

3.3.3 Trajectory of change *(Chapter 6.2.3)*

The trajectory of change is described for each component and the resulting EC provided.

3.3.4 PES Ecostatus *(Chapter 6.2.4)*

A rule-based model is being developed to derive the Ecostatus. At this stage the Habitat Driver Status is used as indicator as well as the Habitat Integrity Status. A consensus decision is then made on the PES category that most likely represents the Ecostatus for the site and Resource Unit (RU).

3.4 EIS *(CHAPTER 6.3)*

The results of the Ecological Importance and Sensitivity rule-based models are all attached as Appendix G. A summary of the results appears in the chapter. The model and the explanation is provided in DWAF, 1999.

3.5 RANGE OF ECS (*CHAPTER 6.4)*

The Recommended EC is determined by assessing the EIS and the PES. If the EIS is high or very high the PES should be improved a full category unless the PES is a B (stays a B) or a B/C (improves to a B). If the EIS is moderate or low, the PES should be maintained unless the PES is below a D (improves to a D).

All the information generated is summarised in a figure (see Figure 3-4 below). Following the guidelines in Table 3.2, a range of ECs is provided in Figure 3-4. ***(This process is being revised).***

Figure 3-4 EC figure

AVAILABLE INFORMATION:

INSTREAM HABITAT INTEGRITY: C RIPARIAN HABITAT INTEGRITY: D

COMPONENT	PES	TRAJ	SHORT TERM (5 Y)	LONG TERM (20 Y)	EIS	REC	Alt EC	Alt EC
DRIVER HI	C				MODERATE	C	D	C
RIPARIAN VEGETATION	D	-- (nf)	D	D/E		D	D	C
FISH	C/D	0	C/D	C/D		C/D	D	C
AQUATIC INVERTS	B	0	B	B		B	C	B
ECOSTATUS	C	0 (F)	C	C		C	D	B/C

3.6 DEFINING ECS (*CHAPTER 6.5)*

For each of the component categories, the objectives in terms of flows must be defined. General flow objectives, indicator species, communities and/or guilds must be defined and specific objectives in terms of flows or stresses must be described for each EC.

Using the table above, fish would need to provide information for a C/D, a D and a C category. Invertebrates would however only have to describe their requirements for a B and a C.

The objectives are defined for fish, aquatic invertebrates and riparian vegetation. Geomorphology input is provided in a qualitative form to describe whether characteristics of the template can improve and to provide the likely characteristics of the river if the geomorphology degrades. This provides the basis/template for the other components to describe their components.

Where rule-based models are available, they must be used in a predictive manner to aid in defining the EC. Examples of the fish rule based model, and the invertebrate approach are provided in Table 3.8 and 3.9.

Table 3.7 Fuzzy Fish Index used in a predictive manner

IFR site 1	Recommended EC C/D	Alternative EC C	Alternative EC D
Native species richness	5	5	5
Abundance of native species	2	3	1
Frequency of occurrence of native	4	4	4
Health/condition of native and introduced species	3	3	3
Presence of introduced fish species	2	2	2
In-stream habitat modification	2	3	1
TOTAL SCORE	**18**	**20**	**16**
%	60.0	66.7	53.3
FISH ASSEMBLAGE CATEGORY	**C**	**C**	**D**

Table 3.8 Aquatic invertebrate table

Ref	PES B score	PES B taxa	Alternative EC C score	Alternative EC C taxa
SASS: >150 Taxa: >30 ASPT: >6	SASS: 147 Taxa: 25 ASPT: 5.9	Porifera, Turbellaria, Oligochaetes, Hydracarina, Baetidae (>2 spp), Caenidae, Leptophlebiidae, Tricorythidae, Aeshnidae, Corduliidae, Gomphidae, Libellulidae, Corixidae, Hydropsychidae, Leptoceridae, Gyrinidae, Ceratopogonidae, Chironomidae, Simuliidae, Tabanidae, Ancylidae, Planorbidae, Sphaeriidae, Unionidae	SASS: 120 Taxa: 5.5 ASPT: 22	Porifera, Turbellaria, Oligochaetes, Hydracarina, Baetidae (>2 sp), Caenidae, Leptophlebiidae, Aeshnidae, Gomphidae, Libellulidae, Corixidae, Hydropsychidae, Leptoceridae, Gyrinidae, Ceratopogonidae, Chironomidae, Simuliidae, Tabanidae, Ancylidae, Planorbidae, Sphaeriidae.

Category	Improve to a D (PES, D/E)	Improve to a C/D
Habitat	From a flow pt of view, PES is related to the dominance of coarse substrate (boulders) in the channel and their packing and embeddedness, and to the lack of available surface area in SIC and MV habitats (due both to exposure of stems and covering of surfaces with fines and algae).	Substrate remains the same. Greater possibility of inundation of MV stems, both in fast and slow flow areas. Greater flushing of fines and flow through cobble areas (presently out of current) which will provide more SIC habitat.
Flows	Maintain base flows through summer with flow depth ideally >0.4m. Stress should be maintained around 5 for at least 80% of the time and should not exceed 8 (depth 0.28, flow 0.02) during summer. In winter flow cessations for up to 10% of the time. Ideal flow depth >0.25 (flow 0.01).	Maintain base flows through summer with flow depth ideally >0.4m. Stress should be maintained around 5 for at least 85% of the time, stress of 4 for 80% of the time. Stress should not exceed 8 (depth 0.28, flow 0.02). In winter flow cessations for max 10% of the time. Ideal flow depth >0.25 (flow 0.01).
Component	If sufficient flow maintained through critical SIC and MV habitat then present community should persist and possibly will be recruitment of additional non-flow dependent taxa.	If flows are maintained in general and increased over short durations, it is likely that greater expanses of usable habitat will become available and recruitment of FD species and non- is possible. Diversity of FD and MV taxa should increase, and overall sensitivity of the community should increase (higher ASPT).
Target spp	Maintain flow depth and velocity for Simuliids and Hydropsychids throughout the year.	Sufficient flow to inundate areas which are presently backwaters, for up to 20% of the time, to extend optimal habitat for flow dependent species.

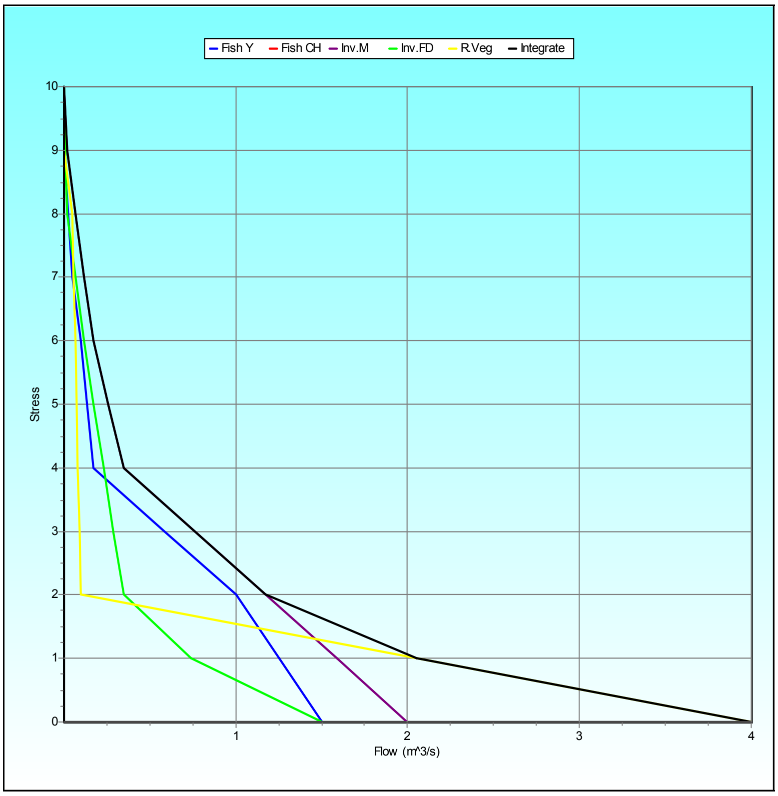
4 APPROACH: DETERMINATION OF IFR SCENARIOS *(CHAPTER 7)*

4.1 LOW FLOW REQUIREMENTS *(CHAPTER 7.1)*

4.1.1 Component Integrated / System stress *(Chapter 7.1.1)*

Once the stress indices (for low flows) have been identified for each component (Chapter 2), the numbers are tabled and the unidentified flow stresses interpolated. At any one flow, the component with the highest stress point represents the integrated or system stress curve. Figure 4-1 illustrates the interpolated individual component stresses as well as the integrated curve. The black line represents the integrated curve and the other lines the stress flow relationships for the various components. The integrated curve in this case consists of the marginal invertebrates (purple line) for the stress range 2 to 10, and the riparian vegetation (yellow line) for the stress range 0 to 1.

Figure 4-1 Component and integrated/stress curves

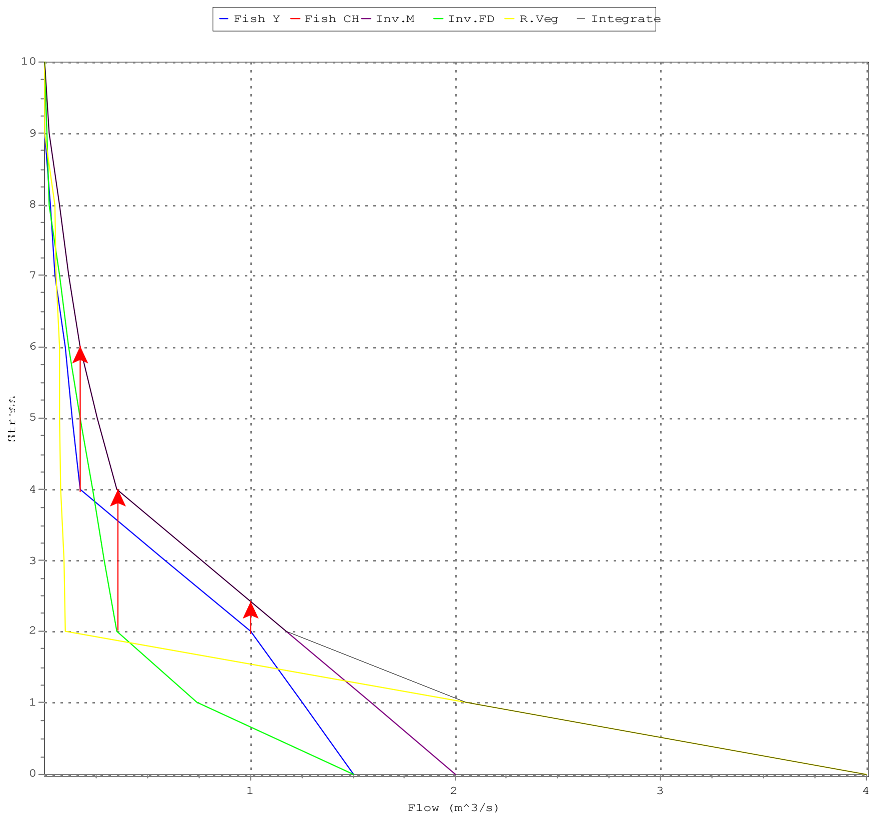


From this point on, all requirements are provided in terms of the integrated and not the component stresses. Specialists refer back to their component stress index in order to convert any one critical stress value to their corresponding component stress value. The critical stress and corresponding component stresses are tabled in the spreadsheets (Appendix H).

The question is often asked why this is necessary. The problem is that the component stress indices have different flow-stress relationships. For example, the marginal vegetation stress of 2 implies a flow of 0.08m^3/s whereas the marginal invertebrate stress of 2 equates to 1.2 m^3/s. When the requirements are set, they are provided as certain stresses occurring at a certain % of time for the different components and plotted on a duration graph (axes consisting of stress and a % time (Figure 4-2)). The x axis (stress) can only have one flow-stress relationship and the integrated stress-flow relationships are therefore used.

The conversion from component stress to the integrated stress is illustrated in the Figure 4-2.

Figure 4-2 Conversion from component stress to integrated stress



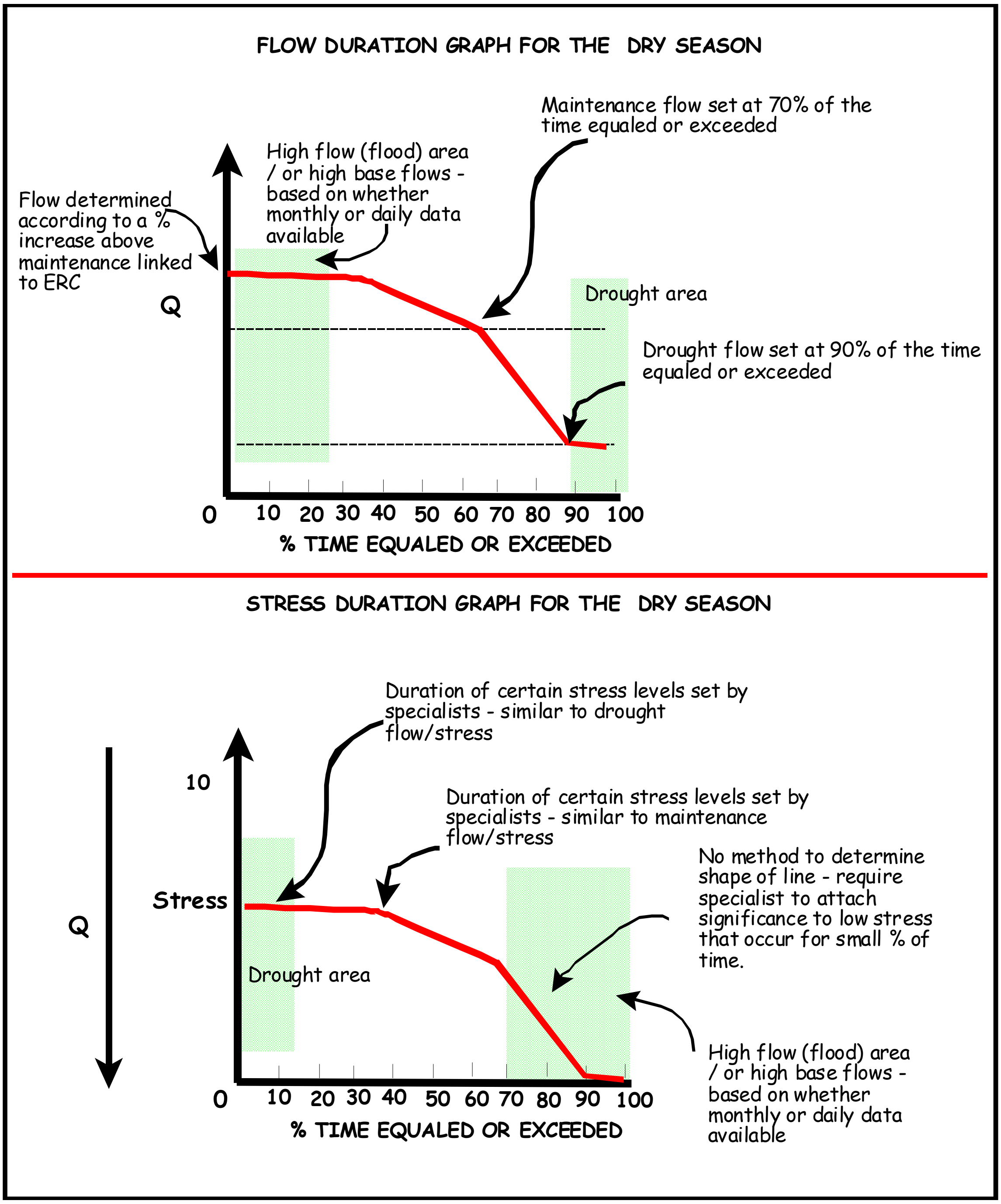
In Figure 4-2 the conversion is illustrated by the red arrows and described below from left to right:

- A fish stress of 4 equals a system stress of 6 (both implies a flow of $0.2m^3/s$) The explanation of this situation is that while the fish are not significantly stressed at $0.2m^3/s$, the aquatic invertebrates, which at that point represents the system stress, are stressed (stress of 6).
- A flow dependent invertebrate stress of 2 equals a system stress of 4.
- A fish stress of 2 equals a system stress of 2.5.

4.1.2 Generating stress requirements *(Chapter 7.1.2)*

The interpretation of stress durations is complex as the discharge values decrease up the y-axis, as opposed to the standard flow duration graphs, in which discharge values increase up the y-axis. This difference is accommodated for in the step-wise procedure as explained below. The relationship between flow duration graphs, as used during the determination of flows during the application of the BBM process, and the stress duration graph is illustrated in Figure 4-3. The stepwise procedure for recommending the low flow IFR is discussed using the fish stress index for the illustration.

Figure 4-3 A comparison between flow duration and stress duration graphs



The specialist must be able to interpret the stress-duration graph, as there must be no confusion with flow-duration graphs. The differences are illustrated in Figure 4-3.

The process and sequence of events are the same for fish and aquatic invertebrates. Fish are used below as an example.

- The fish specialist expresses the fish requirement as a percentage of time during which stress would be equalled or less for each different season, i.e. stress-duration for a specific EC (This is in contrast to flow-duration, in which the requirement would be expressed as % time during which flow would be equalled or exceeded.)
- The stress graph depicting natural and present flows is used to plot the fish stress requirements.

- The process followed to determine the requirements for the REC is set out in the block below and a case study/example is provided in Section 4.1.3.

<table>
<tr><th>DRY SEASON</th></tr>
<tr><td>Note: The hydrologist to provide a general description of the system, how often droughts occur, and how to interpret the seasonal duration graphs.

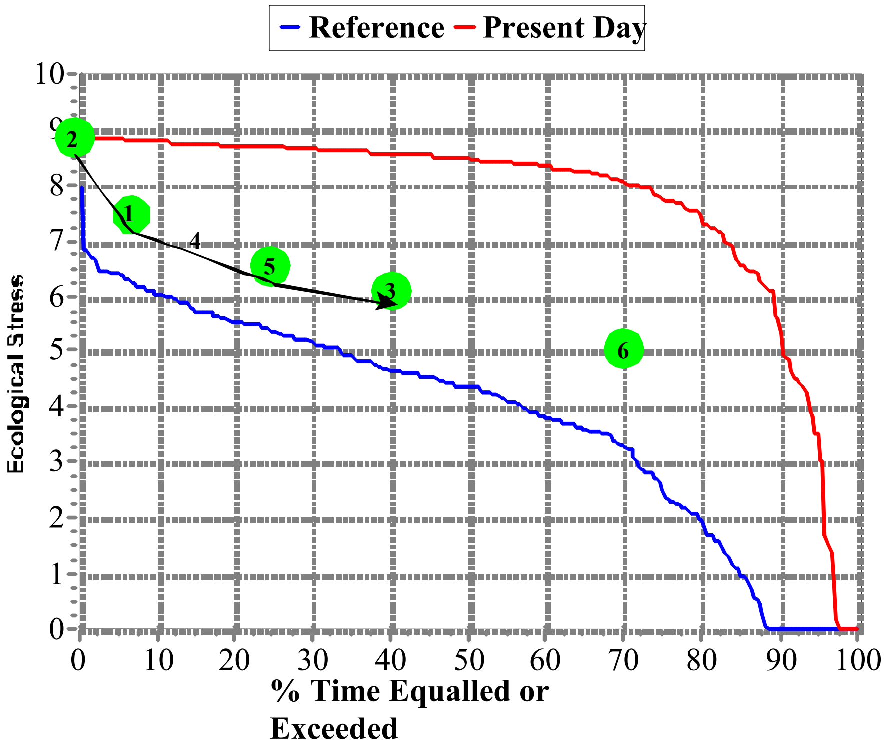
Determine the months that comprise the dry and wet season and/or select single months to use.

Droughts
Droughts normally occur about 5 to 10% of the time. The stress requirement is relevant for drought conditions that occur over a reasonable period of time (i.e. at least a month in a season - not just an odd day or two).
If you want to set drought conditions for the lowest that it should ever go, i.e. even for a day, you should also provide a stress for the 0 or 1%.
The questions that must then be answered are:
• What are the identified stress conditions associated with this?
• What are the reason that you cannot go lower than the habitat conditions and stress you have set?
Action: Plot the point/s you require (see example Figure 4-4). Document the requirement and reasoning as in the example (Section 4.1.3).

REMEMBER, DROUGHTS ARE THE SAME FOR ALL ECOLOGICAL CATEGORIES.</td></tr>
<tr><td>Maintenance flows for a specific EC
The % flows representing maintenance conditions provided by the hydrologist is representative of conditions occurring on average (based on the natural hydrology representing the natural variation and hydrological characteristics of the river).
In this case you therefore have a KNOWN percentage. The questions you then need to answer are:
• What are the habitat conditions you want to see on average for the species you are dealing with?
• What stress conditions does this habitat relate to?
• Why does it need this condition on average?
Action: Plot the point/s you require (see example Figure 4-4). Document the requirement and reasoning as in the example (Section 4.1.3).</td></tr>
<tr><td>Check
Connect the drought and maintenance points. Spot-check any stress, or duration, in between the two points and verify that this is the stress (habitat conditions) that is acceptable during dry periods between maintenance and drought for the specific duration (Figure 4-4). If the habitat conditions are not acceptable, then the drought and/or maintenance stresses must be re-evaluated.</td></tr>
<tr><td>Other durations for a specific EC
You then determine whether there are any other requirement for a habitat condition outside of the range between drought and the maintenance flow, i.e. lower stress/more flows (wet periods) than maintenance (Figure 4-4).
What other significant habitat conditions and stress is required for a specific duration?
Provide the duration and the motivation.
Action: Plot these points (see example Figure 4-4). Document the requirement and reasoning as in the example (Section 4.1.5).</td></tr>
<tr><th>WET SEASON</th></tr>
<tr><td>Repeat the procedure for the wet season
NOTE: Due to the breeding and life cycle issues during the wet season, more points than just those for droughts and maintenance should be completed. However, do not provide points above approximately 60% as this is in the range of flood conditions.</td></tr>
</table>

- **Note:** The motivations/reasons as described above is relevant for all the IFR sites you are dealing with IF the indicator species/guilds are the same. In future these motivations will become generic for rivers in the same Level II Ecoregion and with the same indicator species/guilds.

Figure 4-4 Sequence of steps followed during the determination of stress requirement (This graph is not related to any specific river and serves as an example)



1. Determine drought
2. If required, determine the worst instantaneous droughts
3. Determine maintenance stress at 40%
4. Connect line between points
5. Verify duration and stress at a point between or set a point between
6. Provide additional points at a duration and stress which have ecological sig nificance
7. Repeat the checking procedure and connection of lines if necessary

4.1.3 Provision of motivations for determining stress requirements

An example is provided below using the Elands River site and the fish species that occur there. Note: It does not link to any of the graphic examples provided. The stresses provided are only examples.

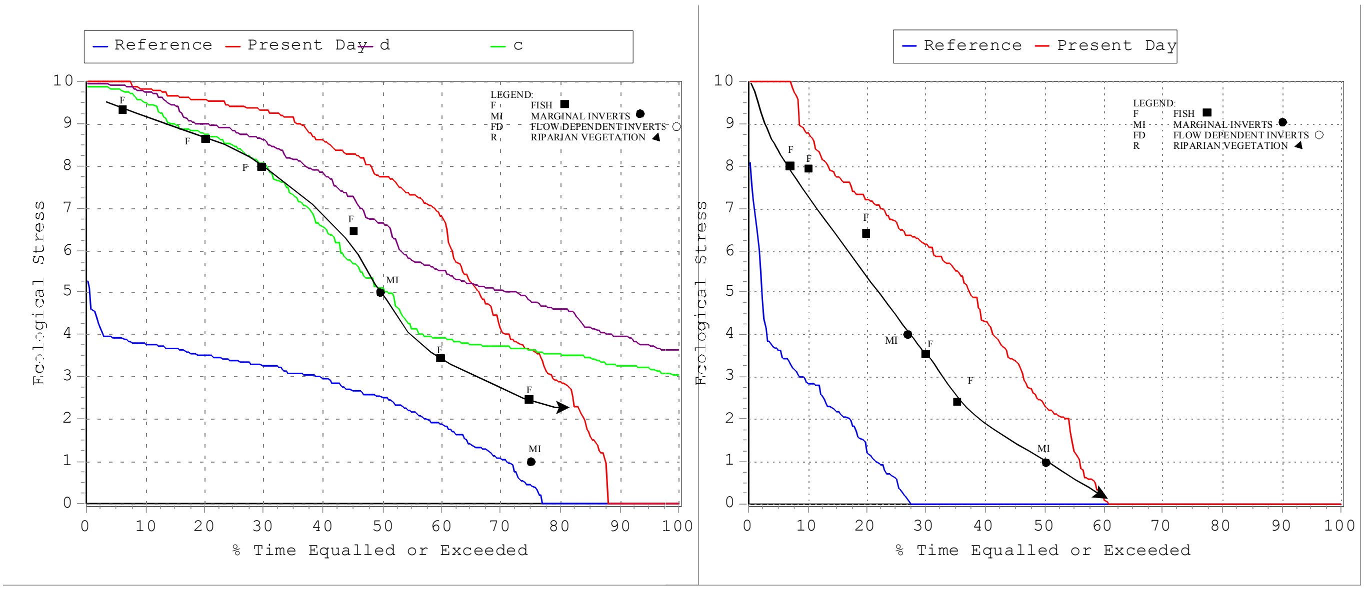
FISH: DURATIONS AND MOTIVATIONS TO BE USED FOR DETERMINING STRESS REQUIREMENTS
Indicator: Fish: The indicators are rheophilic species dependant on the perennial flow.
STRESS REQUIREMENTS FOR THE REC
DRY SEASON
DROUGHT: i.e. ± 10% Survival conditions = Minimal fast shallow in patches (minimum depth of 15 cm - approximate 1 - 2 abundance) provides cover and trophic requirements (stress of 7). **0% of the time:** Still need flowing water (trickle), but however, if these conditions happen for more than 1% of the time, the species could be lost (stress of 8).
MAINTENANCE: 30%. Require good habitat for the dry season. Minimum of patches of fast deep and fast shallow, but need connectivity to ensure maintenance of population dynamics and abundances (stress of 4).
WET SEASON
DROUGHT: i.e. ± 10%

Still spawn, but few situations with favourable habitat conditions. When favourable conditions occur, it will not necessarily be optimum conditions. (Therefore, start with maintenance which will describe the optimum conditions and then drive the 'less favourable conditions'). **Relatively limited - 5 stress:** FD, FS, available but limited and fragmented (patchy). **0 duration:** Summer, temperature, oxygen and water quality play a role and survival conditions therefore different than dry season (stress of 7).
MAINTENANCE: 30%. (Stress of 2) *Amphilius uranoscopus* *Eggs:* Margins of FS (>0.2 m, <0.2 m/s) gravel cobble substrate. October – January. >16°C. Duration 7 days 3 - 30% *Larva:* Feeding and Growth: Nursery areas (>0.20m deep <0.2m/s), margins of FS, SS and overhanging vegetation. Duration larval period: 2 months. 3 - 30%. *Juvenile:* Feeding and Growth: Mostly FD, FS (>0.20m deep >0.1m/s). Cover: Cobbles and rocks overhanging vegetation. Duration 3 - 6 months, 3 - 30%. *Adult:* SS, FS (>0.25m), gravel, cobble substrate. Spawning season: October – January. Cue: increased temperature, flow and changes in water quality (e.g. conductivity), 3 - 30%.
Other: Population boost is required at times. 75% of the time. Close to natural conditions - limited risk. Stress of 1. (Note: Should as standard use “50% of the time”, i.e. stress of 2 (could also derive this by connecting the lines and checking.))
STRESS REQUIREMENTS FOR THE ALTERNATIVE EC
C conditions Same diversity of habitat conditions, but occurring less often. Durations of stress going to be longer. Increased risk. Category below: Purely derived - more quantified methods will require modelling approaches that are outside the scope of these studies.

The stress (integrated values) for the wet and dry season at specific percentage points are provided to the facilitator who plots them on a blank stress profile.

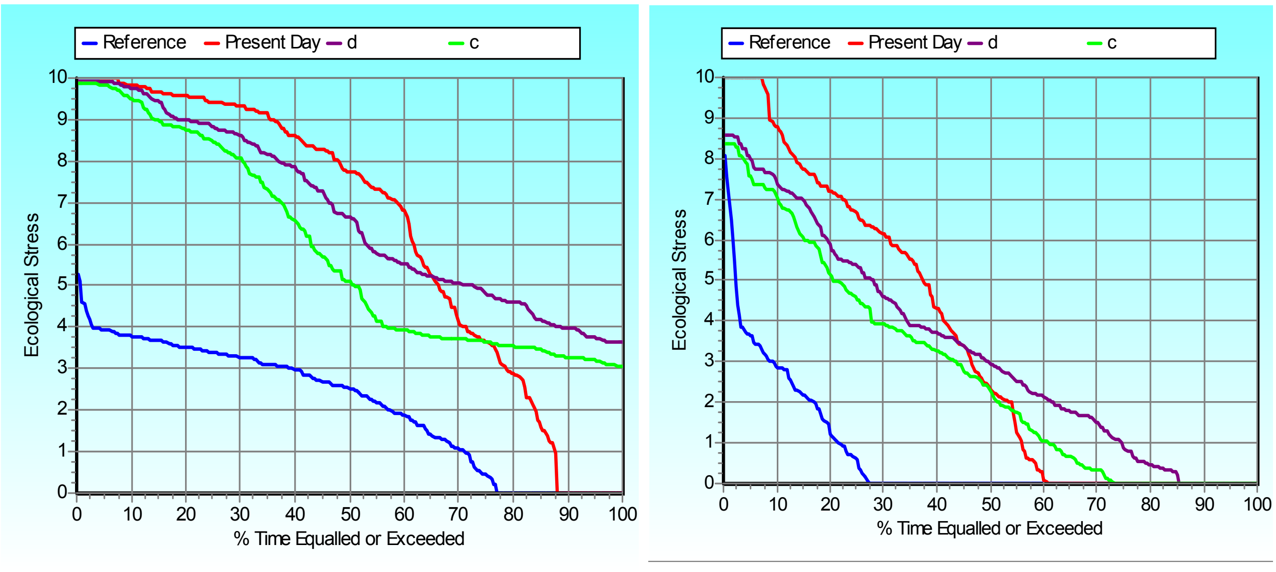
- The stress (critical values) for the wet and dry season at specific percentage points are provided to the facilitator who tables these on a flip chart and plots them on a blank stress profile.
- The stress profile is then overlain with the natural stress profile, a modelled present day hydrology (or preferably observed gauged data if at all possible), and desktop estimated Reserves for each relevant REC.
- The natural and present day (or observed) hydrology is used to determine whether the points recommended by specialists are realistic. The following are basic rules to consider:
  - In a river where present flows are greater than natural (e.g. where the river is used as a conduit), recommendations can be greater than natural.
  - If specialists have identified the modified present flow regime as a problem for their component, and require a flow improvement for the component ecological condition, their points should fall between natural and present, i.e. closer to the natural than to the present flow.
  - If specialists have identified the modified present flow regime as a reason for the PES, but the present state must be maintained, and there is no negative trajectory, points should fall beyond both the natural and present lines. If however there is a negative trajectory, improvement will be required to MAINTAIN, and therefore points can again fall between natural and present flows.
  - If specialists have identified that all the causes of the PES are non-flow related, points should not reflect any improvement of the present flow regime.
  - In a river where present flows are greater than natural, it is highly likely that the points would fall between present and natural, i.e. representing more flow than natural, but less than present.
- In general, the points plotted for the components representing the lowest stress at any time guide the shape of the recommended low flow. Outliers are investigated and if confidence associated with these recommendations are very low; these points are not used to shape the curves.
- The curve is then drawn in by hand. This hand-drawn line represents a band (of flow /stress requirements). Figure 4-4 illustrates the process to the point at which the curve is drawn

Figure 4-5 The hand-drawn line representing a band of flow/stress requirements from the individual specialists



- The hydrologist then investigates which Desktop-generated curve most closely represents the recommended curve, and adjusts the hydrology to fit the hand-drawn curve.
- This curve is presented to the specialists, who indicate whether further manipulation is required or whether the curve represents their requirements adequately.
- The final generated curve is then presented graphically (Figure 4-7) in the report.

Figure 4-6 The final curve



At this point the low flow recommendations for each Reserve scenario has been finalised and high flow recommendations are not required to enable the final Reserve scenarios to be provided.

4.2 APPROACH TO HIGH FLOWS *(CHAPTER 7.2)*

A FS-R approach is being developed for high flows but have not yet been used in a Reserve determination study. The approach used for high flows in this study has elements of both the BBM and the DRIFT methodologies. The fish, invertebrate and riparian vegetation and geomorphologist specialists provide the functions of floods and identify the size of the events using the hydraulic cross-sections, photos and videos of known flows and interaction with the geomorphologists. The geomorphologists use the sediment transport modelling to determine the size of the events they require, as well as the number of events.

The stepwise approach to determining the high flows was as follows:

- Each specialist identified the range of high flows that will undertake similar functions. These were overlain and integrated to provide various classes of high flow events. Class 1 high flows are the smallest events - the freshes - and the larger the classes, the larger the size of the events. The largest class flood will represent flows with a return period of 1:2 years or more. An example is provided below of the integrated floods to provide the size classes

Table 4.1 A summary of the flood class ranges, and the recommended high flow events for each scenario.

	Flood classes				
Component	**I (m^3/s)**	**II (m^3/s)**	**III (m^3/s)**	**IV (m^3/s)**	**V (m^3/s)**
Fish	1-2,2-4	7-10			
Invertebrates	2-4, 4-7	7-10			
Vegetation	2-7	8-15	15-45		
Geomorphology	1-4	7-12	17-32	40-65	
Integrated	**1-7**	**7-15**	**15-45**	**40-65 (1:5)**	
Daily average*	3	8	18	30	
Duration (days)	1	2	2		

- Specialists documented the functions and described the critical hydraulic parameters associated with each class of flood per component. This information is documented in the spreadsheets (Appendix H). An example of the spreadsheet is provided as Table 4.3

Table 4.2 High flows - Functions and associated critical hydraulic parameters

FLOOD CLASS I 1.5 -3 m^3/s				Recommended EC D Fish D; Inverts D; Rip veg C/D			Alternative EC C Fish C; Inverts C Rip veg B/C		
Com.	**Function/s (what does it have to do)**	**Description (what is the flood characteristic that does that)**	**Season**	**No of events**	**Frequency**	**Reasoning**	**No of events**	**Frequency**	**Reasoning**
Inverts	Flush out fines. Cue for breeding/emergence.		Late winter	1	2 Per year	To maintain reasonably clear surfaces in SIC and prevent further embeddedness.	1	3 Per year	As for EC D, increases confidence in cueing for breeding and emergence. Improvement of general condition in pools as well as SIC and marginal vegetation.
			Late Summer	1	2 Per year	Cue relevant taxa for emergence or for breeding.	1	3 Per year	
Fish	Flush out riffle areas and create suitable spawning habitat for *Barbus aeneus*, flood vegetation for spawning habitat for B. anoplus. Create backwater areas for larval development of both species. Allow sufficient depth for migration of eels, and *B. aeneus* upstream over shallow riffle and rapids	1.5 to 2.0 m^3/s	Summer Oct to March	2		Only limited suitable habitat created, low number of events means high risk of failure and limited breeding success Few chances for migration	3	Summer: October to March	Same as for EC D, but more suitable habitat for spawning and larval rearing created, more opportunities for migration
Rip veg	Maintain marginal vegetation and marginal zone by the provision of water and nutrients to marginal vegetation.	Floods marginal zone several times a year and inundates all marginal zone species to crown level.	Spring Summer	3 - 5	Evenly in summer	Maintain existing distribution of marginal vegetation.	6		Improve water availability to the marginal zone and increase its distribution.
Geom.	Maintain present bed form.	Depth: 0.8 – 1.1m Velocity: 0. – 1.07 m^3/s		Wet	4				

- The hydrologist checks the validity of these floods against naturalised daily hydrology, or in the absence of this, any observed hydrological data or by means of monthly volumes (as a last resort only).
- Where possible, the hydrologist provides the number of events, which would occur under natural flow conditions for each of the flood classes. If any sort of daily hydrology is not available, an upstream reach of similar area and where information is available is used to provide some indication.
- The specialists then identify which of those number of events should occur for each of the Reserve scenarios (ECs). The number of events should not exceed the natural and should only be similar to natural if the EC being considered is high. The objectives and criteria set for the recommended and alternative ECs must be kept in mind when motivating the number of events per REC. Motivations linked to the number of events selected are supplied in the spreadsheets. The results are provided in Table 4.4.

Table 4.3 The recommended high flow events for each scenario.

Category	I C	Time C	I B/C	Time B/C	II C	Time C	II B/C	Time B/C	III C	Time C	III B/C	Timing B/C
Fish	6		6									
Inverts	5		5		1	Summer	1	Summer				
Vegetation	7		7		3	Summer	3	Summer	1	Summer	1	Summer
Geomorph	4		4		3		3		1		1	
Number of events	7	10-4	7	10-4	3	10-4	3	10-4	1	10-4	1	10-4

At this stage the high flows are incorporated with the low flows already identified into a flow regime. The process followed and the hydrologists provide adjustments required to convert the instantaneous peaks provided by the specialists into the final results.

4.3 FINAL RESULTS *(CHAPTER 7.3)*

The low flows and high flows have now been incorporated into an integrated flow regime. The final output, i.e. the IFR rules (presented as duration tables), is provided from either the Desktop Model or the IFR Model. The IFR assurance rules are documented in the report. Results are also provided as IFR tables (the .tab tables) and are presented in the report.

4.4 CONFIDENCE EVALUATIONS OF THE RESULTS *(CHAPTER 7.4)*

Each specialist provides a confidence evaluation on a scale of 0 (no confidence) to 5 (high confidence) for their component for various parameters. The information regarding each parameter is provided below. The rationale for their evaluations is also provided in the table in the row below each parameter.

IFR site: The potential of site for providing reasonable cues to set the IFR requirements.
Available data: Assess the confidence you have in the available data, both historical and collected, and your ability to interpret the data to accurately recommend flows.
Ecological classification: Evaluate the confidence you have in all contributions you provided towards the PES and EC. (Reference conditions, PES, trajectory of change, EIS, EC)
Output Low: Evaluate the final output and provide the confidence you have in the flow to achieve your component objectives. EG, if the requirements for your component were superseded by another component, the final flow represents more flows that you recommended and your confidence should therefore be high. If however the flow regime was based on your requirements, you should assess your confidence in the requirements you set.
Output High: Evaluate the final high flow regime that will be provided; size, frequency etc.

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

Table 4.4 Confidence table

	IFR Site	Available data	Ecological Classification	Output low flow	Output high flow
Hydrology		2			
	No gauges in mainstream. No daily data available. Problems with the natural flow regime as is suspected the natural MAR is too high.				
Hydraulics	3	4		4	3
	IFR site: Moderately difficult site to characterise hydraulically (steep riffle). Output: Two flows monitored at 0.24 and 5m^3/s, resulting in medium to high confidence for the output which falls within the range for low flows.				
Water quality	4	4	3		
	IFR site: High confidence in the data collected at the dam to characterise water quality conditions at the IFR site where flow is dominated by releases from the dam. Available data: High confidence in salts data set but low confidence in nutrient data set due to high variability in the data. Moderate confidence in the representivity of the river between Waterdown Dam and the confluence with the Oxkraal River which includes the IFR 1 site, low confidence in the representivity for the reach downstream of the Oxkraal confluence and Whittlesea. Ecological classification: Moderate overall confidence because the category for some of the physical variables (temperature, dissolved oxygen, algal abundance etc.) had to be inferred from site observations. High confidence for salt categories and moderate for nutrient categories.				
Geomorphology	3	2	3		3
	IFR site: Good geomorphology cues for present flow conditions. Unsure about how geomorphologically representative this site is. Available data: No sediment modelling and poor hydrological data: Ecological classification: Good aerial photo record. High flows: All flows recommended matched the hydrological record. However, the hydrological record is poor due to a lack of daily data and confidence therefore only moderate.				
Riparian vegetation	3	2	3	5	4
	IFR site: Medium due to fact that most riparian stress had been removed from the site for fuel. Only marginal vegetation useful. Ecological Category: Uncertainties exist regarding the extent of shift in sp composition and structure from the reference site to presence and target species. Output: Low flow: The vegetation at the site is hardy and as long as the river does not dry up for longer periods than present, it will persist. Therefore, the instream biota requirements more than cater for the vegetation requirements. Output: High flow: Good cues are present and the flows recommended matched the hydrological availability.				
Fish	2	2	3	3	2
	IFR site: Low evaluation as not representative of all fish habitats that are important for life history. Available data: Little historical data available, poorly sampled at site, bad conditions during site visit. Ecological classification: Moderate knowledge of fish species present and importance known. Output low: Confidence high as fish to the primary, i.e. the final requirements are based on higher invertebrate requirements. More water than requested therefore provided. Output high: Uncertainty re impact of high flows on fish habitats.				
Invertebrates	3	2	4	3	1
	IFR site: Medium due to position of site downstream of dam, however, habitat plentiful and sufficiently far d/s of dam for biota to have recovered. Available data: Low conf to data being available only from present (no historical information) field studies and one previous sampling of this section of the river. Buffalo River data was therefore used. Ecological classification: Due to high SASS scores and moderate ASPT which indicates reasonably high sensitivity. Low flows: Medium confidence due to knowledge of how habitat changes with depth reduction. Invertebrates guided the requirements therefore this confidence is the overall level. High flows: Low confidence due to having no record of naturally occurring high flood events and their distribution through and between years.				

5 IFR 1 – KLIPPLAAT RIVER: STRESS INDICES

IFR 1 is situated in the Klipplaat River, downstream of the Waterdown Dam. The site is illustrated in Figure 5-1. A site situated 8 km downstream of the Waterdown Dam was selected.

Figure 5-1 IFR 1: 15 July 2003, 0.24m^3/s

5.1 FISH STRESS INDEX

The fish stress indices for Eurytopic and Limnophilic fish species were developed during site visits and at the specialist meeting (see Appendix F).

Table 5.1 Stress table – Eurytopic fish species

Flow-Depth Response index	Habitat abundance and suitability				Total flow depth score	Eurytopic		
	FD[1]	FS[2]	SD[3]	SS[4]		Response: Abundance	Species stress	Flow (m^3/s)
0	5	5	5	5	20	All very abundant	0	
1	4	5	5	5	19	All very abundant	0	
2	4	4	5	5	18	All very abundant	0	
3	3	4	5	5	17	Abundant	1	
4	2	3	5	5	15	Abundant	2	1
5	2	2	4	5	13	Moderate	4	0.36
6	1	2	3	4	10	Moderate	4	0.17
7	0	2	2	3	7	Low	6	0.1
8	0	1	1	2	4	Low	7	0.05
9	0	0	0	1	1	Rare	9	0
10	0	0	0	0	0	None	10	0

1 FD: Fast (>0.3m/s) Deep (>0.3m)
2 FS: Fast (>0.3m/s) Shallow (<0.3m)
3 SD: Slow (<0.3m/s) Deep (>0.5m)
4 SS: Slow (<0.3m/s) Shallow (<0.5m)

Table 5.2 Stress table – Limnophilic fish species

Flow-Depth Response index	Habitat abundance and suitability				Total flow depth score	Limnophilic		
	FD[1]	FS[2]	SD[3]	SS[4]		Response: Abundance	Species stress	Flow (m^3/s)
0	5	5	5	5	20	All very abundant	0	
1	4	5	5	5	19	All very abundant	0	
2	4	4	5	5	18	All very abundant	0	
3	3	4	5	5	17	All very abundant	0	
4	2	3	5	5	15	All very abundant	0	1
5	2	2	4	5	13	Abundant	3	0.36
6	1	2	3	4	10	Moderate	3	0.17
7	0	2	2	3	7	Low	4	0.1
8	0	1	1	2	4	Low	5	0.05
9	0	0	0	1	1	Rare	9	0
10	0	0	0	0	0	None	10	0

1 FD: Fast (>0.3m/s) Deep (>0.3m)
2 FS: Fast (>0.3m/s) Shallow (<0.3m)
3 SD: Slow (<0.3m/s) Deep (>0.5m)
4 SS: Slow (<0.3m/s) Shallow (<0.5m)

5.2 AQUATIC INVERTEBRATES STRESS INDEX

The stress indices for aquatic invertebrates were developed during site visits and at the specialist meeting. An index for the flow dependent (FD) invertebrates was developed at this site.

Table 5.3 Stress table – Flow Dependent invertebrate's species

Flow-Depth Response index	Habitat abundance and suitability					Modifier	Depth (m)	Flow (m^3/s)	Velocity (m/s)	Habitat response** (Specific to site)	Biotic response	Species stress
	SIC[1]	SOC[2]	MVIC[3]	MVOC[4]	GS[5] pool						FD Inverts (Based on Kleynhans, 1999)	
Observation*	**5**	**4**	**3**	**3**	**4**							
Site rating	4	3	2	1	3	Filamentous algae, vegetation stems only, root zones submerged.						
0	5	5	5	4	5		0.5	1.88	0.6	All habitats in excess, very high quality.	FD: Very abundant 0.	0
1	5	5	4	3	4		0.4	0.92	0.43	All habitats plentiful, very high quality.	FD: Very abundant 0.	0
2	4	4	3	2	3		0.35	0.6	0.4	SIC and VIC sufficient, quality slightly reduced.	FD: Abundant 1.	1
3	4	3	2	1	3		0.26	0.24	0.24	Reduced SIC and VIC, Reduced quality.	Slight reduction for FD: Abundant 2.	2
4	3	2	2	1	3		0.23	0.15	0.21	SIC and VIC limited, of moderate quality.	Reduction for FDI species: Moderate 3.	3
5	2	2	2	1	2		0.2	0.1	0.18	SIC and VIC very reduced, of moderate quality.	Further reduction for FDI species: Moderate 4.	4
6	2	2	1	1	2		0.16	0.05	0.15	SIC and VIC residual and of low quality.	Remnant populations of all FDI species: Low 5	5
7	1	2	0	0	1		0.14	0.03	0.13	No VIC or VOC, little SIC.	Sensitive FDI species: Low 6.	6
8	1	1	0	0	1		0.1	0.01	0.1	Flowing water present, little SIC, no VIC.	Only remnant populations of hardy FDI species: Rare 8.	8
9	0	1	0	0	1		0.05	0	0	No surface flow.	Only pool dwellers: FDIs absent: None 9.	9
10	0	0	0	0	0		0	0	0	No surface water.	None 10.	

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

5.3 RIPARIAN VEGETATION STRESS INDEX

Table 5.4 Stress table – Riparian vegetation - Restionaceae

Flow-Depth Response index	Flow (m^3/s)	Biotic response	Species stress
0	0.9	More than half of the root mass is inundated. Plants are healthy with reproduction vigour, with a full above ground biomass.	0
1			
2	0.1	Above ground biomass showing first signs of plant moisture stress and thinning. Reproduction is reduced.	2
3			
4			
5	0.07	Loss of above ground biomass, impairment of reproduction and seed production.	5
6			
7			
8	0.02	Death of clumps after extensive loss of above ground biomass.	8
9			
10	0	Total desiccation and loss of clumps.	10

6 IFR 1 – KLIPPLAAT RIVER: ECOLOGICAL CLASSIFICATION

6.1 REFERENCE CONDITIONS

Geomorphology
As with site IFR2, the site is within the geomorphological zone `E`, Lower Foothills (Refer to Appendix C). In its reference state, this is a lower gradient mixed bed alluvial channel with sand and gravel dominating the bed, local areas may be bedrock controlled. Reach types typically include pool-riffle or pool-rapid, sand bars are common in pools. In this zone typically pools are of significantly greater extent than rapids or riffles and a floodplain is often present.

Riparian vegetation
A distinctly wider river with clear zones of marginal vegetation on both banks. Sandy substrate with limited number of islands occupied by marginal vegetation except for occasionally vegetated bars are present. Marginal vegetation is characterised by *Miscanthus* and *Juncus*. Riparian vegetation forming distinct medium sized galleries immediately behind the marginal zone occupied by a mixture of riparian species, including *Celtis*, *Combretum* and *Acacia karroo*.

Water quality
Refer to the water quality report.

Fish (C/D)
Only one species of primary freshwater fish species occurs naturally in this reach of the upper Kei system, namely *Barbus anoplus* (chubbhead minnow). In addition 3 species of catadromous freshwater eel are thought to be present. Large numbers of young eels migrate up to the Waterdown Dam wall, which blocks their natural upstream migrations.

Under natural conditions the increased amount of shallow backwater habitat would have been beneficial to *B. anoplus*. It is expected that large numbers of *Barbus anoplus* would be present with a range in size and age classes would be present throughout this reach in all preferred habitats such as in structure, among marginal vegetation and undercut banks in shallow slow and shallow fast habitats .would be present.

Inverts

Bio	Description of invert communities expected in reference conditions			
	Ref	**Summer**	**Ref**	**Winter**
SIC[1]	SASS: >120 Taxa: >20 ASPT: 6+	A diverse community of flow dependent species with a relatively high EPT (Ephemeroptera, Plecoptera, Tricoptera) ratio. Diverse Ephemeroptera, including (at least) several Baetid species, Caenids, Tricorythids, Leptophlebiids, Heptageniids. A healthy community of Trichopterans including non-cased caddis. Possibility of Perlid (check) stoneflies. More than one Simuliid species likely, and abundant. Ancylid and Sphaeriid snails. Chironomids.	SASS: >100 Taxa: >15 ASPT: >5	A less diverse community of FD species than summer conditions. The ratio of Ephemeroptera:Trichoptera is likely to be reduced. Simuliids likely to be reduced relative to summer conditions, and possibly in pupal state. Ancylids and Sphaerids likely. Chironomids likely.
MV[2]	SASS: >100 Taxa: >15 ASPT: >5.5	A marginal vegetation community rich in juvenile Ephemeroptera, particularly Baetids and Caenids, and in Hemipterans. Some Coleopterans and Odonates. Lymnaeid and Physid snails may be present.	SASS: >80 Taxa: >13 ASPT: >5	A similar community to summer, however lacking Ephemeroptera likely to be reduced in numbers.

Bio	Description of invert communities expected in reference conditions			
	Ref	Summer	Ref	Winter
TOT	SASS: >160 Taxa: >35 ASPT: >6	A robust and diverse community supporting FD, some MV and pool-dwelling species. A greater diversity of Trichopterans, Ephemeropteran, Odonate, Hemipterans, Coleopterans and Dipteran families and species. Possibly Plecopterans (Perlids). The early summer community is likely to have a high percentage of juvenile Ephemeropteran taxa. The mid and late summer communities are likely to have an altered ET (Ephemeropteran Trichopterans) age-distribution due to the growth of juveniles, and the emergence of mature winged adults.	SASS: >150 Taxa: >30 ASPT: >6	The winter community would be expected to be similar to the summer community, however with reduced Ephemeropteran diversity, and a more uniform age-distribution in the Ephemeroptera and Trichoptera fauna.

1 SIC: Stones in current
2 MV: Marginal vegetation

6.2 PES

6.2.1 Habitat Driver Status

Question	Score	Reasoning
Geomorphology		
To what extent is the channel structure artificial?	1	No change.
To what extent has event (high flows) hydrology changed?	3	Intermediate flows probably altered by the presence of Waterdown Dam 8km upstream.
To what extent has sediment input changed?	4	Reduced sediment coming down the channel due to the dam and due to improved catchment condition.
To what extent has riparian vegetation changed?	3	Thicker riparian zone and encroachment onto bars and banks.
To what extent has in-channel sediment storage changed?	4	Large change due to clean water releases (erosion of bed) also reduced width and increased depth causing an increased velocity.
Water Quality (Wq)		
Modified 30 Sept 03, assessment based on in-lake water quality and assessment of impacts release water at the IFR site.		
To what extent has the 95%tile of the natural Wq changed? pH	1	PES = largely natural.
To what extent are these changes related to water quantity changes.	1	PH not related to flow although the release depth may affect the pH of the released water.
To what extent has the 95%tile of the natural Wq changed? Salts	1	Salts PES = largely natural.
To what extent are these changes related to water quantity changes.	1	Salts at the IFR not related to flow. In-lake concentrations vary very little over time.
To what extent has the 95%tile of the natural Wq changed? Nutrients	2	Nutrients PES = Good to fair (C/D)
To what extent are these changes related to water quantity changes.	1	Nutrients at the IFR site are hardly related to flow, but is more affected by the abstraction depth.
To what extent has the 95%tile of the natural Wq changed? Temp	4	Temperature PES = large change from natural if released from bottom layers.
To what extent are these changes related to water quantity changes.	3	Temperature is moderately related to flow because it affects the water retention time and recovery distance. Temperature is more affected by the abstraction depth.
To what extent has the 95%tile of the natural Wq changed? Turbidity	2	Turbidity PES at the IFR site is probably moderately modified because the dam acts as a sediment trap. Although the surface layer may have low turbidity, the bottom layers may still be turbid with fine suspended sediments.

Question	Score	Reasoning
To what extent are these changes related to water quantity changes.	2	Turbidity is slightly related to flow at the IFR site. The fine suspended sediment load at the IFR site comes from the bottom releases from the dam and is probably not generated by scouring between the dam and the IFR site.
To what extent has the 95%tile of the natural Wq changed? Oxygen	2	The dissolved oxygen concentrations at the IFR site is probably slightly modified from natural due to the bottom releases (low DO) and re-aeration (add DO) downstream of the dam.
To what extent are these changes related to water quantity changes.	3	DO is moderately related to flow because the release rate would affect the recovery distance downstream of the dam (the re-aeration rate and turbulent mixing).
Hydrology		
To what extent has low flows (70%ile) changed?	3	Changes in flow duration graph.
To what extent has the duration of zero flows changed?	3	Changes in flow duration graph.
To what extent has the seasonality changed?	1	Changes in flow duration graph.
To what extent have moderate events been reduced?	4	Changes in flow duration graph.

Geomorphology: 20% Flow related
Water quality: 43% Flow related
Overall: 50% Flow related
Category: C

6.2.2 Biological Response PES

Geomorphology (C)
The Present state demonstrates a changed geomorphological template from a "natural" condition–the river is narrower (approximately 20%) and deeper due to some incision into the alluvial bed. Large, immovable, boulders now dominate the riverbed. Rapids with limited interstitial spaces dominate habitat. Many of the changes can be attributed to the Waterdown Dam 8km upstream that has been closed since 1957 (46 years). Catchment condition has also improved since 1938 therefore less sediment inputs into this reach of the river. The present state will not be improved by a change in flow.

Riparian vegetation (D)
The PES is attributed to both flow and non-flow. Change in flow regime, seen as reduced base flows and elimination of elevated flows, have lead to a reduced river and template change resulting in changes in riparian and marginal zone species composition and structure.

Fish (C/D)

Table 6.1 Fuzzy Fish Index – IFR 1: PES

IFR site 1	**PES C/D**
Resource unit	
Native species richness	5
Presence of native intolerant species	5
Abundance of native species	2
Frequency of occurrence of native species	4
Health/condition of native and introduced species	3
Presence of introduced fish species	2
In-stream habitat modification	2
TOTAL SCORE	**23**
%	65.7
FISH ASSEMBLAGE CATEGORY	**C**

Invertebrates (B)

Table 6.2 Invert communities observed – IFR 1: PES

Bio	PES	Invert communities observed during winter
SIC	SASS: 93 Taxa: 16 ASPT: 5.8	Porifera, Turbellaria, Oligochaetes, Baetidae (>2 spp), Caenidae, Heptageniidae, Leptophlebiidae, Tricorythidae, Aeshnidae, Hydropsychidae, Chironomidae, Simuliidae, Tabanidae, Ancylidae, Sphaeriidae, Unionidae.
MV	SASS: 72 Taxa: 13 ASPT: 5.5	Porifera, Hydracarina, Baetidae (>2 spp), Corduliidae, Corixidae, Hydropsychidae, Leptoceridae, Gyrinidae, Ceratopogonidae, Chironomidae, Simuliidae, Ancylidae, Planorbidae.
TOT	SASS: 147 Taxa: 25 ASPT: 5.9	Porifera, Turbellaria, Oligochaetes, Hydracarina, Baetidae (>2 spp), Caenidae, Leptophlebiidae, Tricorythidae, Aeshnidae, Corduliidae, Gomphidae, Libellulidae, Corixidae, Hydropsychidae, Leptoceridae, Gyrinidae, Ceratopogonidae, Chironomidae, Simuliidae, Tabanidae, Ancylidae, Planorbidae, Sphaeriidae, Unionidae

6.2.3 Trajectory of change

Geomorphology
The PES is stable.

Riparian vegetation
From a flow related perspective the riparian vegetation is stable, however, a negative trajectory of change is evident in terms of non-flow related aspects such as vegetation removal, grazing and exotic species resulting in a Class D/E river in the long term.

Water quality
There is an insignificant increasing trend in mean TDS (+0.73 mg/l per year) in Waterdown Dam and slight increasing trend was observed in the nutrient concentrations. The increase in nutrient concentrations is probably related to the agricultural sources in the catchment (fertilizer wash-off). If current trends continue, no change is expected in salinity in the short and long term but nutrients can decrease by half a category in the long term.

Fish
Water quality and flow (as well as catchment management) is not expected to change apart from riparian vegetation removal, thus fish PES expected to remain as C/D category.

Invertebrates
Stable. The Waterdown Dam has been present for over 45 years and it is likely that the system, both physical and biological has now adapted to the changes imposed by the dam. There is unlikely to be any flow-related deterioration or improvement in this section.

6.2.4 Ecostatus

The PES for the various components is illustrated in Figure 6-1. The habitat driver status indicates a C system and specialists felt that this is a good representation of the Ecostatus, considering that the inverts are in a B state.

6.3 EIS

The results of the Ecological Importance and Sensitivity (EIS) are attached as Appendix G.

EIS rating: Moderate
Confidence: Moderate
Determinants: There are 25 invert taxa present. These taxa are high on a regional scale.

6.4 RANGE OF ECS

The Ecological importance was moderate (natural and present). The aim was set to maintain the Present Ecological State of a C. The component EC categories are provided in Figure 6-1. The additional EC categories to be assessed will be B/C (half a category higher, as a full category increase is deemed to be unrealistic) and D (a category lower) and also illustrated in the Figure 6-1.

Figure 6-1 IFR 1 – Ecological categories

AVAILABLE INFORMATION:

INSTREAM HABITAT INTEGRITY: C RIPARIAN HABITAT INTEGRITY: D

COMPONENT	PES	TRAJ	SHORT TERM (5 Y)	LONG TERM (20 Y)	EIS	REC	Alt EC	Alt EC
DRIVER HI	C				MODERATE	C	D	C
RIPARIAN VEGETATION	D	-- (nf)	D	D/E		D	D	C
FISH	C/D	0	C/D	C/D		C/D	D	C
AQUATIC INVERTS	B	0	B	B		B	C	B
ECOSTATUS	C	0 (F)	C	C		C	D	B/C

6.5 DEFINING ECs

Geomorphology (C)
The present state will not be improved by a change in flow. No objectives for an improved geomorphology have therefore been supplied

Riparian vegetation (C and D)
Recommended EC D
In order to maintain the vegetation in a D state, it is important to ensure that adequate base flows are present which will provide sufficient water to consistently supply the roots of marginal vegetation currently present as well as sufficient elevated flows to cover its full distribution within the marginal zone.

Alternative EC C
An improved flow regime, such as improved summer base flows and elevated flows is likely to improve the current condition of riparian and marginal vegetation to a category C at best. This will be characterised by a river with more distinct marginal and riparian zones, however, due to the basic geomorphological template change which has occurred, it is unlikely to improve to a higher category. The substrate is now generally not suitable for a healthy mixed stand of riparian vegetation such as that present under reference conditions. Improved structural characteristics are therefore unlikely to take place.

Target species:
Species such as *Celtis aricana* and *Combretum capensis*, however, it is uncertain whether these are likely to become significant given the general trend of the encroachment of *Acacia karroo* in the region. It is therefore unlikely that an improvement in species composition to a more mixed stand of riparian species will be achieved.

Any improvement in riparian condition is therefore only likely to occur in terms of the abundance of riparian species in a wider riparian zone only.

Fish (C/D, C and D)
Recommended EC C/D
Maintain present-day flow patterns and discharges, with the increase of base flows for 10 days important for fish in summer to stimulate spawning of both *B. aeneus* and *B. anoplus*. The existing winter and summer base flows (although less than natural) should be maintained as important to maintain the habitat, ensure cover for fish and ensure good water quality.

Alternative EC C
Releases of base flows for 10 days increased to 15 days by gradually reducing shut-off flows to ensure eggs and larvae are not stranded by rapidly falling water levels. Pulses important in November to January as peak spawning months.

Increased discharges for base flows in both summer and winter would improve habitat, water quality and cover available for both fish species. In addition, flows to allow migration of both fish species and 3 freshwater eel species through the system over riffles required.

Surface water rather than bottom water should be released from dams in summer – to ensure temperatures of over 18 degrees and good water quality, which are required for spawning.

The above improvements should result in increased numbers of both fish species and the improved passage of eels through this river reach.

NOTE:
Barbus aeneus is non-endemic to system but now considered an important component as has social benefits (angling, tourism, food fish). This species is more dependent on flowing water as requires riffles for spawning and prefers fast shallow and fast deep habitats.

Alternative EC D
Flow patterns less natural and all releases from lower sluices.

Table 6.3 Fuzzy Fish Index – IFR 1: Alternative ECs

IFR site 1	**PES C/D**	**Alternative EC C**	**Alternative EC D**
Native species richness	5	5	5
Abundance of native species	5	3	1
Frequency of occurrence of native	2	4	4
Health/condition of native and introduced species	4	3	3
Presence of introduced fish species	3	2	2
In-stream habitat modification	2	3	1
TOTAL SCORE	2	**20**	**16**
%	**23**	66.7	53.3
FISH ASSEMBLAGE CATEGORY	65.7	**C**	**D**
	C		

Invertebrates (C)

Ref	PES B score[1]	PES B taxa[2]	Alternative EC C score	Alternative EC C taxa
SASS: >150 Taxa: >30 ASPT: >6	SASS: 147 Taxa: 25 ASPT: 5.9	Porifera, Turbellaria, Oligochaetes, Hydracarina, Baetidae (>2 spp), Caenidae, Leptophlebiidae, Tricorythidae, Aeshnidae, Corduliidae, Gomphidae, Libellulidae, Corixidae, Hydropsychidae, Leptoceridae, Gyrinidae, Ceratopogonidae, Chironomidae, Simuliidae, Tabanidae, Ancylidae, Planorbidae, Sphaeriidae, Unionidae	SASS: 120 Taxa: 5.5 ASPT: 22	Porifera, Turbellaria, Oligochaetes, Hydracarina, Baetidae (>2 sp), Caenidae, Leptophlebiidae, Aeshnidae, Gomphidae, Libellulidae, Corixidae, Hydropsychidae, Leptoceridae, Gyrinidae, Ceratopogonidae, Chironomidae, Simuliidae, Tabanidae, Ancylidae, Planorbidae, Sphaeriidae.

1 Scores are applicable to the recommended EC B/C category
2 Taxa are applicable to the recommended EC B/C category

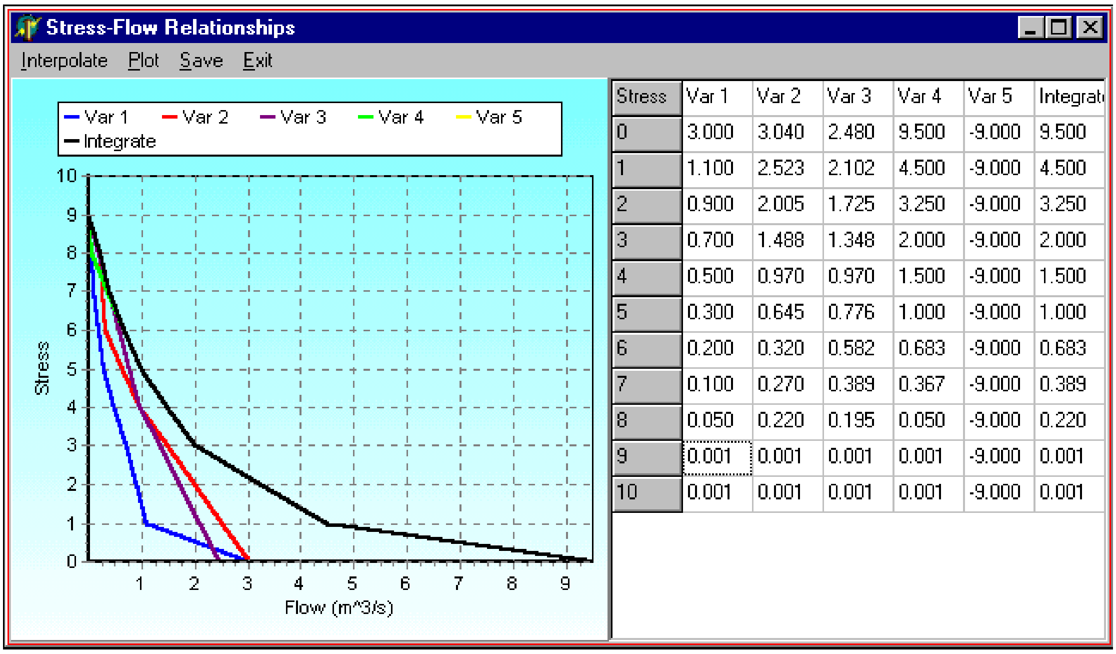
7 IFR 1 - KLIPPLAAT RIVER: DETERMINATION OF IFR SCENARIOS

7.1 LOW FLOW REQUIREMENTS

7.1.1 Component and integrated stress curves

The individual component stresses are illustrated as well as the system stress line (black line).

Figure 7-1 Component and integrated stress curves



Stress	Var 1	Var 2	Var 3	Var 4	Var 5	Integrat
0	3.000	3.040	2.480	9.500	-9.000	9.500
1	1.100	2.523	2.102	4.500	-9.000	4.500
2	0.900	2.005	1.725	3.250	-9.000	3.250
3	0.700	1.488	1.348	2.000	-9.000	2.000
4	0.500	0.970	0.970	1.500	-9.000	1.500
5	0.300	0.645	0.776	1.000	-9.000	1.000
6	0.200	0.320	0.582	0.683	-9.000	0.683
7	0.100	0.270	0.389	0.367	-9.000	0.389
8	0.050	0.220	0.195	0.050	-9.000	0.220
9	0.001	0.001	0.001	0.001	-9.000	0.001
10	0.001	0.001	0.001	0.001	-9.000	0.001

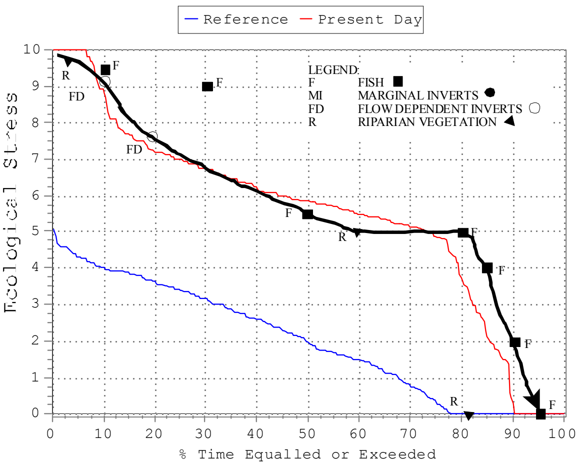
Var 1 and 2: Fish
Var 3: MD Inverts
Var 4: FD Inverts
Var 5: Riparian vegetation

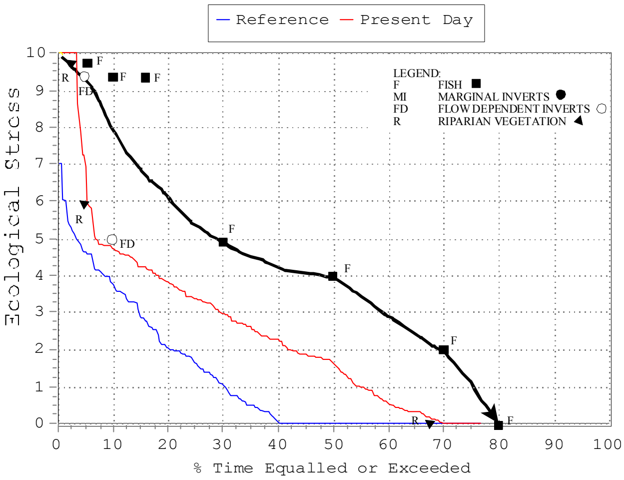
7.1.2 Generating stress requirements

The requirements are provided in the attached Appendix H.

The requirements are illustrated in Fig 3-2 - 3-4. Where all the points are plotted and the requirements are drawn.

Figure 7-2 IFR 1 – Stress duration curve for a recommended scenario of a C REC



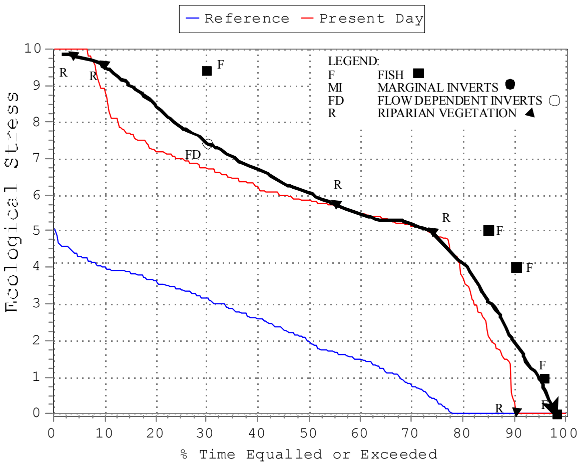


Dry season

Wet season

Figure 7-3 IFR 1 – Stress duration curve for an alternative scenario of a D EC

Dry season **Wet season**



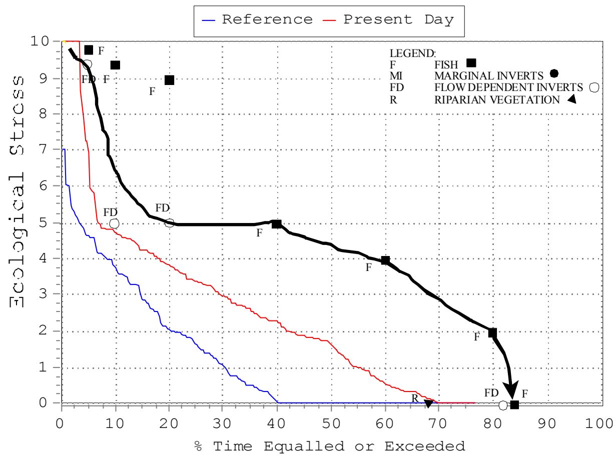
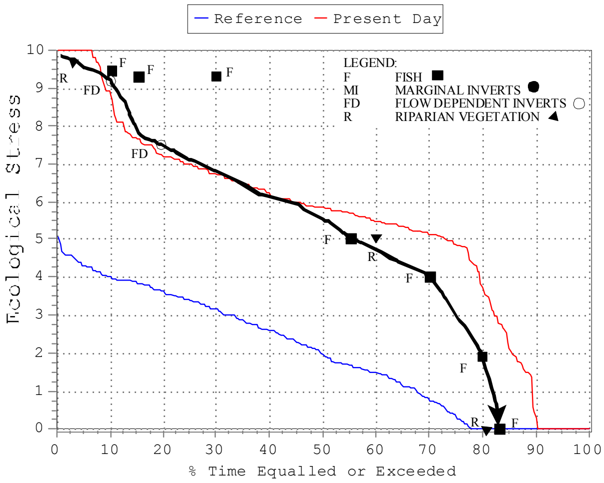


Figure 7-4 IFR 1 – Stress duration curve for an alternative scenario of a B/C EC

Dry season



Wet season

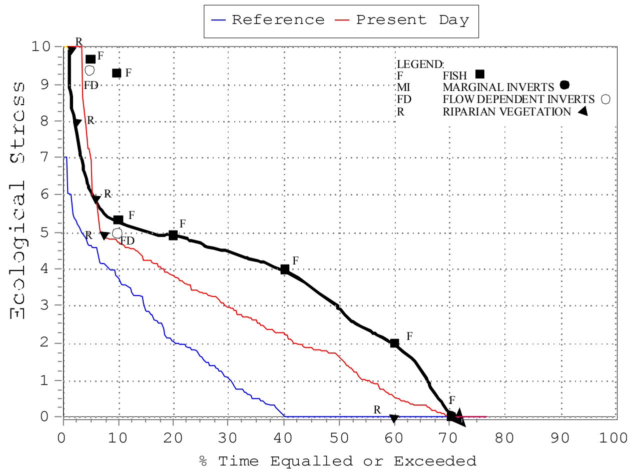
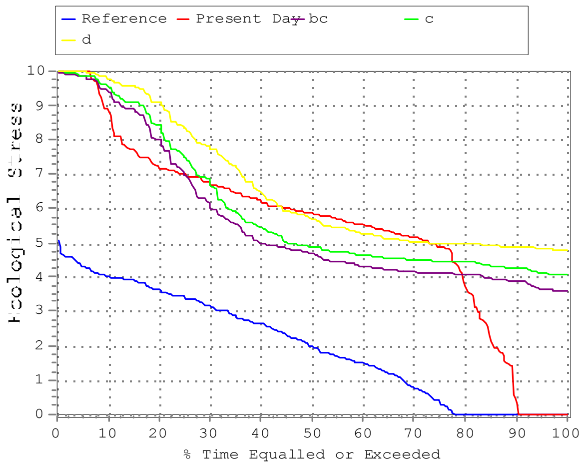
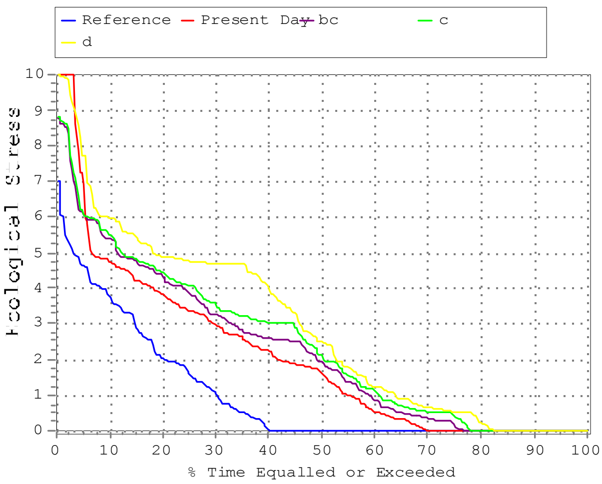


Figure 7-5 IFR 1 – Final curve

Dry season



Wet season



The desktop D was driven by riparian vegetation component. The Desktop D was adjusted accordingly. The desktop B/C was driven by the fish component and the desktop B/C was adjusted accordingly.

7.2 HIGH FLOW REQUIREMENTS

The functions for each Flood Class are described in spreadsheets. A summary of the Flood Class ranges for IFR 1 is provided in Table 7.1 – 7.2 below. The number of events for each Flood Class required for D and C and B/C EC are also summarised in Table 7.1.

Table 7.1 Flood Class ranges for IFR 1

	Flood classes			
Component	**I (m^3/s)**	**II (m^3/s)**	**III (m^3/s)**	**IV (m^3/s)**
Fish	1-2,2-4	7-10		
Invertebrates	2-4, 4-7	7-10		
Vegetation	2-7	8-15	15-45	
Geomorphology	1-4	7-12	17-32	40-65
Integrated	**1-7**	**7-15**	**15-45**	**40-65 (1:5)**
Daily average*	3	8	18	30
Duration (days)	1	2	2	

The number of high flow events required for each EC is provided below.

Table 7.2 The number of high flow events required for each EC – IFR 1

	I*	Time**	I	Time	I	Time	II	Time	II	Time	II	Time	III	Time	III	Time	III	Timing
Category	**D**	**D**	**C**	**C**	**B/C**	**D**	**D**	**D**	**C**	**C**	**B/C**	**B/C**	**D**	**D**	**C**	**C**	**B/C**	**B/C**
Fish	4	10-4	6		6		-											
Inverts	3	Spring - Summer	5		5		1	Summer	1	Summer	1	Summer						
Vegetation	5	Spring - Summer	7		7		3	Summer	3	Summer	3	Summer	1		1		1	
Geomorph	4		4		4		3		3		3		1		1		1	
Number of events	5	10-4	7	10-4	7	10-4	3	2, 3, 12	3		3		1	3	1		1	

* Denotes Class Floods
** Time is in months were 1-12 portrays January to December

These results were checked with the hydrology and were found to be acceptable.

7.3 FINAL RESULTS

7.3.1 IFR table for recommended scenario: C REC

```
Desktop Version 2, Printed on 2003/10/01
Summary of IFR estimate for: kei_1 Natural Monthly Flows
Determination based on defined BBM Table with site-specific assurance
rules.

        Annual Flows (Mill. cu. m or index values):
        MAR                 =   51.119
        S.Dev.              =   30.951
        CV                  =    0.605
        Q75                 =    1.090
        Q75/MMF             =    0.256
        BFI Index           =    0.383
        CV(JJA+JFM) Index =    2.573


        Total IFR           =   12.681 (24.81 %MAR)
        Maint. Lowflow      =    5.787 (11.32 %MAR)
        Drought Lowflow     =    0.000 ( 0.00 %MAR)
        Maint. Highflow     =    6.895 (13.49 %MAR)

        Monthly Distributions (cu.m./s)
        Distribution Type : Amatole
```

Month	Natural Flows			Modified Flows (IFR)			
				Low flows		High Flows	Total Flows
	Mean	SD	CV	Maint.	Drought	Maint.	Maint.
Oct	1.583	2.089	0.493	0.165	0.000	0.097	0.262
Nov	2.184	2.864	0.506	0.190	0.000	0.100	0.290
Dec	2.506	3.476	0.518	0.201	0.000	0.458	0.659
Jan	1.949	2.274	0.436	0.192	0.000	0.097	0.289
Feb	2.225	2.369	0.440	0.220	0.000	0.507	0.727
Mar	2.826	3.498	0.462	0.225	0.000	1.271	1.496
Apr	1.771	1.703	0.371	0.212	0.000	0.100	0.312
May	1.169	1.315	0.420	0.187	0.000	0.000	0.187
Jun	0.780	0.713	0.353	0.168	0.000	0.000	0.168
Jul	0.690	0.873	0.472	0.148	0.000	0.000	0.148
Aug	0.861	1.781	0.772	0.146	0.000	0.000	0.146
Sep	0.940	1.087	0.446	0.151	0.000	0.000	0.151

7.3.2 IFR table for alternative scenario: D EC

```
Desktop Version 2, Printed on 2003/10/01
Summary of IFR estimate for: kei_1 Natural Monthly Flows
Determination based on defined BBM Table with site specific assurance
rules.

        Annual Flows (Mill. cu. m or index values):
        MAR                 =   51.119
        S.Dev.              =   30.951
        CV                  =    0.605
        Q75                 =    1.090
        Q75/MMF             =    0.256
        BFI Index           =    0.383
        CV(JJA+JFM) Index =    2.573


        Total IFR           =    8.948 (17.50 %MAR)
        Maint. Lowflow      =    2.572 ( 5.03 %MAR)
        Drought Lowflow     =    0.000 ( 0.00 %MAR)
        Maint. Highflow     =    6.376 (12.47 %MAR)
```

Monthly Distributions (cu.m./s)
Distribution Type : Amatole

Month	Natural Flows			Modified Flows (IFR)			
				ow flows		High Flows	Total Flows
	Mean	SD	CV	Maint.	Drought	Maint.	Maint.
Oct	1.583	2.089	0.493	0.074	0.000	0.097	0.171
Nov	2.184	2.864	0.506	0.084	0.000	0.100	0.184
Dec	2.506	3.476	0.518	0.089	0.000	0.458	0.547
Jan	1.949	2.274	0.436	0.085	0.000	0.000	0.085
Feb	2.225	2.369	0.440	0.097	0.000	0.507	0.604
Mar	2.826	3.498	0.462	0.098	0.000	1.174	1.272
Apr	1.771	1.703	0.371	0.093	0.000	0.100	0.193
May	1.169	1.315	0.420	0.083	0.000	0.000	0.083
Jun	0.780	0.713	0.353	0.075	0.000	0.000	0.075
Jul	0.690	0.873	0.472	0.067	0.000	0.000	0.067
Aug	0.861	1.781	0.772	0.066	0.000	0.000	0.066
Sep	0.940	1.087	0.446	0.069	0.000	0.000	0.069

7.3.3 IFR table for alternative scenario: B/C EC

Desktop Version 2, Printed on 2003/10/01
Summary of IFR estimate for: kei_1 Natural Monthly Flows
Determination based on defined BBM Table with site specific assurance rules.

Annual Flows (Mill. cu. m or index values):

MAR	=	51.119
S.Dev.	=	30.951
CV	=	0.605
Q75	=	1.090
Q75/MMF	=	0.256
BFI Index	=	0.383
CV(JJA+JFM) Index	=	2.573

Total IFR	=	14.909	(29.17 %MAR)
Maint. Lowflow	=	8.015	(15.68 %MAR)
Drought Lowflow	=	0.000	(0.00 %MAR)
Maint. Highflow	=	6.895	(13.49 %MAR)

Monthly Distributions (cu.m./s)
Distribution Type : Amatole

Month	Natural Flows			Modified Flows (IFR)			
				Low flows		High Flows	Total Flows
	Mean	SD	CV	Maint.	Drought	Maint.	Maint.
Oct	1.583	2.089	0.493	0.227	0.000	0.097	0.324
Nov	2.184	2.864	0.506	0.264	0.000	0.100	0.364
Dec	2.506	3.476	0.518	0.280	0.000	0.458	0.738
Jan	1.949	2.274	0.436	0.267	0.000	0.097	0.364
Feb	2.225	2.369	0.440	0.305	0.000	0.507	0.812
Mar	2.826	3.498	0.462	0.314	0.000	1.271	1.585
Apr	1.771	1.703	0.371	0.296	0.000	0.100	0.396
May	1.169	1.315	0.420	0.259	0.000	0.000	0.259
Jun	0.780	0.713	0.353	0.231	0.000	0.000	0.231
Jul	0.690	0.873	0.472	0.204	0.000	0.000	0.204
Aug	0.861	1.781	0.772	0.200	0.000	0.000	0.200
Sep	0.940	1.087	0.446	0.207	0.000	0.000	0.207

7.3.4 IFR rule table for recommended scenario: C REC

Desktop Version 2, Printed on 2003/10/01
Summary of IFR rule curves for : kei_1 Natural Monthly Flows
Determination based on defined BBM Table with site specific assurance rules.
Regional Type : Amatole REC = C

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

	% Points									
Month	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	0.332	0.327	0.315	0.292	0.253	0.196	0.128	0.066	0.025	0.012
Nov	0.477	0.433	0.391	0.346	0.271	0.210	0.138	0.071	0.027	0.012
Dec	1.231	1.077	0.945	0.823	0.607	0.506	0.367	0.214	0.092	0.050
Jan	0.368	0.364	0.353	0.329	0.286	0.221	0.143	0.071	0.025	0.012
Feb	0.882	0.871	0.844	0.787	0.686	0.534	0.354	0.189	0.086	0.056
Mar	2.966	2.541	2.185	1.870	1.313	1.105	0.820	0.502	0.241	0.086
Apr	0.385	0.379	0.366	0.339	0.293	0.227	0.148	0.075	0.028	0.012
May	0.226	0.222	0.211	0.190	0.156	0.110	0.063	0.027	0.007	0.001
Jun	0.201	0.196	0.184	0.160	0.124	0.082	0.044	0.018	0.005	0.001
Jul	0.177	0.172	0.161	0.140	0.108	0.071	0.038	0.016	0.005	0.001
Aug	0.175	0.170	0.160	0.139	0.108	0.071	0.038	0.016	0.005	0.001
Sep	0.190	0.186	0.178	0.160	0.131	0.092	0.053	0.023	0.006	0.001

Reserve flows without High Flows

Oct	0.219	0.216	0.208	0.193	0.166	0.127	0.081	0.038	0.011	0.001
Nov	0.253	0.249	0.241	0.223	0.193	0.148	0.094	0.045	0.012	0.002
Dec	0.271	0.269	0.262	0.249	0.224	0.184	0.128	0.067	0.018	0.002
Jan	0.256	0.253	0.245	0.228	0.197	0.151	0.095	0.043	0.011	0.002
Feb	0.293	0.289	0.279	0.259	0.224	0.170	0.107	0.049	0.012	0.002
Mar	0.304	0.300	0.293	0.278	0.250	0.206	0.146	0.079	0.024	0.002
Apr	0.271	0.267	0.257	0.238	0.205	0.157	0.100	0.047	0.013	0.002
May	0.226	0.222	0.211	0.190	0.156	0.110	0.063	0.027	0.007	0.001
Jun	0.201	0.196	0.184	0.160	0.124	0.082	0.044	0.018	0.005	0.001
Jul	0.177	0.172	0.161	0.140	0.108	0.071	0.038	0.016	0.005	0.001
Aug	0.175	0.170	0.160	0.139	0.108	0.071	0.038	0.016	0.005	0.001
Sep	0.190	0.186	0.178	0.160	0.131	0.092	0.053	0.023	0.006	0.001

7.3.5 IFR rule table for alternative scenario: D EC

Desktop Version 2, Printed on 2003/10/01
Summary of IFR rule curves for : kei_1 Natural Monthly Flows
Determination based on defined BBM Table with site specific assurance rules.
Regional Type : Amatole REC = D

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

	% Points									
Month	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	0.263	0.259	0.250	0.232	0.201	0.156	0.103	0.054	0.022	0.011
Nov	0.372	0.329	0.291	0.253	0.191	0.149	0.098	0.052	0.022	0.011
Dec	1.124	0.971	0.841	0.725	0.519	0.434	0.317	0.187	0.085	0.049
Jan	0.150	0.148	0.143	0.133	0.115	0.088	0.055	0.025	0.006	0.001
Feb	0.868	0.857	0.831	0.775	0.675	0.526	0.349	0.187	0.085	0.056
Mar	2.641	2.249	1.923	1.636	1.131	0.953	0.709	0.438	0.215	0.086
Apr	0.294	0.289	0.279	0.259	0.224	0.174	0.114	0.059	0.024	0.012
May	0.132	0.129	0.123	0.111	0.091	0.064	0.037	0.016	0.004	0.001
Jun	0.114	0.111	0.104	0.091	0.071	0.047	0.025	0.010	0.003	0.001
Jul	0.102	0.099	0.093	0.080	0.062	0.041	0.022	0.009	0.003	0.001
Aug	0.101	0.098	0.092	0.080	0.062	0.041	0.022	0.009	0.003	0.001
Sep	0.113	0.111	0.105	0.095	0.078	0.055	0.032	0.014	0.004	0.001

Reserve flows without High Flows

Oct	0.130	0.128	0.123	0.114	0.098	0.075	0.048	0.023	0.006	0.001
Nov	0.148	0.145	0.141	0.130	0.113	0.086	0.055	0.026	0.007	0.001
Dec	0.164	0.163	0.159	0.151	0.136	0.111	0.078	0.041	0.011	0.001
Jan	0.150	0.148	0.143	0.133	0.115	0.088	0.055	0.025	0.006	0.001
Feb	0.170	0.168	0.163	0.151	0.130	0.099	0.062	0.028	0.007	0.001
Mar	0.181	0.179	0.174	0.165	0.149	0.123	0.087	0.047	0.014	0.001
Apr	0.159	0.156	0.151	0.139	0.120	0.092	0.058	0.028	0.008	0.001
May	0.132	0.129	0.123	0.111	0.091	0.064	0.037	0.016	0.004	0.001
Jun	0.114	0.111	0.104	0.091	0.071	0.047	0.025	0.010	0.003	0.001
Jul	0.102	0.099	0.093	0.080	0.062	0.041	0.022	0.009	0.003	0.001
Aug	0.101	0.098	0.092	0.080	0.062	0.041	0.022	0.009	0.003	0.001

```
Sep     0.113    0.111    0.105    0.095    0.078    0.055    0.032    0.014    0.004    0.001
```

7.3.6 IFR rule table for alternative scenario: B/C EC

```
Desktop Version 2, Printed on 2003/10/01
Summary of IFR rule curves for : kei_1 Natural Monthly Flows
Determination based on defined BBM Table with site specific assurance
rules.
Regional Type : Amatole     REC = B/C

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

       % Points
Month     10%      20%      30%      40%      50%      60%      70%      80%      90%      99%
Oct     0.384    0.378    0.365    0.338    0.293    0.226    0.147    0.075    0.028    0.012
Nov     0.546    0.501    0.458    0.408    0.324    0.251    0.164    0.083    0.030    0.013
Dec     1.305    1.149    1.016    0.890    0.668    0.556    0.402    0.232    0.097    0.051
Jan     0.434    0.428    0.415    0.387    0.337    0.260    0.167    0.082    0.028    0.012
Feb     0.934    0.923    0.894    0.833    0.725    0.565    0.373    0.198    0.088    0.056
Mar     3.049    2.623    2.265    1.946    1.382    1.162    0.860    0.523    0.248    0.086
Apr     0.454    0.448    0.432    0.401    0.346    0.267    0.173    0.087    0.032    0.013
May     0.290    0.285    0.271    0.244    0.200    0.141    0.081    0.035    0.009    0.002
Jun     0.256    0.250    0.234    0.204    0.158    0.104    0.056    0.023    0.007    0.002
Jul     0.226    0.220    0.205    0.178    0.137    0.090    0.048    0.020    0.006    0.001
Aug     0.222    0.216    0.203    0.177    0.137    0.090    0.048    0.020    0.006    0.001
Sep     0.242    0.237    0.226    0.204    0.167    0.118    0.068    0.029    0.008    0.002

Reserve flows without High Flows
Oct     0.277    0.273    0.263    0.243    0.209    0.160    0.102    0.048    0.013    0.002
Nov     0.322    0.318    0.307    0.285    0.246    0.189    0.120    0.057    0.016    0.002
Dec     0.345    0.341    0.333    0.316    0.284    0.233    0.163    0.085    0.023    0.002
Jan     0.326    0.322    0.312    0.291    0.252    0.193    0.121    0.055    0.014    0.002
Feb     0.373    0.368    0.355    0.330    0.284    0.217    0.136    0.062    0.016    0.002
Mar     0.386    0.382    0.373    0.353    0.319    0.263    0.186    0.101    0.031    0.002
Apr     0.346    0.341    0.329    0.304    0.262    0.200    0.127    0.060    0.017    0.002
May     0.290    0.285    0.271    0.244    0.200    0.141    0.081    0.035    0.009    0.002
Jun     0.256    0.250    0.234    0.204    0.158    0.104    0.056    0.023    0.007    0.002
Jul     0.226    0.220    0.205    0.178    0.137    0.090    0.048    0.020    0.006    0.001
Aug     0.222    0.216    0.203    0.177    0.137    0.090    0.048    0.020    0.006    0.001
Sep     0.242    0.237    0.226    0.204    0.167    0.118    0.068    0.029    0.008    0.002
```

7.4 CONFIDENCE

The confidence is evaluated according to a score of 0-5 with zero reflecting ‘no confidence’ and 5 reflecting ‘very high’ confidence.

Table 7.3 Confidence table – IFR 1

	IFR Site	Available data	Ecological Classification	Output low flow	Output high flow
Hydrology		2			
	No gauges in main stream. No daily data available. Problems with the natural flow regime as is suspected the natural MAR is too high.				
Hydraulics	3	4		4	3
	IFR site: Moderately difficult site to characterise hydraulically (steep riffle). Output: Two flows monitored at 0.24 and 5m^3/s, resulting in medium to high confidence for the output which falls within the range for low flows.				
Water quality	4	4	3		
	IFR site: High confidence in the data collected at the dam to characterise water quality conditions at the IFR site where flow is dominated by releases from the dam. Available data: High confidence in salts data set but low confidence in nutrient data set due to high variability in the data. Moderate confidence in the representivity of the river between Waterdown Dam and the confluence with the Oxkraal River which includes the IFR 1 site, low confidence in the representivity for the reach downstream of the Oxkraal confluence and Whittlesea. Ecological classification: Moderate overall confidence because the category for some of the physical variables (temperature, dissolved oxygen, algal abundance etc.) had to be inferred from site observations. High confidence for salt categories and moderate for nutrient categories.				
Geomorphology	3	2	3		3

	IFR Site	Available data	Ecological Classification	Output low flow	Output high flow
	IFR site: Good geomorphology cues for present flow conditions. Unsure about how geomorphologically representative this site is. Available data: No sediment modelling and poor hydrological data: Ecological classification: Good aerial photo record. High flows: All flows recommended matched the hydrological record. However, the hydrological record is poor due to a lack of daily data and confidence therefore only confidence.				
Riparian vegetation	**3**	**2**	**3**	**5**	**4**
	IFR site: Medium due to fact that most riparian tress had been removed from the site for fuel. Only marginal vegetation useful. Ecological Category: Uncertainties exist regarding the extent of shift in sp composition and structure from the reference site to presence and target species. Output: Low flow: The vegetation at the site is hardy and as long as the river does not dry up for longer periods than present, it will persist. Therefore, the instream biota requirements more than cater for the vegetation requirements. Output: High flow: Good cues are present and the flows recommended matched the hydrological availability.				
Fish	**2**	**2**	**3**	**3**	**2**
	IFR site: Low evaluation as not representative of all fish habitats that are important for life history. Available data: Little historical data available, poorly sampled at site, bad conditions during site visit. Ecological classification: Moderate knowledge of fish species present and importance known. Output low: Confidence high as fish to the primary, i.e. the final requirements are based on higher invertebrate requirements. More water than requested therefore provided. Output high: Uncertainty re impact of high flows on fish habitats.				
Invertebrates	**3**	**2**	**4**	**3**	**1**
	IFR site: Medium due to position of site downstream of dam, however, habitat plentiful and sufficiently far d/s of dam for biota to have recovered. Available data: Low conf to data being available only from present (no historical information) field studies and one previous sampling of this section of the river. Buffalo River data was therefore used. Ecological classification: Due to high SASS scores and moderate ASPT which indicates reasonably high sensitivity. Low flows: Medium confidence due to knowledge of how habitat changes with depth reduction. Invertebrates guided the requirements therefore this confidence is the overall level. High flows: Low confidence due to having no record of naturally occurring high flood events and their distribution through and between years.				

8 IFR 2 – UPPER BLACK KEI RIVER: STRESS INDICES

IFR 2 is situated in the Black Kei River, downstream of the Klaas Smits confluence on the farm Imvani. The site is illustrated in Figure 8-1.

Figure 8-1 IFR 2: 15 July 2003, 0.36m^3/s

8.1 FISH STRESS INDEX

The fish stress indices for Eurytopic and Limnophilic fish species were developed during site visits and at the specialist meeting (see Appendix F).

Table 8.1 Stress table – Eurytopic fish species

Flow-Depth Response index	Habitat abundance and suitability				Total flow depth score	Eurytopic		
	FD[1]	FS[2]	SD[3]	SS[4]		Response: Abundance	Species stress	Flow (m^3/s)
0	5	5	5	5	20	All very abundant	0	
1	4	5	5	5	19	All very abundant	0	
2	4	4	5	5	18	All very abundant	0	
3	3	4	5	5	17	Abundant	1	
4	2	3	5	5	15	Abundant	2	1
5	2	2	4	5	13	Moderate	4	0.36
6	1	2	3	4	10	Moderate	4	0.17
7	0	2	2	3	7	Low	6	0.1
8	0	1	1	2	4	Low	7	0.05
9	0	0	0	1	1	Rare	9	0
10	0	0	0	0	0	None	10	0

1 FD: Fast (>0.3m/s) Deep (>0.3m)
2 FS: Fast (>0.3m/s) Shallow (<0.3m)
3 SD: Slow (<0.3m/s) Deep (>0.5m)
4 SS: Slow (<0.3m/s) Shallow (<0.5m)

Table 8.2 Stress table – Limnophilic fish species

Flow-Depth Response index	Habitat abundance and suitability				Total flow depth score	Limnophilic		
	FD[1]	FS[2]	SD[3]	SS[4]		Response: Abundance	Species stress	Flow (m^3/s)
0	5	5	5	5	20	All very abundant	0	
1	4	5	5	5	19	All very abundant	0	
2	4	4	5	5	18	All very abundant	0	
3	3	4	5	5	17	All very abundant	0	
4	2	3	5	5	15	All very abundant	0	1
5	2	2	4	5	13	Abundant	3	0.36
6	1	2	3	4	10	Moderate	3	0.17
7	0	2	2	3	7	Low	4	0.1
8	0	1	1	2	4	Low	5	0.05
9	0	0	0	1	1	Rare	9	0
10	0	0	0	0	0	None	10	0

1 FD: Fast (>0.3m/s) Deep (>0.3m)
2 FS: Fast (>0.3m/s) Shallow (<0.3m)
3 SD: Slow (<0.3m/s) Deep (>0.5m)
4 SS: Slow (<0.3m/s) Shallow (<0.5m)

8.2 AQUATIC INVERTEBRATES STRESS INDEX

The stress indices for aquatic invertebrates were developed during site visits and at the specialist meeting. An index only for the marginal vegetation invertebrates (MV) only was developed at this site as limited habitat for flow dependent (FD) invertebrates occur and the stress requirements for marginal invertebrates were more critical than those for flow dependent invertebrates.

Table 8.3 Stress table – Marginal vegetation invertebrate species

Flow-Depth Response index	Habitat abundance and suitability					Modifier	Habitat response** (site specific)	Biotic response	Species stress
	SIC[1]	SOC[2]	MVIC[3]	MVOC[4]	GS[5] pool			FD Inverts (Based on Kleynhans, 1999)	
Observation*	**3**	**4**	**2**	**2**	**3**				
Site rating**	2	3	2	1	3	Boulders embedded, Filamentous algae, vegetation stems only (out of current).	SIC habitat reduced by embeddedness. SOC habitat reduced due to algal covering over cobbles and some boulders. Marginal vegetation - only roots and base of stems. SIC average depth 0.13m. If flow is reduced by a depth of 5-20cm, it will alter SIC to SOC. If flow is removed from the exposed surfaces of boulders will remove SIC altogether. For MVIC: A reduction in depth of 15cm will expose stems (in the MVIC area). For MVOC, only root zone submerged at present.		
0	5	5	5	5	5		All habitats in excess, very high quality.	MVs: Abundant 1.	1
1	5	5	4	4	4		All habitats plentiful, very high quality.		
2	4	4	4	3	3		SIC and VIC sufficient, quality slightly reduced.	Slight reduction for MVs: Abundant 2.	
3	3	4	3	3	3		Reduced SIC and VIC, Reduced quality.	Further reduction for MV species: Moderate 4.	4
4	3	4	3	2	3		SIC and VIC limited, of moderate quality.		
5	2	3	2	2	3		SIC and VIC very reduced, of moderate quality.	Sensitive MV species: Low 6.	6
6	2	3	1	1	2		SIC and VIC residual and of low quality.		
7	1	2	0	1	2		No VIC, Some VOC, little SIC.	All MV species: Rare 7.	
8	1	2	0	0	2		Flowing water present, little SIC, no VIC.	Only pool dwellers: MVs: absent: None 9.	9
9	0	1	0	0	1		No surface flow.		
10	0	0	0	0	0		No surface water.	None.	10

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

9 IFR 2 – UPPER BLACK KEI RIVER: ECOLOGICAL CLASSIFICATION

9.1 REFERENCE CONDITIONS

Geomorphology
This site falls within the geomorphological zone `E`, Lower Foothills (Refer to Appendix C). In its reference state, this is a lower gradient mixed bed alluvial channel with sand and gravel dominating the bed, local areas may be bedrock controlled. Reach types typically include pool-riffle or pool-rapid, sand bars are common in pools. In this zone typically pools are of significantly greater extent than rapids or riffles and a floodplain is often present.

Riparian vegetation
The river will be distinctly wider river with clear zones of marginal vegetation on both banks. A limited number of islands occupied by marginal vegetation are present except for occasionally vegetated bars. Marginal vegetation is characterised by *Miscanthus* and *Juncus*. The riparian vegetation forms distinct medium sized galleries immediately behind the marginal zone and are occupied by a mixture of riparian species, including *Celtis*, *Combretum* and *Acacia*.

Water quality
Refer to the water quality report.

Fish
Only one species of primary freshwater fish species occurs naturally in this section of the upper Kei system, namely *Barbus anoplus* (chubbhead minnow). In addition, 3 species of catadromous (i.e. marine-spawning) freshwater eel will also occur. No barriers would have been present and migration would have taken place utilising the full length of the river.

Large numbers of *Barbus anoplus* with a range in size and age classes should thus be present in preferred habitats such as near fallen logs and brushwood and among marginal vegetation and undercut banks in shallow slow and shallow fast habitats throughout this reach.

Invertebrates

Bio	Description of invert communities expected in reference conditions			
	Ref	Summer	Ref	Winter
SIC[1]	SASS: >100 Taxa: >15 ASPT: >6	A diverse community of flow dependent species with a relatively high EPT (Ephemeroptera, Plecoptera, Trichoptera) ratio. Diverse Ephemeroptera, including (at least) several Baetid species, Caenids, Tricorythids, Leptophlebiids, Heptageniids and possibly Oligoneurids and Teloganodids. A healthy community of Trichopterans including non-cased caddis. Possibility of Perlid stoneflies. More than one Simuliid species likely, and abundant. Ancylid and Sphaeriid snails. Chironomids.	SASS: >100 Taxa: >15 ASPT: >5	A less diverse community of flow dependent species than summer conditions. The ratio of Ephemeroptera:Trichoptera is likely to be reduced. Simuliids likely to be reduced relative to summer conditions, and possibly in pupal state. Ancylids and Sphaerids likely. Chironomids likely.
MV[2]	SASS: >100 Taxa: >15 ASPT: >6	A marginal vegetation community rich in juvenile Ephemeroptera, particularly Baetids and Caenids, and in Hemipterans. Some Coleopterans and Odonates. Lymnaeid and Physid snails may be present.	SASS : >80 Taxa: >13 ASPT: >5	A similar community to summer, however Ephemeroptera and Simuliid larvae likely to be reduced in diversity and abundance.

Bio	Description of invert communities expected in reference conditions			
	Ref	Summer	Ref	Winter
TOT	SASS: >150 Taxa: >30 ASPT: >6	A robust and diverse community supporting flow dependent, MV and pool-dwelling species. A greater diversity of Trichopterans, Ephemeropteran, Odonate, Hemipterans, Coleopterans and Dipteran families and species. The early summer community is likely to have a high percentage of juvenile Ephemeropteran taxa. The mid and late summer communities are likely to have an altered EPT (Ephemeroptera, Plecoptera, Trichoptera) age-distribution due to the growth of juveniles, and the emergence of mature winged adults.	SASS: >150 Taxa: >30 ASPT: >6	The winter community would be expected to be similar to the summer community, however with reduced Ephemeropteran diversity, and a more uniform age-distribution in the EPT (Ephemeroptera, Plecoptera, Trichoptera) fauna.

1 SIC: Stones in current
2 MV: Marginal vegetation

9.2 PES

9.2.1 Habitat Driver Status

Question	Score	Reasoning
Geomorphology		
To what extent is the channel structure artificial?	1	No change.
To what extent has event (high flows) hydrology changed?	2	Some small change in event hydrology due to upstream dams in wet tributaries.
To what extent has sediment input changed?	3	Sediment input reduced because of dams and mostly due to improved catchment condition.
To what extent has riparian vegetation changed?	3	Change in species composition from a mixed riparian to an area dominated by Acacia Karroo.
To what extent has in-channel sediment storage changed?	4	Large change as channel has become confined by vegetation causing incision and scour of sands and gravels in narrow channel.
Water Quality (Wq)		
Modified 1 October 2003, Qualitative assessment, no monitoring points in this river reach		
To what extent has the 95%tile of the natural Wq changed? pH	2	PES = Good (B/C), slightly elevated from natural conditions.
To what extent are these changes related to water quantity changes.	2	Slightly related to flow because water retention time and algal growth affects pH.
To what extent has the 95%tile of the natural Wq changed? Salts	4	PES = Poor (E/F), high changed from natural.
To what extent are these changes related to water quantity changes.	3	Largely related to flow, especially winter low flow periods and reduced dilution from Klipplaat River and from Klaas Smits River.
To what extent has the 95%tile of the natural Wq changed? Nutrients	4	PES = Poor (E/F), large change from natural due to effluents from Whittlesea and Queenstown.
To what extent are these changes related to water quantity changes.	2	Moderately related to flow, high nutrients affected by point and non-point sources. Point sources are diluted by higher flows, non-point sources affected by wash-off processes.
To what extent has the 95%tile of the natural Wq changed? Temp	1	PES = Good (B), no data to assess present state but expected to be large difference from natural.
To what extent are these changes related to water quantity changes.	1	Not related to flow in this case.
To what extent has the 95%tile of the natural Wq changed? Turbidity	2	PES = Good/Fair (B/C), no data but the amount of silty material observed indicate no large change away from natural.
To what extent are these changes related to water	4	Highly related to flow and transport processes and

Question	Score	Reasoning
quantity changes.		retention time in the system.
To what extent has the 95%tile of the natural Wq changed? Oxygen	2	PES = Good (B), some change in diel changes probably due to algal growth on substrate.
To what extent are these changes related to water quantity changes.	2	Some relation to flow because it affects water retention and travel time and diel changes.
Hydrology		
To what extent has low flows (70%ile) changed?	5	Changes in flow duration graph.
To what extent has the duration of zero flows changed?	4	Changes in flow duration graph.
To what extent has the seasonality changed?	2	Changes in flow duration graph.
To what extent have moderate events been reduced?	3	Changes in flow duration graph.

Geomorphology: 15% Flow related
Water quality: 49% Flow related
Overall: 53% Flow related
Category: C/D

9.2.2 Biological Response PES

Geomorphology (C/D)
The present state demonstrates a changed geomorphological template from a "natural" condition. The river is narrow and deep (some incision) and the riverbed is dominated by large, immovable, boulders. Rapids with limited interstitial spaces dominate the habitat.

Riparian vegetation (C/D)
The PES is partially non-flow related as a consequence of grazing and utilisation. However the change in flow regime has lead to a reduced river and template change resulting in changes in riparian and marginal zone species composition and structure.

Fish (D)
Maintain present-day flow patterns and discharges, with increased base flows of 10 days is important for fish in summer to stimulate spawning of both *B. aeneus* and *B. anoplus*. The existing winter and summer base flows (although less than natural) should be maintained as it is important to maintain the habitat, ensure cover for fish and ensure good water quality.

Table 9.1 Fuzzy Fish Index – IFR 2: PES

IFR site 2	**PES D**
Resource unit	
Native species richness	5
Presence of native intolerant species	0
Abundance of native species	2
Frequency of occurrence of native species	3
Health/condition of native and introduced species	3
Presence of introduced fish species	2
In-stream habitat modification	2
TOTAL SCORE	**17**
%	56.7
FISH ASSEMBLAGE CATEGORY	**D**

Invertebrates (D/E)
The PES is illustrated in Table 9.2.

Table 9.2 Invert communities observed during winter – IFR 2: PES

Bio	PES	Invert communities observed during winter
SIC	SASS: 17 Taxa: 4 ASPT: 4.3	Baetidae (2sp), Hydropsychidae, Chironomidae, Simuliidae
MV	SASS: 53 Taxa: 12 ASPT: 4.4	Turbellaria, Baetidae (2sp), Caenidae, Coenagrionidae, Gomphidae, Libellulidae, Corixidae, Gyrinidae, Hydropsychidae, Chironomidae, Culicidae, Simuliidae, Ancylidae, Lymnaeidae.
TOT	SASS: 58 Taxa: 14 ASPT: 4.1	Turbellaria, Baetidae (2sp), Caenidae, Coenagrionidae, Gomphidae, Libellulidae, Hydropsychids, Corixidae, Gyrinidae, Chironomidae, Simuliidae, Ancylidae, Lymnaeidae.

9.2.3 Trajectory of change

Geomorphology
The present geomorphological and habitat condition is stable.

Riparian vegetation
From a flow related perspective the riparian vegetation is stable, however, a negative trajectory of change is evident in terms of non-flow related aspects such as grazing, utilisation and exotic species resulting in a category D river in the long term.

Water quality
Salinity is improving from the PES whereas nutrients are degrading. Both fish and aquatic invertebrates are not responding to water quality changes (tolerant to theses changes) therefore this trajectory is not considered further.

Fish
The possible introduction of *Clarias gariepinus* and the potential of predation on the existing fish communities have been identified in the long term. In the long term the fish PES will change to a D. This can be seen as a non-flow related trajectory of change although flow will indirectly impact on the success of the persistence of alien species.

Invertebrates
The trajectory of change is stable.

9.2.4 Ecostatus

The PES for the various components is illustrated in Figure 9-1. The habitat driver status indicates a C/D system. However, due to the low aquatic invertebrate PES the consensus was that this system is representative of a D Ecostatus.

9.3 EIS

The results of the Ecological Importance and Sensitivity (EIS) are attached as Appendix G.

EIS rating: Moderate
Confidence: Moderate
Determinants: Private natural reserve is present. A small proportion of the invert community is dependent on flow during some of their life stages.

9.4 RANGE OF ECs

The Ecological importance was low (natural) and moderate (present). The aim was set to maintain the Present Ecological State of a D. The component EC categories are provided in Figure 9-1. The additional EC category to be assessed will be a C and the associated component ECs are also illustrated in the Figure 9-1

Figure 9-1 IFR 2 – Ecological categories

AVAILABLE INFORMATION:

INSTREAM HABITAT INTEGRITY: **C** RIPARIAN HABITAT INTEGRITY: **D**

COMPONENT	PES	TRAJ	SHORT TERM (5 Y)	LONG TERM (20 Y)	EIS	REC	Alt EC
DRIVER HI	C				MODERATE	C	C
RIPARIAN VEGETATION	C/D	-- (nf)	C/D	D		C/D	B/C
FISH	D	-- (nf)	D	D		D	C
AQUATIC INVERTS	D/E	0	D/E	D/E		D	C
ECOSTATUS	D	-- (nf)	D	D		D	C

9.5 DEFINING ECs

Geomorphology (C)
The present geomorphological and habitat condition will not be improved by a change in flow. No objectives for an improved geomorphology have therefore been supplied.

Riparian vegetation (C/D and B/C)
Recommended EC C/D
In order to maintain the vegetation in a C/D, it is important to ensure that adequate base flows are present which will provide sufficient water to consistently supply the roots of marginal vegetation currently present as well as sufficient elevated flows to cover its full distribution within the marginal zone.

Alternative EC B/C
An improved flow regime, such as improved summer base flows and elevated flows is likely to improve the current condition of riparian and marginal vegetation to a Category B/C. This will be characterised by a river with more distinct marginal and riparian zones with fewer islands. However, due to the basic geomorphological template change which has occurred, it is unlikely to improve to a higher category. The substrate is now generally not suitable for a healthy mixed stand of riparian vegetation such as that present under reference conditions. Improved structural characteristics are therefore unlikely to take place.

Target species:
The target species are those such as *Celtis africana* and *Combretum capensis*, however, it is uncertain whether these are likely to become significant given the general trend of the encroachment of *Acacia karroo* in the region. It is therefore unlikely that an improvement in species composition to a more mixed stand of riparian species will be achieved.

Any improvement in riparian condition is therefore only likely to occur in terms of the abundance of riparian species in a wider riparian zone.

Fish (C and D)

Recommended EC D

Maintain present-day flow patterns and discharges, with increased base flows of 10 days is important for fish in summer to stimulate spawning of both *B. aeneus* and *B. anoplus*. The existing winter and summer base flows (although less than natural) should be maintained as it is important to maintain the habitat, ensure cover for fish and ensure good water quality.

Alternative EC C

Increased base flows of up to 15 days to ensure eggs and rapidly falling or fluctuating water levels do not strand larvae. This, as well as freshes are important in November - January as peak spawning months. In addition, flows to allow migration of both fish species and 3 freshwater eel species through the system over riffles required. Surface water rather than bottom water should be released from dams in summer, to ensure temperatures of over 18°C and good water quality, which are required for spawning.

The above improvements should result in increased numbers of both fish species and the improved passage of eels through river reach.

Note: *Barbus aeneus* is non-endemic to system but now considered an important component as has social benefits (angling, tourism, food fish). This species is more dependent on flowing water as requires riffles for spawning and prefers fast shallow and fast deep habitats.

Table 9.3 Fuzzy Fish Index – IFR 2: Alternative EC

IFR site 2	**PES D**	**Alternative EC C**
Native species richness	5	5
Presence of native intolerant species	0	0
Abundance of native species	2	3
Frequency of occurrence of native	3	3
Health/condition of native and introduced species	3	3
Presence of introduced fish species	2	2
In-stream habitat modification	2	3
TOTAL SCORE	**17**	**19**
%	56.7	63.3
FISH ASSEMBLAGE CATEGORY	**D**	**C**

Invertebrates (C and D)

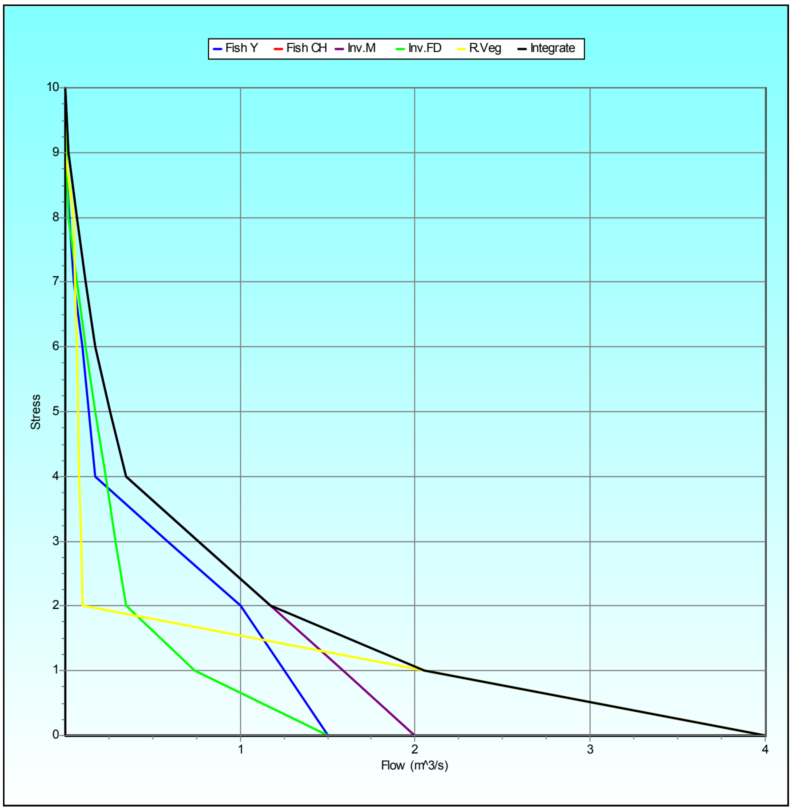
Ref	**PES D/E score**	**PES D/E taxa**	**REC D score**	**REC D taxa**	**Alternative EC C score**	**Alternative EC C taxa**
SASS: >150 Taxa: >30 ASPT: >6	SASS: 58 Taxa: 14 ASPT: 4.1	Turbellaria, Baetidae (2sp), Caenidae, Coenagrionidae, Gomphidae, Libellulidae, Hydropsychids, Corixidae, Gyrinidae, Chironomidae, Simuliidae, Ancylidae, Lymnaeidae.	SASS: 70 Taxa: 16 ASPT: 4.5	Turbellaria, Baetidae (2sp), Caenidae, Coenagrionidae, Hydropsychidae (2sp) Gomphidae, Libellulidae, Corixidae, Gyrinidae, Chironomidae, Simuliidae, Ancylidae, Lymnaeidae, possibly Naucoridae,Veliidae, Aeshnidae, Dytsicidae, Elmidae, Leptophlebiids, Psephenids, Tricorythids, Dytiscids, Tipulids, Hydrometrids, Sphaeriids, Corbiculids,	SASS: 100 Taxa: 20 ASPT: 5	Turbellaria, Baetidae (2sp), Caenidae, Coenagrionidae, Hydropsychidae (2sp) Gomphidae, Libellulidae, Corixidae, Gyrinidae, Chironomidae, Simuliidae, Ancylidae, Lymnaeidae, possibly Naucoridae,Veliidae, Aeshnidae, Dytsicidae, Elmidae, Leptophlebiids, Psephenids, Tricorythids, Dytiscids, Tipulids, Hydrometrids, Sphaeriids, Corbiculids,

10 IFR 2 – UPPER BLACK KEI RIVER: DETERMINATION OF IFR SCENARIOS

10.1.1 Component and integrated stress curves

The individual component stresses are illustrated as well as the system stress line (black line).

Figure 10-1 Component and integrated stress curves



Purple 3: MD Inverts
Green: FD Inverts
Yellow: Riparian vegetation
Black: Integrated

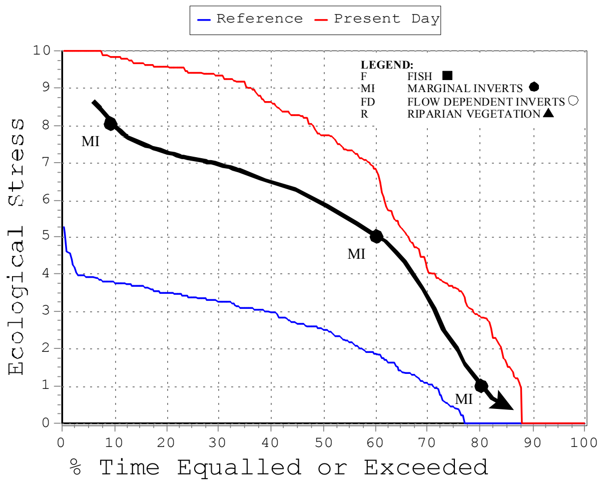
10.1.2 Generating stress requirements

The requirements are provided in the attached Appendix H.

The requirements are illustrated in Figure 10-2 – 10-3. Where all the points are plotted and the stress duration requirements are drawn in by hand.

Figure 10-2 IFR 2 – Stress duration curve for a recommended scenario of a D REC

Dry season



Wet season

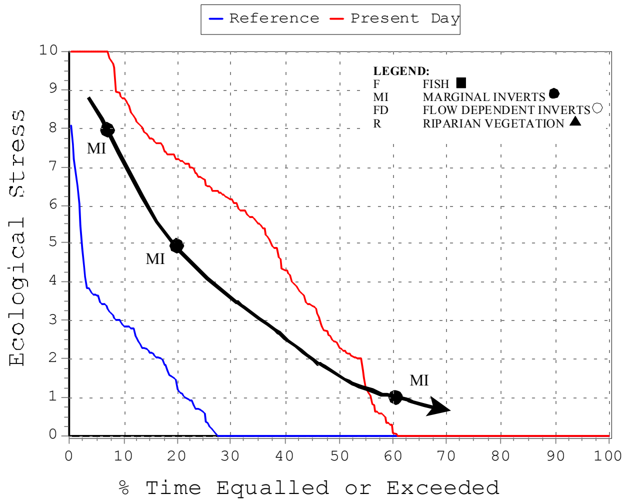
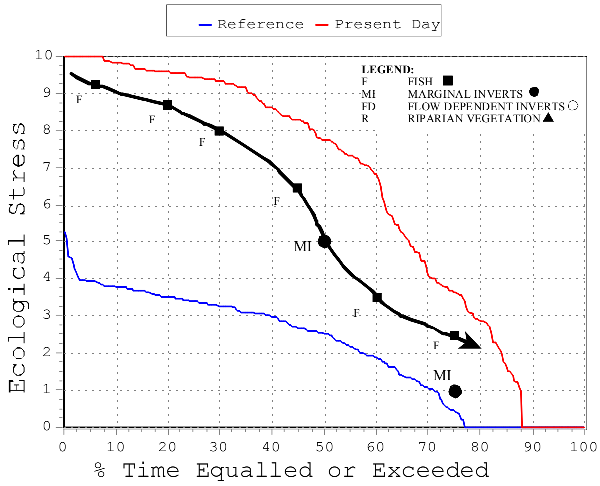
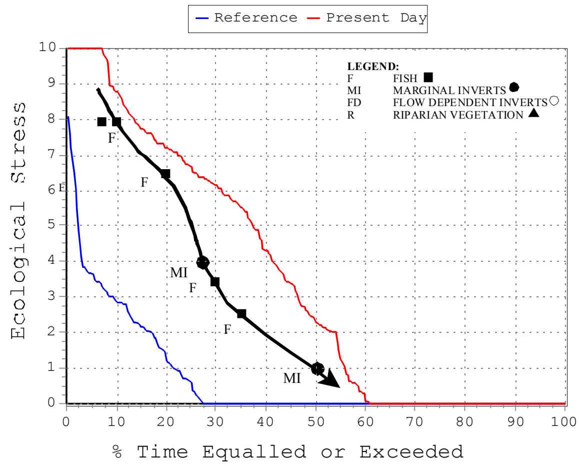


Figure 10-3 IFR 2 – Stress duration curve for a alternative scenario of a C EC

Dry season



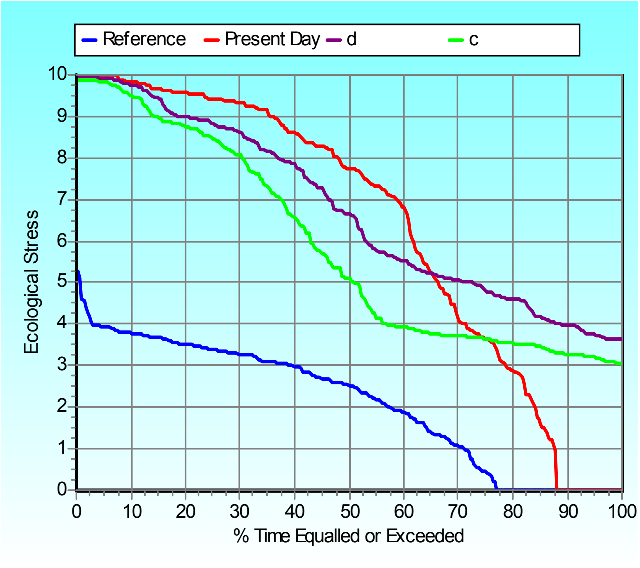
Wet season



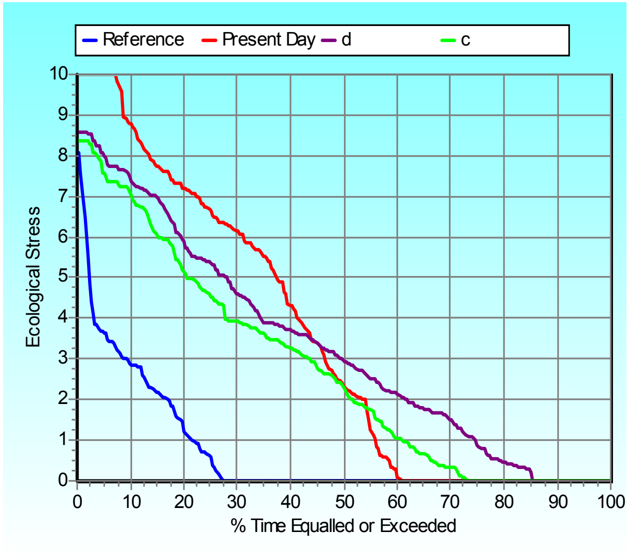
The final stress profiles are illustrated below.

Figure 10-4 IFR 2 – Final curve

Dry season



Wet season



The desktop D was found to be similar to the marginal invertebrates requirements. The drought however was changed to 0 as one of the objectives was not to recreate perenniality. With these changes the desktop D was accepted. Both marginal invertebrates and fish drove the C EC requirements. During the wet season fish was more critical than marginal invertebrates at certain percentage of times. The desktop C fell slightly below the marginal invertebrates requirements and catered for the higher fish requirements. With the same drought changes the desktop C was therefore accepted as the final requirement.

10.2 HIGH FLOW REQUIREMENTS

The functions for each Flood Class are described in spreadsheets. A summary of the Flood Class ranges for IFR 2 is provided in Table 10.1 and 10.2 below. As only monthly data was available, the number of events under natural and present conditions could not be improved.

A summary of the flood class ranges for IFR 2 is shown below.

Table 10.1 Flood Class ranges for IFR 2

	Flood classes				
Component	**I (m^3/s)**	**II (m^3/s)**	**III (m^3/s)**	**IV (m^3/s)**	**V (m^3/s)**
Fish	1.5-2.5	2.5-10			
Invertebrates	1.5-3	3-8			
Vegetation		2.5-10	15-30	35-40	
Geomorphology		3-12	12-22	22-50	50-130
Integrated	**1.5-3**	**2.5-12**	**12-30**	**22-50**	**50-130**
Daily average*	1	3	8	30	
Duration (days)	1	1	2	3	

The number of high flow events required for each EC is provided below.

Table 10.2 Number of high flow events for each EC - IFR 2

	I*	Time**	I	Time	II	Time	II	Time	III	Time	III	Time	IV	Time	IV	Time
Category	**D**		**C**		**D**		**C**		**D**		**C**		**D**		**C**	
Fish	2	10-4	3	10-4	1											
Inverts	2	10-4	3	10-4	1	12,1										
Vegetation					5	S[1]	6		3	S[1]	3		1		1	
Geomorph					4	Wet season,			3		3		1		1	
Number of events	2	10-4	3	10-4	5	10-12,2,4	6		3	2,3,11	3	2,3,11	1	3	1	3

* Denotes Class Floods
** Time is in months where 1-12 portrays January to December.
S[1] Summer

These results were checked with the hydrology and were found to be acceptable.

10.3 FINAL RESULTS

10.3.1 IFR table for recommended scenario: D REC

```
Desktop Version 2, Printed on 2003/09/30
Summary of IFR estimate for: Kei_2 Natural Monthly Flows
Determination based on defined BBM Table with site specific assurance
rules.

        Annual Flows (Mill. cu. m or index values):
        MAR                  =  173.440
        S.Dev.               =  129.343
        CV                   =    0.746
        Q75                  =    2.120
        Q75/MMF              =    0.147
        BFI Index            =    0.298
        CV(JJA+JFM) Index =    3.216


        Total IFR            =   15.964 ( 9.20 %MAR)
        Maint. Lowflow       =    6.858 ( 3.95 %MAR)
        Drought Lowflow      =    0.000 ( 0.00 %MAR)
        Maint. Highflow      =    9.107 ( 5.25 %MAR)

        Monthly Distributions (cu.m./s)
        Distribution Type : E.Cape
```

Month	Natural Flows Mean	SD	CV	Modified Flows (IFR) Low flows Maint.	Drought	High Flows Maint.	Total Flows Maint
Oct	4.306	7.406	0.642	0.176	0.000	0.129	0.305
Nov	8.258	15.588	0.728	0.233	0.000	0.473	0.706
Dec	8.437	11.596	0.513	0.243	0.000	0.097	0.340
Jan	7.264	10.593	0.544	0.240	0.000	0.000	0.240
Feb	9.969	11.796	0.489	0.299	0.000	0.507	0.806
Mar	11.863	16.739	0.527	0.319	0.000	2.129	2.448
Apr	5.372	6.754	0.485	0.258	0.000	0.133	0.391
May	2.794	3.576	0.478	0.206	0.000	0.000	0.206
Jun	1.691	1.728	0.394	0.177	0.000	0.000	0.177
Jul	1.652	2.817	0.637	0.153	0.000	0.000	0.153
Aug	2.332	6.688	1.071	0.155	0.000	0.000	0.155
Sep	2.351	3.542	0.581	0.157	0.000	0.000	0.157

10.3.2 IFR table for alternative scenario: C EC

```
Desktop Version 2, Printed on 2003/09/30
Summary of IFR estimate for: Kei_2 Natural Monthly Flows
Determination based on defined BBM Table with site-specific assurance
rules.

        Annual Flows (Mill. cu. m or index values):
        MAR                  =  173.440
        S.Dev.               =  129.343
        CV                   =    0.746
        Q75                  =    2.120
        Q75/MMF              =    0.147
        BFI Index            =    0.298
        CV(JJA+JFM) Index =    3.216


        Total IFR            =   25.490 (14.70 %MAR)
        Maint. Lowflow       =   15.986 ( 9.22 %MAR)
```

Drought Lowflow = 0.000 (0.00 %MAR)
Maint. Highflow = 9.504 (5.48 %MAR)

Monthly Distributions (cu.m./s)
Distribution Type : E.Cape

Month	Natural Flows			Modified Flows (IFR)			
				Low flows		High Flows	Total Flows
	Mean	SD	CV	Maint.	Drought	Maint.	Maint
Oct	4.306	7.406	0.642	0.403	0.000	0.129	0.532
Nov	8.258	15.588	0.728	0.546	0.000	0.473	1.019
Dec	8.437	11.596	0.513	0.573	0.000	0.129	0.702
Jan	7.264	10.593	0.544	0.564	0.000	0.000	0.564
Feb	9.969	11.796	0.489	0.710	0.000	0.507	1.217
Mar	11.863	16.739	0.527	0.765	0.000	2.245	3.010
Apr	5.372	6.754	0.485	0.609	0.000	0.133	0.742
May	2.794	3.576	0.478	0.479	0.000	0.000	0.479
Jun	1.691	1.728	0.394	0.403	0.000	0.000	0.403
Jul	1.652	2.817	0.637	0.345	0.000	0.000	0.345
Aug	2.332	6.688	1.071	0.348	0.000	0.000	0.348
Sep	2.351	3.542	0.581	0.354	0.000	0.000	0.354

10.3.3 IFR rules for recommended scenario: D REC

Desktop Version 2, Printed on 2003/09/30
Summary of IFR rule curves for : Kei_2 Natural Monthly Flows
Determination based on defined BBM Table with site-specific assurance rules.
Regional Type : E.Cape REC = D

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

% Points										
Month	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	0.473	0.453	0.411	0.340	0.247	0.153	0.079	0.036	0.018	0.016
Nov	1.579	1.287	1.029	0.778	0.453	0.285	0.156	0.084	0.055	0.053
Dec	0.658	0.594	0.522	0.431	0.302	0.193	0.099	0.040	0.014	0.013
Jan	0.423	0.408	0.375	0.317	0.236	0.145	0.069	0.022	0.003	0.003
Feb	1.224	1.183	1.094	0.938	0.717	0.469	0.255	0.119	0.062	0.058
Mar	5.860	4.603	3.558	2.625	1.418	0.918	0.537	0.323	0.237	0.228
Apr	0.618	0.592	0.537	0.444	0.322	0.197	0.100	0.044	0.020	0.017
May	0.351	0.335	0.303	0.250	0.179	0.107	0.050	0.018	0.004	0.002
Jun	0.294	0.278	0.246	0.194	0.131	0.074	0.033	0.012	0.003	0.002
Jul	0.254	0.241	0.214	0.170	0.116	0.066	0.031	0.011	0.003	0.002
Aug	0.257	0.244	0.215	0.170	0.115	0.064	0.029	0.010	0.003	0.002
Sep	0.267	0.256	0.231	0.190	0.136	0.081	0.038	0.014	0.003	0.002
Reserve flows without High Flows										
Oct	0.299	0.287	0.259	0.213	0.153	0.091	0.043	0.015	0.004	0.002
Nov	0.396	0.379	0.342	0.279	0.198	0.116	0.053	0.018	0.004	0.003
Dec	0.429	0.413	0.381	0.324	0.243	0.153	0.074	0.025	0.004	0.003
Jan	0.423	0.408	0.375	0.317	0.236	0.145	0.069	0.022	0.003	0.003
Feb	0.527	0.509	0.469	0.399	0.300	0.188	0.092	0.031	0.005	0.003
Mar	0.543	0.519	0.468	0.382	0.271	0.158	0.073	0.025	0.005	0.003
Apr	0.439	0.420	0.380	0.313	0.224	0.133	0.063	0.022	0.005	0.003
May	0.351	0.335	0.303	0.250	0.179	0.107	0.050	0.018	0.004	0.002
Jun	0.294	0.278	0.246	0.194	0.131	0.074	0.033	0.012	0.003	0.002
Jul	0.254	0.241	0.214	0.170	0.116	0.066	0.031	0.011	0.003	0.002
Aug	0.257	0.244	0.215	0.170	0.115	0.064	0.029	0.010	0.003	0.002
Sep	0.267	0.256	0.231	0.190	0.136	0.081	0.038	0.014	0.003	0.002

10.3.4 IFR rules for alternative scenario: C EC

Desktop Version 2, Printed on 2003/09/30
Summary of IFR rule curves for : Kei_2 Natural Monthly Flows
Determination based on defined BBM Table with site-specific assurance rules.
Regional Type : E.Cape EC = C

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

% Points										
Month	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	0.708	0.678	0.615	0.508	0.368	0.224	0.113	0.048	0.021	0.017

Nov	1.935	1.627	1.336	1.029	0.630	0.389	0.204	0.101	0.059	0.055
Dec	1.103	1.010	0.897	0.745	0.530	0.338	0.171	0.066	0.021	0.019
Jan	0.785	0.756	0.695	0.588	0.437	0.269	0.127	0.041	0.005	0.005
Feb	1.591	1.536	1.419	1.215	0.925	0.599	0.318	0.141	0.065	0.060
Mar	6.662	5.315	4.168	3.108	1.736	1.109	0.631	0.362	0.254	0.244
Apr	0.997	0.955	0.865	0.714	0.515	0.312	0.155	0.063	0.025	0.020
May	0.661	0.632	0.572	0.470	0.337	0.201	0.095	0.033	0.008	0.004
Jun	0.550	0.522	0.461	0.364	0.246	0.138	0.062	0.022	0.006	0.004
Jul	0.471	0.447	0.397	0.316	0.216	0.123	0.057	0.021	0.006	0.003
Aug	0.475	0.450	0.398	0.314	0.213	0.119	0.054	0.019	0.005	0.003
Sep	0.488	0.467	0.423	0.348	0.249	0.148	0.070	0.025	0.006	0.003

Reserve flows without High Flows

Oct	0.556	0.532	0.481	0.396	0.283	0.169	0.080	0.028	0.007	0.004
Nov	0.753	0.719	0.649	0.530	0.375	0.220	0.101	0.034	0.007	0.005
Dec	0.797	0.769	0.709	0.603	0.453	0.284	0.139	0.047	0.007	0.005
Jan	0.785	0.756	0.695	0.588	0.437	0.269	0.127	0.041	0.005	0.005
Feb	0.988	0.953	0.878	0.747	0.561	0.352	0.172	0.058	0.009	0.006
Mar	1.055	1.008	0.909	0.743	0.526	0.308	0.142	0.048	0.010	0.007
Apr	0.840	0.804	0.727	0.598	0.428	0.255	0.121	0.043	0.010	0.005
May	0.661	0.632	0.572	0.470	0.337	0.201	0.095	0.033	0.008	0.004
Jun	0.550	0.522	0.461	0.364	0.246	0.138	0.062	0.022	0.006	0.004
Jul	0.471	0.447	0.397	0.316	0.216	0.123	0.057	0.021	0.006	0.003
Aug	0.475	0.450	0.398	0.314	0.213	0.119	0.054	0.019	0.005	0.003
Sep	0.488	0.467	0.423	0.348	0.249	0.148	0.070	0.025	0.006	0.003

10.4 CONFIDENCE

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

Table 10.3 Confidence table – IFR 2

	IFR Site	Available data	Ecological Classification	Output low flow	Output high flow
Hydrology		3			
Hydraulics	2	4		5	3
	IFR site: Difficult site to characterise hydraulically (steep rapid with large resistance elements (including boulders) and complex flow patterns. Output: Four flows were monitored in the range 0.17 to 8.2m^3/s, resulting in medium to high confidence at this site.				
Water quality	1	1	2		
	IFR site: Low confidence because there is no water quality monitoring points close to the IFR site. Available data: Low confidence due the absence of observed of observed water quality monitoring in this resource unit. Present state conditions were inferred from monitoring upstream of the resource unit and on the main tributaries, and observations made during the site visits. Ecological classification: moderate confidence because the PES categories are aligned with the biota and fish categories and the inferred water quality conditions.				
Geomorphology	3	2	3		3
	IFR site: Good geomorphology cues for present day flow. Available data: No sediment model, poor hydrological data, i.e. no gauging weir for flood flows. Ecological classification: Good aerial photo record and classification. High flows: Moderate confidence from the physical cues and hydraulics. Unsure of the no of events due to lack of hydrological date.				
Riparian vegetation	3	1	4	4	4
	IFR site: Site dominated by *Juncus* and other cues limited. Available data: Limited data on *Juncus* and the fact that it does not provide cues for low flows. Ecological classification: Good understanding of PES. High flow: Good cues present. Terraces present on both banks. Requirements as set were available according to the limited hydrological record.				
Fish	4	3	3	4	2
	IFR site: Good cues at site and habitat model available. Available data: Some historical information available. Ecological data: Some historical information available. Low flow: Fish was not the primary motivator and more water than requested is available. High flows: Lack of ecological knowledge.				
Invertebrates	3	2	3	3	2

	IFR Site	Available data	Ecological Classification	Output low flow	Output high flow
	IFR site: Only accessible site in the area, good habitat diversity despite habitat quality. Available data: Only one previous collection and present collection as well as a review of the Buffalo River data. Ecological classification: High confidence in PES based on empirical tables and experience in Eastern Cape. Low confidence in reference conditions but higher confidence in the trajectory of change. Overall confidence therefore medium. Low flows: Used marginal vegetation invertebrates as the critical component with knowledge from the field of what the effects of reduced flows would be. Fairly high confidence that the flows would maintain the community. High flows: Low confidence since no information about the natural high flow regime as well as lack of knowledge re flow requirements of bugs.				

11 IFR 3 – LOWER BLACK KEI RIVER: STRESS INDICES

IFR 3 is situated in the Black Kei River, 2 km upstream of the White Kei River confluence. To ensure that the site is useful, it had to be as far downstream as possible from IFR 2. A suitable site was found immediately downstream of a gauging weir being constructed. The site is illustrated in Figure 11-1.

Figure 11-1 IFR 3, 14 July 2003, 0.16m^3/s

11.1 FISH STRESS INDEX

The fish stress indices for Eurytopic and Limnophilic fish species (combined) were developed during site visits and at the specialist meeting (see Appendix F).

Table 11.1 Stress table – Limnophilic and Eurytopic fish species

Flow-Depth Response index	Habitat abundance and suitability				Total flow depth score	Limnophilic and Eurytopic species combined		
	FD[1]	FS[2]	SD[3]	SS[4]		Response: Abundance	Species stress	Flow (m^3/s)
0	5	5	5	5	20	All very abundant	0	1.5
1	4	5	5	5	19	All very abundant		
2	4	4	5	5	18	All very abundant	1	1.04
3	3	4	5	5	17	All very abundant	3	0.47
4	2	3	5	5	15	All very abundant		
5	2	2	4	5	13	Abundant	5	0.16
6	1	2	3	4	10	Moderate		
7	0	2	2	3	7	Low	7	0.03
8	0	1	1	2	4	Low		
9	0	0	0	1	1	Rare	9	0
10	0	0	0	0	0	None	10	0

1 FD: Fast (>0.3m/s) Deep (>0.3m)
2 FS: Fast (>0.3m/s) Shallow (<0.3m)
3 SD: Slow (<0.3m/s) Deep (>0.5m)
4 SS: Slow (<0.3m/s) Shallow (<0.5m)

11.2 AQUATIC INVERTEBRATES STRESS INDEX

The stress indices for aquatic invertebrates were developed during site visits and at the specialist meeting. An index for the Marginal Vegetation (MV) invertebrates and flow dependent (FD) invertebrates were developed at this site.

Table 11.2 Stress table – Flow Dependent invertebrate species

Flow-Depth Response index	Habitat abundance and suitability					Modifier	Depth (m)	Flow (m^3/s)	Velocity (m/s)	Habitat response** (site specific)	Biotic response	Species stress
	SIC[1]	SOC[2]	MVIC[3]	MVOC[4]	GS[5] pool						MV Inverts (Based on Kleynhans,1999)	
Observation	**2**	**3**	**2**	**1**	**3**							
Site rating**	**2**	**2**	**2**	**1**	**3**	Embeddedness, big substrate, algae on rock faces, sediment.						
0	5	5	5	4	5		0.75	1.81	0.2	All habitats in excess, very high quality.	FDs: Very abundant 0	
1	5	5	4	3	5		0.7	1.34	0.17	All habitats plentiful, very high quality.	FDs: Abundant 1	0
2	4	4	3	2	4		0.65	0.97	0.15	SIC and VIC sufficient, quality slightly reduced.	Slight reduction for FDs: Abundant 2	1
3	3	4	3	2	3		0.55	0.47	0.1	Reduced SIC and VIC, Reduced quality.	Reduction for FD species: Moderate 3	
4	3	3	2	1	3		0.5	0.31	0.08	SIC and VIC limited, of moderate quality.	Further reduction for FD species: Moderate 4	
5	2	2	2	1	3		0.43	0.16	0.06	SIC and VIC very reduced, of moderate quality.	Remnant populations of all FD species: Low 5	5
6	2	2	1	0	2		0.4	0.12	0.05	SIC and VIC residual and of low quality.	Sensitive FD species: Low 6	
7	1	2	0	0	2		0.35	0.07	0.03	No VIC, No VOC, little SIC.	All FD species: Rare 7	8
8	1	1	0	0	2		0.25	0.02	0.02	Flowing water present, little SIC, no VIC.	Only remnant populations of hardy FD species: Rare 8	
9	0	1	0	0	1		0.19	0	0.01	No surface flow.	Only pool dwellers: FDs absent: None 9	
10	0	0	0	0	0					No surface water.	None 10	

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

12 IFR 3 – LOWER BLACK KEI RIVER: ECOLOGICAL CLASSIFICATION

12.1 REFERENCE CONDITIONS

Geomorphology
This site falls within the geomorphological zone `Er`, Rejuvenated foothills (Refer to Appendix C). These zones are steepened sections within middle reaches of the river caused by uplift. The zone has characteristics similar to foothills (gravel/cobble bed rivers with pool-riffle/pool-rapid morphology) but of a higher order. A compound channel is often present with an active channel contained within a macro channel activated only during infrequent flood events. A limited flood plain may be present between the active and macro-channel.

Riparian vegetation
A wider river with distinct rocky islands within a compound channel colonised by marginal vegetation and clear marginal zones on both banks is characteristic. These are characterised *by Juncus, Miscanthus* and *Restionaceae*. Riparian vegetation forming distinct medium sized galleries occupied by a mixture of riparian species, including *Celtis*, *Combretum, Schotia* and *Acacia.*

Water quality
Refer to the water quality report.

Fish (C/D)
Only one species of primary freshwater fish species occurs naturally in the upper Kei system, namely *Barbus anoplus* (chubbhead minnow). In addition 3 species of catadromous freshwater eel will occur. No barriers would have been present and migration would have taken place utilising the full length of the river.

Under natural conditions the wider more alluvial and increased amount of shallow backwater habitat would have been beneficial to *B. anoplus*. Large numbers of *Barbus anoplus* would be expected to be present with a range in size and age classes throughout this reach in all preferred habitats such as near fallen logs and brushwood, among marginal vegetation and undercut banks in shallow slow and shallow fast habitats throughout this reach.

Inverts

Bio	Description of invert communities expected in reference conditions			
	Ref	Summer	Ref	Winter
SIC[1]	SASS: > 120 Taxa: >20 ASPT: 6+	A diverse community of flow-dependent species with a relatively high ET (Ephemeroptera, Trichoptera) ratio. Diverse Ephemeroptera, including (at least) several Baetid species, Caenids, Tricorythids, Leptophlebiids, Heptageniids. A healthy community of Trichopterans including non-cased caddis. More than one Simuliid species likely, and abundant. Ancylid and Sphaeriid snails. Chironomids.	SASS: >100 Taxa: >15 ASPT: >5	A less diverse community of FD species than in summer conditions. The ratio of Ephemeroptera: Trichoptera is likely to be reduced. Simuliids likely to be reduced relative to summer conditions, and possibly in pupal state. Ancylids and Sphaerids likely. Chironomids likely.
MV[2]	SASS: >100 Taxa: > 15 ASPT: > 5.5	A marginal vegetation community rich in juvenile Ephemeroptera, particularly Baetids and Caenids, and in Hemipterans. Some Coleopterans and Odonates. Lymnaeid and Physid snails may be present.	SASS: > 80 Taxa: > 13 ASPT: > 5	A similar community to summer likely to be reduced in numbers however, lacking Ephemeroptera.

Bio	Description of invert communities expected in reference conditions			
	Ref	Summer	Ref	Winter
TOT	SASS: > 160 Taxa: > 35 ASPT: > 6	A robust and diverse community supporting FD, MV and pool-dwelling species. A greater diversity of Trichopterans, Ephemeropteran, Odonate, Hemipterans, Coleopterans and Dipteran families and species. The early summer community is likely to have a high percentage of juvenile Ephemeropteran taxa. The mid and late summer communities are likely to have an altered EPT (Ephemeroptera, Plecoptera, Trichoptera) age-distribution due to the growth of juveniles, and the emergence of mature winged adults.	SASS: > 150 Taxa: > 30 ASPT: > 6	The winter community would be expected to be similar to the summer community, however with reduced Ephemeropteran diversity, and a more uniform age-distribution in the EPT (Ephemeroptera, Plecoptera, Trichoptera) fauna.

1 SIC: Stones in current
2 MV: Marginal vegetation

12.2 PES

12.2.1 Habitat Driver Status

Question	Score	Reasoning
Geomorphology		
To what extent is the channel structure artificial?	1	No change.
To what extent has event (high flows) hydrology changed?	3	Flows have been altered by the presence of upstream dams, irrigation demand etc.
To what extent has sediment input changed?	3	Reduced sediment coming down the channel due to upstream dams. Increased sediment accumulation on channel margins due to vegetation encroachment.
To what extent has riparian vegetation changed?	3	Vegetation encroachment onto bars and banks.
To what extent has in-channel sediment storage changed?	4	Large change due to clean water releases (erosion of bed), also reduced width and increased depth causing an increased velocity.
Water Quality (Wq)		
Modified 1 October 2003, Qualitative assessment, no monitoring points in this river reach		
To what extent has the 95%tile of the natural Wq changed? pH	2	PES = Good (B/C), slightly elevated from natural conditions.
To what extent are these changes related to water quantity changes.	2	Slightly related to flow because water retention time and algal growth affects pH.
To what extent has the 95%tile of the natural Wq changed? Salts	4	PES = Poor (E/F), high changed from natural.
To what extent are these changes related to water quantity changes.	3	Largely related to flow, especially winter low flow periods and reduced dilution from Klipplaat River and from Klaas Smits River.
To what extent has the 95%tile of the natural Wq changed? Nutrients	4	PES = Poor (E/F), large change from natural due to effluents from Whittlesea and Queenstown.
To what extent are these changes related to water quantity changes.	2	Moderately related to flow, high nutrients affected by point and non-point sources. Point sources are diluted by higher flows, non-point sources affected by wash-off processes.
To what extent has the 95%tile of the natural Wq changed? Temp	1	PES = Good (B), no data to assess present state but expected to be large difference from natural.
To what extent are these changes related to water quantity changes.	1	Not related to flow in this case.
To what extent has the 95%tile of the natural Wq changed? Turbidity	2	PES = Good/Fair (B/C), no data but the amount of silty material observed indicate no large change away from natural.
To what extent are these changes related to water quantity	4	Highly related to flow and transport processes

Question	Score	Reasoning
changes.		and retention time in the system.
To what extent has the 95%tile of the natural Wq changed? Oxygen	2	PES = Good (B), some change in diel changes probably due to algal growth on substrate.
To what extent are these changes related to water quantity changes.	2	Some relation to flow because it affects water retention and travel time and diel changes.
Hydrology		
To what extent has low flows (70%ile) changed?	3	Changes in flow duration graph.
To what extent has the duration of zero flows changed?	3	Changes in flow duration graph.
To what extent has the seasonality changed?	1	Changes in flow duration graph.
To what extent have moderate events been reduced?	4	Changes in flow duration graph.

Geomorphology: 21% Flow related
Water quality: 49% Flow related
Overall: 52% Flow related
Category: C

12.2.2 Biological Response PES

Geomorphology (C)
The Present state demonstrates a changed geomorphological template from a "natural" condition – the river has undergone some shrinkage in width (25% reduction). The river morphology is dominated by rapids and pools with large, immovable, boulders. Rapids have limited interstitial spaces.

Riparian vegetation (C)
The PES is attributed to both flow and non-flow. A change in flow regime, seen as reduced base flows and the elimination of elevated flows, have lead to a reduced river and template change resulting in changes in the riparian and marginal zone species composition and structure.

Fish (D)

Note that the low ecological category for fish is due largely to non-flow related reasons – alien predatory fish species and reduced water quality due to nutrients/pollutants from water treatment works and bad land-use practices in catchment.

Table 12.1 Fuzzy Fish Index – IFR 3: PES

IFR site 3	**PES D**
Resource unit	
Native species richness	5
Abundance of native species	2
Frequency of occurrence of native species	3
Health/condition of native and introduced species	3
Presence of introduced fish species	2
In-stream habitat modification	2
TOTAL SCORE	**17**
%	56.7
FISH ASSEMBLAGE CATEGORY	**D**

Invertebrates (B)

Table 12.2 Invert communities observed – IFR 3: PES

Bio	PES	Invert communities observed during winter
SIC	SASS: 26 Taxa: 5 ASPT: 5.2	Turbellaria, Hydropsychidae (2sp), Psephenidae(!!), Chironomidae, Simuliidae.
MV	SASS: 41 Taxa: 9 ASPT: 4.6	Baetidae, Coenagrionidae, Corduliidae, Libellulidae, Corixidae, Naucoridae, Notonectidae, Lymnaeidae.
SOC	SASS: 48 Taxa: 7 ASPT: 6.9	Baetidae, Caenidae, Heptageniidae, Libellulidae, Corixidae, Hydropsychidae Chironomidae, Simuliidae, Tipulidae.
TOT	SASS: 93 Taxa: 19 ASPT: 1.9	Turbellaria, Oligochaeta, Baetidae, Caenidae, Heptageniidae, Coenagrionidae, Corduliidae, Libellulidae, Hydropsychidae, Corixidae, Naucoridae, Notonectidae, Pleidae, Veliidae, Hydropsychidae (2sp), Psephenidae(!!), Chironomidae, Culicidae, Simuliidae, Tipulidae, Lymnaeidae

12.2.3 Trajectory of change

Geomorphology
The present state is stable.

Riparian vegetation
From a flow related perspective the riparian vegetation is stable. However non-flow related aspects provide a negative trajectory mainly due to encroachment of *Acacia karroo*, grazing and exotic species.

Water quality
There is a slight increasing trend in salinity and nutrient concentrations.

Fish
Water quality and flow (as well as catchment management) is not expected to change apart from riparian vegetation removal, thus the fish PES is expected to remain in a D category.

Invertebrates
The aquatic invertebrates are stable.

12.2.4 Ecostatus

The PES for the various components is illustrated in Figure 12-1. The habitat driver status indicates a C system. However, the biological component invertebrates have a C/D PES and Fish a D PES. It was decided that the system is representative of a C/D Ecostatus.

12.3 EIS

The results of the Ecological Importance and Sensitivity (EIS) are attached as Appendix G.

EIS rating: Moderate
Confidence: Moderate
Determinants: The invert community (Heptageniidae and Psephenids) are dependent on flow during all life stages. The river is well buffered and a gorge is present.

12.4 RANGE OF ECS

The Ecological importance was moderate (natural and present). The aim was set to maintain the Present Ecological State of a C/D. The driver component riparian vegetation has a negative trajectory due to non-flow related issues and the fish and invertebrate components have a stable trajectory; no improvement will be necessary to maintain the PES. The component EC categories are provided in

Figure 12-1. The additional EC categories to be assessed will be B/C (a category higher) and D (half a category lower). The associated component ECs are also illustrated in the Figure 12-1.

Figure 12-1 IFR 3 – Ecological categories

AVAILABLE INFORMATION:

INSTREAM HABITAT INTEGRITY: C RIPARIAN HABITAT INTEGRITY: C

COMPONENT	PES	TRAJ	SHORT TERM (5 Y)	LONG TERM (20 Y)	EIS	REC	Alt EC	Alt EC
DRIVER HI	C				MODERATE	C	D	C
RIPARIAN VEGETATION	C	-- (nf)	C	C/D		C	D	B/C
FISH	D	0	D	D		D	D	C
AQUATIC INVERTS	C/D	0	C/D	C/D		C/D	D	B/C
ECOSTATUS	C/D	0 (F)	C	C/D		C/D	D	B/C

12.5 DEFINING ECs

Geomorphology (C)
The present geomorphological and habitat condition will not be improved by a change in flow. No objectives for an improved geomorphology have therefore been supplied.

Riparian vegetation (C, D and B/C)
Recommended EC C
In order to maintain the vegetation in a C state, it is important to ensure that adequate base flows are available to provide sufficient water to consistently supply the roots of marginal vegetation present. Sufficient elevated flows are required to cover the full distribution of marginal vegetation in the marginal zone. Target species include *Celtis aricana, Schotia brachypetala* and *Combretum capensis*, however, it is uncertain whether these are likely to become significant given the general trend of the encroachment of *Acacia karroo* in the region. Target marginal species include *Miscanthus* and *Restionaceae* and the *Juncus*.

Improved (B/C)
An improved flow regime, such as improved summer base flows and elevated flows, is likely to improve the current condition of riparian and marginal vegetation to a category B/C at best. An improvement would be displayed in terms of the expansion in the width of the marginal zone on both banks as well as an increase in the density of vegetated islands. This would also be evident, along with non-flow related measures, in the germination and growth of plants in the lower riparian zone. This will be characterised by a river with more distinct marginal and riparian zones, however, due to the basic geomorphological template change which has occurred, it is unlikely to improve to a higher category. The substrate is now generally not suitable for a healthy mixed stand of riparian vegetation such as that present under reference conditions. Improved structural characteristics are therefore unlikely to take place.

Target species:
The target riparian species are those such as *Celtis aricana, Schotia brachypetala* and *Combretum capensis*, however, it is uncertain whether these are likely to become significant given the general trend of the encroachment of *Acacia karroo* in the region. It is therefore unlikely that an improvement in species composition to a more mixed stand of riparian species will be achieved. Target marginal species include *Miscanthus* and Restionaceae and *Juncus*.

Any improvement in riparian condition is therefore only likely to occur in terms of the abundance of riparian plants in a wider riparian zone only.

Fish (C and D)
Recommended EC D
Maintain present-day flow patterns and discharges, with the water releases in pulses is important for fish in the summer to stimulate spawning of both *B. aeneus* and *B. anoplus* and to allow migration of Barbus species to suitable habitats and migration of eels. The existing winter and summer base flows (although less than natural) should be maintained, as these flows are important for maintaining the habitat. Ensure cover for fish and ensure depths and good water quality in large refuge pools.

Alternative C
Pulses of higher flow in November to March to coincide with peak spawning months of both species of fish, and following to some extent the natural flood/freshet hydrograph with slow falling limb is required.

Increased discharges for base flows in both summer and winter would improve habitat, water quality and cover available for both fish species. In addition, flows to allow migration of both fish species and 3 freshwater eel species through the system over shallow riffles and rapids are required.

The above improvements should result in increased numbers of both fish species by increasing survival of young (and adults) and improved spawning conditions and the improved passage of eels through this river reach.

Note: *Barbus aeneus* is non-endemic to system but now considered an important component as has social benefits (angling, tourism, food fish). This species is more dependent on flowing water as requires riffles for spawning and prefers fast shallow and fast deep habitats.

Table 12.3 Fuzzy Fish Index – IFR 3: Alternative ECs

IFR site 3	**PES and Alternative EC D**	**Alternative EC C**
Native species richness	5	5
Abundance of native species	2	3
Frequency of occurrence of native	3	3
Health/condition of native and introduced species	3	3
Presence of introduced fish species	2	2
In-stream habitat modification	2	3
TOTAL SCORE	**17**	**19**
%	56.7	63.3
FISH ASSEMBLAGE CATEGORY	**D**	**C**

Invertebrates (C, C/D and B/C)

Ref	PES C score	PES C taxa	Recommended EC C/D score	Recommended EC C/D taxa	Alternative EC B/C score	Alternative EC B/C taxa	Alternative EC D score	Alternative EC D taxa
SASS: > 150 Taxa: > 30 ASPT: > 6	SASS: 93 Taxa: 19 ASPT: 1.9	Turbellaria, Oligochaeta, Baetidae, Caenidae, Heptageniidae, Coenagrionidae, Corduliidae, Libellulidae, Hydropsychidae, Corixidae, Naucoridae, Notonectidae, Pleidae, Veliidae, Hydropsychidae (2sp), Psephenidae(!!), Chironomidae, Culicidae, Simuliidae, Tipulidae, Lymnaeidae	SASS: 93 Taxa: 19 ASPT: 1.9	Turbellaria, Oligochaeta, Baetidae, Caenidae, Heptageniidae, Coenagrionidae, Corduliidae, Libellulidae, Hydropsychidae, Corixidae, Naucoridae, Notonectidae, Pleidae, Veliidae, Hydropsychidae (2sp), Psephenidae(!!), Chironomidae, Culicidae, Simuliidae, Tipulidae, Lymnaeidae	SASS: 130 Taxa: 6 ASPT: 22	Turbellaria, Oligochaeta, Baetidae(>2sp), Caenidae, Heptageniidae, Coenagrionidae, Corduliidae, Libellulidae, Corixidae, Naucoridae, Notonectidae, Pleidae, Veliidae, Hydropsychidae (2sp), Psephenidae(!!), Chironomidae, Culicidae, Simuliidae, Tipulidae, Lymnaeidae, addition of possibly Leptophlebiids, Leptocerids, Gyrinids, Dytiscids, Hydrophilids, Ancylids, Planorbids, Tabanids, Aeshnids.	SASS: 70 Taxa: 4.5 ASPT: 16	Turbellaria, Oligochaeta, Baetidae, Caenidae, Coenagrionidae, Corduliidae, Libellulidae, Hydropsychidae, Corixidae, Naucoridae, Notonectidae, Pleidae, Veliidae, Chironomidae, Culicidae, Simuliidae, Tipulidae, Lymnaeidae

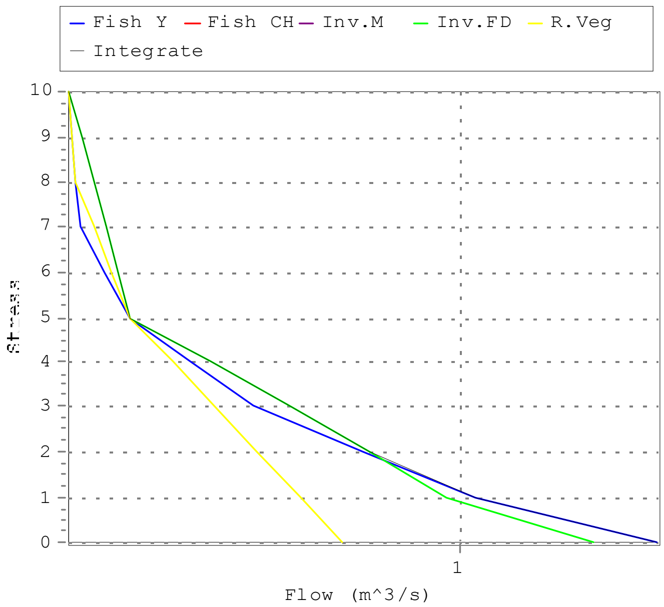
13 IFR 3 – LOWER BLACK KEI RIVER: IFRs

13.1 LOW FLOW REQUIREMENTS

13.1.1 Component and integrated stress curves

The individual component stresses are illustrated as well as the system stress line (black line).

Figure 13-1 Component and integrated stress curves



Purple 3: MD Inverts
Green: FD Inverts
Yellow: Riparian vegetation
Black: Integrated

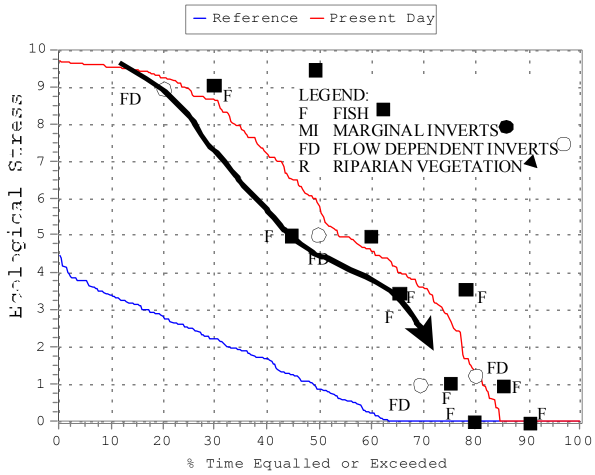
13.1.2 Generating stress requirements

The requirements are provided in the attached Appendix H.

The requirements are illustrated in Figure 13-2 - 13-4. Where all the points are plotted and the requirements are drawn in.

Figure 13-2 IFR 3 – Stress duration curve for a recommended scenario of a C/D REC

Dry season **Wet season**



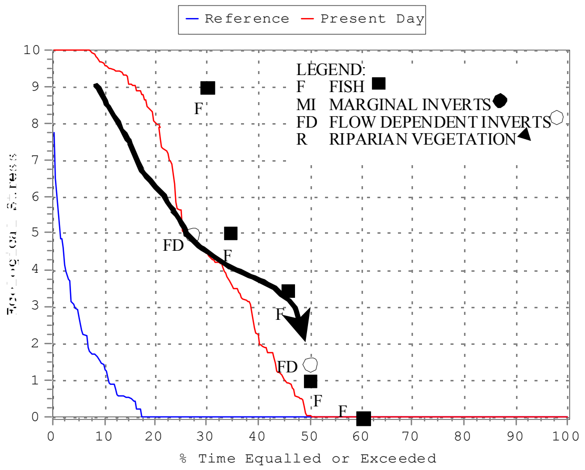
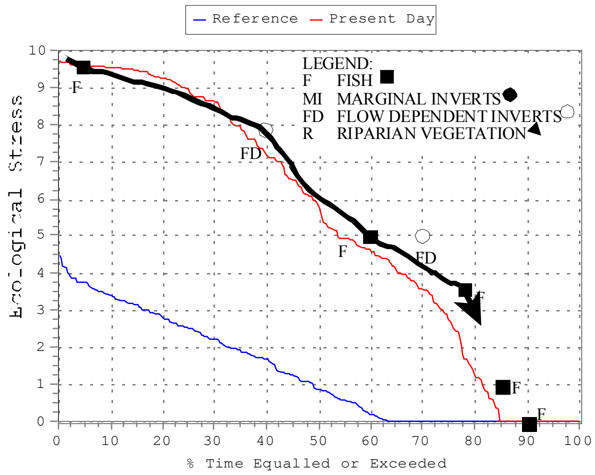


Figure 13-3 IFR 3 – Stress duration curve for an alternative scenario of a D EC

Dry season **Wet season**



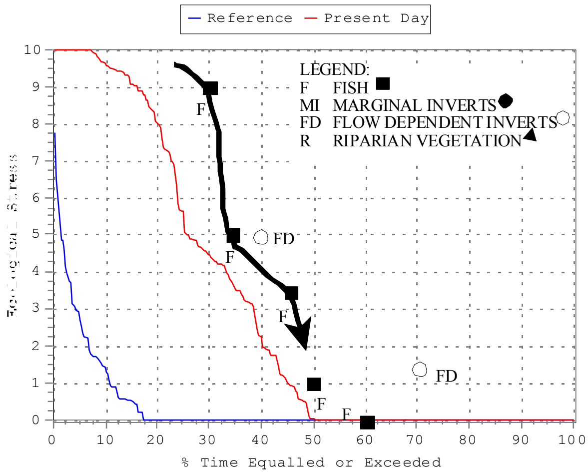
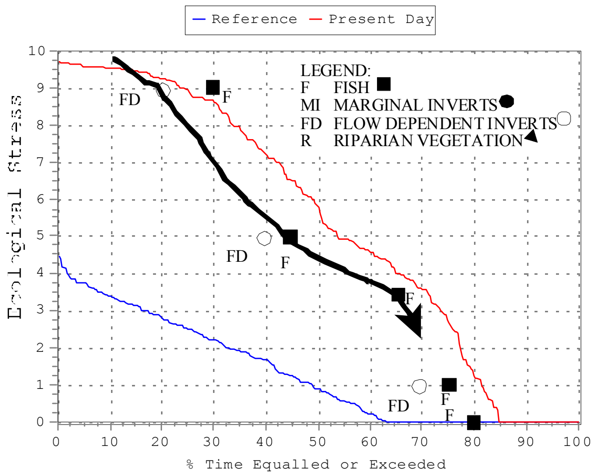


Figure 13-4 IFR 3 – Stress duration curve for an alternative scenario of a B/C EC

Dry season



Wet season

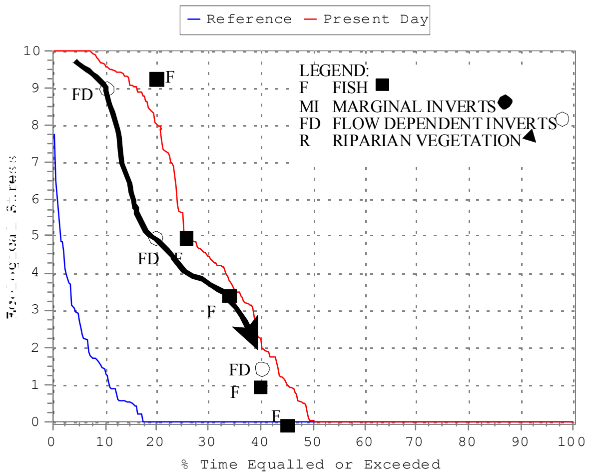
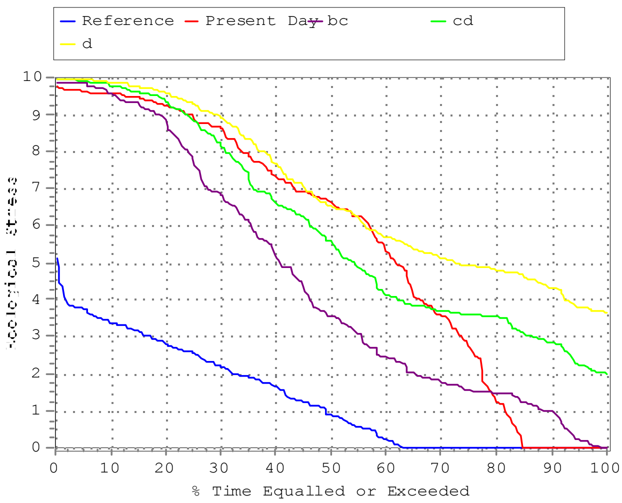
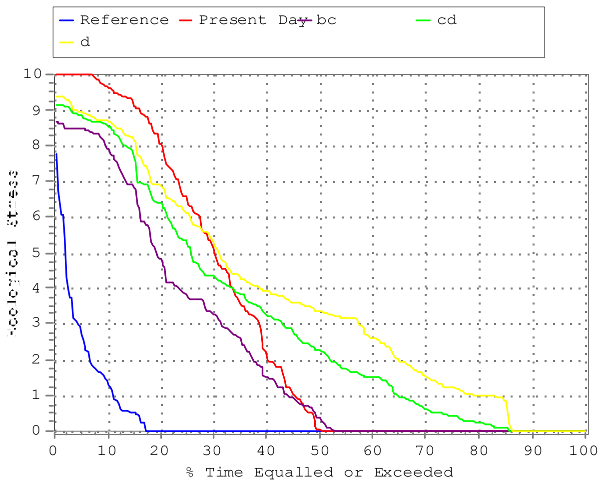


Figure 13-5 IFR 3 – Final curve

Dry season



Wet season



Fish drove the D EC requirements. The desktop D fell slightly below the flow dependent invertebrates requirements and catered for the higher fish requirements. With the same drought changes the desktop D was therefore adjusted accordingly. The desktop B/C was driven both by the fish and aquatic invertebrate requirements. The desktop B/C was adjusted accordingly.

13.2 HIGH FLOW REQUIREMENTS

The functions for each Flood Class are described in spreadsheets. A summary of the Flood Class ranges for IFR 3 is provided in Table 13.1 – 13.2 below. As only monthly data was available, the number of events under natural and present conditions could not be provided.

Table 13.1 Flood Class ranges for IFR 3

	Flood classes			
Component	**I (m^3/s)**	**II (m^3/s)**	**III (m^3/s)**	**IV (m^3/s)**
Fish	2.5-6	6-12		
Invertebrates	2.5-6	6-10		
Vegetation	2.5-8	8-15	16-20	
Geomorphology	2.5-4	4-10	14-20	20-40
Integrated	**2.5-8**	**4-15**	**14-20**	**20-40**
Daily average*	1.5	5	10	38
Duration (days)	1	1	2	3

The number of high flow events required for each EC is provided below

Table 13.2 Number of high flow events required for each EC – IFR 3

	I*	**Time****	**I**	**Time**	**I**	**Time**	**II**	**Time**	**II**	**Time**	**II**	**Time**	**III**	**Time**	**III**	**Time**	**III**	**Time**
Category	**D**	**D**	**C/D**	**C/D**	**B/C**	**B/C**	**D**	**D**	**C/D**	**C/D**	**B/C**	**B/C**	**D**	**D**	**C/D**	**C/D**	**B/C**	**B/C**
Fish	3	10-3	5	10-3	7	10-3	1	10-3	1	10-3	2	10-3						
Inverts	3	S^1 & S^2	4	S^1 & S^2	6	S^1 & S^2	1	11,12,2	2	11,12,2	2	11,12,2						
Vegetation	4	S^1 & S^2	5		6		2	S^1	3		4		1	S^1	1		1	
Geomorph	4	Wet	4	Wet	4	Wet	3	Wet	3	Wet	3	Wet	1	Wet	1	Wet	1	Wet
Number of events	4	10-3	5	10-3	7	10-3	3	10-3	3	10-3	4	10-3	1	10-3	1	10-3	1	10-3

* Denotes Class Floods
** Time is in months were 1-12 portrays January to December.
S^1 Summer
S^2 Spring

Class: 16-40: Whenever it occurs

These results were checked with the hydrology and were found to be acceptable.

13.3 FINAL RESULTS

13.3.1 IFR table for recommended scenario: C/D REC

```
Desktop Version 2, Printed on 2003/10/02
        Summary of IFR estimate for: Kei_3 Natural Monthly Flows
        Determination based on defined BBM Table with site-specific
assurance rules.

        Annual Flows (Mill. cu. m or index values):
        MAR                 =  228.090
        S.Dev.              =  179.105
        CV                  =    0.785
        Q75                 =    2.440
        Q75/MMF             =    0.128
        BFI Index           =    0.281
        CV(JJA+JFM) Index =    3.632

        REC = C/D

        Total IFR           =   25.488 (11.17 %MAR)
        Maint. Lowflow      =   16.252 ( 7.13 %MAR)
        Drought Lowflow     =    0.289 ( 0.13 %MAR)
        Maint. Highflow     =    9.236 ( 4.05 %MAR)

        Monthly Distributions (cu.m./s)
        Distribution Type : E.Cape

        Month    Natural Flows           Modified Flows (IFR)
                                         Low flows    High Flows Total
Flows
               Mean    SD       CV     Maint.  Drought    Maint.    Maint.
         Oct   5.674  10.528   0.693    0.400   0.010      0.048     0.448
         Nov  10.341  20.100   0.750    0.500   0.020      0.050     0.550
         Dec  10.148  13.987   0.515    0.600   0.020      0.210     0.810
         Jan   9.350  13.576   0.542    0.500   0.000      0.000     0.500
         Feb  14.320  18.807   0.543    0.700   0.010      0.232     0.932
         Mar  16.992  25.678   0.564    0.900   0.020      2.884     3.784
         Apr   7.489  10.547   0.543    0.700   0.020      0.050     0.750
         May   3.304   4.206   0.475    0.500   0.010      0.000     0.500
         Jun   1.876   1.914   0.394    0.400   0.000      0.000     0.400
         Jul   2.125   5.192   0.912    0.300   0.000      0.000     0.300
         Aug   2.837   8.958   1.179    0.300   0.000      0.000     0.300
         Sep   2.816   4.872   0.667    0.400   0.000      0.000     0.400
```

13.3.2 IFR table for alternative scenario: D EC

```
Desktop Version 2, Printed on 2003/10/02
        Summary of IFR estimate for: Kei_3 Natural Monthly Flows
        Determination based on defined BBM Table with site-specific
assurance rules.

        Annual Flows (Mill. cu. m or index values):
        MAR                 =  228.090
        S.Dev.              =  179.105
        CV                  =    0.785
        Q75                 =    2.440
        Q75/MMF             =    0.128
        BFI Index           =    0.281
        CV(JJA+JFM) Index =    3.632

        EC = D

        Total IFR           =   17.829 ( 7.82 %MAR)
```

Maint. Lowflow = 8.722 (3.82 %MAR)
Drought Lowflow = 0.289 (0.13 %MAR)
Maint. Highflow = 9.107 (3.99 %MAR)

Monthly Distributions (cu.m./s)
Distribution Type : E.Cape

Month	Natural Flows			Modified Flows (IFR)			
				Low flows		High Flows	Total Flows
	Mean	SD	CV	Maint.	Drought	Maint.	Maint.
Oct	5.674	10.528	0.693	0.200	0.010	0.048	0.248
Nov	10.341	20.100	0.750	0.300	0.020	0.000	0.300
Dec	10.148	13.987	0.515	0.300	0.020	0.210	0.510
Jan	9.350	13.576	0.542	0.300	0.000	0.000	0.300
Feb	14.320	18.807	0.543	0.400	0.010	0.232	0.632
Mar	16.992	25.678	0.564	0.450	0.020	2.884	3.334
Apr	7.489	10.547	0.543	0.400	0.020	0.050	0.450
May	3.304	4.206	0.475	0.250	0.010	0.000	0.250
Jun	1.876	1.914	0.394	0.200	0.000	0.000	0.200
Jul	2.125	5.192	0.912	0.180	0.000	0.000	0.180
Aug	2.837	8.958	1.179	0.170	0.000	0.000	0.170
Sep	2.816	4.872	0.667	0.180	0.000	0.000	0.180

13.3.3 IFR table for alternative scenario: B/C EC

Desktop Version 2, Printed on 2003/10/02
Summary of IFR estimate for: Kei_3 Natural Monthly Flows
Determination based on defined BBM Table with site-specific assurance rules.

Annual Flows (Mill. cu. m or index values):
MAR = 228.090
S.Dev. = 179.105
CV = 0.785
Q75 = 2.440
Q75/MMF = 0.128
BFI Index = 0.281
CV(JJA+JFM) Index = 3.632

EC = B/C

Total IFR = 45.818 (20.09 %MAR)
Maint. Lowflow = 35.865 (15.72 %MAR)
Drought Lowflow = 0.289 (0.13 %MAR)
Maint. Highflow = 9.953 (4.36 %MAR)

Monthly Distributions (cu.m./s)
Distribution Type : E.Cape

Month	Natural Flows			Modified Flows (IFR)			
				Low flows		High Flows	Total Flows
	Mean	SD	CV	Maint.	Drought	Maint.	Maint.
Oct	5.674	10.528	0.693	0.800	0.010	0.048	0.848
Nov	10.341	20.100	0.750	1.200	0.020	0.217	1.417
Dec	10.148	13.987	0.515	1.300	0.020	0.210	1.510
Jan	9.350	13.576	0.542	1.200	0.000	0.000	1.200
Feb	14.320	18.807	0.543	1.800	0.010	0.232	2.032
Mar	16.992	25.678	0.564	1.900	0.020	2.942	4.842
Apr	7.489	10.547	0.543	1.500	0.020	0.050	1.550
May	3.304	4.206	0.475	1.100	0.010	0.048	1.148
Jun	1.876	1.914	0.394	0.800	0.000	0.000	0.800
Jul	2.125	5.192	0.912	0.700	0.000	0.000	0.700

Aug	2.837	8.958	1.179	0.700	0.000	0.000	0.700
Sep	2.816	4.872	0.667	0.700	0.000	0.000	0.700

13.3.4 IFR rule table for recommended scenario: C/D REC

Desktop Version 2, Printed on 2003/10/02
Summary of IFR rule curves for : Kei_3 Natural Monthly Flows
Determination based on defined BBM Table with site-specific assurance rules.
Regional Type : E.Cape REC = C/D

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

Month	% Points 10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	0.663	0.635	0.576	0.476	0.345	0.212	0.108	0.048	0.022	0.019
Nov	0.898	0.835	0.741	0.603	0.422	0.258	0.132	0.061	0.033	0.030
Dec	1.450	1.312	1.156	0.957	0.676	0.439	0.235	0.106	0.051	0.048
Jan	0.794	0.765	0.703	0.594	0.442	0.272	0.129	0.041	0.005	0.005
Feb	1.410	1.361	1.257	1.074	0.815	0.524	0.272	0.114	0.046	0.042
Mar	8.629	6.896	5.418	4.048	2.275	1.459	0.838	0.488	0.347	0.333
Apr	1.145	1.097	0.995	0.823	0.596	0.366	0.186	0.082	0.038	0.032
May	0.753	0.721	0.653	0.539	0.389	0.236	0.117	0.048	0.019	0.015
Jun	0.593	0.562	0.497	0.392	0.265	0.149	0.067	0.024	0.007	0.004
Jul	0.445	0.422	0.375	0.298	0.204	0.116	0.054	0.020	0.006	0.003
Aug	0.445	0.422	0.373	0.294	0.199	0.112	0.050	0.018	0.005	0.003
Sep	0.602	0.576	0.521	0.429	0.307	0.183	0.087	0.031	0.007	0.004

Reserve flows without High Flows

Oct	0.603	0.577	0.523	0.432	0.312	0.190	0.095	0.040	0.017	0.014
Nov	0.775	0.749	0.693	0.596	0.457	0.299	0.160	0.069	0.029	0.025
Dec	0.955	0.930	0.876	0.780	0.630	0.440	0.248	0.103	0.031	0.026
Jan	0.796	0.773	0.727	0.642	0.511	0.346	0.182	0.062	0.005	0.005
Feb	1.114	1.084	1.021	0.907	0.731	0.506	0.279	0.108	0.022	0.017
Mar	1.433	1.395	1.317	1.175	0.956	0.675	0.385	0.160	0.042	0.029
Apr	1.085	1.049	0.973	0.839	0.648	0.428	0.230	0.098	0.036	0.027
May	0.753	0.721	0.653	0.539	0.389	0.236	0.117	0.048	0.019	0.015
Jun	0.593	0.562	0.497	0.392	0.265	0.149	0.067	0.024	0.007	0.004
Jul	0.445	0.422	0.375	0.298	0.204	0.116	0.054	0.020	0.006	0.003
Aug	0.445	0.422	0.373	0.294	0.199	0.112	0.050	0.018	0.005	0.003
Sep	0.602	0.576	0.521	0.429	0.307	0.183	0.087	0.031	0.007	0.004

13.3.5 IFR rule table for alternative scenario: D EC

Desktop Version 2, Printed on 2003/10/02
Summary of IFR rule curves for : Kei_3 Natural Monthly Flows
Determination based on defined BBM Table with site-specific assurance rules.
Regional Type : E.Cape EC = D

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

Month	% Points 10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	0.405	0.389	0.353	0.293	0.214	0.134	0.071	0.035	0.019	0.017
Nov	0.528	0.506	0.458	0.378	0.274	0.168	0.088	0.043	0.025	0.023
Dec	1.047	0.923	0.798	0.652	0.447	0.296	0.165	0.083	0.048	0.046
Jan	0.550	0.530	0.487	0.412	0.306	0.188	0.089	0.028	0.003	0.003
Feb	1.060	1.024	0.946	0.810	0.616	0.399	0.212	0.093	0.043	0.040
Mar	8.026	6.320	4.899	3.623	1.974	1.283	0.757	0.461	0.341	0.330
Apr	0.773	0.741	0.673	0.558	0.407	0.252	0.132	0.063	0.034	0.030
May	0.426	0.408	0.370	0.306	0.222	0.136	0.070	0.031	0.015	0.013
Jun	0.332	0.314	0.278	0.219	0.148	0.083	0.038	0.013	0.004	0.002
Jul	0.299	0.283	0.251	0.200	0.137	0.078	0.036	0.013	0.004	0.002
Aug	0.282	0.267	0.236	0.186	0.126	0.071	0.032	0.011	0.003	0.002
Sep	0.306	0.293	0.265	0.218	0.156	0.093	0.044	0.016	0.004	0.002

Reserve flows without High Flows

Oct	0.341	0.326	0.296	0.245	0.179	0.110	0.057	0.027	0.014	0.012
Nov	0.530	0.512	0.475	0.409	0.315	0.208	0.115	0.053	0.026	0.023
Dec	0.552	0.537	0.507	0.452	0.367	0.259	0.149	0.067	0.026	0.023
Jan	0.551	0.536	0.503	0.444	0.354	0.240	0.126	0.043	0.003	0.003
Feb	0.735	0.715	0.674	0.599	0.483	0.336	0.187	0.074	0.018	0.015
Mar	0.827	0.806	0.761	0.680	0.555	0.394	0.228	0.100	0.033	0.025
Apr	0.706	0.683	0.634	0.548	0.425	0.283	0.155	0.070	0.030	0.024

May	0.426	0.408	0.370	0.306	0.222	0.136	0.070	0.031	0.015	0.013
Jun	0.332	0.314	0.278	0.219	0.148	0.083	0.038	0.013	0.004	0.002
Jul	0.299	0.283	0.251	0.200	0.137	0.078	0.036	0.013	0.004	0.002
Aug	0.282	0.267	0.236	0.186	0.126	0.071	0.032	0.011	0.003	0.002
Sep	0.306	0.293	0.265	0.218	0.156	0.093	0.044	0.016	0.004	0.002

13.3.6 IFR rule table for alternative scenario: B/C EC

Desktop Version 2, Printed on 2003/10/02
Summary of IFR rule curves for : Kei_3 Natural Monthly Flows
Determination based on defined BBM Table with site-specific assurance rules.
Regional Type : E.Cape EC = B/C

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

	% Points									
Month	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	1.088	1.042	0.944	0.779	0.562	0.341	0.169	0.069	0.027	0.022
Nov	2.102	1.908	1.662	1.334	0.905	0.547	0.274	0.121	0.059	0.053
Dec	2.191	2.027	1.815	1.518	1.097	0.704	0.364	0.150	0.058	0.053
Jan	1.564	1.507	1.385	1.171	0.870	0.536	0.254	0.081	0.010	0.010
Feb	2.612	2.520	2.325	1.983	1.498	0.952	0.481	0.184	0.057	0.050
Mar	9.819	8.006	6.403	4.845	2.827	1.785	0.991	0.544	0.364	0.346
Apr	2.009	1.923	1.742	1.438	1.037	0.628	0.310	0.126	0.048	0.038
May	1.475	1.412	1.279	1.055	0.760	0.459	0.225	0.089	0.032	0.024
Jun	1.030	0.976	0.863	0.681	0.461	0.258	0.117	0.042	0.012	0.007
Jul	0.902	0.856	0.759	0.604	0.414	0.236	0.109	0.040	0.012	0.006
Aug	0.901	0.854	0.755	0.596	0.403	0.226	0.102	0.037	0.010	0.006
Sep	0.904	0.865	0.782	0.644	0.461	0.275	0.130	0.046	0.011	0.006

Reserve flows without High Flows

Oct	1.033	0.989	0.895	0.739	0.532	0.321	0.157	0.062	0.022	0.017
Nov	1.565	1.511	1.398	1.199	0.914	0.591	0.307	0.121	0.038	0.030
Dec	1.699	1.653	1.557	1.383	1.116	0.775	0.429	0.168	0.039	0.031
Jan	1.568	1.524	1.432	1.264	1.007	0.682	0.359	0.123	0.010	0.010
Feb	2.352	2.288	2.155	1.912	1.538	1.063	0.580	0.217	0.036	0.025
Mar	2.484	2.418	2.281	2.034	1.652	1.161	0.656	0.263	0.059	0.036
Apr	1.957	1.891	1.753	1.510	1.162	0.762	0.402	0.161	0.049	0.032
May	1.420	1.360	1.231	1.014	0.729	0.439	0.213	0.081	0.027	0.019
Jun	1.030	0.976	0.863	0.681	0.461	0.258	0.117	0.042	0.012	0.007
Jul	0.902	0.856	0.759	0.604	0.414	0.236	0.109	0.040	0.012	0.006
Aug	0.901	0.854	0.755	0.596	0.403	0.226	0.102	0.037	0.010	0.006
Sep	0.904	0.865	0.782	0.644	0.461	0.275	0.130	0.046	0.011	0.006

13.4 CONFIDENCE

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

Table 13.3 Confidence table – IFR 3

	IFR Site	Available data	Ecological Classification	Output low flow	Output high flow
Hydrology		3			
Hydraulics	2	3		4	2
	IFR site: Difficult site to characterise hydraulically due to influence of large resistance elements, including boulders. Available data: Two flows of 0.16 and 3.8m^3/s gauged at this site, providing medium confidence.				
Water quality	1	1	2		
	IFR site: Low confidence because there is no water quality monitoring points close to the IFR site. Available data: Low confidence due the absence of observed of observed water quality monitoring in this resource unit. Present state conditions were inferred from monitoring upstream of the resource unit and on the main tributaries, and observations made during the site visits. Ecological classification: moderate confidence because the PES categories are aligned with the biota and fish categories and the inferred water quality conditions.				
Geomorphology	2	2	3		2
	IFR site: Site seems reasonably representative for the area but has limited cues for geomorphology.				

	IFR Site	Available data	Ecological Classification	Output low flow	Output high flow
	Available data: No sediment model, poor hydrology and limited hydraulics for higher flows. Ecological classification: Good set of aerial photos and geomorphology classification. High flows: Limited cues on cross-section for the flood classes.				
Riparian vegetation	**3**	**2**	**3**	**5**	**3**
	IFR site: Site has good cues for high flows and some for low flows: Available data: Low confidence as limited information available about *Juncus.* Ecological classification: Uncertainties regarding non-flow aspects and trajectories. Low flows: Fish and invertebrate requirements more than adequate. High flows: Some uncertainties on flood requirements exist.				
Fish	**3**	**3**	**3**	**3**	**4**
	IFR site: Provide adequate habitat diversity. Available data: Recent summer sampling for fish at site, more historical data but August sampling trip occurred at an unfavourable period.				
Invertebrates	**2**	**2**	**2**	**3**	**3**
	IFR site: Due to the gauging weir construction, this site was not sampled. A site upstream was sampled and it was difficult to relate the information to the actual IFR site. Available data: Only one previous collection and present collection as well as a review of the Buffalo River data. Ecological classification: Expert judgement would have rated this site as higher than the results indicated and confidence therefore lower. Low flows. Invertebrates critical but reasonable confidence that adequate flows are provided. High flows: Medium due to lack of information on natural floods.				

14 IFR 4 – WHITE KEI RIVER: STRESS INDICES

IFR 4 is situated in the White Kei River, approximately 30km downstream of the Xonxa Dam and downstream of the Indwe River confluence. A site was found on a deserted farm which consisted of bedrock and boulder habitat. This was the only option as the other sites consisted mostly of alluvial habitats in disturbed areas. The site is illustrated in Figure14-1.

Figure 14-1 IFR 4: 15 July 2003, 1.07m^3/s.

14.1 FISH STRESS INDEX

The fish stress indices for Eurytopic and Limnophilic fish species were developed during site visits and at the specialist meeting (see Appendix F).

Table 14.1 Stress table – Limnophilic and Eurytopic fish species

Flow-Depth Response index	Habitat abundance and suitability				Total flow depth score	Limnophilic and Eurytopic species combined		
	FD[1]	FS[2]	SD[3]	SS[4]		Response: Abundance	Species stress	Flow (m^3/s)
0	5	5	5	5	20	All very abundant	0	2.55
1	4	5	5	5	19	All very abundant	1	1.1
2	4	4	5	5	18	All very abundant		
3	3	4	5	5	17	All very abundant		
4	2	3	5	5	15	All very abundant		
5	2	2	4	5	13	Abundant	5	0.55
6	1	2	3	4	10	Moderate	6	0.24
7	0	2	2	3	7	Low		
8	0	1	1	2	4	Low	8	0.08
9	0	0	0	1	1	Rare	9	0
10	0	0	0	0	0	None	10	0

1 FD: Fast (>0.3m/s) Deep (>0.3m)
2 FS: Fast (>0.3m/s) Shallow (<0.3m)
3 SD: Slow (<0.3m/s) Deep (>0.5m)
4 SS: Slow (<0.3m/s) Shallow (<0.5m)

14.2 AQUATIC INVERTEBRATES STRESS INDEX

The stress indices for aquatic invertebrates were developed during site visits and at the specialist meeting. An index for the Marginal Vegetation (MV) invertebrates and flow dependent (FD) invertebrates were developed at this site.

Table 14.2 Stress table – Flow Dependent invertebrate species

Flow-Depth Response index	Habitat abundance and suitability					Modifier	Depth (m)	Flow (m^3/s)	Velocity (m/s)	Habitat response** (Specific to site)	Biotic response	Species stress
	SIC[1]	SOC[2]	MVIC[3]	MVOC[4]	GS[5] pool						FD Inverts (Based on Kleynhans)	
Observation*	**2**	**3**	**2**	**1**	**3**							
Site rating**	**2**	**2**	**2**	**1**	**3**	Embeddedness, big substrate, algae on rock faces, sediment.						
0	5	5	5	4	5		0.75	1.81	0.2	All habitats in excess, very high quality.	FDs: Very abundant 0	
1	5	5	4	3	5		0.7	1.34	0.17	All habitats plentiful, very high quality.	FDs: Abundant 1	0
2	4	4	3	2	4		0.65	0.97	0.15	SIC and VIC sufficient, quality slightly reduced.	Slight reduction for FDs: Abundant 2	1
3	3	4	3	2	3		0.55	0.47	0.1	Reduced SIC and VIC, Reduced quality.	Reduction for FDI species: Moderate 3	
4	3	3	2	1	3		0.5	0.31	0.08	SIC and VIC limited, of moderate quality.	Further reduction for FDI species: Moderate 4	
5	2	2	2	1	3		0.43	0.16	0.06	SIC and VIC very reduced, of moderate quality.	Remnant populations of all FDI species: Low 5	5
6	2	2	1	0	2		0.4	0.12	0.05	SIC and VIC residual and of low quality.	Sensitive FDI species: Low 6	
7	1	2	0	0	2		0.35	0.07	0.03	No VIC, No VOC, little SIC.	All FDI species: Rare 7	8
8	1	1	0	0	2		0.25	0.02	0.02	Flowing water present, little SIC, no VIC.	Only remnant populations of hardy FDI species: Rare 8	
9	0	1	0	0	1		0.19	0	0.01	No surface flow.	Only pool dwellers: FDIs absent: None 9	
10	0	0	0	0	0					No surface water.	None 10	

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

15 IFR 4 – WHITE KEI RIVER: ECOLOGICAL CLASSIFICATION

15.1 REFERENCE CONDITIONS

Geomorphology
This site falls within the geomorphological zone `Er`, Rejuvenated foothills (Refer to Appendix C). These zones are steepened sections within middle reaches of the river caused by uplift. The zone has characteristics similar to foothills (gravel/cobble bed rivers with pool-riffle/ pool-rapid morphology) but of a higher order. A compound channel is often present with an active channel contained within a macro channel activated only during infrequent flood events. A limited flood plain may be present between the active and macro-channel.

Riparian vegetation
Well-defined single channel river characterised by rocky islands colonised by marginal vegetation and clear marginal zones on both banks. These are characterised *by Juncus, Miscanthus* and *Restionaceae*. Riparian vegetation forms distinct medium sized galleries in the lower and middle riparian zones occupied by a mixture of riparian species, including *Celtis africana*, *Combretum capensis*, *Schotia brachypetala* and *Acacia karroo.*

Water quality
Refer to the water quality report.

Fish
Higher population densities of three species expected in this reach. (*B anoplus*, three species of eels, Anguillidae). More suitable fish habitat in the form of substrate cover and marginal vegetation in slow flow habitats. Less fine silt and backwater areas, rocks only slightly embedded, thus more suitable for small fish species, *B. Anoplus* and eels. Less silt means better spawning conditions for *B anoplus*.

Inverts

Bio	Description of invert communities expected in reference conditions			
	Ref	**Summer**	**Ref**	**Winter**
SIC[1]	SASS: > 120 Taxa >20 ASPT: 6+	A diverse community of flow-dependent species with a relatively high ET (Ephemeroptera, Trichoptera) ratio. Diverse Ephemeroptera, including (at least) several Baetid species, Caenids, Tricorythids, Leptophlebiids, Heptageniids. A healthy community of Trichopterans including non-cased caddis. More than one Simuliid species likely, and abundant. Ancylid and Sphaeriid snails. Chironomids.	SASS: >100 Taxa >15 ASPT: >5	A less diverse community of FD species than summer conditions. The ratio of Ephemeroptera: Trichoptera is likely to be reduced. Simuliids likely to be reduced relative to summer conditions, and possibly in pupal state. Ancylids and Sphaerids likely. Chironomids likely.
MV[2]	SASS: >100 Taxa > 15 ASPT: > 5.5	It is unlikely that even under reference conditions this site would have had leafy marginal vegetation. Also, MVOC may have been exposed more than submersed. A marginal vegetation community with diverse juvenile Ephemeroptera, particularly Baetids and Caenids, Cased Trichopterans, Hemipterans, and Dipterans. Some Coleopterans and Odonates. Lymnaeid and Physid snails may be present.	SASS: > 80 Taxa > 13 ASPT: > 5	A similar community to summer, however lacking Ephemeroptera likely to be reduced in numbers.

Bio	Description of invert communities expected in reference conditions			
	Ref	Summer	Ref	Winter
TOT	SASS: > 160 Taxa > 35 ASPT: > 6	A diverse community supporting FD, MV and pool-dwelling species. A greater diversity of Trichopterans, Ephemeropteran, Odonate, Hemipterans, Coleopterans and Dipteran families and species than at present. The early summer community would likely have a high percentage of juvenile Ephemeropteran taxa. The mid and late summer communities are likely to have an altered EPT (Ephemeroptera, Plecoptera, Trichoptera) age-distribution due to the growth of juveniles, and the emergence of mature winged adults.	SASS: > 150 Taxa > 30 ASPT: > 6	The winter community would be expected to be similar to the summer community, however with reduced Ephemeropteran diversity, and a more uniform age distribution in the ET (Ephemeroptera, Trichoptera) fauna.

1 SIC: Stones in current
2 MV: Marginal vegetation

15.2 PES

15.2.1 Habitat Driver Status

Question	Score	Reasoning
Geomorphology		
To what extent is the channel structure artificial?	1	No change.
To what extent has event (high flows) hydrology changed?	4	Flows have been altered by the presence of upstream dams, irrigation demand etc.
To what extent has sediment input changed?	2	Sediment input has changed little over time
To what extent has riparian vegetation changed?	3	Some vegetation encroachment onto bars and banks.
To what extent has in-channel sediment storage changed?	3	Some change due to reduced width (vegetation encroachment) and increased depth causing an increased velocity.
Water Quality (Wq)		
To what extent has the 95%tile of the natural Wq changed? pH	1	pH, PES is Natural to Good (A/B), is slightly changed from natural, slightly elevated above 8.
To what extent are these changes related to water quantity changes.	1	pH is hardly related to flow.
To what extent has the 95%tile of the natural Wq changed? Salts	2	PES = Good (B), slightly changed from natural.
To what extent are these changes related to water quantity changes.	2	Salts are slightly related to flow in this catchment.
To what extent has the 95%tile of the natural Wq changed? Nutrients	2	PES = Natural to Good (A/B), slightly changed from natural.
To what extent are these changes related to water quantity changes.	1	Nutrients are hardly related to flow. No major point sources in the catchment, mostly related to non-point sources in the catchment.
To what extent has the 95%tile of the natural Wq changed? Temp	2	PES probably slightly changed from natural due to reduced flow in the catchment.
To what extent are these changes related to water quantity changes.	3	Releases from Xonxa Dam would affect temperature in the upper reaches, lower flows increase water clarity and light penetration and increase water temperature.
To what extent has the 95%tile of the natural Wq changed? Turbidity	2	PES probably slightly changed during the winter low flow months.
To what extent are these changes related to water quantity changes.	4	Low flows promote settling of bottom sediments. The fines are easily mobilised during elevated flows, increasing the turbidity of the water.
To what extent has the 95%tile of the natural Wq changed?	1	Probably slightly changed from natural due to

Question	Score	Reasoning
Oxygen		increased water temperature.
To what extent are these changes related to water quantity changes.	1	Dissolved oxygen is slightly related to flow and flow related impacts on water temperature.
Hydrology		
To what extent has low flows (70%ile) changed?	4	Changes in flow duration graph.
To what extent has the duration of zero flows changed?	1	Changes in flow duration graph.
To what extent has the seasonality changed?	3	Changes in flow duration graph.
To what extent have moderate events been reduced?	4	Changes in flow duration graph.

Geomorphology: 30% Flow related
Water quality: 44% Flow related
Overall: 57% Flow related
Category: C

15.2.2 Biological Response PES

Geomorphology(C)
The Present state appears to be quite stable i.e. largely unchanged for 65 years. The river at this site consists of a locally steepened section dominated by coarse angular material (rapids). The rough bed provides many areas of velocity reduction and these eddies or backwaters are covered with fine material (silts) which is an indication of poor catchment conditions. Away from the rejuvenated section, the river is largely alluvial or in its "natural" state.

Riparian vegetation (C)
The Present Ecological State is attributed to both flow and non-flow related changes. A change in flow regime, seen as reduced base flows and elevated flows, have lead mainly to changes in marginal zone species composition. *Juncus* currently dominates the site, whereas this was previously a mixed zone.

Fish (D)

Table 15.1 Fuzzy Fish Index – IFR 4: PES D

IFR site 4	**PES D**
Resource unit	
Native species richness	5
Abundance of native species	2
Frequency of occurrence of native	2
Health/condition of native and introduced species	4
Presence of introduced fish species	2
In-stream habitat modification	2
TOTAL SCORE	**17**
%	56.7
FISH ASSEMBLAGE CATEGORY	**D**

Invertebrates (C/D)

Table 15.2 Invert communities observed – IFR 4: PES C/D

Bio	PES	Invert communities observed during winter Winter
SIC	SASS: 53 Taxa: 11 ASPT: 4.8	Oligochaetes, Caenids, Leptophlebiids, Aeshnids, Hydropsychids (2sp), Gyrinids, Chironomids, Culicids, Simuliids, Tabanids, Tipulids.
MV	SASS: 43 Taxa: 9 ASPT: 4.8	Baetids, Caenids, Hydropsychids, Gyrinids, Chironomids, Simuliids, Tabanids, Tipulids.
SOC	SASS 28 Taxa: 6 ASPT: 4.7	Baetids (>2sp), Caenids, Leptophlebiids, Gomphids, Corixids, Ceratopogonids, Chironomids, Culicids, Simuliids, Tabanids.
TOT	SASS: 83 Taxa: 16 ASPT: 5.2	Oligochaetes, Baetids, Caenids, Leptophlebiids, Aeshnids, Gomphids, Hydropsychids, Libellulids Corixids, Gyrinids, Ceratopogonids, Chironomids, Culicids, Simuliids, Tabanids, Tipulids.

15.2.3 Trajectory of change

Geomorphology
The present state is stable.

Riparian vegetation
From a flow related perspective the riparian vegetation is probably stable. However, non-flow related aspects provide a negative trajectory mainly due to grazing, vegetation removal and encroachment of *Acacia karroo*. This will probably lead to a C/D in the long term.

Water quality
No significant trend in salinity or nutrients.

Fish
The trajectory seems stable as, according to aerial photos, the catchment problems (bad land-use, destruction of riparian vegetation, cattle trampling and bank collapse, etc.) seem to have stabilised. But flow patterns (releases from dams upstream) could be adjusted/improved.

Invertebrates
The inverts are stable.

15.2.4 Ecostatus

The habitat driver status indicates a C system. As both instream biological responses indicate a lower PES, the Ecostatus was set at a C/D i.e. lower than the drivers.

15.3 EIS

The results of the Ecological Importance and Sensitivity (EIS) are attached as Appendix G.

EIS rating: Moderate
Confidence: Moderate
Determinants: A large river, well buffered with alluvial stretches and a gorge.

15.4 RANGE OF ECS

The Ecological importance was moderate (natural and present). The component EC categories are provided in Figure 15-1. The additional EC categories to be assessed will be B/C (one category higher) and D (a half a category lower). The associated component ECs is also illustrated in the Figure 15-1.

Figure 15-1 IFR 4 – Ecological categories

AVAILABLE INFORMATION:

INSTREAM HABITAT INTEGRITY: D RIPARIAN HABITAT INTEGRITY: D

COMPONENT	PES	TRAJ	SHORT TERM (5 Y)	LONG TERM (20 Y)	EIS	REC	Alt EC	Alt EC
DRIVER HI	C				MODERATE	C	D	C
RIPARIAN VEGETATION	C	-- (nf)	C	C/D		C	D	B/C
FISH	D	0	D	D		D	D	C
AQUATIC INVERTS	C/D	0	C/D	C/D		C/D	D	B/C
ECOSTATUS	C/D	0 (F)	C/D	C/D		C/D	D	B/C

15.5 DEFINING ECs

Geomorphology (C)
The present geomorphological and habitat condition will not be improved by a change in flow. No objectives for an improved geomorphology have therefore been supplied.

Riparian vegetation (C, B/C and D)
Recommended EC C
In order to maintain the vegetation in a C state, it is important to ensure that adequate base flows are available to provide sufficient water to consistently supply the roots of marginal vegetation present. Sufficient elevated flows are required to cover the full distribution of marginal vegetation in the marginal zone, including the distinct secondary channel on the right bank. Riparian target species include *Celtis aricana, Schotia brachypetala* and *Combretum capensis*; however, it is uncertain whether these are likely to become significant given the general trend of the encroachment of *Acacia karroo* in the region. Target marginal species include *Miscanthus* and *Restionaceae* and *Juncus*.

Alternative EC (B/C)
An improved flow regime, such as improved summer base flows and elevated flows, is likely to improve the current condition of riparian and marginal vegetation to a category B/C at best. An improvement would be displayed in terms of the expansion in the width of the marginal zone on both banks as well as an increase in the density of vegetated islands. This would also be evident, along with non-flow related measures, in the germination and growth of plants in the lower riparian zone. This will be characterised by a river with more distinct marginal and riparian zones, however, due to the basic geomorphological template change which has occurred, it is unlikely to improve to a higher category. The substrate is now generally not suitable for a healthy mixed stand of riparian vegetation such as that present under reference conditions. Improved structural characteristics are therefore unlikely to take place.

The target riparian species are those such as *Celtis aricana, Schotia brachypetala* and *Combretum capensis*, however, it is uncertain whether these are likely to become significant given the general trend of the encroachment of *Acacia karroo* in the region. It is therefore unlikely that an improvement in species composition to a more mixed stand of riparian species will be achieved. Target marginal species include *Miscanthus* and *Restionaceae* and *Juncus*.

Any improvement in riparian condition is therefore only likely to occur in terms of the abundance of riparian plants in a wider riparian zone only.

Alternative EC D
The lower EC of a D could be achieved, from a flow perspective, by a further reduction in base flows and reduction in the frequency and extent of class 2 elevated flows. Reductions in base flows would result in the eventual loss of marginal vegetation on the outer edge of the marginal zone with an eventual reduction in the width of the marginal zone and a reduction in the vegetation density on islands.
The target riparian species are those such as *Celtis aricana, Schotia brachypetala* and *Combretum capensis.* Target marginal species include *Miscanthus* and *Restionaceae* and *Juncus*.

Fish (C)
Alternative EC C
An improvement will be due to an increase in abundance of native fish because of instream habitat. This improvement in instream habitat will be due to improved water quality, marginal vegetation and less silt deposited due to increased flow in a category C.

Table 15.3 Fuzzy Fish Index for Alternative ECs

IFR site 4	**PES and Alternative EC D**	**Alternative EC C**
Native species richness	5	5
Abundance of native species	2	3
Frequency of occurrence of native	2	2
Health/condition of native and introduced species	4	4
Presence of introduced fish species	2	2
In-stream habitat modification	2	3
TOTAL SCORE	**17**	**19**
%	56.7	63.3
FISH ASSEMBLAGE CATEGORY	**D**	**C**

Invertebrates (B/C, C and B/C)

Ref	PES C/D[1] score	PES C/D taxa[2]	Alternative EC B/C score	Alternative EC B/C taxa	Alternative EC D score	Alternative EC D taxa
SASS: > 160 Taxa > 35 ASPT: > 6	SASS: 83 Taxa: 16 ASPT: 5.2	Oligochaetes, Baetids, Caenids, Leptophlebiids, Aeshnids, Gomphids, Hydropsychids, Libellulids Corixids, Gyrinids, Ceratopogonids, Chironomids, Culicids, Simuliids, Tabanids, Tipulids.	SASS: 130 Taxa: 6 ASPT: 22	Oligochaetes, Baetids, Caenids, Leptophlebiids, Aeshnids, Gomphids, Hydropsychids, Libellulids Corixids, Gyrinids, Ceratopogonids, Chironomids, Culicids, Simuliids, Tabanids, Tipulids, addition of possibly Leptophlebiids, Leptocerids, Gyrinids, Dytiscids, Hydrophilids, Ancylids, Planorbids, Tabanids, Aeshnids.	SASS: 70 Taxa: 4.5 ASPT: 16	Oligochaetes, Baetids, Caenids, Aeshnids, Gomphids, Hydropsychids, Libellulids Corixids, Gyrinids, Ceratopogonids, Chironomids, Culicids, Simuliids, Tabanids, Tipulids

1 Scores are applicable to the recommended EC B category
2 Taxa are applicable to the recommended EC B category

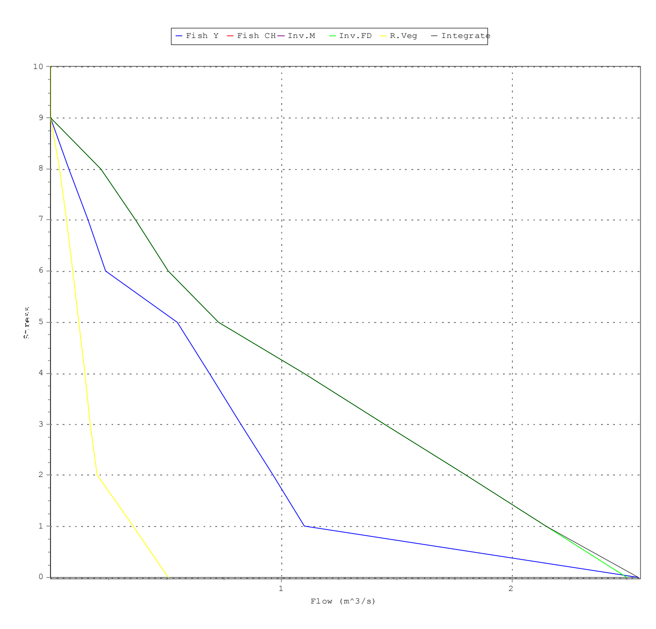
16 IFR 4 – WHITE KEI RIVER: IFRs

16.1 LOW FLOW REQUIREMENTS

16.1.1 Component and integrated stress curves

The individual component stresses are illustrated as well as the system stress line (black line).

Figure 16-1 Component and integrated stress curves



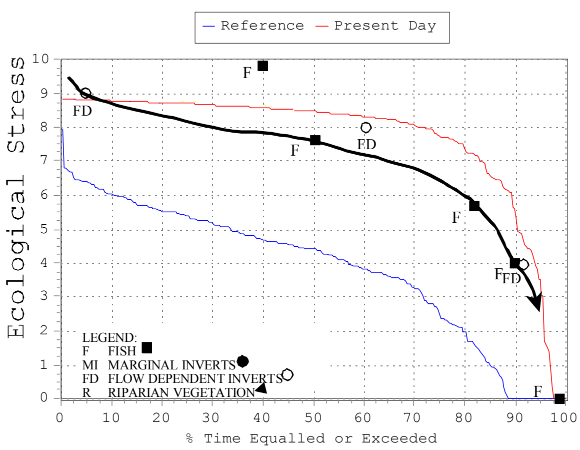
16.1.2 Generating stress requirements

The requirements are provided in the attached Appendix H.

The requirements are illustrated in Fig 16-2 – 16-4. Where all the points are plotted and the requirements are drawn in.

Figure 16-2 IFR 4 – Stress duration curve for a recommended scenario of a C/D REC

Dry season



Wet season

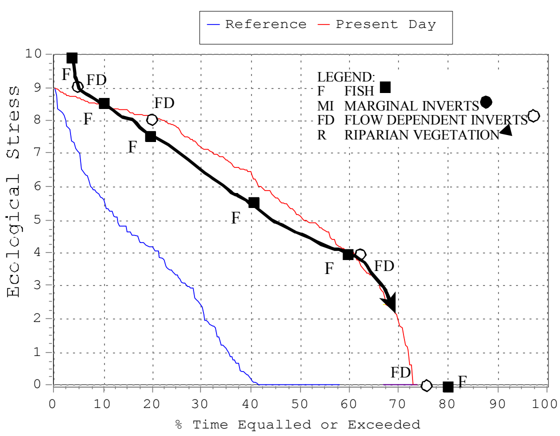
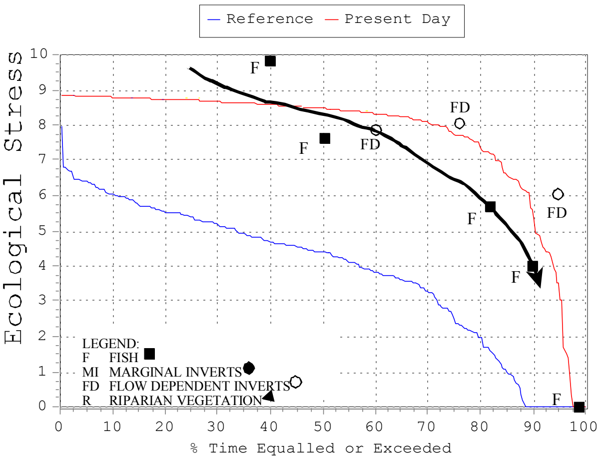


Figure 16-3 IFR 4 – Stress duration curve for an alternative scenario of a D EC

Dry season **Wet season**



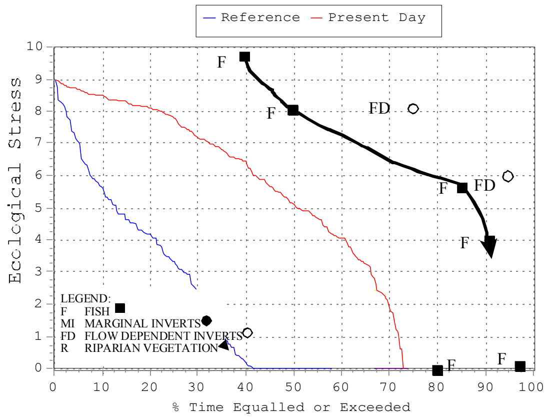
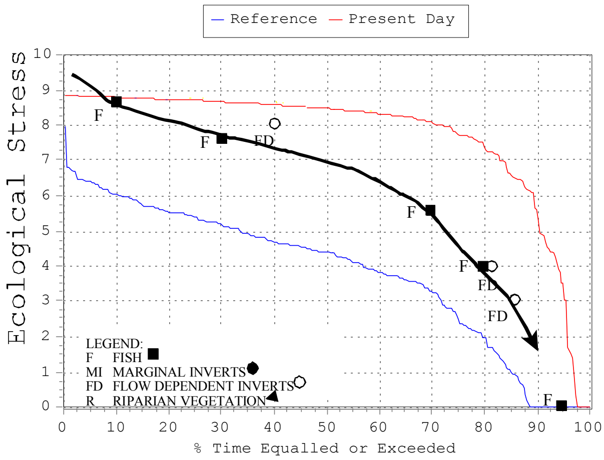
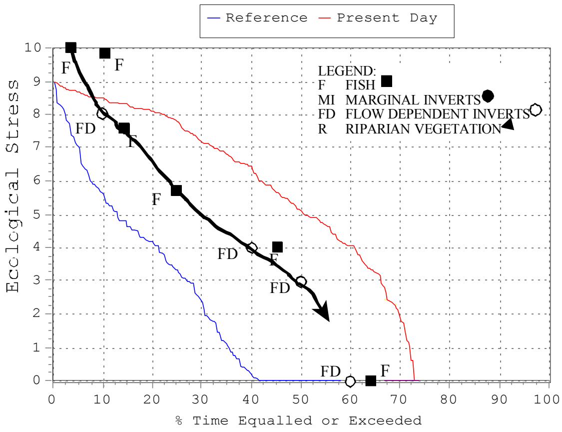


Figure 16-4 IFR 4 – Stress duration curve for an alternative scenario of a B/C EC

Dry season **Wet season**

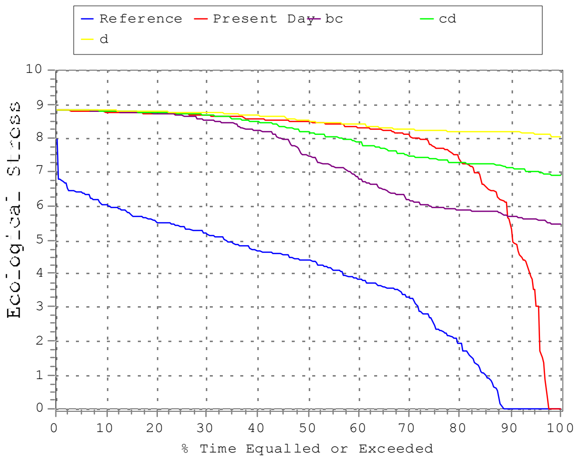


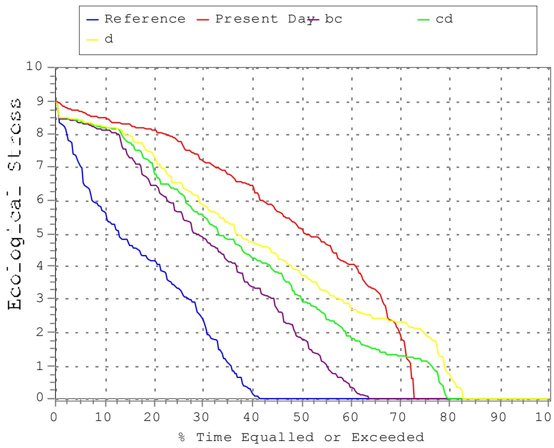


The final stress profiles are illustrated below.

Figure 16-5 IFR 4 – Final curve

Dry season **Wet season**





Fish drove the D EC requirements. The desktop D was adjusted accordingly. The desktop B/C was driven both by fish and aquatic invertebrate requirements. The desktop B/C was adjusted accordingly.

16.2 HIGH FLOW REQUIREMENTS

The functions for each Flood Class are described in spreadsheets. A summary of the Flood Class ranges for IFR 4 is provided in Table 16.1 – 16.2 below. As only monthly data was available, the number of events under natural and present conditions could not be provided.

A summary of the flood class ranges for IFR 4.

Table 16.1 Flood Class ranges for IFR 4

	Flood classes				
Component	**I (m^3/s)**	**II (m^3/s)**	**III (m^3/s)**	**IV (m^3/s)**	**V (m^3/s)**
Fish	3-10		10-15		
Invertebrates	3-6;	6-12			
Vegetation	3-10		10-40	40-80	
Geomorphology	3-6	6-14	14-40	40-75	75-130
Integrated	**3-10**	**6-14**	**10-40**	**40-80**	**75-130**
Daily average*	3	8	12	45	
Duration (days)	1	2	2	3	

The number of high flow events required for each EC is provided below

Table 16.2 High flow events required for each EC – IFR 4

	I*	Time**	I	Time	I	Time	II	Time	II	Time	II	Time	III	Time	III	Time	III	Timing
Category	**D**	**D**	**C/D**	**C/D**	**B/C**	**B/C**	**D**	**D**	**C/D**	**C/D**	**B/C**	**B/C**	**D**	**D**	**C/D**	**C/D**	**B/C**	**D**
Fish	2	10-3	4	10-3	4	10-3							1	10-3	2	10-3	2	10-3
Inverts	3		4		6		1		2		2							3
Vegetation	4	S^1&S^2	5	S^1&S^2	6	S^1&S^2	2	S^1	3	S^1	4	S^1	1	S^1	1	S^1	1	S^1
Geomorph							4	S^1	4	S^1	4	S^1	2	S^1	2	S^1	2	S^1
Number of events	4	10-3	5	10-3	6	10-3	4	10-3	4	10-3	4	10-3	2	10-3	2	10-3	2	10-3

* Denotes Class Floods
** Time is in months were 1-12 portrays January to December
S^1 Summer
S^2 Spring

These results were checked with the hydrology and were found to be acceptable.

16.3 FINAL RESULTS

16.3.1 IFR table for recommended scenario: C/D REC

```
Desktop Version 2, Printed on 2003/10/02
Summary of IFR estimate for: Kei_4 Natural Monthly Flows
Determination based on defined BBM Table with site-specific assurance
rules.

        Annual Flows (Mill. cu. m or index values):
        MAR                =  148.379
        S.Dev.             =  124.982
        CV                 =    0.842
        Q75                =    2.036
        Q75/MMF            =    0.165
        BFI Index          =    0.304
        CV(JJA+JFM) Index =    3.236


        Total IFR          =   30.659 (20.66 %MAR)
        Maint. Lowflow     =   15.435 (10.40 %MAR)
        Drought Lowflow    =    1.705 ( 1.15 %MAR)
        Maint. Highflow    =   15.224 (10.26 %MAR)

        Monthly Distributions (cu.m./s)
        Distribution Type : E.Cape

        Month    Natural Flows          Modified Flows (IFR)
                                     Low flows    High Flows Total Flows
               Mean    SD      CV    Maint.  Drought    Maint.    Maint.
         Oct   3.656  10.625   1.085    0.260   0.040     0.097     0.357
         Nov   5.050   9.404   0.718    0.600   0.060     0.473     1.073
         Dec   6.276   8.655   0.515    0.700   0.080     0.903     1.603
         Jan   6.832   8.931   0.488    0.500   0.060     0.000     0.500
         Feb  10.218  15.261   0.617    0.900   0.070     0.507     1.407
         Mar  11.244  21.490   0.714    1.000   0.080     3.310     4.310
         Apr   5.227   8.462   0.625    0.800   0.080     0.473     1.273
         May   1.955   2.032   0.388    0.250   0.050     0.000     0.250
         Jun   1.299   0.913   0.271    0.240   0.040     0.000     0.240
         Jul   1.393   2.519   0.675    0.220   0.030     0.000     0.220
         Aug   1.822   4.530   0.928    0.220   0.030     0.000     0.220
         Sep   1.850   2.888   0.602    0.220   0.030     0.000     0.220
```

16.3.2 IFR table for alternative scenario: D EC

```
Desktop Version 2, Printed on 2003/10/02
Summary of IFR estimate for: Kei_4 Natural Monthly Flows
Determination based on defined BBM Table with site-specific assurance
rules.

        Annual Flows (Mill. cu. m or index values):
        MAR                =  148.379
        S.Dev.             =  124.982
        CV                 =    0.842
        Q75                =    2.036
        Q75/MMF            =    0.165
        BFI Index          =    0.304
        CV(JJA+JFM) Index =    3.236


        Total IFR          =   23.736 (16.00 %MAR)
        Maint. Lowflow     =    8.771 ( 5.91 %MAR)
        Drought Lowflow    =    1.705 ( 1.15 %MAR)
        Maint. Highflow    =   14.964 (10.09 %MAR)
```

Monthly Distributions (cu.m./s)
Distribution Type : E.Cape

Month	Natural Flows			Modified Flows (IFR)			
				Low flows		High Flows	Total Flows
	Mean	SD	CV	Maint.	Drought	Maint.	Maint.
Oct	3.656	10.625	1.085	0.140	0.040	0.000	0.140
Nov	5.050	9.404	0.718	0.350	0.060	0.473	0.823
Dec	6.276	8.655	0.515	0.410	0.080	0.903	1.313
Jan	6.832	8.931	0.488	0.300	0.060	0.000	0.300
Feb	10.218	15.261	0.617	0.530	0.070	0.507	1.037
Mar	11.244	21.490	0.714	0.590	0.080	3.310	3.900
Apr	5.227	8.462	0.625	0.470	0.080	0.473	0.943
May	1.955	2.032	0.388	0.120	0.050	0.000	0.120
Jun	1.299	0.913	0.271	0.110	0.040	0.000	0.110
Jul	1.393	2.519	0.675	0.110	0.030	0.000	0.110
Aug	1.822	4.530	0.928	0.110	0.030	0.000	0.110
Sep	1.850	2.888	0.602	0.120	0.030	0.000	0.120

16.3.3 IFR table for alternative scenario: B/C EC

Desktop Version 2, Printed on 2003/10/02
Summary of IFR estimate for: Kei_4 Natural Monthly Flows
Determination based on defined BBM Table with site-specific assurance rules.

Annual Flows (Mill. cu. m or index values):

MAR	=	148.379
S.Dev.	=	124.982
CV	=	0.842
Q75	=	2.036
Q75/MMF	=	0.165
BFI Index	=	0.304
CV(JJA+JFM) Index	=	3.236

Total IFR	=	45.116	(30.41 %MAR)
Maint. Lowflow	=	29.633	(19.97 %MAR)
Drought Lowflow	=	1.705	(1.15 %MAR)
Maint. Highflow	=	15.483	(10.43 %MAR)

Monthly Distributions (cu.m./s)
Distribution Type : E.Cape

Month	Natural Flows			Modified Flows (IFR)			
				Low flows		High Flows	Total Flows
	Mean	SD	CV	Maint.	Drought	Maint.	Maint.
Oct	3.656	10.625	1.085	0.499	0.040	0.097	0.596
Nov	5.050	9.404	0.718	1.152	0.060	0.473	1.625
Dec	6.276	8.655	0.515	1.344	0.080	1.000	2.344
Jan	6.832	8.931	0.488	0.960	0.060	0.000	0.960
Feb	10.218	15.261	0.617	1.728	0.070	0.507	2.235
Mar	11.244	21.490	0.714	1.920	0.080	3.310	5.230
Apr	5.227	8.462	0.625	1.536	0.080	0.473	2.009
May	1.955	2.032	0.388	0.480	0.050	0.000	0.480
Jun	1.299	0.913	0.271	0.461	0.040	0.000	0.461
Jul	1.393	2.519	0.675	0.422	0.030	0.000	0.422
Aug	1.822	4.530	0.928	0.422	0.030	0.000	0.422
Sep	1.850	2.888	0.602	0.422	0.030	0.000	0.422

16.3.4 IFR rule table for recommended scenario: C/D REC

Desktop Version 2, Printed on 2003/10/02
Summary of IFR rule curves for : Kei_4 Natural Monthly Flows
Determination based on defined BBM Table with site-specific assurance rules.
Regional Type : E.Cape REC = C/D

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

% Points

Month	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	0.513	0.493	0.451	0.380	0.286	0.190	0.116	0.073	0.055	0.053
Nov	2.051	1.786	1.529	1.250	0.853	0.584	0.346	0.192	0.123	0.116
Dec	3.131	2.726	2.352	1.966	1.367	0.995	0.617	0.332	0.191	0.171
Jan	0.797	0.776	0.733	0.654	0.533	0.381	0.229	0.118	0.065	0.065
Feb	2.087	2.034	1.921	1.718	1.404	1.004	0.600	0.294	0.143	0.052
Mar	8.980	7.560	6.327	5.163	3.353	2.468	1.557	0.850	0.481	0.439
Apr	1.841	1.783	1.660	1.446	1.138	0.783	0.466	0.252	0.153	0.138
May	0.378	0.364	0.334	0.283	0.217	0.150	0.097	0.067	0.054	0.052
Jun	0.357	0.340	0.305	0.250	0.182	0.119	0.076	0.053	0.044	0.042
Jul	0.327	0.312	0.280	0.229	0.166	0.108	0.066	0.043	0.034	0.032
Aug	0.327	0.311	0.279	0.226	0.163	0.104	0.064	0.042	0.033	0.032
Sep	0.332	0.319	0.291	0.245	0.184	0.122	0.073	0.045	0.034	0.032

Reserve flows without High Flows

Month	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	0.392	0.377	0.345	0.291	0.220	0.147	0.091	0.058	0.044	0.042
Nov	0.931	0.900	0.836	0.724	0.564	0.382	0.222	0.117	0.070	0.066
Dec	1.116	1.087	1.028	0.921	0.756	0.545	0.332	0.171	0.092	0.087
Jan	0.797	0.776	0.733	0.654	0.533	0.381	0.229	0.118	0.065	0.065
Feb	1.434	1.396	1.319	1.177	0.960	0.683	0.402	0.190	0.085	0.052
Mar	1.593	1.553	1.469	1.317	1.083	0.781	0.470	0.229	0.104	0.090
Apr	1.241	1.202	1.119	0.973	0.765	0.525	0.309	0.165	0.097	0.087
May	0.378	0.364	0.334	0.283	0.217	0.150	0.097	0.067	0.054	0.052
Jun	0.357	0.340	0.305	0.250	0.182	0.119	0.076	0.053	0.044	0.042
Jul	0.327	0.312	0.280	0.229	0.166	0.108	0.066	0.043	0.034	0.032
Aug	0.327	0.311	0.279	0.226	0.163	0.104	0.064	0.042	0.033	0.032
Sep	0.332	0.319	0.291	0.245	0.184	0.122	0.073	0.045	0.034	0.032

16.3.5 IFR rule table for alternative scenario: D EC

Desktop Version 2, Printed on 2003/10/02
Summary of IFR rule curves for : Kei_4 Natural Monthly Flows
Determination based on defined BBM Table with site-specific assurance rules.
Regional Type : E.Cape EC = D

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

% Points

Month	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	0.239	0.231	0.212	0.182	0.142	0.101	0.069	0.050	0.042	0.041
Nov	1.740	1.485	1.251	1.012	0.673	0.468	0.288	0.171	0.119	0.114
Dec	2.770	2.375	2.022	1.673	1.132	0.832	0.529	0.300	0.187	0.171
Jan	0.552	0.538	0.509	0.457	0.376	0.274	0.173	0.099	0.063	0.063
Feb	1.691	1.648	1.558	1.396	1.145	0.826	0.503	0.259	0.138	0.052
Mar	8.472	7.066	5.861	4.747	3.016	2.233	1.426	0.799	0.473	0.436
Apr	1.482	1.436	1.339	1.170	0.926	0.646	0.395	0.226	0.148	0.136
May	0.205	0.199	0.184	0.161	0.129	0.097	0.072	0.058	0.052	0.051
Jun	0.183	0.176	0.160	0.135	0.104	0.076	0.056	0.046	0.042	0.041
Jul	0.183	0.175	0.159	0.133	0.100	0.070	0.049	0.037	0.032	0.031
Aug	0.183	0.175	0.158	0.131	0.099	0.068	0.047	0.036	0.032	0.031
Sep	0.205	0.197	0.181	0.155	0.119	0.083	0.055	0.039	0.032	0.031

Reserve flows without High Flows

Month	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	0.239	0.231	0.212	0.182	0.142	0.101	0.069	0.050	0.042	0.041
Nov	0.619	0.599	0.558	0.486	0.384	0.267	0.164	0.097	0.067	0.064
Dec	0.755	0.736	0.698	0.628	0.520	0.383	0.244	0.140	0.088	0.084
Jan	0.552	0.538	0.509	0.457	0.376	0.274	0.173	0.099	0.063	0.063
Feb	0.975	0.950	0.899	0.805	0.661	0.477	0.290	0.150	0.080	0.052
Mar	1.086	1.059	1.003	0.902	0.746	0.546	0.339	0.179	0.096	0.086
Apr	0.831	0.806	0.752	0.658	0.523	0.368	0.228	0.135	0.091	0.085
May	0.205	0.199	0.184	0.161	0.129	0.097	0.072	0.058	0.052	0.051
Jun	0.183	0.176	0.160	0.135	0.104	0.076	0.056	0.046	0.042	0.041
Jul	0.183	0.175	0.159	0.133	0.100	0.070	0.049	0.037	0.032	0.031
Aug	0.183	0.175	0.158	0.131	0.099	0.068	0.047	0.036	0.032	0.031

Sep	0.205	0.197	0.181	0.155	0.119	0.083	0.055	0.039	0.032	0.031

16.3.6 IFR rule table for alternative scenario: B/C EC

Desktop Version 2, Printed on 2003/10/02
Summary of IFR rule curves for : Kei_4 Natural Monthly Flows
Determination based on defined BBM Table with site-specific assurance rules.
Regional Type : E.Cape   EC = B/C

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

% Points

Month	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	0.755	0.725	0.660	0.552	0.410	0.264	0.151	0.085	0.058	0.054
Nov	2.624	2.339	2.040	1.687	1.185	0.795	0.453	0.229	0.130	0.119
Dec	3.989	3.526	3.082	2.599	1.852	1.331	0.804	0.406	0.209	0.171
Jan	1.255	1.222	1.151	1.024	0.828	0.580	0.334	0.154	0.068	0.068
Feb	2.841	2.766	2.611	2.329	1.896	1.343	0.783	0.361	0.151	0.052
Mar	9.897	8.453	7.170	5.913	3.960	2.893	1.793	0.940	0.495	0.445
Apr	2.546	2.464	2.292	1.989	1.554	1.054	0.605	0.304	0.163	0.143
May	0.621	0.596	0.544	0.456	0.341	0.224	0.132	0.079	0.057	0.054
Jun	0.595	0.566	0.505	0.407	0.288	0.179	0.103	0.063	0.046	0.044
Jul	0.544	0.518	0.463	0.374	0.266	0.165	0.092	0.053	0.037	0.033
Aug	0.544	0.517	0.461	0.370	0.260	0.159	0.088	0.051	0.036	0.033
Sep	0.545	0.523	0.476	0.397	0.293	0.187	0.104	0.056	0.036	0.033

Reserve flows without High Flows

Oct	0.645	0.619	0.564	0.471	0.349	0.224	0.127	0.071	0.047	0.044
Nov	1.503	1.453	1.347	1.161	0.896	0.594	0.328	0.155	0.077	0.069
Dec	1.758	1.712	1.616	1.442	1.175	0.834	0.489	0.228	0.099	0.091
Jan	1.255	1.222	1.151	1.024	0.828	0.580	0.334	0.154	0.068	0.068
Feb	2.259	2.199	2.074	1.848	1.499	1.054	0.603	0.263	0.095	0.052
Mar	2.511	2.446	2.311	2.067	1.690	1.206	0.707	0.320	0.118	0.095
Apr	2.005	1.939	1.802	1.561	1.215	0.817	0.460	0.221	0.109	0.092
May	0.621	0.596	0.544	0.456	0.341	0.224	0.132	0.079	0.057	0.054
Jun	0.595	0.566	0.505	0.407	0.288	0.179	0.103	0.063	0.046	0.044
Jul	0.544	0.518	0.463	0.374	0.266	0.165	0.092	0.053	0.037	0.033
Aug	0.544	0.517	0.461	0.370	0.260	0.159	0.088	0.051	0.036	0.033
Sep	0.545	0.523	0.476	0.397	0.293	0.187	0.104	0.056	0.036	0.033

16.4 CONFIDENCE

The confidence is evaluated according to a score of 0 - 5 with zero reflecting ‘no confidence’ and 5 reflecting ‘very high’ confidence.

Table 16.3 Confidence table – IFR 4

	IFR Site	Available data	Ecological Classification	Output low flow	Output high flow
Hydrology					
Hydraulics					
Water quality	2	2	3		
	IFR site: Low/moderate confidence because the most recent water quality data set is available from Xonxa Dam which is a large distance away from the IFR site and there is a general increase in salinity in a downstream direction. Available data: Low/moderate confidence in the available data because the data record is quite poor (28 samples). Ecological classification: Moderate confidence in the ecological classification because the PES is quite good and not very variable at the PES site. The trend also indicates a stable condition.				
Geomorphology	3	2	3		3
	IFR site: Moderate confidence as this site seems quite typical of this zone. There are some physical cues at this site. Available data: Low confidence as no sediment modelling and no daily hydrology data available. Ecological classification: Moderate as a good set of aerial photos is available to determine the reference condition and trajectory of change.				

	IFR Site	Available data	Ecological Classification	Output low flow	Output high flow
	High flow: Moderate as there are some cues on the cross-section.				
Riparian vegetation	**3**	**2**	**3**	**3**	**3**
	IFR site: Medium due to vague cues indicative of the lower and middle riparian zones, as well as vegetation removal and the impact of grazing. Available data: Low. Only *Juncus* present at this site which is very persistent and has replaced a mixed marginal vegetation composition. Little is known about stress levels in the area between 0 and 8 level stresses and therefore the stress curve and its value were questioned. Ecological classification: Medium as this is difficult to assess due to uncertainties regarding riverine conditions and PES. Non-flow aspects complicate the assessment. Low flow: The recommendations are to maintain marginal vegetation due to its persistence, but it is not certain whether improved species composition will be achieved for the higher EC. High flow: Flow cues are confusing for the estimation of high flows as there are complicated riparian zone delineations.				
Fish	**3**	**1**	**2**	**3**	**3**
	IFR site: Representative section with most fish habitats and critical spawning and migration areas were modelled Available data: Low. No historical data (excluding Ciskei) on fish, therefore findings were extrapolated from the Black Kei River. Poor conditions for sampling during site visit (mid-winter). Ecological classification: Low. Lack of reference condition fish data and no adjacent undisturbed river. A low confidence in the PES due to lack of sampling. Low flows: Medium as the low flows were set for inverts which were higher than for fish. High flows: Medium as the fish requirements are not very sensitive and will be accommodated by higher flows required for other components.				
Invertebrates	**3**	**2**	**3**	**3**	**3**
	IFR site: Medium on account of knowing that most of the rest of the RU is sand bed. Reasonably good quality habitat and flood cues. Available data: Only one previous collection and present collection as well as a review of the Buffalo River data. Ecological classification: Medium on the basis of PES, traj, and experience in all the upstream sites. Low flows: Inverts are the driver for this site. Medium confidence that flows provided will meet Ecological objectives of maintaining present communities and increasing diversity (improving the PES). High flows: Medium confidence that high flows will perform the required functions for either maintenance or improvement of the EC.				

17 ECOLOGICAL CONSEQUENCES OF OPERATIONAL FLOW SCENARIOS

17.1 OBJECTIVES

The objective of this phase of the study was the following:

To determine the ecological (or more correctly biophysical) consequences of different flow scenarios at each IFR site.

17.2 EVALUATE IMPACT OF THE IFRs ON THE YIELD OF THE SYSTEM

Previously, IFRs were assessed for various ecological river states, called Ecological Categories (ECs). During this assessment, no consideration is given on whether the IFRs are available, can be managed or supplied. Various alterations of the IFR to achieve the same objective or EC were also not considered. The result of this work is documented in chapters 7 - 16. It must be noted that a number of different flow regimes can achieve a specific objective. For practical reasons, one flow regime (IFR) to achieve or maintain the EC is set and other flow regimes are tested against the EC.

The IFR flows for difference ECs were then tested to determine whether they were available, utilising a systems model, the Water Resources Yield Model (WRYM). The WRYM models the IFRs as priority so that the impact on the yield and therefore on other users (present and/or future) can be assessed. The way that the model is set up is decided upon with ecological specialists and described in DWAF, 2005.

17.3 DESIGN OF ADDITIONAL FLOW SCENARIOS

The modellers and the ecological specialists assess the impacts of the IFRs on the yield. The IFRs considered initially consisted of an IFR to achieve an EC lower than the Recommended EC (REC)[1] (Scenario 1), one to achieve the REC (Scenario 2) and one to achieve a higher than REC. Knowing now where potential shortages exist as well as the IFR characteristics that cause the shortages, potential changes to the IFRs are suggested. At this stage the operational constraints are also considered in the adjustments to the IFRs. Examples of such constraints are the following:

- Existing dams with limited outlet capacity.
- Existing dams far upstream from IFR sites, i.e. released floods could be attenuated.
- Downstream demand, i.e. domestic water supply that has to be supplied at high assurance and uses the river as a conduit.
- No large operating structures – only abstractions by means of pumping for example. No flows can therefore be ‘released’, and low/base flows can only be managed by restricting demand.
- Any international agreements which could be seen as existing constraints.

The following operational scenarios were designed during an initial meeting held on 15 December 2003 at Ninham Shand, Cape Town.

17.4 SCENARIO 4

Scenario 2 for the Recommended EC with the following changes at the various IFR sites:

IFR 1
Remove the $18m^3/s$ flood and substitute it with $5m^3/s$.
Smaller events were still included as they could be supplied.

1 Note that the REC is determined only from an ecological viewpoint by ecological specialists according to the Ecological Classification system. This is not necessarily the Management Class for the river which must be determined with stakeholder input amongst others.

IFR 2
Remove the $30m^3/s$ event.
IFR 3
Remove the 10 m^3/s and 38 m^3/s as they are not operationally possible to manage.
Other events were still included.
IFR 4
Xonxa Dam has an outlet of 10 m^3/s and therefore the 45 m^3/s was removed.
The other events were included assuming that Xonxa and Lubisi Dams combined can supply them.
Drought flows were removed, as the workshop requested no flows during that period.

17.5 SCENARIO 5

Scenario 2 with all changes as for Scenario 4.

Apart from the three IFR scenarios resulting in different ECs, two operational scenarios were therefore evaluated, i.e. Scenario 4 and 5. A 'No IFR' scenario was also evaluated. This differs from the present flow as future development and increased use are also considered. This is the so-called worst-case scenario.

After the necessary changes were made to the IFR rules, the files were provided to the yield modeller. The outcome of this modelling was the provision of flow sequences to be provided at each IFR site for each scenario (See section J.7).

17.6 ECOLOGICAL EVALUATION OF DIFFERENT FLOW SCENARIOS

The ecological evaluation is based on an assessment of the impact on the states or ECs recommended for each component (i.e. fish, invertebrates, etc.) as well the overall state (Ecostatus).

The tools used to undertake the evaluation are the following:

- Flow duration graphs for the wettest and driest flow months consisting of graphs for natural flow, present day, the IFRs and each flow scenario to be evaluated.
- Stress duration graphs (stress profiles) of the wet and dry season illustrating the natural, present day and flow scenario stress profiles. (The Flow-Stressor Response (FS-R) method is described in O'Keeffe *et al.*, 2002.)
- Stress indices for each component providing all the descriptions for stresses ranging from 0 - 10 as well as the motivations for the stress levels at specific durations that were selected to represent the requirements for each component in each category.

The processes normally followed prior to and during the specialist meeting are sequentially described below:

- The stress duration graphs were provided to the instream specialists, and are attached to this document.
- Specialists compare the stresses associated with each scenario against the characteristic stresses for each of the IFRs for the various categories as provided during the IFR specialist meeting. The original stress requirements are plotted on the stress duration graphs for assessment purposes (see section 17.7).
- Specialists determine which category each scenario represents for their components. An example of this process would be as follows. Fish required a stress of 5 to occur for 60% of the time to achieve a C category. It was also determined that a stress of 5 that occurs for 50% of the time would represent a D category. The scenario to be evaluated consists of a stress of 5 that occurs for 57% of the time. An evaluation must now be made whether this still represents a C category, a C/D or a D category and the motivation for the decision must be supplied. This is an over-simplified example as a variety of stresses and durations would normally be identified during both the wet and dry season and the high flows would also be evaluated. NOTE: During this assessment, the emphasis was, where possible, only on flow-

related consequences. It must be noted however that it is especially difficult in some cases to disentangle the flow and non-flow related issues for the geomorphological assessment. Furthermore, the process (rules/guidelines/criteria followed to decide on the categories) varied for different circumstances at different sites and different specialists and requires further method development (see last bullet).

- The various component categories for each flow scenario were then evaluated to determine the Ecostatus. The initial process used was to compare all the component states, identify the significant drivers and, by means of discussion, agree on an Ecostatus. This was then checked against the FS-R profiles which have been previously determined and which represent certain Ecological states. These of course provide an indicator of what the resulting Ecostatus category should be and are used as guidance. If, for example, the stress profiles for a C and D EC have previously been defined, a C/D line would lie mostly between the C and D. If the scenario were to be evaluated as a B/C, such an assessment should be carefully reassessed, as likely to be wrong. This is however an over-simplification as the scenarios to be evaluated seldom represents a linear change. For 20% of the time the line might lie above the predefined stress profile (i.e. representing lower flows), for 30 % of the time on the line, and for 50% of the time below (i.e. representing higher flows). The ecological significance of the scenario profile should then be evaluated to determine which Ecostatus categories the scenario represents.
- An assessment was also made of how likely it would be that these evaluated states would be achieved when non-flow related issues are taken into account. This is done in a descriptive and probably subjective way at this stage.

As the Kei process followed the Intermediate Ecological Reserve Methodology, the comprehensive processes described above were adjusted as follows:

- The focus was on the instream components and low flows. Only instream ecological specialists were therefore involved (fish and aquatic invertebrates).
- High flows are normally problematic to evaluate as the output of the yield model is monthly (compared to daily). The monthly time series for the natural flow regime, the requested IFRs and the scenarios were compared to obtain some indications of whether flood volumes were available.
- Detailed motivations were not documented due to the limited time available.
- The focus was on whether ecological objectives were achieved. Were it is possible that the Ecological Category could be increased, this was only expressed with the 'more than' symbol. No effort was made to assess the scale of the increase.

17.7 ECOLOGICAL CONSEQUENCES: RESULTS

To aid the evaluation, the fish and invertebrate points as required were plotted on the stress duration graphs (see appendix J). The impact on category was evaluated separately for low and high flows (See results in Table 17.1) and a reasoning process was followed to determine the fish and invertebrate EC (See comment column in Table 17.1). The high flows were checked to determine whether this was likely to impact on the component Ecostatus (see comment column in Table 17.1). The fish and invertebrate categories were then integrated to represent an instream Ecostatus (See Table 17.2). The results are summarised in Figure 17-1 - 17-4. Note that the resulting Ecostatus is more relevant of an instream status only as the geomorphology and riparian vegetation could not be evaluated.

Table 17-1 Fish and aquatic invertebrate categories for low flows

Note:

- As the fish species that occur in the Kei River are only flow dependent during the wet season, the EC is likely to be driven by the wet season category. It is likely that during the dry season, increased flows will not increase the category as the fish might not utilise these flows to the same degree as they would during winter.
- Flow dependent invertebrates do occur and in this case, the dry season is often more important.

IFR	Scenarios	Dry - category	Wet category	EC	Comment
FISH					
1 REC D	1	=>D	=>C	C/D	Smaller floods required by fish and inverts are probably still happening and due to the highly flashy nature of the river, the high flow impacts probably do not impact on the categories estimated using the low flows.
	2	=>C/D	=>C	=>C/D	
	3	C	=>C	C	
	4	=>B/C	=>C	=>C	
	5	=>D	=>C	C/D	
	No IFR	=<D	C	=<C/D	
AQUATIC INVERTEBRATES					
1 REC B	1	=>B	=>B	=>B	Smaller floods required by fish and inverts are probably still happening and due to the highly flashy nature of the river, the high flow impacts probably do not impact on the categories estimated using the low flows.
	2	=>B	=>B	=>B	
	3	=>B	=>B	=>B	
	4	=>B	=>B	=>B	
	5	=>B	=>B	B	
	No IFR	C/D	=>B	=>C/D	Stress has increased about 50% of the time 1 invert stress level from the invert C requirements.

IFR	Scenarios	Dry - category	Wet category	EC	Comment
FISH					
2 REC D	1	D or C/D	=>C/D	C/D	
	2	=>C/D	=>C/D	=>C/D	
	3	=>C	=>C/D	C	
	4	=>C/D	=>D	=>D	
	5	=>D	=>D	=>D	
	No IFR	D	=>D	D	
AQUATIC INVERTEBRATES					
2 REC D	1	D	=>C/D	=>D	Floods are very similar to present, therefore the scenarios are evaluated based on the base flows. No IFR: No IFR would be unacceptable as it is likely that the invertebrate EC would fall below a D.
	2	=>D	=>C/D	=>D	
	3	=>C	=>C	C	
	4	=>D	D	=>D	
	5	D	D	D	
	No IFR	D/E	D	=<D (!)	

IFR	Scenarios	Dry - category	Wet category	EC	Comment
FISH					
3 REC D	1	D	C	=>C/D	Floods are very similar to present, therefore the scenarios are evaluated based on the base flows.
	2	=>D	C	=>C/D	
	3	C	C	C	
	4	=>D	C	=>C/D	

IFR	Scenarios	Dry - category	Wet category	EC	Comment
	5	D	C	=>C/D	
	No IFR	<D (!)	D	<D(!)	
AQUATIC INVERTEBRATES					
3 REC C/D	1	D	=>C/D	=>D	No IFR is unacceptable as for both fish and invertebrates it would result in an EC below a D.
	2	C/D	=>C/D	=>C/D	
	3	B/C	B/C	B/C	
	4	C/D	=>C/D	=>C/D	
	5	D	C/D	D	
	No IFR	<D	<D	<D(!)	

IFR	Scenarios	Dry - category	Wet category	EC	Comment
FISH					
4 REC D	1	D	B/C	=>D	Floods are very similar to present, therefore the scenarios are evaluated based on the base flows.
	2	D	B/C	=>D	
	3	D	B/C	=>D(?)	
	4	=>D	=>D	=>D	
	5	=<D	=>D	D	
	No IFR	D	D	D	
AQUATIC INVERTEBRATES					
4 REC C/D	1	D	B/C	=>D	Floods are very similar to present; therefore the scenarios are evaluated based on the base flows.
	2	C/D	B/C	=>C/D	
	3	B/C	=>C/D	B/C	
	4	C/D	=>C/D	=>C/D	
	5	D	C	=>D	
	No IFR	D	C/D	=>D	

Table 17-2 Instream Ecostatus for each flow scenario at each IFR site

IFR	Scenarios	Fish EC	Inverts EC	Ecostatus (instream) EC	Comment
1 REC C	1	C/D	=>B	C	REC is achieved
	2	=>C/D	=>B	C	REC is achieved
	3	C	=>B	B/C	A better EC than recommended could be achieved.
	4	=>C	=>B	B/C	A better EC than recommended could be achieved
	5	C/D	=>B	C	REC is achieved
	No IFR	=>C/D	=>C/D	C/D(?)	The question mark refers to uncertainty whether this is a C/D or a C.
2 REC D	1	C/D	=>D	=>D	In all cases the minimum requirement of a D is met.
	2	=>C/D	=>D	=>D	
	3	C	C	C	
	4	=>D	=>D	=>D	
	5	=>D	D	D	
	No IFR	D	=<D(!)	=<D(!)	A conservative estimate has been made that the REC of a D will not be met. More information will be required to address this uncertainty.

IFR	Scenarios	Fish EC	Inverts EC	Ecostatus (instream) EC	Comment
3 REC D	1	=>C/D	=>D	C/D (?)	This assessment is problematic as the fish are in a better state and the invertebrates in a worse state than required. It is however likely that the Ecostatus of a D will be achieved. A C/D has been documented as the invertebrates border between a D and a C/D and it is therefore more likely that the integrated category is a C/D.
	2	=>C/D	=>C/D	=>C/D	REC of a D will be met.
	3	C	B/C	B/C	REC of a D will be met.
	4	=>C/D	=>C/D	=>C/D	REC of a D will be met.
	5	=>C/D	D	C/D(?)	See comment at Sc 1
	No IFR	<D(!)	<D(!)	<D(!)	The REC will not be met.
4 REC C/D	1	=>D	=>D	=>D	REC will not be met
	2	=>D	=>C/D	C/D	REC of a C/D will be met.
	3	=>D(?)	B/C	B/C	REC of a C/D will be met.
	4	=>D	=>C/D	C/D(?)	Uncertainty exists whether the REC will be met as the decreased floods could result in a D EC.
	5	D	=>D	D(?)	REC will not be met. There is however some uncertainty associated with this as the potential increase in category for invertebrates would have to be assessed in more detail and the other components will have to be included.
	No IFR	D	=>D	D	REC of a D will be met.

Figure 17-1 Ecological consequences of various flow scenarios at IFR 1

AVAILABLE INFORMATION: IFR 1

INSTREAM HABITAT INTEGRITY: C RIPARIAN HABITAT INTEGRITY: D

COMPONENT	PES	LONG TERM (20 Y)	REC	Alt EC DOWN	Alt EC UP	SC 1	SC 2	SC 3	SC 4	SC 5	NO IFR
DRIVER HI	C		C	D	C						
RIPARIAN VEGETATION	D	D/E	D	D	C						
FISH	C/D	C/D	C/D	D	C	C/D	=>C/D	C	=>C	C/D	=<C/D
AQUATIC INVERTS	B	B	B	C	B	=>B	=>B	=>B	=>B	=>B	=>C/D
ECOSTATUS	C	C	C	D	B/C	C	C	B/C	B/C	C	C/D?

Figure 17-2 Ecological consequences of various flow scenarios at IFR 2

AVAILABLE INFORMATION: IFR 2

INSTREAM HABITAT INTEGRITY: C RIPARIAN HABITAT INTEGRITY: D

COMPONENT	PES	LONG TERM (20 Y)	REC	Alt EC UP	SC 1	SC 2	SC 3	SC 4	SC 5	NO IFR
DRIVER HI	C		C	C						
RIPARIAN VEGETATION	C/D	D	C/D	B/C						
FISH	D	D	D	C	C/D	=>C/D	C	=>D	=>D	D
AQUATIC INVERTS	D/E	D/E	D	C	=>D	=>D	C	=>D	D	=<D !
ECOSTATUS	D	D	D	C	=>D	=>D	C	=>D	D	=<D!

Figure 17-3 Ecological consequences of various flow scenarios at IFR 3

AVAILABLE INFORMATION: IFR 3

INSTREAM HABITAT INTEGRITY: C RIPARIAN HABITAT INTEGRITY: C

COMPONENT	PES	LONG TERM (20 Y)	REC	Alt EC DOWN	Alt EC UP	SC 1	SC 2	SC 3	SC 4	SC 5	NO IFR
DRIVER HI	C		C	D	C						
RIPARIAN VEGETATION	C	C/D	C	D	B/C						
FISH	D	D	D	D	C	=>C/D	=>C/D	C	=>C/D	=>C/D	<D !
AQUATIC INVERTS	C/D	C/D	C/D	D	B/C	=>D	=>C/D	B/C	=>C/D	D	<D !
ECOSTATUS	C/D	C/D	C/D	D	B/C	C/D (?)	=>C/D	B/C	=>C/D	C/D (?)	<D !

Fish better, invertebrate worse: However, invertebrate borders between D and C/D so more likely integrated category is a C/D.

Figure 17-4 Ecological consequences of various flow scenarios at IFR 4

AVAILABLE INFORMATION: IFR 4

INSTREAM HABITAT INTEGRITY: D RIPARIAN HABITAT INTEGRITY: D

COMPONENT	PES	LONG TERM (20 Y)	REC	Alt EC DOWN	Alt EC UP	SC 1	SC 2	SC 3	SC 4	SC 5	NO IFR
DRIVER HI	C		C	D	C						
RIPARIAN VEGETATION	C	C/D	C	D	B/C						
FISH	D	D	D	D	C	=>D	=>D	=>D (?)	D	D	D
AQUATIC INVERTS	C/D	C/D	C/D	D	B/C	=>D	=>C/D	B/C	=>C/D	=>D (?)	=>D
ECOSTATUS	C/D	C/D	C/D	D	B/C	=>D	C/D	B/C	C/D (?2)	D (?)	D

?2: Possible a D due to decreased floods

17.8 CONCLUSIONS

The ability of the flow scenarios to meet the REC is summarised in the following table:

Table 17-3 Summary of the number of IFR sites where the REC can be met
Y=yes; N=no

	PES	REC	SC1	SC2	SC3	SC4	SC5	NO IFR
IFR 1	C	C	Y	Y	Y	Y	Y	N (?)
IFR 2	D	D	Y	Y	Y	Y	Y	N
IFR 3	C/D	C/D	Y	Y	Y	Y	Y (?)	N (?)
IFR 4	C/D	C/D	N	Y	Y	Y(?)	N	N
Number of IFR sites where ecological objectives are achieved			3Y 1N	4Y	4Y	4Y(?)	3Y 1N	4N

Scenario 4, 5 and No IFR are the only practical scenarios to assess as they consider existing constraints. Of these scenarios, Scenario 4 has the least ecological impact as it meets the ecological objectives at all the IFR sites. The 'No IFR' scenario is not an acceptable scenario from an ecological point of view as it does not meet the REC at any site.

The Scenario 5 has the least impact on yield but cannot meet the REC at IFR 4 on the White Kei. For the Black Kei and Klipplaat River, Scenario 5 would be acceptable. A decision must be made comparing the socio-economic value and importance of the White Kei system compared to the Ecological Importance. Other factors such as the present use of Goods and Services as part of Resource Economics and the potential impact on this if the river is allowed to degrade, as well as the confidence in the IFR 4 assessment and the ecological consequences assessments should be considered to aid in the decision.

18 REFERENCES

Brown, C. and King, J. 2001. Environmental flow assessment for rivers. A summary of the DRIFT process. Southern Waters information Report No 01/00.

DWAF, 1999. Department of Water Affairs and Forestry, Pretoria, South Africa. Resource Directed Measures for the Protection of Water Resources. Volume 3: River ecosystems, version 1.0.

DWAF, 2005. Department of Water Affairs and Forestry, South Africa. 2005. Lukhanji Regional Water Supply Feasibility Study: Main Report. Prepared by Ninham Shand. DWAF Report no:

Gonzalez, O.T., 1996. Formulating an ecosystem approach to environmental protection. Environmental Management 20: 597-605.

King, J. M. and Louw, D. 1998. Instream flow assessments for regulated rivers in South Africa using the Building Block Methodology. Aquatic Ecosystem Health and Management 1: 109-124.

O'Keeffe, J., Hughes, D. and Tharme, R. 2002. Linking ecological responses to altered flow, for use in environmental flow assessments: the flow stressor-response method. *Verh. Internat. Verein. Limnol*. 28: 1-9.

O'Keefe J. & Louw D. 1999. Chapter 10: Ecological Management Class. In: King JM. And Tharme R. The building Block Methodology – A manual. IWR, PO Box 94, Grahamstown, 6140.

Stuber, R.J., Gebhart, G., & Maughan, O.E. 1982. Habitat suitability index models: Bluegill. U.S.D.I. Fish and Wildlife Service. FWS/OBS-82/10.8.

Suter, G.W. 1993. A critique of ecosystem health concepts and indexes. *Env. Tox. & Chem.* 12: 1533-1539

APPENDIX A

IFR site selection and IFR sites

MD Louw (IWR Source-to-Sea)

TABLE OF CONTENTS

A.1 PURPOSE OF IFR SITES A-1
A.2 IFR SITE SELECTION PROCESS A-2
A.3 SELECTION OF IFR SITES A-2
A.3.1 IFR 1: Klipplaat River A-2
A.3.2 IFR 2: Upper Black Kei River A-3
A.3.3 IFR 3: Lower Black Kei River A-3
A.3.4 IFR 4: White Kei River A-4

The IFR site selection team consisted of the following:
M Delana Louw (Study manager and IFR coordinator)
Dr Drew Birkhead (Hydraulician)

The advantages and disadvantages of the IFR site, as tabled in this appendix were provided by the relevant specialists.

A.1 PURPOSE OF IFR SITES

IFRs are determined during a specialist meeting where descriptions of flow in parameters such as depth and water surface level linked to habitat requirements of the various disciplines are stipulated. These parameters, e.g. a 10cm depth, need to be converted to flow by means of a stage discharge curve for a specific cross-section. **The description of flows in depths therefore takes place at a specific cross-section in the river called an IFR site which should represent a variety of habitats.**

The selection of the IFR sites form the basis of the preparatory work to be undertaken for the IFR specialist meeting and some of the studies (e.g. hydraulics and hydrology) are directly linked and are calculated specifically for the IFR sites.

The IFRs are set for each of the IFR sites, and it is therefore vital that the sites are selected to provide as much info as possible about the variety of conditions in a river reach and that the persons that need to use these sites to set IFRs for their discipline can relate to the habitat they represent; the persons involved in selecting the sites understand and are experienced with the use of sites in IFR studies.

In order to determine the Instream Flow Requirements (IFRs) of a river system, it is necessary to determine the flow requirements at a number of points within the system.

More than one IFR site is usually selected within the system for a number of reasons:

- Tributaries entering the system may introduce different channel, bank and or habitat conditions which may need to be considered separately.
- The Present Ecological State (PES) and Ecological Category (EC) of particular reaches of the river may differ and may therefore require a specific IFR.
- A river system displays biological diversity along its length, and consequently, a single IFR point is unlikely to adequately reflect this range of diversity.
- Various hydrological stage points are required within the system to cater for the inflows of tributaries and losses down the length of the system.

The more IFR sites selected for which IFRs are determined, the better the chance that all the habitat diversity in the system will be covered and therefore, the higher the confidence in the IFR result. The decision as to how many sites are chosen is therefore a function of the length and diversity of the river to be assessed, and a trade-off between the need to characterise the river adequately, and the constrains of time and resources.

A.2 IFR SITE SELECTION PROCESS

The detailed process to select IFR sites is described in the BBM manual (King and Louw, 1998). An IFR or Ecological Reserve must be determined for each Resource Unit (RU) (Appendix B).

Use of the river video for the identification of possible IFR sites

Determining where possible sites are located in rugged and undisturbed surroundings can be a difficult, frustrating and time-consuming process. It is seldom possible to obtain a comprehensive overview of a river from a ground survey. The process of selecting IFR sites is therefore aided by means of a helicopter flight. As this was a Reserve study at the Intermediate level, a video was not available and sites were found by visiting various access points on the river.

Selection of IFR sites

The selection of IFR sites is guided by a number of considerations such as:

- The locality of gauging weirs with good quality hydrological data.
- The locality of the proposed developments.
- The locality and characteristics of tributaries.
- The habitat integrity/conservation status of the different river reaches.
- The reaches where social communities depend on a healthy river ecosystem.
- The suitability of the sites for follow-up monitoring.
- **The habitat diversity for aquatic organisms, marginal and riparian vegetation.**
- **The suitability of the sites for accurate hydraulic modelling throughout the range of possible flows, especially low flows.**
- **Accessibility of the sites.**
- **An area or site that could be critical for ecosystem functioning. This is often a riffle which will stop flowing during periods of low or no flow. Cessation of flow constitutes a break in the functioning of the river. Those biota dependant on this habitat and/or on continuity of flow will be adversely affected. Pools are not considered as critical since they are still able to function as refuge habitats during periods of no flow.**
- The locality of geomorphological reaches and representative reaches within the geomorphological reaches.

The criteria in bold are the most important and therefore the overriding criteria.

A.3 SELECTION OF IFR SITES

A.3.1 IFR 1: Klipplaat River

Locality: S32° 15,4min
N26° 51.35min

One IFR site was required in the Klipplaat River downstream of Waterdown Dam. Various points on the river were visited as it was reasonably accessible. The river degrades significantly from approximately 10 km downstream of the dam and it was therefore not possible to find a suitable site apart form with the 10 km stretch downstream of the dam. A site situated 8 km downstream of the dam was selected.

The advantages and disadvantages of the site for the purpose of providing sufficient information to set IFRs for are provided below:

Component	Advantages	Disadvantages
Fish	Full range of habitat types including marginal vegetation. Riffle critical for spawning migration (eels and large fish).	Riparian vegetation disturbed. Presence of a dam upstream and potential problems with temperature changes due to releases. Too much algae present in slow habitats.
Riparian vegetation	Extensive clumps of *Juncus* at various levels. Resurrection bush is present on rock islands	Low species diversity. Riparian trees extensively removed. Useful for low flow requirements only as marginal vegetation only is present. Extensive grazing.
Aquatic invertebrates	Good hydraulic habitat diversity present. Good diversity of substrate sizes.	Limited marginal vegetation.
Hydraulics	Reasonably uniform riffle feature approximately 50m in extent (longitudinally). Possibility of a release from upstream (8.5km) Waterdown Dam to improve hydraulic (rating) data set.	Resistance a function of stage due to large bed roughness and range of roughness elements (sands to small boulders). Difficult to measure low-flows accurately.

A.3.2 IFR 2: Upper Black Kei River

Locality: S32° 03,7min
N27° 01.8min

One IFR site was required in the Upper Kei and RU B. As future development could possibly take place in this RU, it was specified that the site must be downstream of the Klaas Smuts confluence. The Kei River is reasonably inaccessible in this area. However, access on a farm with a track next to the river resulted in a reasonable site being found and selected.

The advantages and disadvantages of the site for the purpose of providing sufficient information to set IFRs for are provided below:

Component	Advantages	Disadvantages
Fish	Full range of habitat types including marginal and instream vegetation. Riffle critical for spawning migration. Backwater and secondary channels present under certain flow conditions.	Algae present on rocks. Downstream of Klaas Smuts River which has point source releases.
Riparian vegetation	Three indicator species suitable for low flows are present.	Low species diversity. No high flow triggers. Some local disturbance due to grazing and agriculture.
Aquatic invertebrates	Characteristic of this part of the river. Possibly only site with this diversity.	Limited hydraulic habitat, embeddedness, poor diversity of substrate sizes; limited vegetation.
Hydraulics	Possibility of a release from upstream Waterdown and Oxkraal Dams (approximately 50 to 65km) to improve hydraulic (rating) data set.	Non-uniform rapid feature with large bed roughness. Resistance consequently a function of stage. Difficult to measure low-flows accurately.

A.3.3 IFR 3: Lower Black Kei River

Locality: S32° 10,5min
N27° 22.3min

One IFR site was required in the Lower Kei and RU C. To ensure that the site is useful, it had to be as far downstream as possible from IFR 2. The Black Kei River close to the confluence of the White Kei

River has access by means of a farm road. The character of the river (large and long pools with short bedrock rapids) was problematic. Only one suitable site was found immediately downstream of a gauging weir being constructed.

The advantages and disadvantages of the site for the purpose of providing sufficient information to set IFRs for are provided below:

Component	Advantages	Disadvantages
Fish	Full range of habitat types including marginal vegetation.	Downstream of gauging weir. Cross-section not over the full riffle. Temporary impacts present from weir construction.
Riparian vegetation	Two indicator species suitable for low flows are present (*Juncus* and resurrection bush).	Low flow indicators only present. *Juncus* is responding to various channels on the LB and cannot be used.
Aquatic invertebrates	Good flow depth over habitat.	Downstream of weir, embeddedness, poor diversity substrate size, poor vegetation
Hydraulics	Possibility of a release from upstream Waterdown and Oxkraal Dams (approximately 50 to 65km) to improve hydraulic (rating) data set.	Non-uniform rapid feature with large bed roughness. Resistance consequently a function of stage. Difficult to measure low-flows accurately.

A.3.4 IFR 4: White Kei River

Locality: S32° 02,6min
N27 °22min

One IFR site was required in the White Kei downstream from Xonxa Dam. Most of this river is either inaccessible or in highly disturbed area. A site was found on a deserted farm which consisted of bedrock and boulder habitat. This was the only option as the other sites consisted mostly of alluvial habitats in disturbed areas.

The advantages and disadvantages of the site for the purpose of providing sufficient information to set IFRs for are provided below:

Component	Advantages	Disadvantages
Fish	Full range of habitat types available including backwaters and marginal vegetation.	Excessive silt present which makes slow flowing habitats not useful. Embedded rocks.
Riparian vegetation	Obvious terraces present which allows for high flow requirements to be set. A variety of habitats present. Good clumps of *Juncus* at different levels present.	Low species diversity (but could be natural) Extensive grazing. Catchment mismanagement. Cattle/goat trampling.
Aquatic invertebrates	Good diversity of hydraulic habitat; abundant stones in current.	High sediment loads (Silts); Vegetation consists mostly of stems.
Hydraulics	Possibility of a release from upstream Xonxa Dam (approximately 50km) to improve hydraulic (rating) data set.	Non-uniform rapid feature with large bed roughness. Resistance consequently a function of stage. Difficult to measure low-flows accurately.

APPENDIX B

Kei River delineation report

MD Louw (IFR co-ordinator)
IWR Source-to-Sea

TABLE OF CONTENTS

B.1 APPROACH B-1
B.2 ECOREGIONS B-2
B.3 WATER QUALITY RESOURCE UNITS B-4
B.4 STREAM CLASSIFICATION B-4
B.5 HABITAT INTEGRITY B-4
B.6 RESOURCE UNITS B-4
B.6.1 Oxkraal River B-4
B.6.2 Klipplaat River B-5
B.6.3 Black Kei River B-7
B.6.4 White Kei River B-9

LIST OF FIGURES

Figure B.1 Ecoregions B-3
Figure B.2 Oxkraal River B-6
Figure B.3 Black Kei River B-8
Figure B.4 White Kei River B-10

B.1 APPROACH

If an Ecological Reserve determination is required, say for a whole catchment, it is necessary to break down the catchment into Resource Units which are each significantly different to warrant their own specification of the Reserve, and to clearly delineate the geographic boundaries of each. (DWAF, 1999, vol 3).

The reason for this is because, for example, it would not be appropriate to set the same numerical Reserve for the headwaters of a river as for the lowland reaches; these sections of a river frequently have different natural flow patterns, react differently to stress according to their sensitivity, and require individual specifications of the Reserve appropriate for that reach.

The breakdown of a catchment into Resource Units for the purpose of determining the Reserve for rivers is done primarily on a biophysical basis, according to the occurrence of different ecological regions (see Figure 1 ecoregions) within the catchment. Since the endpoint of a Reserve determination is an ecological one, the idea is to break down the catchment into units that are relatively homogenous on an ecological basis, to ensure the Reserve is set in appropriate terms. (DWAF, 1999, vol 3)

The breakdown into Resource Units via ecoregions and/or geohydrological response units could then be further resolved into smaller Resource Units which are more suited to management requirements. (DWAF 99, vol 3) An example could be where large dams and/or transfer schemes occur. The difference in operation of different river reaches also results in biophysically different river reaches and should be considered.

The process considers all of the above issues, as well as the results of the Habitat Integrity (an evaluation of river sectors according to instream and riparian Habitat Integrity). Overlaying all the data does not necessarily result in a logical and clear delineation and expert judgement, a consultative process and local knowledge are required for the final delineation. The practicalities of dealing with numerous reaches within one study must also be considered to determine a logical and practical suite of Resource Units.

The Reserve is determined for each Resource Unit by means of either the following:

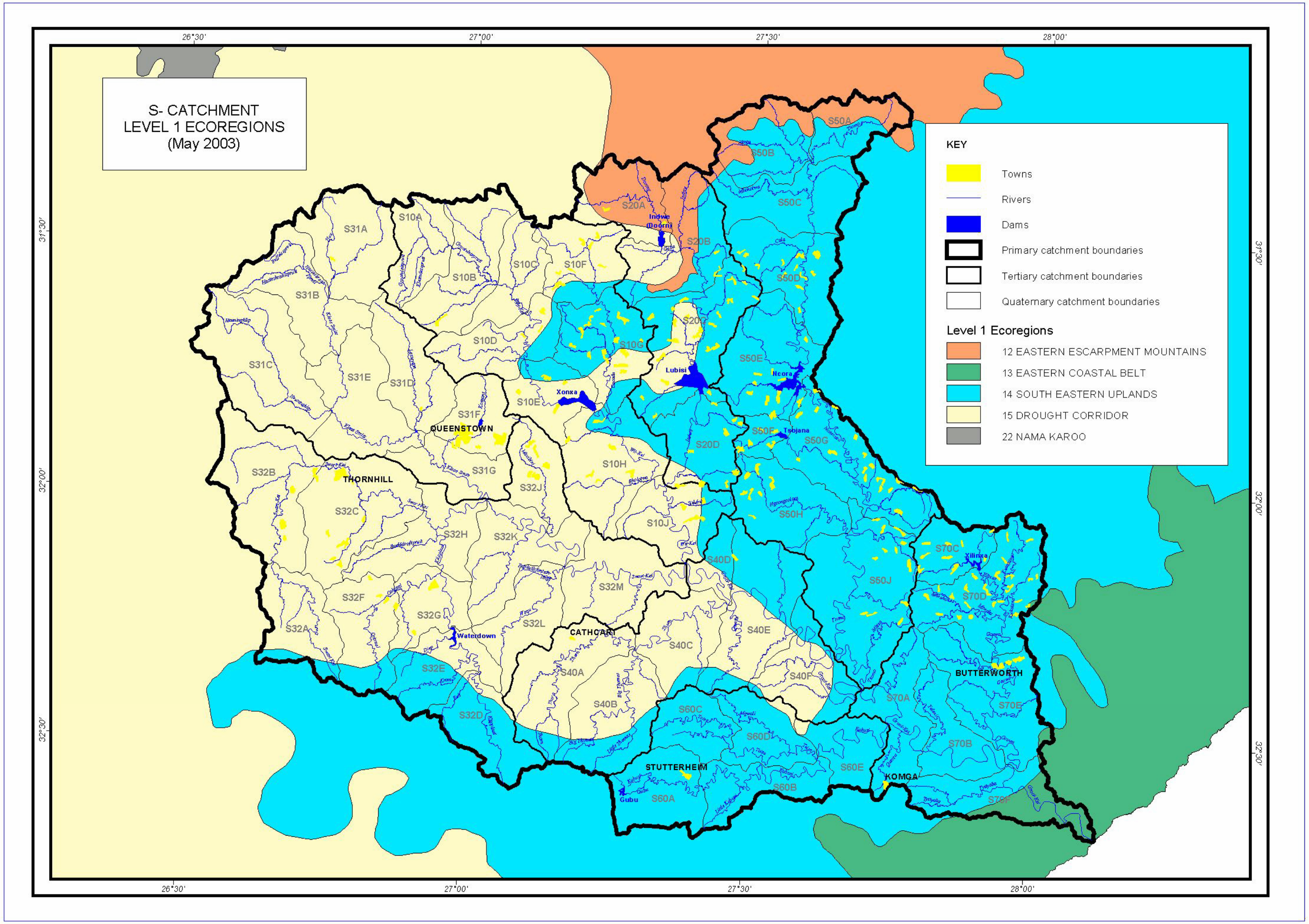
- An IFR site is selected within the Resource Unit and represents a critical site within the relevant river section. Results generated for the Resource Unit at the IFR site will then be relevant for the Resource Unit as a whole.
- No IFR site is selected within the Resource Unit and extrapolated results from adjacent Resource Units with IFR sites are used. The reasons for an IFR site not being selected within the Resource Unit can be the following:
    - o The characteristics of the river within the Resource Unit do not meet the criteria for IFR sites.
    - o Due to the amount of Resource Units within the study area, it is not practical and/or cost-effective to address IFR sites within each Resource Unit.

B.2 ECOREGIONS

Ecoregional classification or typing will allow the grouping of rivers according to similarities based on a top-down approach. The purpose of this approach is to simplify and contextualise assessments and statements on ecological water requirements. One of the advantages of such a system is the extrapolation of information from data rich rivers to data poor rivers within the same hierarchical typing context.

Only a Level I Ecoregional classification (See Figure B.1) has been undertaken for the Eastern Cape. This information was obtained from DWAF, RQS.

Figure B.1 Ecoregions



B.3 WATER QUALITY RESOURCE UNITS

The water quality Resource Units were established by Mr Nico Rossouw (Ninham Shand), who is responsible for the water quality component of the EWR study. Detail is provided in a separate Document (DWAF, 2005, Appendix 3). The results are illustrated in Figures B.2 –B.4.

B.4 STREAM CLASSIFICATION

The geomorphological processes, which shape the channel, determine the physical structure of a river ecosystem. They determine the material from which the channel is formed, the shape of the channel and the stability of the bed and banks. The channel geomorphology in turn determines the substrate conditions for the stream fauna and flora and the hydraulic conditions for any given flow discharge. Geomorphology therefore provides an appropriate basis of classification for the purpose of describing the physical habitat of riparian and aquatic ecosystems.

In the Intermediate and Comprehensive determination of the ecological Reserve, geomorphological zones are used to guide the spatial framework for the delineation of water Resource Units, the assessment of habitat integrity, and IFR site selection. This information is provided in Appendix C and the zones illustrated in Figures B.2-B.4.

B.5 HABITAT INTEGRITY

Instream Intermediate Habitat Integrity

The scores range from 36 to 62 percent which corresponds with a Class D river overall. The assessment clearly shows a decrease in integrity from the Waterdown Dam towards the confluence with the Swart Kei River. This is largely due to the influence of reducing water quality and bed modification. The area is used extensively for cattle grazing and dry land farming which has resulted in extensive erosion and localised water fouling. The riverbed and instream habitat was covered with thick algae and sediments and the cobbles and rocks were extensively embedded, particularly towards the confluence of the Swart Kei River. The abstraction of water for irrigation and stock farming has also contributed to the decreasing integrity of the system. The modified flow regime due to the presence of and the current management of the dam is a major contributing factor to the generally low instream habitat integrity score.

Riparian Zone Intermediate Habitat Integrity

The scores range from 35 to 65 percent corresponding with Class C (higher parts of the river) to a Class E (lower parts). Similar to the instream component, a decreasing trend was evident for the riparian zone habitat integrity. Extensive grazing and trampling, the removal of riparian trees for fuel and construction and the presence of large patches of exotic trees are largely responsible for this trend. The modified flow regime imposed by the dam and its current management also contributed to a generally low riparian zone integrity, which provides environment that favours exotic species encroachment.

B.6 RESOURCE UNITS

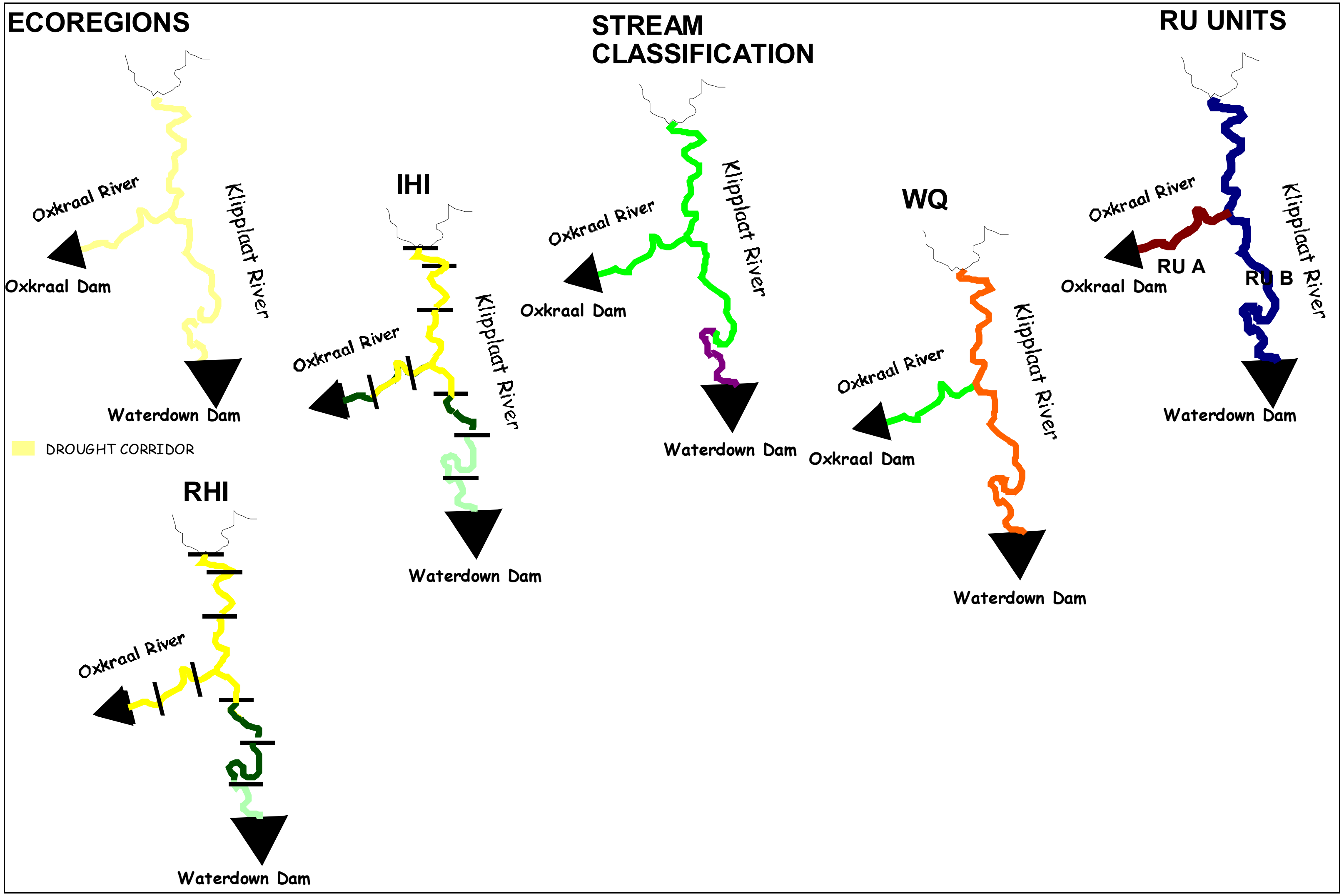
B.6.1 Oxkraal River

The study area is down stream of the Oxkraal dam to the Klipplaat River confluence. The Oxkraal River was not delineated as all the factors considered, addressed the section of river as one unit. This was therefore delineated as RU A (See Figure B.2).

B.6.2 Klipplaat River

The study area is downstream of Waterdown Dam to the Black Kei confluence. The only components evaluated, that illustrated delineation, were Stream classification and Habitat Integrity. As the Lower foothills section was less than 5km long this would not warrant a separate Resource Unit with no other supporting motivation. Additional breaks basically illustrates that the river improves from the Waterdown dam towards the confluence. Again, on its own this does not warrant separate Resource Units. Due to the operation of the Oxkraal dam the confluence of the Oxkraal River could have provided a logical break within the Klipplaat river, however as this is an intermediate study with limited resources it was decided that one Resource Unit would suffice. (RU B) (See Figure B.2).

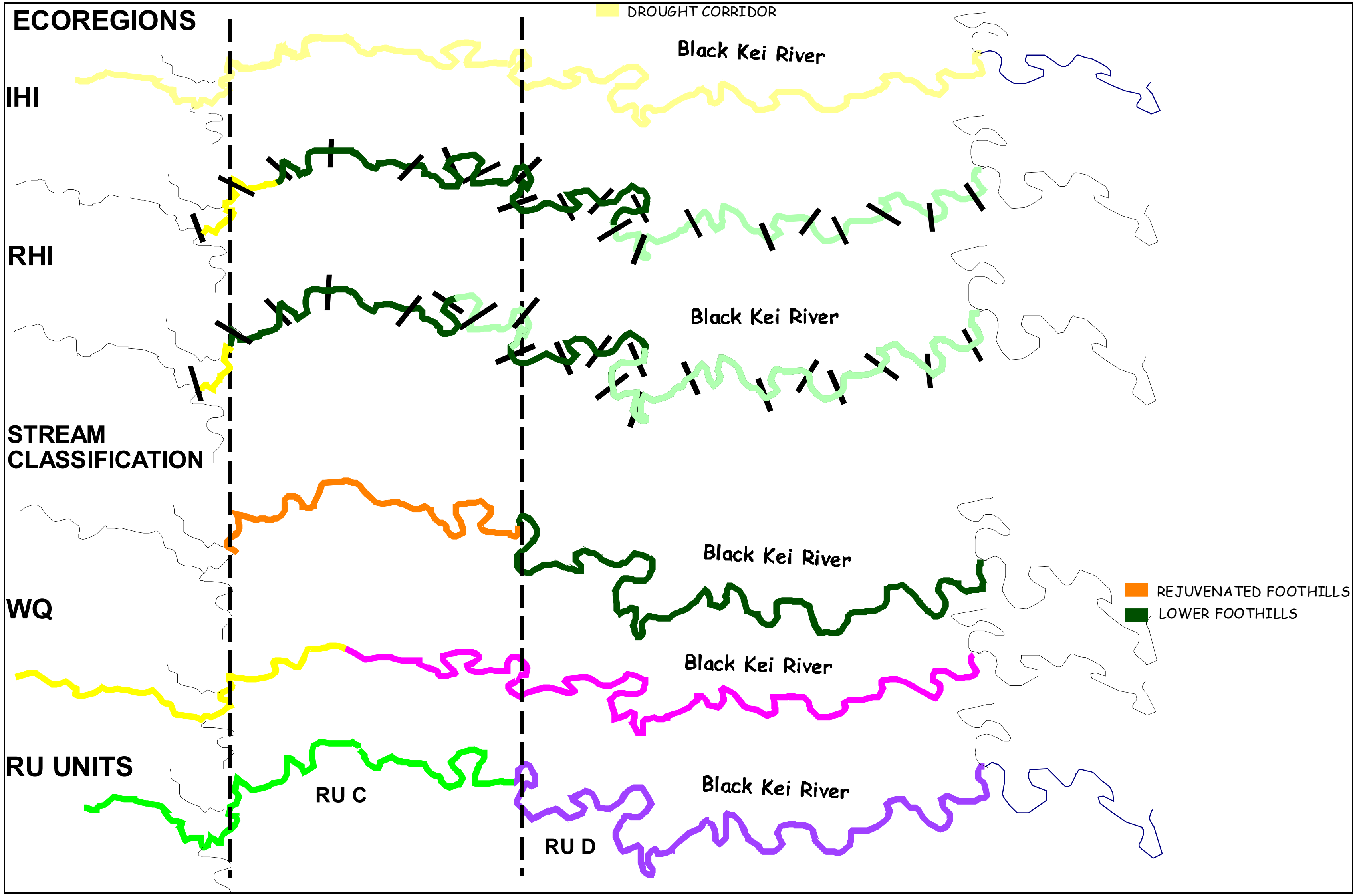
Figure B.2 Oxkraal River



B.6.3 Black Kei River

The section of Black Kei River which is considered, is from the Klipplaat confluence to the White Kei confluence. There are no instream dams present in this section of the Black Kei and the operation of the system provides no motivation for a break. Although this reach falls into the Level I ecoregion both the stream classification and water quality has indicated two separate reaches (see Figure B.2). The Habitat Integrity seems to vary between a B and a C category with the first break coinciding with the water quality break. It was decided to use the stream classification as the guide and the Black Kei was delineated into 2 Resource Units. The break coincides with the stream classification break (Figure B.3).

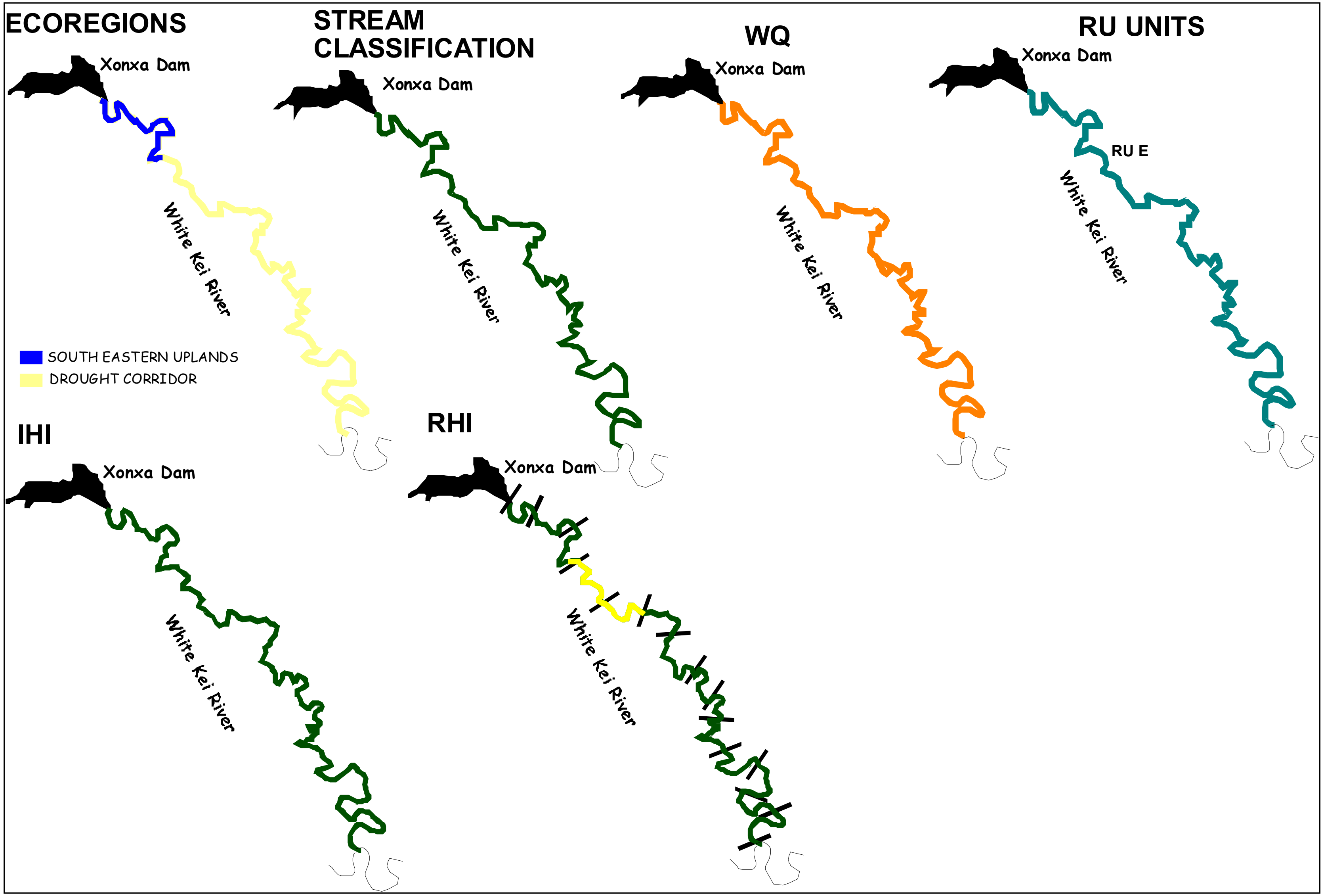
Figure B.3 Black Kei River



B.6.4 White Kei River

The study area is downstream of Xonxa Dam to the Black Kei confluence. The only components evaluated that illustrated delineation was Ecoregions and Habitat Integrity. As the drought corridor Ecoregion only consists of a fifth of the river down stream of Xonxa Dam this would not warrant a separate Resource Unit. Additional breaks basically illustrate that the river improves from the Xonxa dam towards the confluence. On its own this does not warrant separate Resource Units. As this is an intermediate study with limited resources it was decided that one Resource Unit would suffice. (RU E) (Figure B.4).

Figure B.4 White Kei River



APPENDIX C

Geomorphological classification

Dr Roy Wadeson
Private

TABLE OF CONTENTS

C.1 GEOMORPHOLOGICAL RIVER ZONATION C-1
C.2 LONGITUDINAL PROFILES OF THE KEI STUDY AREA TOGETHER WITH ZONATION MAPS C-2
C.2.1 Black Kei River C-2
C.2.2 The White Kei River C-3
C.2.3 The Klipplaat River C-4
C.2.4 The Oxkraal River C-4

LIST OF TABLES

Table C.1 Geomorphological Zonation of River Channels C-1

LIST OF FIGURES

Figure C.1 Geomorphological Zonation map of the Kei Study area C-5

C.1 GEOMORPHOLOGICAL RIVER ZONATION

The longitudinal zonation of South Africa rivers reflects regional geology, tectonic events and long term fluvial action which together have affected the shape of their long profiles. The classic concave long profile may be disrupted by a number of features including outcrops of more resistant rock and rejuvenation due to tectonic uplift or a fall in sea-level. Rowntree and Wadeson (1999) have developed a zonal classification system for South Africa based on work carried out on a number of different rivers around the country (Table C.1).

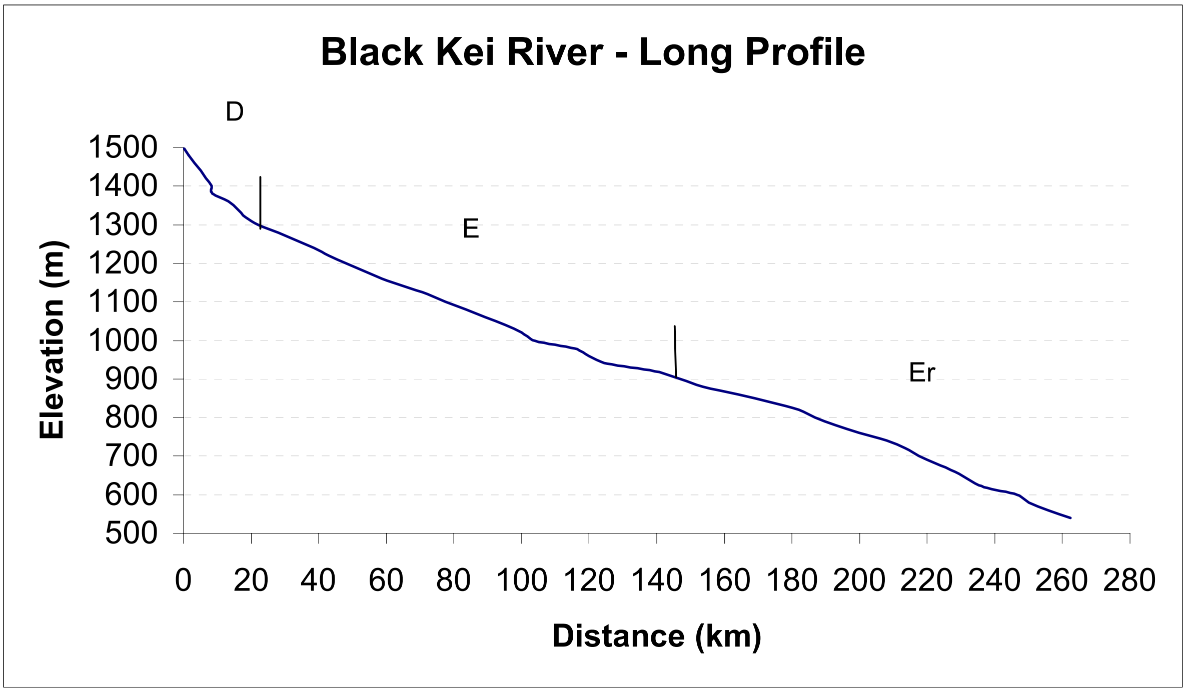
Table C.1 Geomorphological Zonation of River Channels

Zone	Zone class	Gradient class	Characteristic channel features
A. Zonation associated with a 'normal' profile			
Source zone	S	not specified	Low gradient, upland plateau or upland basin able to store water. Spongy or peaty hydromorphic soils.
Mountain headwater stream	A	> 0.1	A very steep gradient stream dominated by vertical flow over bedrock with waterfalls and plunge pools. Normally first or second order. Reach types include bedrock fall and cascades.
Mountain stream	B	0.04 - 0.099	Steep gradient stream dominated by bedrock and boulders, locally cobble or coarse gravels in pools. Reach types include cascades, bedrock fall, step-pool, Approximate equal distribution of 'vertical' and 'horizontal' flow components.
Transitional	C	0.02 - 0.039	Moderately steep stream dominated by bedrock or boulder. Reach types include plain-bed, pool-rapid or pool riffle. Confined or semi-confined valley floor with limited flood plain development.
Upper Foothills	D	0.005 - 0.019	Moderately steep, cobble-bed or mixed bedrock-cobble bed channel, with plain-bed, pool-riffle or pool-rapid reach types. Length of pools and riffles/rapids similar. Narrow flood plain of sand, gravel or cobble often present.

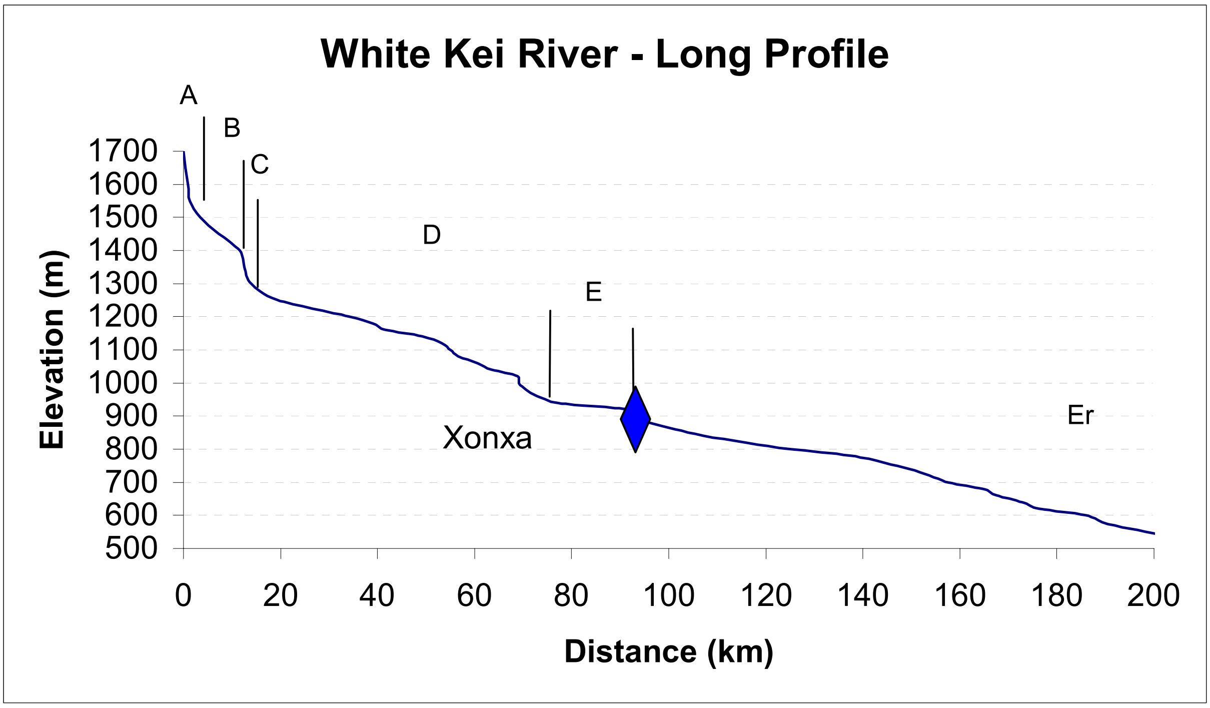
Lower Foothills	E	0.001 - 0.005	Lower gradient mixed bed alluvial channel with sand and gravel dominating the bed, locally may be bedrock controlled. Reach types typically include pool- riffle or pool-rapid, sand bars common in pools. Pools of significantly greater extent than rapids or riffles. Flood plain often present.
Lowland river	F	0.0001- 0.0009	Low gradient alluvial fine bed channel, typically regime reach type. May be confined, but fully developed meandering pattern within a distinct flood plain develops in unconfined reaches where there is an increased silt content in bed or banks.
B. Additional zones associated with a rejuvenated profile			
Rejuvenated bedrock fall / cascades	Ar Br Cr	>0.02	Moderate to steep gradient, confined channel (gorge) resulting from uplift in the middle to lower reaches of the long profile, limited lateral development of alluvial features, reach types include bedrock fall, cascades and pool-rapid.
Rejuvenated foothills:	Dr Er	0.001 - 0.019	Steepened section within middle reaches of the river caused by uplift, often within or downstream of gorge; characteristics similar to foothills (gravel/cobble bed rivers with pool-riffle/ pool-rapid morphology) but of a higher order. A compound channel is often present with an active channel contained within a macro channel activated only during infrequent flood events. A limited flood plain may be present between the active and macro-channel.
Upland flood plain	Fr	< 0.005	An upland low gradient channel, often associated with uplifted plateau areas as occur beneath the eastern escarpment.

C.2 LONGITUDINAL PROFILES OF THE KEI STUDY AREA TOGETHER WITH ZONATION MAPS

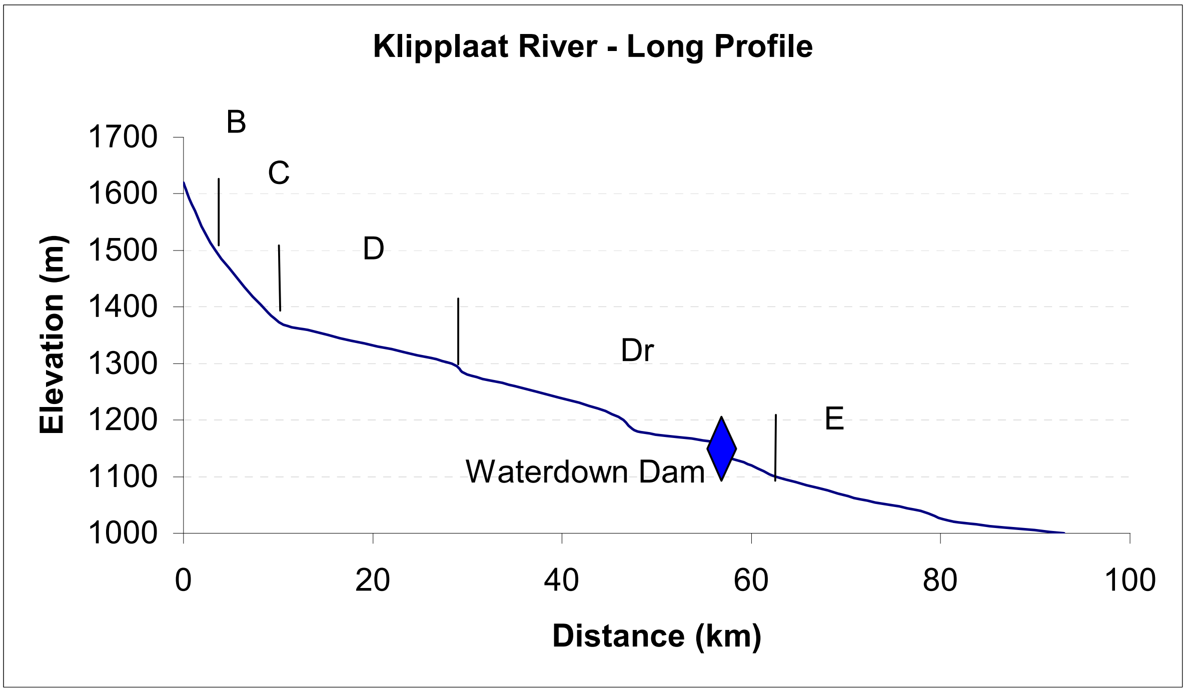
C.2.1 Black Kei River



C.2.2 The White Kei River



C.2.3 The Klipplaat River



C.2.4 The OXkraal River

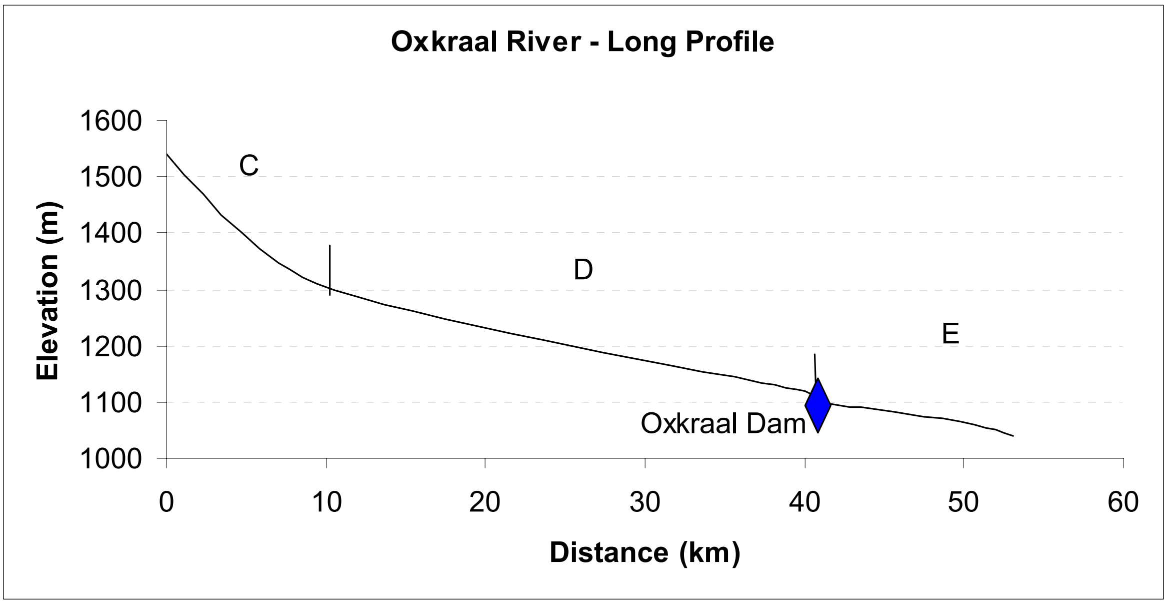
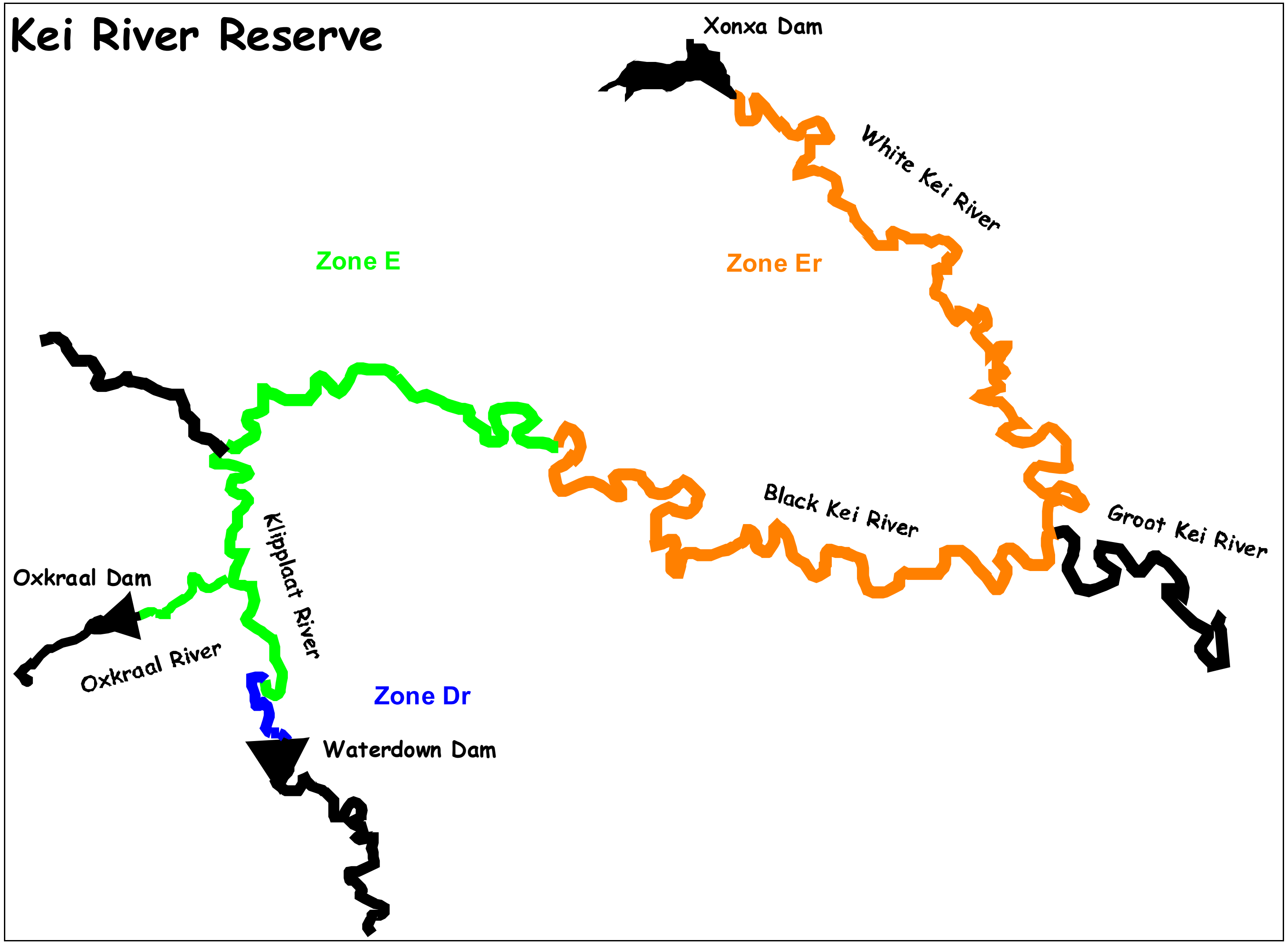


Figure C.1 Geomorphological Zonation map of the Kei Study area



APPENDIX D

Geomorphological aerial photographic analysis of the Kei Reserve study

Dr Roy Wadeson
Private

TABLE OF CONTENTS

D.1 INTRODUCTION D-1
D.2 IFR 1 – Kliplaat River D-1
D.3 IFR 2 – Black Kei River D-2
D.4 IFR 3 – Black Kei River, upstream of White Kei confluence D-2
D.5 IFR 4 – White Kei River D-3

D.1 INTRODUCTION

The method utilised in this study was to obtain a succession of aerial photographs for the study area and to compare the physical form of the channel and catchment over time. Both stereo pair photography and individual enlargements were used for this task. The analysis consists of four sets of photographs for each IFR site; 1938, 1967, 1985 and 1996.

D.2 IFR 1 – KLIPLAAT RIVER

This site falls within the geomorphological zone `E`, Lower Foothills. This is a lower gradient mixed bed alluvial channel with sand and gravel dominating the bed, local areas may be bedrock controlled. Reach types typically include pool- riffle or pool-rapid, sand bars common in pools. In this zone typically pools are of significantly greater extent than rapids or riffles and a floodplain is often present.

Photographic analysis of IFR 1 clearly shows a significant change in channel morphology between 1938 and 1996. The channel appears to have become narrower (approximately 20% reduction) and deeper over time.

1938: Catchment condition is poor with the majority of the area devoid of large woody vegetation. Flat areas along the channel margins have been utilised for cultivation.

The river channel appears to be relatively wide and shallow with numerous bars and islands. There is some riparian vegetation in patches along the river banks. There is no bridge near the site but there does appear to be a drift for crossing.

1968: Waterdown dam was completed in 1957 so is already in place at this time. Catchment condition is better with more large woody vegetation. There is an increase in the amount of vegetation on the channel margins. A road bridge across the channel is now present near the site.

The river channel is significantly narrower at this time but there are still numerous bars. Channel morphology is generally the same.

1985: The catchment has significantly more large woody vegetation present at this time. There is an increase in development within the catchment. There is a new road bridge present.

Channel morphology is difficult to assess due to the poor quality of the photographs.

1996: There is a further increase in large woody vegetation within the catchment.

The channel appears to be narrower and deeper as a result of stable, vegetated channel banks. Channel morphology appears to be significantly different from that seen in 1938.

D.3 IFR 2 – BLACK KEI RIVER

As with the previous site, this site falls within the geomorphological zone `E`, Lower Foothills. This is a lower gradient mixed bed alluvial channel with sand and gravel dominating the bed, local areas may be bedrock controlled. Reach types typically include pool- riffle or pool-rapid, sand bars common in pools. In this zone typically pools are of significantly greater extent than rapids or riffles and a floodplain is often present.

Photographic analysis of IFR 2 shows a significant change in channel morphology and channel dimensions (up to 70% reduction in width) during the time period considered.

1938: Catchment condition is poor with limited large woody vegetation present. Photographs illustrate the presence of large erosion gullies at this time. Channel margins are utilised for cultivation wherever possible. There is limited development within the catchment.

The river channel is wide and shallow. Bed material is dominated by alluvium (sand and gravel?). There are numerous bars and occasional vegetated islands. Channel pattern is braided.

1968: There is an increase in the amount of large woody vegetation in the catchment. There is significantly more development along the channel margins i.e. flood plain cultivation. There are also many more roads within the catchment. There appears to be some limited stabilisation of gullies as evidenced by the presence of vegetation.

The river channel demonstrates some narrowing as vegetation inhabits the margins and encroaches onto bars and islands. The major difference between 1968 and 1938 is the colonisation and stabilisation of bars.

1985: There is a continued increase in the amount of large woody vegetation present in the catchment. There appears to be an increased sedimentation (sediment aggradation). There are more roads present within the catchment.

Channel morphology is difficult to determine for this time period due to the poor quality of the photographs. It does seem possible however that a large flood has come through and removed some of the newly colonising vegetation.

1996: There is a significant increase in the amount of large woody vegetation in the catchment. The erosion gullies appear to be more stable at this time. There is no significant difference in catchment development between this time period and 1985.

There is a significant reduction in channel width with the encroachment of channel margins by small plants. There is a significant change in channel morphology with the river appearing deeper and narrower. Channel banks are well defined. Channel pattern has changed to a largely single channel with occasional vegetated islands. Bed material is dominated by large immovable boulders forming many rapids.

D.4 IFR 3 – BLACK KEI RIVER, UPSTREAM OF WHITE KEI CONFLUENCE

This site falls within the geomorphological zone `Er`, Rejuvenated foothills. These zones are steepened sections within middle reaches of the river caused by uplift. The zone has characteristics similar to foothills (gravel/cobble bed rivers with pool-riffle/ pool-rapid morphology) but of a higher order. A compound channel is often present with an active channel contained within a macro channel activated only during infrequent flood events. A limited flood plain may be present between the active and macro-channel.

Photographic analysis of IFR 3 shows few changes in river dimensions. The river demonstrates approximately a 25 % reduction in width. The most noticeable changes are an increase in sediment accumulation, the encroachment of vegetation and stabilisation of bars and banks.

1938: Catchment condition appears to be relatively good with a healthy cover of large woody vegetation. The river channel margins are not heavily utilised for agriculture as in the previous sites.

The river channel is wide and shallow with numerous alluvial bars. There appear to be occasional bedrock rapids in this area.

1968: There is an increased vegetation cover in the catchment and there is some encroachment of vegetation onto the channel banks and bars.

The river channel shows signs of sediment accumulation with an active narrowing of the channel. Channel morphology is largely the same as for 1938.

1985: As with all the previous sites, the photo quality does not allow an accurate assessment. There does not appear to be much change between 1968 and this time period.

There does appear to be some loss of marginal vegetation.

1996: The catchment is well vegetated as are the channel margins. There are no significant changes in catchment development.

The river channel consists of a well-defined active channel and there are virtually no further changes to channel morphology.

D.5 IFR 4 – WHITE KEI RIVER

This site falls within the geomorphological zone `Er`, Rejuvenated foothills. These zones are steepened sections within middle reaches of the river caused by uplift. The zone has characteristics similar to foothills (gravel/cobble bed rivers with pool-riffle/ pool-rapid morphology) but of a higher order. A compound channel is often present with an active channel contained within a macro channel activated only during infrequent flood events. A limited flood plain may be present between the active and macro-channel.

The photographic analysis of site IFR 4 shows little change between 1938 and 1996. The catchment remains in poor condition throughout the period. There appears to be a slight increase in the vegetation of the channel banks, bars and islands. There also appears to be an overall decrease in sedimentation as evidenced by the removal and re-working of some bars.

1938: Catchment condition is poor with little vegetation cover. There is some urban development (St Marks). There is extensive soil erosion in places.

The river channel is single thread, wide and shallow.

1968: This photographic record was during a period of very low flow. The catchment condition is generally the same with an increase in urbanisation.

The river channel demonstrates numerous bars and islands and appears to be braided (alluvial).

1985: There is a significant increase in urban development.

There is no significant difference in channel morphology i.e. the river consists of numerous bars and islands. There is an increased vegetation of some of the larger bars.

1996: Catchment condition remains poor and appears to be getting steadily worse due to the continued development of the urban area. Soil erosion is a dominant feature.

The river channel has changed little over the 60-year period.

APPENDIX E

An assessment of the Intermediate Habitat Integrity for the Kei River system

Mr N Kemper
Integrated Environmental Assessments

TABLE OF CONTENTS

E.1 INTRODUCTION E-2
E.2 METHOD E-2
E.2.1 Background E-2
E.2.2 Data sources E-2
E.2.3 Site visit E-2
E.3 DATA MANAGEMENT AND ANALYSIS E-5
E.4 RESULTS AND DISCUSSION E-8
E.4.1 Klipplaat River E-8
E.4.2 Oxraal River E-11
E.4.3 Black Kei River E-14
E.4.4 White Kei River E-17
E.5 ACKNOWLEDGEMENTS AND REFERENCES E-20

LIST OF FIGURES

Figure E.1 The location of observation points on the Klipplaat and Oxkraal Rivers relative to the river segment breaks and other topographical features E-3
Figure E.2 Location of observation points on the Black Kei River relative to topographical features E-4
Figure E.3 Location of observation points on the White Kei River relative to segment breaks and other topographical features E-4
Figure E.4 Instream habitat integrity results for the Klipplaat River E-9
Figure E.5 Riparian zone habitat integrity results for the Klipplaat River E-10
Figure E.6 Instream habitat integrity results for the Oxkraal River E-12
Figure E.7 Riparian zone habitat integrity results for the Oxkraal River E-13
Figure E.8 Instream habitat integrity results for the Black Kei River E-15
Figure E.9 Riparian zone habitat integrity results for the Black Kei River E-16
Figure E.10 Instream habitat integrity results for the White Kei River E-18
Figure E.11 Riparian zone habitat integrity results for the White Kei River E-19

LIST OF TABLES

Table E.1 Descriptive classes for the assessment of modification to the present status E-6
Table E.2 Criteria and weights used for the assessment of in-stream and riparian zone present status E-7
Table E.3 Present status assessment classes E-7

E.1 INTRODUCTION

The main Kei River system is characterised by three large dams, the Waterdown, Oxkraal and the Xonxa Dams, which have been used for some time to supply the water requirements for domestic purposes for the main centres such as Queenstown as well as for extensive irrigation and stock farming in the area. Due to increasing demands, it has become necessary to implement an integrated management strategy for the water resources of the region and to comply with the National Water Act. According to the National Water Act it is necessary to undertake an assessment of the Ecological Reserve for any system before further water licensing applications can be considered. In this particular case an Intermediate level of Reserve Assessment is required. The associated level of assessment for the Habitat Integrity is that of the Intermediate Habitat Integrity (IHI) assessment.

This report reflects an assessment of the IHI of the Kei River system according to the accepted IHI Methodology (Kemper and Kleynhans, 1998). The assessment was undertaken on the main rivers within the Catchment as follows:

- Oxkraal River to the confluence with the Klipplaat River.
- Klipplaat River from the Waterdown Dam to the confluence with the Black Kei River.
- Black Kei River downstream of the confluence with the Klipplaat River to the confluence of the White Kei River.
- White Kei River from the Xonxa Dam to the confluence with the Black Kei River.

E.2 METHOD

E.2.1 Background

A pilot study was undertaken on the Pienaars River in 1999, during which various methodologies were applied and tested for determination of the IHI. These methodologies have subsequently been applied and further developed throughout the country on a number of different catchments.

The IHI methodology is aimed at being mainly site based primarily in order to save costs. Being only site based the high costs of videoing the river from a helicopter are saved, which is the standard method used for the comprehensive.

E.2.2 Data sources

The following data sources were used for this assessment:

- Assessments made at a number of river observation points within the system during a one-day visit to the system in August 2003.
- An aerial video of the Black Kei and Klipplaat Rivers taken in 1994.
- A preliminary land cover assessment undertaken by DWAF: Resource Quality Services in 2003.

E.2.3 Site visit

During the site visit all practical points of access to the river were visited and still photographs were taken of representative areas of the river. A total of 14 river observation points were visited. Four points were located on the Klipplaat River, two on the Oxkraal River, seven on the Black Kei and two on the White Kei River. At each point all available IHI assessment data were transcribed onto field data forms along with other pertinent information, which had a bearing on the instream and riparian integrity.

The observation points for the Klipplaat and Oxkraal Rivers are presented in Figure 1, while those for the Black Kei and White Kei Rivers are presented in Figures E.2 and Figures E.3 respectively.

Figure E.1 **The location of observation points on the Klipplaat and Oxkraal Rivers relative to the river segment breaks and other topographical features**

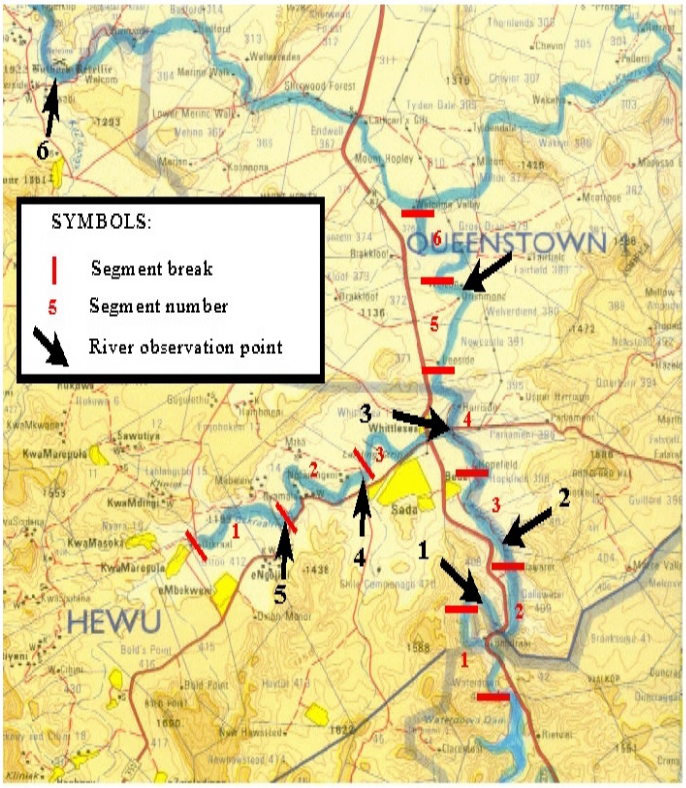


Figure E.2 Location of observation points on the Black Kei River relative to topographical features

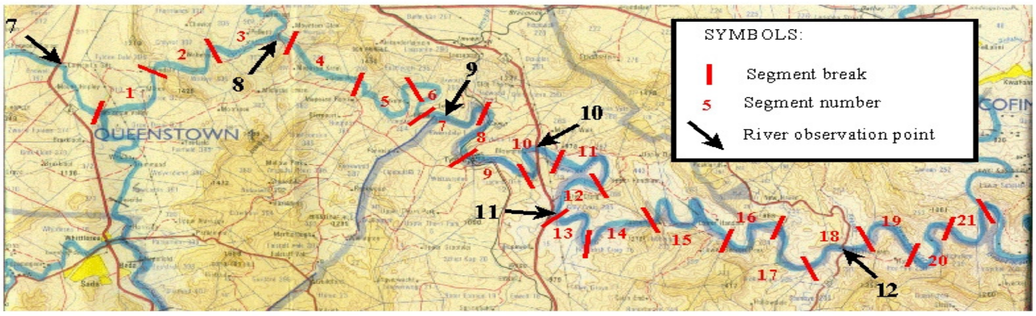
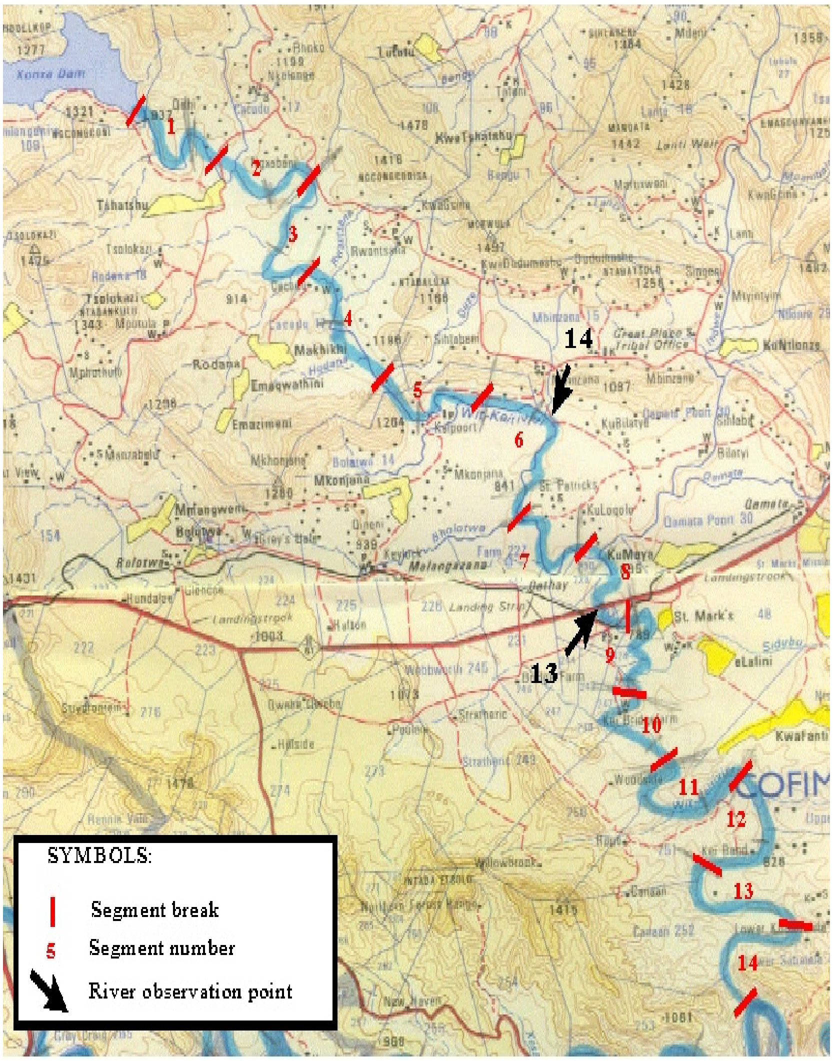


Figure E.3 Location of observation points on the White Kei River relative to segment breaks and other topographical features



E.3 DATA MANAGEMENT AND ANALYSIS

Information on the following aspects as well as an assessment of the severity of modifications were assessed at each observation point on the river:

Flow (relative abundance); dry (0), none (1), little (2), moderate (3), strong (4).
Water habitat types and relative abundance; Types - fast flowing, pools & ponds, weirs and impoundments; abundance - none (1), few (2), moderate (3), common (4), exclusive (5).

Number of; weirs, impoundments and pumps. Impact of; roads & bridges, rubbish dumping, bed and channel modification, stream bank erosion, removal of natural riparian vegetation, encroachment by exotic riparian vegetation, presence of cultivated lands and plantations on stream bank and presence of exotic aquatic macrophytes.

General remarks were also made on the following; species of exotic and indigenous riparian vegetation and exotic macrophytes observed; water fauna observed; general description of stream bed; general description of stream bank; general assessment of habitat diversity (including the stream bank) according to, low (1), moderate (2), large (3), very large (4), unique (5).

Criteria considered indicative of the present status were selected on the basis that modification of their characteristics could generally be regarded as the primary causes of degradation of the present status of the river. The severity of certain modifications will, therefore, have a detrimental impact on the present status of the river. The method is primarily habitat oriented with emphasis on a qualitative interpretation of the habitat quality, size, diversity, variability and predictability as influenced by various human made modifications.

An assessment of the severity of impact of modifications is based on six descriptive classes with scores ranging from 0, indicating no impact and 21-25, signifying extremely severe impact. Scoring is guided by a description of the severity of the impact of the modification for each score. Based on the relative importance of the criteria, scores are weighted. Scores for riparian zone and in-stream criteria are summed separately and expressed as a percentage of the maximum (100%) possible. This figure is subtracted from 100 to arrive at an estimate of the habitat integrity. The general descriptive procedure that was used to estimate the impact of modifications is indicated in Table E.1.

Relative impact was estimated as follows:

Rating for the criteria/maximum value (25) x the weight (%) e.g., it is found that water abstraction is critical and it receives a score of 25. In such a case

It has a weight of 14%. If a score of 10 was awarded, the calculation proceeds as follows: 10/25 x 14=5,6

In the case of in-stream criteria, provision was made for principal and supplementary criteria. Principal in-stream criteria are regarded as being of fundamental importance to the maintenance of the present state of this facet with consideration to the maintenance of the quality and structural characteristics of the habitat. Supplementary in-stream criteria are considered to be of relatively lower importance.

The criteria used as indicators of the status of the in-stream facet of the river and the weights assigned to these criteria are reflected in Table E.2.

An initial assessment of the present status was made based on these weights. However, as a cautionary measure, the final estimate of the principal criteria of the in-stream facet received an additional negative weight if their impacts were considered to be large, serious or critical. The aim of this approach was to accommodate the possible cumulative (and integrated) negative effects of such impacts.

The following arbitrary rules were followed in this respect:

Impact = Large, lower status by 33% of the weight for each criterion of this nature.

Impact = Serious, lower status by 67% of the weight for each criterion of this nature.
Impact = Critical, lower status by 100% of the weight for each criterion of this nature.

These negative weights were added for each facet, where applicable, and the total negative weight subtracted from the provisionally determined status to arrive at a final status estimate. For comparative purposes, both the provisional and final status estimates are indicated for each river.

Table E.1 Descriptive classes for the assessment of modification to the present status

Impact class	Description	Score
None	No discernible impact, or the modification is located in such a way that it has no impact on habitat quality, diversity, size and variability.	0
Small	The modification is limited to very few localities and the impact on habitat quality, diversity, size and variability is also very small.	1 to 5
Moderate	The modifications are present at a small number of localities and the impact on habitat quality, diversity, size and variability is also limited.	6 to 10
Large	The modification is generally present with a clearly detrimental impact on habitat quality, diversity, size and variability. Large areas are, however, not influenced.	11 to 15
Serious	The modification is frequently present and the habitat quality, diversity, size and variability in almost the whole of the defined are affected. Only small areas are not influenced.	16 to 20
Critical	The modification is present overall with a high intensity. The habitat quality, diversity, size and variability in almost the whole of the defined section are influenced detrimentally.	21 to 25

Table E.2 Criteria and weights used for the assessment of in-stream and riparian zone present status

Instream criteria	Weight	Riparian zone criteria	Weight
Principle criteria:		**Principle criteria:**	
Water abstraction	14	Indigenous vegetation removal	13
Flow modification	13	Exotic vegetation encroachment	13
Bed modification	13	Bank erosion	14
Channel modification	13	Channel modification	12
Water Quality	14	Water abstraction	13
Inundation	10	Inundation	11
Supplementary criteria:		**Supplementary criteria:**	
Exotic macrophytes	9	Flow modification	12
Exotic fauna	8	Water quality	13
Solid waste disposal	6		
TOTAL	100	TOTAL	100

Table E.3 Present status assessment classes

Class	Description	Score %
A	Unmodified, natural.	90-100
B	Largely natural with few modifications. A small change in natural habitats and biota may have taken place but the ecosystem functions are essentially unchanged.	80-90
C	Moderately modified. A loss and change of natural habitat and biota have occurred but the basic ecosystem functions are still predominantly unchanged.	60-79
D	Largely modified. A large loss of natural habitat, biota and basic ecosystem functions has occurred.	40-59
E	The loss of natural habitat, biota and basic ecosystem functions is extensive.	20-39
F	Modifications have reached a critical level and the lotic system has been modified completely with an almost complete loss of natural habitat and biota. In the worst instances the basic ecosystem functions have been destroyed and the changes are irreversible.	0-19

E.4 RESULTS AND DISCUSSION

The following must be noted:

- The habitat Integrity results could indicate an assumed poor water quality. This would be derived from the catchment utilization and the diversity of water quality sensitive aquatic invertebrates occurring. This could differ from the water quality assessment which does not measure sufficient variables as well as not addressing turbidity. The water quality assessment is based on available data could therefore be evaluated as good whereas the biological responses indicate that this is probably not the case.
- Riparian Habitat Integrity focuses on the function of the riparian zone as forming part of Instream Habitat. There is therefore not necessarily a relationship between this assessment and statements made as part of the geomorphological assessment. Furthermore the geomorphological assessment was based on aerial photographs of which the most recent could be already out of date. Vegetation removal during the last 10 years e.g. would not be observed from the aerial photography analysis.

E.4.1 Klipplaat River

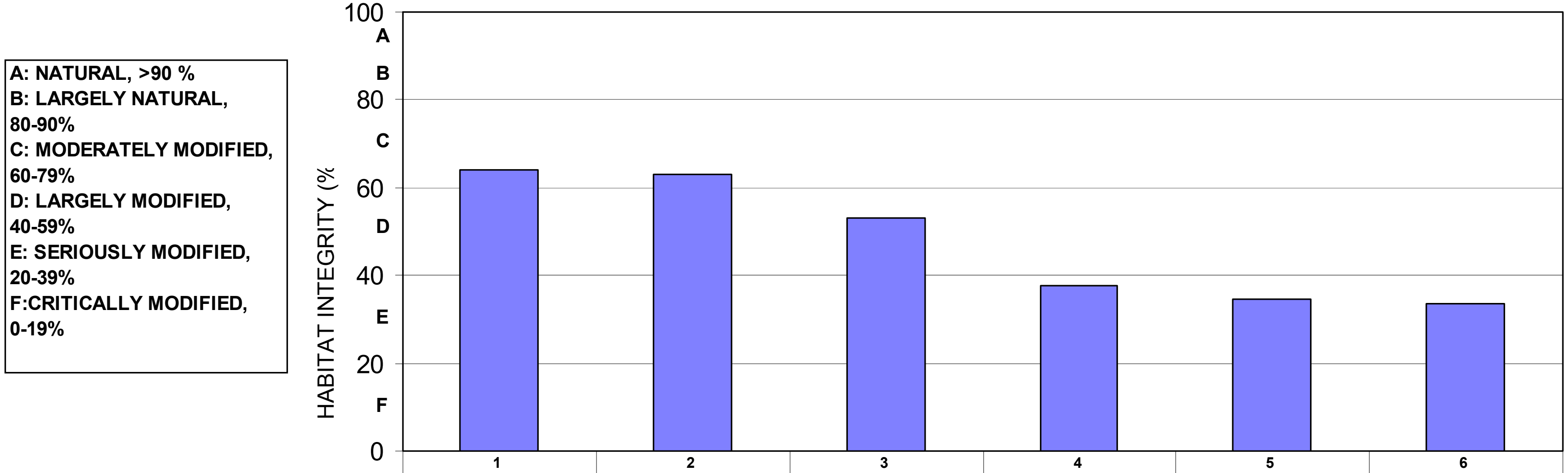
Instream Intermediate Habitat Integrity

The results of the instream integrity assessment are presented in Figure E.4. The scores range from 36 to 62 percent which corresponds with a Class D river overall. The assessment clearly shows a decrease in integrity from the Waterdown Dam towards the confluence with the Black Kei River. This is largely due to the influence of reducing water quality and bed modification. The area is used extensively for cattle grazing and dry land farming which has resulted in extensive erosion and localised water fouling. The riverbed and instream habitat was covered with thick algae and sediments and the cobbles and rocks were extensively embedded, particularly towards the confluence of the Black Kei River. The abstraction of water for irrigation and stock farming has also contributed to the decreasing integrity of the system. The modified flow regime due to the presence of and the current management of the dam is a major contributing factor to the generally low instream habitat integrity score.

Riparian Zone Intermediate Habitat Integrity

The riparian zone habitat integrity results are presented in Figure E.5. The scores range from 35 to 65 percent corresponding with Class C (higher parts of the river) to a Class E (lower parts). Similar to the instream component, a decreasing trend was evident for the riparian zone habitat integrity. Extensive grazing and trampling, the removal of riparian trees for fuel and construction and the presence of large patches of exotic trees are largely responsible for this trend. The modified flow regime imposed by the dam and its current management also contributed to a generally low riparian zone integrity, which provides an environment that favours exotic species encroachment.

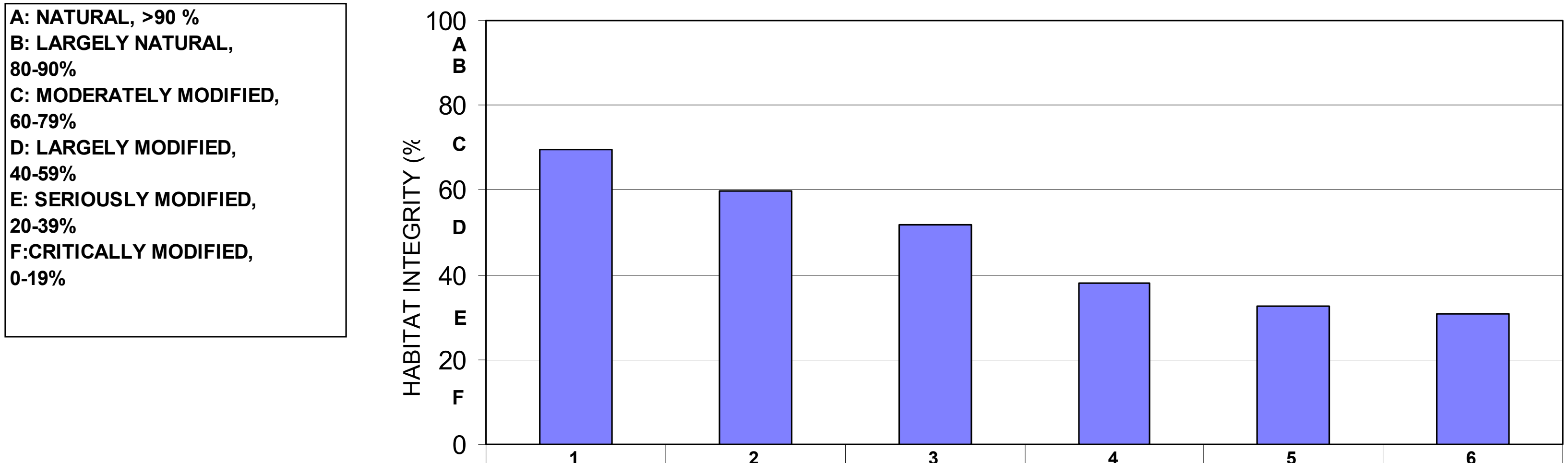
Figure E.4 Instream habitat integrity results for the Klipplaat River



	1	2	3	4	5	6
INSTREAM HABITAT INTEGRITY (%)	64	63	53	38	35	34
WATER ABSTRACTION (IMPACT 1 - 25)	5	7	8	10	12	13
FLOW MODIFICATION ((IMPACT 1 - 25)	19	17	17	18	19	19
BED MODIFICATION (IMPACT 1 - 25)	12	13	15	20	20	20
CHANNEL MODIFICATION (IMPACT 1 - 25)	5	6	8	12	13	13
WATER QUALITY (IMPACT 1 - 25)	9	9	12	18	18	19
INUNDATION (IMPACT 1 - 25)	0	0	5	5	0	0
EXOTIC MACROPHYTES (IMPACT 1 - 25)	0	0	0	0	0	0
EXOTIC FAUNA (IMPACT 1 - 25)	0	0	0	0	0	0
RUBBISH DUMPING (IMPACT 1 - 25)	0	0	5	7	9	10

SECTOR NO (---> FLOW DIRECTION)

Figure E.5 Riparian zone habitat integrity results for the Klipplaat River



	1	2	3	4	5	6
RIPARIAN ZONE HABITAT INTEGRITY	69	60	52	38	33	31
VEGETATION REMOVAL (IMPACT 1 - 25)	8	12	14	16	17	12
EXOTIC VEGETATION (IMPACT 1 - 25)	4	4	10	14	15	15
BANK EROSION (IMPACT 1 - 25)	6	6	8	9	10	12
CHANNEL MODIFICATION (IMPACT 1 - 25)	5	5	9	9	9	8
WATER ABSTRACTION (IMPACT 1 - 25)	3	3	3	5	6	8
INUNDATION (IMPACT 1 - 25)	0	0	5	4	0	0
FLOW MODIFICATION (IMPACT 1 - 25)	14	14	14	14	16	16
WATER QUALITY (IMPACT 1 - 25)	4	4	4	5	8	8

SECTOR (-> FLOW DIRECTION)

E.4.2 Oxkraal River

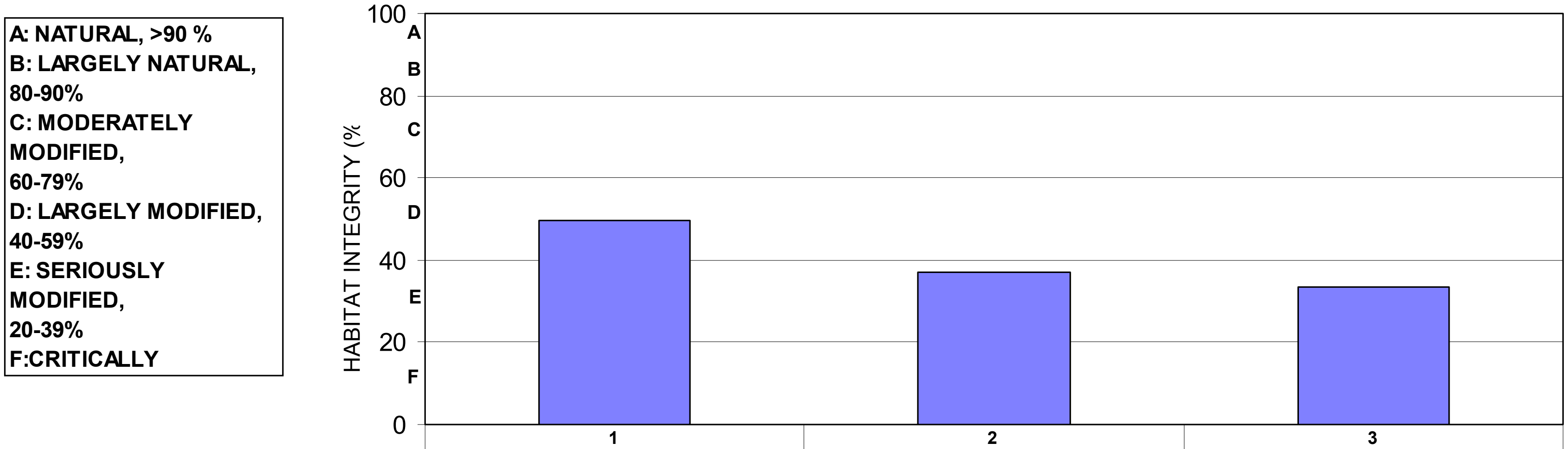
Instream Intermediate Habitat Integrity

The instream habitat integrity results for the Oxkraal River are presented in Figure E.6. The integrity scores are generally between 20 and 45 percent, which corresponds with a Class E river. This is largely due to the large-scale use of the area for cattle grazing which has resulted in bank erosion and the modification of the riverbed by the presence of thick sediments and algal growth. The rocks and cobbles on the riverbed have become extensively embedded. Water quality has also been significantly reduced by the use of the river for washing and cattle drinking. Extensive modifications have also occurred to the flow regime with reduced baseflows and floods resulting in river incision and undercutting.

Riparian Zone Intermediate Habitat Integrity

The riparian zone habitat integrity results for the Oxkraal River are presented in Figure E.7. The scores range between 20 and 40 percent, corresponding to that of a Class E river. This is due to the extensive removal of riparian trees for fuel and building purposes, severe erosion due to cattle grazing and trampling, the presence of exotic trees, the impact of a modified flow regime and the abstraction of water for domestic, farming and stock.

Figure E.6 Instream habitat integrity results for the Oxkraal River

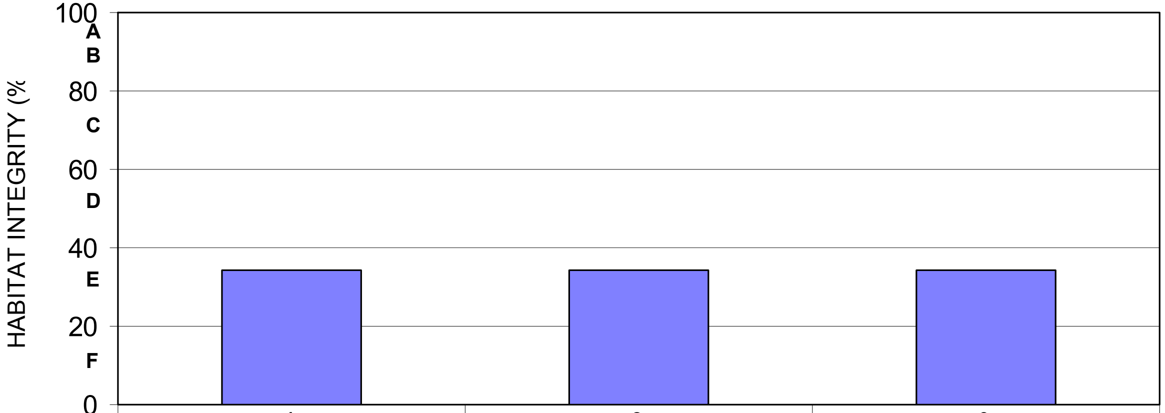


	1	2	3
INSTREAM HABITAT INTEGRITY (%)	50	37	34
WATER ABSTRACTION (IMPACT 1 - 25)	8	10	12
FLOW MODIFICATION ((IMPACT 1 - 25)	18	19	19
BED MODIFICATION (IMPACT 1 - 25)	16	18	18
CHANNEL MODIFICATION (IMPACT 1 - 25)	9	12	12
WATER QUALITY (IMPACT 1 - 25)	12	16	16
INUNDATION (IMPACT 1 - 25)	0	7	7
EXOTIC MACROPHYTES (IMPACT 1 - 25)	0	0	0
EXOTIC FAUNA (IMPACT 1 - 25)	0	0	0
RUBBISH DUMPING (IMPACT 1 - 25)	8	15	15

SECTOR NO (---> FLOW DIRECTION)

Figure E.7 Riparian zone habitat integrity results for the Oxkraal River

A: NATURAL, >90 %
B: LARGELY NATURAL, 80-90%
C: MODERATELY MODIFIED, 60-79%
D: LARGELY MODIFIED, 40-59%
E: SERIOUSLY MODIFIED, 20-39%
F:CRITICALLY MODIFIED, 0-19%



	1	2	3
RIPARIAN ZONE HABITAT INTEGRITY	34	34	34
VEGETATION REMOVAL (IMPACT 1 - 25)	12	12	12
EXOTIC VEGETATION (IMPACT 1 - 25)	9	9	9
BANK EROSION (IMPACT 1 - 25)	14	15	15
CHANNEL MODIFICATION (IMPACT 1 - 25)	9	9	9
WATER ABSTRACTION (IMPACT 1 - 25)	12	12	12
INUNDATION (IMPACT 1 - 25)	0	0	0
FLOW MODIFICATION (IMPACT 1 - 25)	13	12	12
WATER QUALITY (IMPACT 1 - 25)	8	8	8

SECTOR (-> FLOW DIRECTION)

E.4.3 Black Kei River

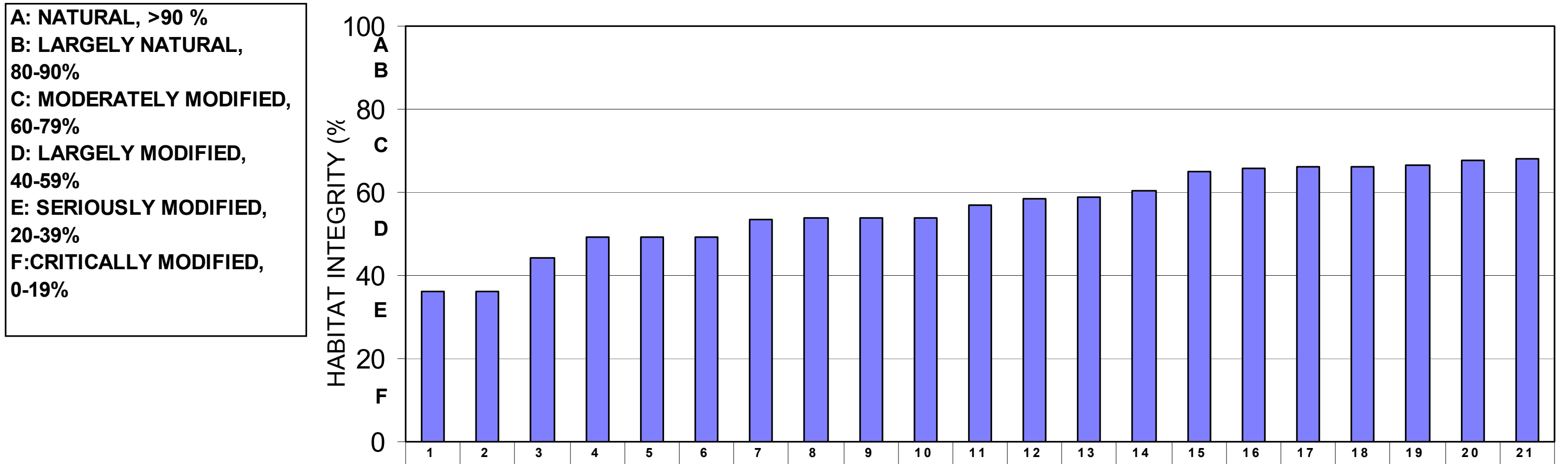
Instream Intermediate Habitat Integrity

The results of the instream habitat integrity for the Black Kei River are presented in Figure E.8. The scores range from 35 to 65 percent corresponding to a Class D and lower Class C river. The major impacts to the system are those of modified flow regime (reduced baseflows and floods); bank erosion with resulting sedimentation and bed modification; reduced water quality due to cattle and human activity and outflow of water care works; and water abstraction for irrigation, domestic and stock. The scores increase gradually from the confluence of the Klipplaat River to the confluence of the White Kei River which is largely due to improved flow regime from tributaries entering the main river, reduced farming activity and human settlement towards the confluence with the White Kei River.

Riparian Zone Intermediate Habitat Integrity

The riparian zone habitat integrity results are presented in Figure E.9. The scores range from 39 to 68 percent, which corresponds with a Class D and Class C river. The major impacts to the system being removal of vegetation; modified flow regime (reduced baseflows and floods); water abstraction; exotic trees and erosion caused mainly by the activity of cattle and farming in the riparian zone.

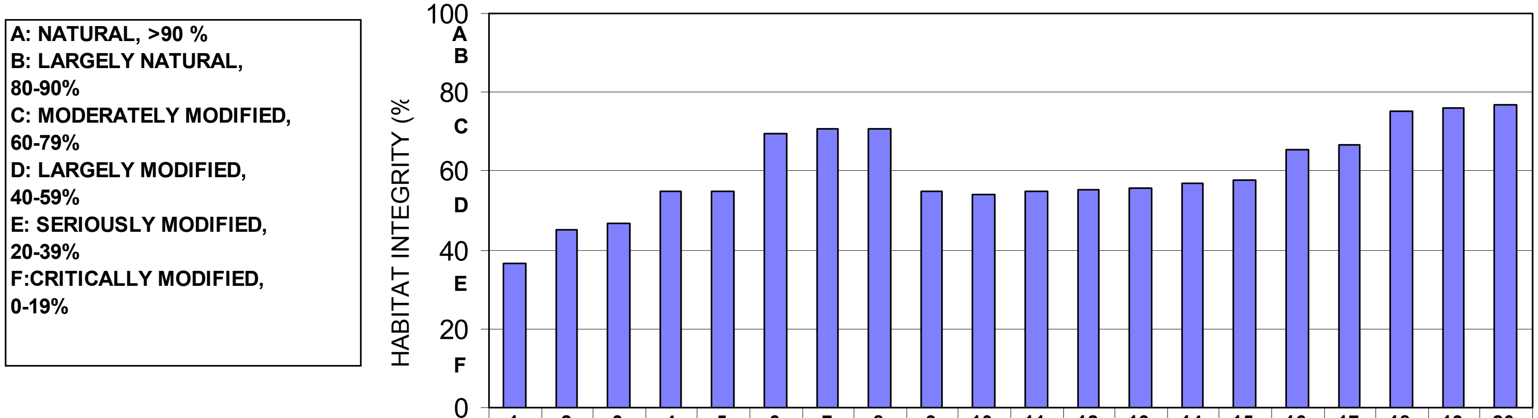
Figure E.8 Instream habitat integrity results for the Black Kei River



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
INSTREAM HABITAT INTEGRITY (%)	36	36	44	49	49	49	53	54	54	54	57	58	59	61	65	66	66	66	67	68	68
WATER ABSTRACTION (IMPACT 1 - 25)	15	15	15	15	15	15	15	15	15	15	14	12	11	11	10	9	9	8	8	5	
FLOW MODIFICATION ((IMPACT 1 - 25)	16	16	12	12	12	12	11	11	11	11	10	10	10	9	9	9	8	8	8	8	
BED MODIFICATION (IMPACT 1 - 25)	17	17	16	16	16	16	15	15	15	15	15	15	15	14	14	14	14	14	14	14	
CHANNEL MODIFICATION (IMPACT 1 - 25)	11	11	9	9	9	9	9	9	9	9	9	9	9	7	7	7	7	8	7	8	
WATER QUALITY (IMPACT 1 - 25)	16	16	16	14	14	14	14	14	14	14	14	14	14	14	13	13	13	13	13	13	
INUNDATION (IMPACT 1 - 25)	5	5	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
EXOTIC MACROPHYTES (IMPACT 1 - 25)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
EXOTIC FAUNA (IMPACT 1 - 25)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
RUBBISH DUMPING (IMPACT 1 - 25)	5	5	8	2	2	2	2	0	0	0	2	0	0	0	0	0	0	0	0	0	

SECTOR NO (---> FLOW DIRECTION)

Figure E.9 Riparian zone habitat integrity results for the Black Kei River



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
RIPARIAN ZONE HABITAT INTEGRITY	37	45	47	55	55	70	71	71	55	54	55	55	56	57	58	65	67	75	76	77
VEGETATION REMOVAL (IMPACT 1 - 25)	12	12	11	11	11	9	9	9	11	12	12	12	11	11	11	10	8	7	6	6
EXOTIC VEGETATION (IMPACT 1 - 25)	12	11	11	11	11	10	10	10	11	12	12	11	11	11	11	11	11	10	10	9
BANK EROSION (IMPACT 1 - 25)	11	10	11	10	10	10	10	10	10	10	10	10	10	8	8	8	8	8	8	8
CHANNEL MODIFICATION (IMPACT 1 - 25)	9	8	8	8	8	8	8	8	8	8	7	7	7	7	7	7	7	6	6	6
WATER ABSTRACTION (IMPACT 1 - 25)	9	10	9	9	9	9	7	7	10	9	9	9	9	9	7	6	6	6	6	6
INUNDATION (IMPACT 1 - 25)	4	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
FLOW MODIFICATION (IMPACT 1 - 25)	13	13	10	10	10	10	10	10	9	9	8	8	9	9	9	9	8	8	7	7
WATER QUALITY (IMPACT 1 - 25)	4	5	5	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4

SECTOR (-> FLOW DIRECTION)

E.4.4 White Kei River

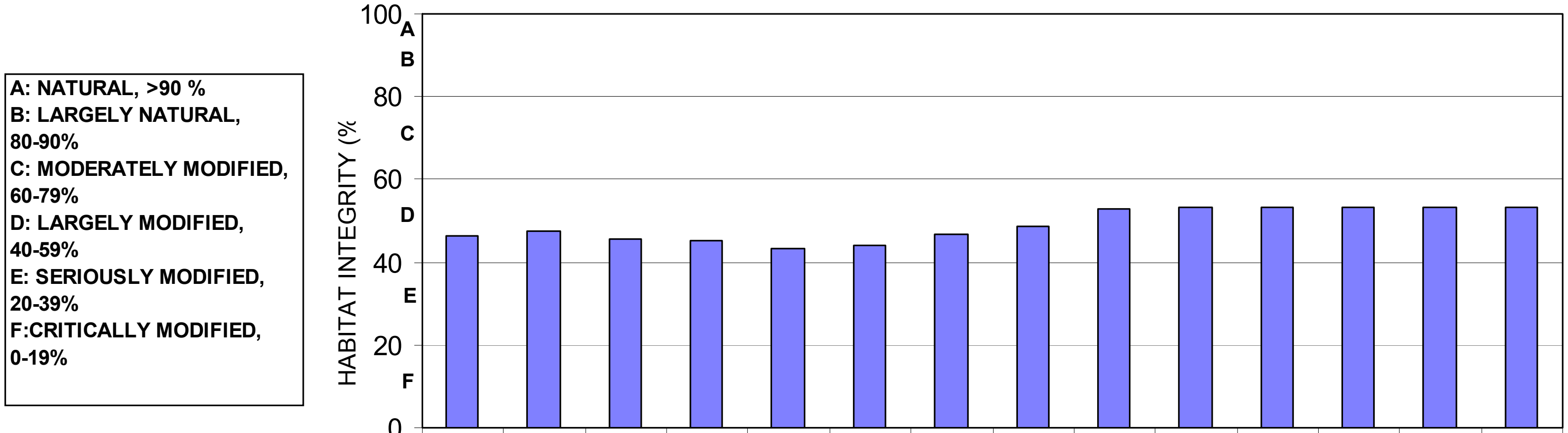
Instream Intermediate Habitat Integrity

The instream habitat integrity results for the White Kei River are presented in Figure E.10. The scores range from 40 to 62 percent, which corresponds with a Class D river. The major impacts on the system are modified flow regime (reduced baseflows and floods from Xonxa and Lubisi Dams); bed modification as a result of sedimentation from cattle and human activity as well as algal growth mainly due to possible poor water quality and the activity of cattle and humans in the river. Channel modification has also taken place due to modified flow regime and human activity.

Riparian Zone Intermediate Habitat Integrity

The riparian zone habitat integrity results for the White Kei River are presented in Figure E.11. The scores range from 38 to 42 percent corresponding to a Class D river. The major impacts being the removal of natural vegetation for building and fuel purposes; modified flow regime (reductions in baseflows and floods below Xonxa and Lubisi Dams) the presence of exotic trees; erosion caused by trampling and grazing of cattle and goats and the abstraction of water for domestic, farming and stock.

Figure E.10 Instream habitat integrity results for the White Kei River

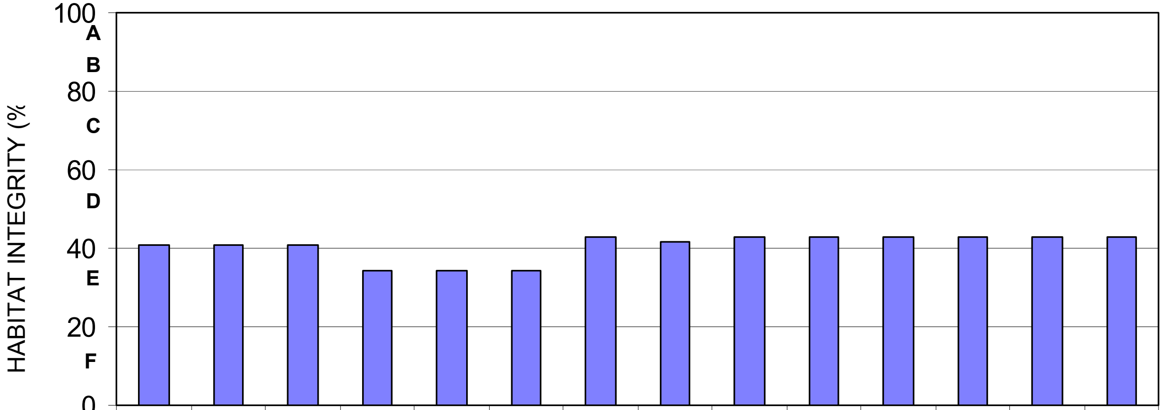


	1	2	3	4	5	6	7	8	9	10	11	12	13	14
INSTREAM HABITAT INTEGRITY (%)	46	47	46	45	43	44	47	49	53	53	53	53	53	53
WATER ABSTRACTION (IMPACT 1 - 25)	2	2	6	8	9	9	9	9	9	9	9	9	9	9
FLOW MODIFICATION ((IMPACT 1 - 25)	18	18	18	18	17	17	15	13	13	13	13	13	13	13
BED MODIFICATION (IMPACT 1 - 25)	16	16	17	17	17	18	18	18	18	19	19	19	19	19
CHANNEL MODIFICATION (IMPACT 1 - 25)	15	15	14	13	13	13	13	13	13	11	11	11	11	11
WATER QUALITY (IMPACT 1 - 25)	13	13	13	12	12	12	12	12	10	10	10	10	10	10
INUNDATION (IMPACT 1 - 25)	4	0	0	0	5	0	4	0	0	0	0	0	0	0
EXOTIC MACROPHYTES (IMPACT 1 - 25)	0	0	0	0	0	0	0	0	0	0	0	0	0	0
EXOTIC FAUNA (IMPACT 1 - 25)	0	0	0	0	0	0	0	0	0	0	0	0	0	0
RUBBISH DUMPING (IMPACT 1 - 25)	5	5	5	8	10	12	12	12	12	12	12	12	12	12

SECTOR NO (---> FLOW DIRECTION)

Figure E.11 Riparian zone habitat integrity results for the White Kei River

A: NATURAL, >90 %
B: LARGELY NATURAL, 80-90%
C: MODERATELY MODIFIED, 60-79%
D: LARGELY MODIFIED, 40-59%
E: SERIOUSLY MODIFIED, 20-39%
F:CRITICALLY MODIFIED, 0-19%



	1	2	3	4	5	6	7	8	9	10	11	12	13	14
RIPARIAN ZONE HABITAT INTEGRITY	41	41	41	34	34	34	43	42	43	43	43	43	43	43
VEGETATION REMOVAL (IMPACT 1 - 25)	10	10	10	12	12	12	11	13	13	13	13	13	13	13
EXOTIC VEGETATION (IMPACT 1 - 25)	9	9	9	9	9	9	9	9	9	9	9	9	9	9
BANK EROSION (IMPACT 1 - 25)	13	13	13	14	15	15	15	15	15	15	15	15	15	15
CHANNEL MODIFICATION (IMPACT 1 - 25)	10	10	10	9	9	9	9	9	8	8	8	8	8	8
WATER ABSTRACTION (IMPACT 1 - 25)	12	12	12	12	12	12	7	6	6	6	6	6	6	6
INUNDATION (IMPACT 1 - 25)	0	0	0	0	0	0	0	0	0		0	0	0	0
FLOW MODIFICATION (IMPACT 1 - 25)	14	14	14	13	12	12	12	12	11	11	11	11	11	11
WATER QUALITY (IMPACT 1 - 25)	8	8	8	8	8	8	8	8	8	8	8	8	8	8

SECTOR (-> FLOW DIRECTION)

E.5 ACKNOWLEDGEMENTS AND REFERENCES

The author would like to thank Dr. Neels Kleynhans of the Department of Water Affairs and Forestry: Resource Quality Services for the use of his Excel spreadsheet shell compiled for the assessment of Habitat Integrity for Southern African rivers.

Kemper, N.P & Kleynhans, C.J. 1998. Methodology for the Assessment of the Intermediate Habitat Integrity of Rivers. Department of Water Affairs: Institute for Water Quality Studies Report for the Pilot Study for the Intermediate Reserve for Rivers.

Kleynhans, C.J. 1996. A Qualitative Procedure for the Assessment of the Habitat Integrity Status of the Luvuvhu River (Limpopo system, South Africa). Journal of Aquatic Ecosystem Health 5: 1-14.

APPENDIX F

Fish

Mr Anton Bok
Anton Bok & Associates

TABLE OF CONTENTS

F.1 FUZZY FISH INDEX F-1
F.2 DISCHARGE AND HABITAT ABUNDANCE F-2
F.3 FLOW DEPTH CLASSES F-3
F.4 HABITAT SUITABILITY AND DERICED FISH STRESS F-7

LIST OF TABLES

Table F.1 Fuzzy Fish Index scores for the different IFR sites F-1
Table F.2 Matrix of discharge against habitat abundance for IFR 2 ..... F-2
Table F.3 Matrix of discharge against habitat abundance for IFR 3 ..... F-2
Table F.4 Matrix of discharge against habitat abundance for IFR 4 ..... F-3
Table F.5 Klipplaat River – IFR 1 ..... F-7
Table F.6 Upper Black Kei River – IFR 2 ..... F-7
Table F.7 Black Kei River – IFR 3 ..... F-7
Table F.8 White Kei River – IFR 4 ..... F-8

LIST OF FIGURES

Figure F.1 Estimated qualitative Fish Integrity Category F-2

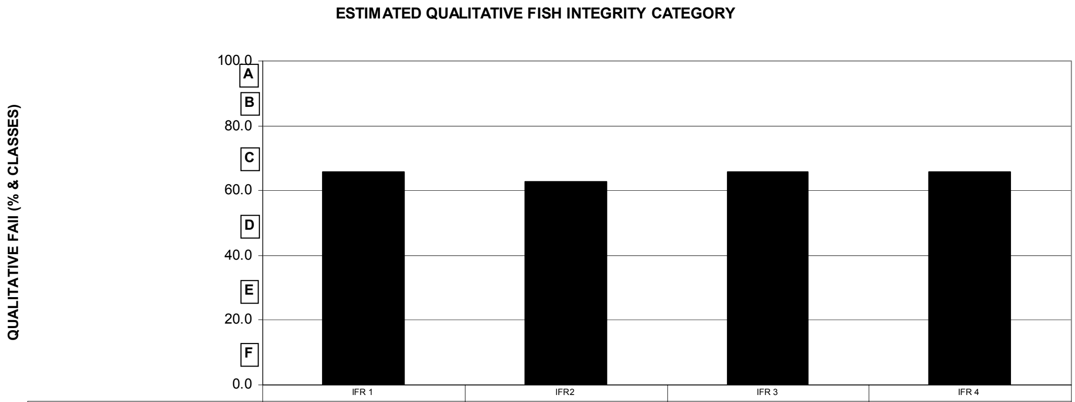
F.1 FUZZY FISH INDEX

The scores for the different IFR sites are as follows

Table F.1 Fuzzy Fish Index scores for the different IFR sites

PES RATINGS PER RESOURCE UNIT (KEI) **Resource unit**	**IFR 1**	**IFR2**	**IFR 3**	**IFR 4**
Native species richness	5	5	5	5
Presence of native intolerant species	5	5	4	5
Abundance of native species	2	2	4	3
Frequency of occurrence of native	4	3	3	2
Health/condition of native and introduced species	3	3	3	4
Presence of introduced fish species	2	2	2	2
In-stream habitat modification	2	2	2	2
TOTAL SCORE	**23**	**22**	**23**	**23**
%	65.7	62.9	65.7	65.7
FISH ASSEMBLAGE CATEGORY	**C**	**C**	**C**	**C**

Figure F.1 Estimated qualitative Fish Integrity Category



	IFR 1	IFR2	IFR 3	IFR 4
■ QUALITATIVE INTEGRITY RATINGS (% OF TOTAL)	65.7	62.9	65.7	65.7
Native species richness	5	5	5	5
Presence of native intolerant species	5	5	4	5
Abundance of native species	2	2	4	3
Frequency of occurrence of native	4	3	3	2
Health/condition of native & introduced species	3	3	3	4
Presence of introduced fish species	2	2	2	2
In-stream habitat modification	2	2	2	2

RESOURCE UNIT (-----> FLOW DIRECTION)

F.2 DISCHARGE AND HABITAT ABUNDANCE

Table F.2 Matrix of discharge against habitat abundance for IFR 2

Discharge *Q* (m^3/s)	Habitat type abundance			
	FD	**FS**	**SD**	**SS**
0	0	0	2	2
0.05	0	0	3	2
0.1	0	1	4	3
0.17	1	1	4	3
0.36	2	2	4	4
1	3	3	5	4

Table F.3 Matrix of discharge against habitat abundance for IFR 3

Discharge *Q* (m^3/s)	Habitat type abundance			
	FD	**FS**	**SD**	**SS**
0.03	0	1	5	4
0.16	1	2	5	5
0.47	3	3	5	5
1.04	4	4	5	5
3.8	5	5	5	5

Table F.4 Matrix of discharge against habitat abundance for IFR 4

Discharge Q (m^3/s)	Rapid			Habitat type abundance			
	y	y_{av}	*v*	FD	FS	SD	SS
0.08	0.3	0.16	0.05	0	1	4	4
0.24	0.41	0.23	0.1	1	2	4	4
0.55	0.05	0.3	0.13	2	3	5	5
1.10	0.62	0.28	0.2	4	4	5	5
2.55	0.77	0.35	0.3	5	5	5	5

y = flow depth (m), y_{av} = average flow depth (m), v = average velocity (m/s)
Grey fill: flow experienced

F.3 FLOW DEPTH CLASSES

IFR 1: Klipplaat River

RELATIVE FLOW-DEPTH RATING:0=NONE;1=RARE;2=SPARSE;3=MODERATE;4=ABUNDANT;5=VERY ABUNDANT							
FAST DEEP	4	FAST SHALLOW	4	SLOW DEEP	5	SLOW SHALLOW	3
COVER TYPES ASSOCIATED WITH EACH FLOW-DEPTH CLASS							
Overhanging vegetation:	0	Overhanging vegetation:	0	Overhanging vegetation:	4	Overhanging vegetation:	3
Undercut banks & root wads:	2	Undercut banks & root wads:	1	Undercut banks & root wads:	4	Undercut banks & root wads:	1
Substrate:	4	Substrate:	4	Substrate:	4	Substrate:	4
Water Column:	1	Water Column:	0	Water Column:	3	Water Column:	0
Aquatic macrophytes:	2	Aquatic macrophytes:	2	Aquatic macrophytes:	3	Aquatic macrophytes:	3
Remarks:		Remarks:		Remarks:		Remarks:	
Approx Width classes: 1-2m=1; 2-4m=2; 4-8m=3; 8-10m=4; 10-15m=5; >15m=6	3	Approx Width classes: 1-2m=1; 2-4m=2; 4-8m=3; 8-10m=4; 10-15m=5; >15m=6	3	Approx Width classes: 1-2m=1; 2-4m=2; 4-8m=3; 8-10m=4; 10-15m=5; >15m=6		Approx Width classes: 1-2m=1; 2-4m=2; 4-8m=3; 8-10m=4; 10-15m=5; >15m=6	3

IFR 2: Upper Black Kei River

RELATIVE FLOW-DEPTH RATING:0=NONE;1=RARE;2=SPARSE;3=MODERATE;4=ABUNDANT;5=VERY ABUNDANT)							
FAST DEEP	3	FAST SHALLOW	4	SLOW DEEP	4	SLOW SHALLOW	2
COVER TYPES ASSOCIATED WITH EACH FLOW-DEPTH CLASS							
Overhanging vegetation:	1	Overhanging vegetation:	3	Overhanging vegetation:	3	Overhanging vegetation:	2
Undercut banks & root wads:	1	Undercut banks & root wads:	2	Undercut banks & root wads:	2	Undercut banks & root wads:	2
Substrate:	4	Substrate:	4	Substrate:	1	Substrate:	3
Water Column:	1	Water Column:	0	Water Column:	2	Water Column:	0
Aquatic macrophytes:	2	Aquatic macrophytes:	3	Aquatic macrophytes:	1	Aquatic macrophytes:	3
Remarks:		Remarks:		Remarks:		Remarks:	
Approx Width classes: 1-2m=1; 2-4m=2; 4-8m=3; 8-10m=4; 10-15m=5; >15m=6	3	Approx Width classes: 1-2m=1; 2-4m=2; 4-8m=3; 8-10m=4; 10-15m=5; >15m=6	3	Approx Width classes: 1-2m=1; 2-4m=2; 4-8m=3; 8-10m=4; 10-15m=5; >15m=6	5	Approx Width classes: 1-2m=1; 2-4m=2; 4-8m=3; 8-10m=4; 10-15m=5; >15m=6	3

IFR 3: Black Kei River

RELATIVE FLOW-DEPTH RATING:0=NONE;1=RARE;2=SPARSE;3=MODERATE;4=ABUNDANT;5=VERY ABUNDANT)							
FAST DEEP	1	FAST SHALLOW	3	SLOW DEEP	5	SLOW SHALLOW	5
COVER TYPES ASSOCIATED WITH EACH FLOW-DEPTH CLASS							
Overhanging vegetation:	1	Overhanging vegetation:	1	Overhanging vegetation:	2	Overhanging vegetation:	1
Undercut banks & root wads:	1	Undercut banks & root wads:	1	Undercut banks & root wads:	5	Undercut banks & root wads:	2
Substrate:	2	Substrate:	3	Substrate:	4	Substrate:	2
Water Column:	1	Water Column:	0	Water Column:	3	Water Column:	0
Aquatic macrophytes:	2	Aquatic macrophytes:	2	Aquatic macrophytes:	4	Aquatic macrophytes:	3
Remarks:		Remarks:		Remarks:		Remarks:	
Approx Width classes: 1-2m=1; 2-4m=2; 4-8m=3; 8-10m=4; 10-15m=5; >15m=6	6	Approx Width classes: 1-2m=1; 2-4m=2; 4-8m=3; 8-10m=4; 10-15m=5; >15m=6	6	Approx Width classes: 1-2m=1; 2-4m=2; 4-8m=3; 8-10m=4; 10-15m=5; >15m=6	6	Approx Width classes: 1-2m=1; 2-4m=2; 4-8m=3; 8-10m=4; 10-15m=5; >15m=6	6

IFR 4: White Kei River

RELATIVE FLOW-DEPTH RATING:0=NONE;1=RARE;2=SPARSE;3=MODERATE;4=ABUNDANT;5=VERY ABUNDANT)							
FAST DEEP	4	FAST SHALLOW	5	SLOW DEEP	5	SLOW SHALLOW	5
COVER TYPES ASSOCIATED WITH EACH FLOW-DEPTH CLASS							
Overhanging vegetation:	3	Overhanging vegetation:	2	Overhanging vegetation:	2	Overhanging vegetation:	2
Undercut banks & root wads:	3	Undercut banks & root wads:	2	Undercut banks & root wads:	2	Undercut banks & root wads:	2
Substrate:	3	Substrate:	1	Substrate:	1	Substrate:	1
Water Column:	2	Water Column:	0	Water Column:	3	Water Column:	0
Aquatic macrophytes:	2	Aquatic macrophytes:	3	Aquatic macrophytes:	2	Aquatic macrophytes:	3
Remarks:		Remarks:		Remarks:		Remarks:	
Approx Width classes: 1-2m=1; 2-4m=2; 4-8m=3; 8-10m=4; 10-15m=5; >15m=6	5	Approx Width classes: 1-2m=1; 2-4m=2; 4-8m=3; 8-10m=4; 10-15m=5; >15m=6	5	Approx Width classes: 1-2m=1; 2-4m=2; 4-8m=3; 8-10m=4; 10-15m=5; >15m=6	6	Approx Width classes: 1-2m=1; 2-4m=2; 4-8m=3; 8-10m=4; 10-15m=5; >15m=6	3

F.4 HABITAT SUITABILITY AND DERIVED FISH STRESS

Table F.5 Klipplaat River – IFR 1

FISH SPECIES RESPONSES: HABITAT SUITABILITY FOR DIFFERENT LIFE-STAGE REQUIREMENTS					
Rheophilic spp =		Semi-rheophilic spp=	*B. aeneus*	Non-rheophilic spp=	*B. anoplus*
Breeding and early life-stages=		Breeding and early life-stages=	2	Breeding and early life-stages=	3
Survival /Abundance =		Survival /Abundance =	3	Survival /Abundance =	4
Cover =		Cover =	3	Cover =	4
Health and condition=		Health and condition=	3	Health and condition=	4
Water quality=		Water quality=	4	Water quality=	4
Habitat flow stress response with breeding requirements	10	**Habitat flow stress response with breeding requirements**	4	**Habitat flow stress response with breeding requirements**	2.4
Habitat flow stress response without breeding requirements	10	**Habitat flow stress response without breeding requirements**	3.5	**Habitat flow stress response without breeding requirements**	2

Table F.6 Upper Black Kei River – IFR 2

FISH SPECIES RESPONSES: HABITAT SUITABILITY FOR DIFFERENT LIFE-STAGE REQUIREMENTS					
Rheophilic spp =		Semi-rheophilic spp=	*B. aeneus*	Non-rheophilic spp=	*B. anoplus*
Breeding and early life-stages=		Breeding and early life-stages=	2	Breeding and early life-stages=	3
Survival /Abundance =		Survival /Abundance =	3	Survival /Abundance =	3
Cover =		Cover =	3	Cover =	4
Health and condition=		Health and condition=	3	Health and condition=	4
Water quality=		Water quality=	4	Water quality=	4
Habitat flow stress response with breeding requirements	10	**Habitat flow stress response with breeding requirements**	4	**Habitat flow stress response with breeding requirements**	2.8
Habitat flow stress response without breeding requirements	10	**Habitat flow stress response without breeding requirements**	3.5	**Habitat flow stress response without breeding requirements**	2.5

Table F.7 Black Kei River – IFR 3

FISH SPECIES RESPONSES: HABITAT SUITABILITY FOR DIFFERENT LIFE-STAGE REQUIREMENTS					
Rheophilic spp =		Semi-rheophilic spp=	*B.aeneus*	Non-rheophilic spp=	*B. anoplus*
Breeding and early life-stages=		Breeding and early life-stages=	2	Breeding and early life-stages=	3
Survival /Abundance =		Survival /Abundance =	3	Survival /Abundance =	4
Cover =		Cover =	3	Cover =	4
Health and condition=		Health and condition=	3	Health and condition=	4
Water quality=		Water quality=	4	Water quality=	4
Habitat flow stress response with breeding requirements	10	**Habitat flow stress response with breeding requirements**	4	**Habitat flow stress response with breeding requirements**	2.4
Habitat flow stress response without breeding requirements	10	**Habitat flow stress response without breeding requirements**	3.5	**Habitat flow stress response without breeding requirements**	2

Table F.8 White Kei River – IFR 4

FISH SPECIES RESPONSES: HABITAT SUITABILITY FOR DIFFERENT LIFE-STAGE REQUIREMENTS					
Rheophilic spp =		Semi-rheophilic spp=	*B. aneus*	Non-rheophilic spp=	*B. anoplus*
Breeding and early life-stages=		Breeding and early life-stages=	2	Breeding and early life-stages=	4
Survival /Abundance =		Survival /Abundance =	3	Survival /Abundance =	3
Cover =		Cover =	2	Cover =	4
Health and condition=		Health and condition=	4	Health and condition=	4
Water quality=		Water quality=	3	Water quality=	3
Habitat flow stress response with breeding requirements	10	**Habitat flow stress response with breeding requirements**	4.4	**Habitat flow stress response with breeding requirements**	2.8
Habitat flow stress response without breeding requirements	10	**Habitat flow stress response without breeding requirements**	4	**Habitat flow stress response without breeding requirements**	3

APPENDIX G

Ecological Importance and Sensitivity

TABLE OF CONTENTS

1 IFR 1 – KLIPPLAAT RIVER G-2

2 IFR 2 – BLACK KEI RIVER G-3

3 IFR 3 – BLACK KEI RIVER G-4

4 IFR 4 – WHITE KEI RIVER G-5

G.1 IFR 1 – KLIPPLAAT RIVER

ECOLOGICAL IMPORTANCE AND SENSITIVITY CLASS (EISC)	NATURAL		PRESENT		
DETERMINANTS	**SCORE**	**CONFIDENCE**	**SCORE**	**CONFIDENCE**	**COMMENTS**
BIOTA (RIPARIAN AND INSTREAM)	**(0-4)**		**(0-4)**		
Rare and endangered (range: 4 = very high 0 = none)	0	3	0	3	
Unique (endemic, isolated, etc.) (range: 4 = very high 0 = none)	0	3	0	3	
Intolerant (flow and flow related water quality) (range: 4 = very high 0 = none)	2	3	2	3	Simulids, Trichoratheds; Heptageniidae; Hydropsychidae.
Species/taxon richness (range: 4 = very high 1 = low/marginal)	3	3	3	3	25 taxa are present. These taxa are high on a regional scale.
RIPARIAN AND INSTREAM HABITATS	**(0-4)**		**(0-4)**		**COMMENTS**
Diversity of types (4 = Very high 1 = marginal/low)	2	3	2	3	Pools, overhanging vegetation, riffles, runs, marginal vegetation, undercut banks.
Refugia (4 = Very high - 1 = marginal/low)	1	2	2	3	The importance of the area especially the interstitial spaces and cobbles, diversity of substrate sizes and undercut banks are important refugia with the dam in place.
Sensitivity to flow changes (4 = Very high - 1 = marginal/low)	3	3	3	3	Low flows are going to pull away from the marginal vegetation and there will be a loss of cobbles.
Sensitivity to flow related water quality changes (4 = Very high - 1 = marginal/low)	1	3	2	3	Because of the dam and the releases there is an effect on temp, nutrient and turbidity.
Migration route/corridor (instream & riparian, range: 4 = very high 0 = none)	3	3	1	2	Migration route for eels in natural conditions.
Importance of conservation & natural areas (range, 4 = very high 0 = very low)	0		0	4	
MEDIAN OF DETERMINANTS	1.5		2		
ECOLOGICAL IMPORTANCE AND SENSITIVITY CLASS (EISC)	**MODERATE**		**MODERATE**		

G.2 IFR 2 – BLACK KEI RIVER

ECOLOGICAL IMPORTANCE AND SENSITIVITY CLASS (EISC)	NATURAL		PRESENT		
DETERMINANTS	**SCORE**	**CONFIDENCE**	**SCORE**	**CONFIDENCE**	**COMMENTS**
BIOTA (RIPARIAN AND INSTREAM)	**(0-4)**		**(0-4)**		
Rare and endangered (range: 4 = very high 0 = none)	0	3	0	3	
Unique (endemic, isolated, etc.) (range: 4 = very high 0 = none)	0	3	0	3	
Intolerant (flow and flow related water quality) (range: 4 = very high 0 = none)	2	3	1	3	Small proportion of the invert community is dependent on flow during some of their life stages. Natural for fish, under present condition *B aneus* would be one.
Species/taxon richness (range: 4 = very high 1 = low/marginal)	3	3	2	3	
RIPARIAN AND INSTREAM HABITATS	**(0-4)**		**(0-4)**		**COMMENTS**
Diversity of types (4 = Very high 1 = marginal/low)	2	2	2	3	Pools, rapids, runs and backwaters are present. Marginal and instream vegetation present.
Refugia (4 = Very high - 1 = marginal/low)	1	2	1	2	Pools.
Sensitivity to flow changes (4 = Very high - 1 = marginal/low)	1	2	2	2	Backwaters.
Sensitivity to flow related water quality changes (4 = Very high - 1 = marginal/low)	1	3	2	3	A larger river, fairly well buffered.
Migration route/corridor (instream & riparian, range: 4 = very high 0 = none)	3	3	3	3	
Importance of conservation & natural areas (range, 4 = very high 0 = very low)			1	4	Private natural reserve is present.
MEDIAN OF DETERMINANTS	1		1.5		
ECOLOGICAL IMPORTANCE AND SENSITIVITY CLASS (EISC)	**LOW**		**MODERATE**		

G.3 IFR 3 – BLACK KEI RIVER

ECOLOGICAL IMPORTANCE AND SENSITIVITY CLASS (EISC)	**NATURAL**		**PRESENT**		
DETERMINANTS	**SCORE**	**CONFIDENCE**	**SCORE**	**CONFIDENCE**	**COMMENTS**
BIOTA (RIPARIAN AND INSTREAM)	**(0-4)**		**(0-4)**		
Rare and endangered (range: 4 = very high 0 = none)	0	3	0	3	
Unique (endemic, isolated, etc.) (range: 4 = very high 0 = none)	0	3	0	3	
Intolerant (flow and flow related water quality) (range: 4 = very high 0 = none)	2	3	1	3	Invertebrates are dependant on flow during all life stages: Heptageniidae, Psephenids. Natural for fish, under present condition *B aneus* would be one.
Species/taxon richness (range: 4 = very high 1 = low/marginal)	3	3	2	3	
RIPARIAN AND INSTREAM HABITATS	**(0-4)**		**(0-4)**		**COMMENTS**
Diversity of types (4 = Very high 1 = marginal/low)	3	2	3	3	Pools, rapids, runs, backwaters, riffles are present. Marginal and instream vegetation present, undercut banks.
Refugia (4 = Very high - 1 = marginal/low)	2	3	2	3	Pools.
Sensitivity to flow changes (4 = Very high - 1 = marginal/low)	2	2	3	2	Backwaters.
Sensitivity to flow related water quality changes (4 = Very high - 1 = marginal/low)	1	3	2	3	A larger river, well buffered.
Migration route/corridor (instream & riparian, range: 4 = very high 0 = none)	3	3	3	3	
Importance of conservation & natural areas (range, 4 = very high 0 = very low)			1	4	Gorge.
MEDIAN OF DETERMINANTS	2		2		
ECOLOGICAL IMPORTANCE AND SENSITIVITY CLASS (EISC)	**MODERATE**		**MODERATE**		

G.4 IFR 4 – WHITE KEI RIVER

ECOLOGICAL IMPORTANCE AND SENSITIVITY CLASS (EISC)	NATURAL		PRESENT		
DETERMINANTS	**SCORE**	**CONFIDENCE**	**SCORE**	**CONFIDENCE**	**COMMENTS**
BIOTA (RIPARIAN AND INSTREAM)	**(0-4)**		**(0-4)**		
Rare and endangered (range: 4 = very high 0 = none)	0	3	0	3	
Unique (endemic, isolated, etc.) (range: 4 = very high 0 = none)	0	3	0	3	
Intolerant (flow and flow related water quality) (range: 4 = very high 0 = none)	2	3	2	3	Natural for fish, under present condition *B aneus* would be one.
Species/taxon richness (range: 4 = very high 1 = low/marginal)	3	3	2	3	
RIPARIAN AND INSTREAM HABITATS	**(0-4)**		**(0-4)**		**COMMENTS**
Diversity of types (4 = Very high 1 = marginal/low)	2	2	2	3	Pools, rapids, runs, backwaters, riffles are present. Undercut banks. Alluvial stretches are present.
Refugia (4 = Very high - 1 = marginal/low)	2	3	2	3	Pools.
Sensitivity to flow changes (4 = Very high - 1 = marginal/low)	3	2	2	2	Natural wider system.
Sensitivity to flow related water quality changes (4 = Very high - 1 = marginal/low)	1	3	2	3	Large river, well buffered.
Migration route/corridor (instream & riparian, range: 4 = very high 0 = none)	3	3	2	3	
Importance of conservation & natural areas (range, 4 = very high 0 = very low)			1	4	Gorge.
MEDIAN OF DETERMINANTS	2		2		
ECOLOGICAL IMPORTANCE AND SENSITIVITY CLASS (EISC)	**MODERATE**		**MODERATE**		

APPENDIX H

LOW FLOW REQUIREMENTS AND FLOOD CLASSES

TABLE OF CONTENTS

1 IFR 1: LOW FLOWS H-2
1.1 Aquatic invertebrates: Flow dependent H-2
1.2 Fish: Eurytopic and Limnophilic fish species H-3
1.3 Riparian vegetation H-4

2 IFR 1 – HIGH FLOWS H-5
2.1 IFR 1 – Class I H-5
2.2 IFR 1 – Class II H-6
2.3 IFR 1 – Class III H-7
2.4 IFR 1 – Class IV H-7

3 IFR 2: LOW FLOWS H-8
3.1 Aquatic invertebrates: Marginal vegetation H-8
3.2 Fish: Eurytopic and Limnophilic fish species H-9

4 IFR 2 – HIGH FLOWS H-10
4.1 IFR 2 – Class I H-10
4.2 IFR 2 - Class II H-11
4.3 IFR 2 - Class III H-12
4.4 IFR 2 - Class IV H-12
4.5 IFR 2 - Class V H-13

5 IFR 3: LOW FLOWS H-14
5.1 Invertebrates: Flow dependent H-14
5.2 Fish: Eurytopic and Limnophilic fish species H-15

6 IFR 3: HIGH FLOWS H-16
6.1 IFR 3 - Class I H-16
6.2 IFR 3 - Class II: H-17
6.3 IFR 3 - Class III H-18
6.4 IFR 3 - Class IV H-18

7 IFR 4: LOW FLOWS H-19
7.1 Invertebrates: Flow dependent H-19
7.2 Fish: Eurytopic and Limnophilic fish species H-20

8 IFR 4: HIGH FLOWS H-21
8.1 IFR 4 - Class I H-21
8.2 IFR 4 – Class II H-22
8.3 IFR 4 – Class III H-22
8.4 IFR 4 – Class IV H-23
8.5 IFR 4 – Class V H-23

H.1 IFR 1: LOW FLOWS

H.1.1 AQUATIC INVERTEBRATES: FLOW DEPENDENT

Species stress	Critical stress	Recommended EC C and Alternative EC B/C (Inverts B)				Alternative EC D (Inverts C)			
		Dry season requirements		Wet season requirements		Dry season requirements		Wet season requirements	
		Dur (%)	Comment	Dur (%)	Comment	Dur (%)	Comment	Dur (%)	Comment
0	0.5							80	Providing optimal flow habitat for approx 1 month to enable rheophilic community to optimise abundance.
0	0.5					9%	This is required chiefly to 'flush' algae and fines and renew habitat.		
1	1.8								
2	4								
3	4.6								
4	5			10	Maintain full community of FD taxa over summer.			20	Maintain flow dependent community.
5	6.1								
6	7.5	20	Sufficient flow depth for the majority of winter to maintain overwintering populations Ephemeropterans, Trichopterans and Simuliids.			30	Sufficient flow depth for the majority of winter to maintain overwintering populations Trichopterans and Simuliids.		
8	9.2								
9	9.5	10	Period of no flow may have slight effects on diversity of FD taxa and allow more resilient taxa to thrive.	5	Short period of no flow will not adversely affect diversity but will reduce abundance and possibly allow for more resilient taxa to thrive.	10	Period of no flow may have slight effects on diversity of FD taxa and allow more resilient taxa to thrive.	5	Short period of no flow will not adversely affect diversity but will reduce abundance and possibly allow for more resilient taxa to thrive.

H.1.2 FISH: EURYTOPIC AND LIMNOPHILIC FISH SPECIES

Species stress	Critical stress	Recommended EC C (Fish C/D)				Alternative EC B/C (Fish C)				Alternative EC D (Fish D)			
		Dry season requirements		Wet season requirements		Dry season requirements		Wet season requirements		Dry season requirements		Wet season requirements	
		Dur (%)	Comment	Dur (%)	Comment	Dur (%)	Comment	Dur (%)	Comment	Dur (%)	Comment	Dur (%)	Comment
0	0	98		80		85		70		98		85	
2	2	90	Some habitats limiting, reduced cover and increased predation.	70	Some habitats limiting, reduced cover and increased predation.	80	Some habitats limiting, reduced cover and increased predation.	60	Some habitats limiting, reduced cover and increased predation.	95	Some habitats limiting, reduced cover and increased predation.	80	Some habitats limiting, reduced cover and increased predation.
4	4	85	Less suitable habitat available, predation increased.	50	Less suitable habitat available, fish breeding less successful as lack of backwaters and cover for larvae.	70	Less suitable habitat available, predation increased.	40	Less suitable habitat available, fish breeding less successful as lack of backwaters and cover for larvae.	90	Less suitable habitat available, predation increased.	60	Less suitable habitat available, fish breeding less successful as lack of backwaters and cover for larvae.
5	5	80		30		55		20		85		40	
6	9.2	30	Little suitable habitat, very limited for all fish, very high predation.	15	Little suitable habitat, no habitat for larvae, limited for adults.	30	Little suitable habitat, very limited for all fish, very high predation.	10	Little suitable habitat, no habitat for larvae, limited for adults.	60	Little suitable habitat, very limited for all fish, very high predation.	20	Little suitable habitat, no habitat for larvae, limited for adults.
7	9.5	10	Fish confined to pools, only adults left, water quality affected.	10	Fish confined to pools, only adults, water quality affected.	15	Fish confined to pools, only adults left, water quality affected.	5	Fish confined to pools, only adults, water quality affected.	30	Fish confined to pools, only adults left, water quality affected.	10	Fish confined to pools, only adults, water quality affected
9	10		Only few fish surviving in stagnant pools.	5	Only few fish surviving in stagnant pools.	10	Only few fish surviving in stagnant pools.	5	Only few fish surviving in stagnant pools.	10	Only few fish surviving in stagnant pools.	5	Only few fish surviving in stagnant pools
10	10					0		0					

H.1.3 RIPARIAN VEGETATION

Species stress	Critical stress	Recommended EC C and Alternative EC D (Vegetation D)				Alternative EC B/C (Vegetation C)			
		Dry season requirements		Wet season requirements		Dry season requirements		Wet season requirements	
		Dur (%)	Comment	Dur (%)	Comment	Dur (%)	Comment	Dur (%)	Comment
0	0	90		68		80		60	
2	5	75	Abundant growth and flowering.	8	Abundant growth and flowering.	60	Abundant growth and flowering.	8	Abundant growth and flowering.
5	5.8	55	Thinning and reproduction impairment.	7	Thinning and reproduction impairment.	30	Thinning and reproduction impairment.	5	Thinning and reproduction impairment.
8	8	10	Death of above ground biomass.	5	Death of above ground biomass.	5	Death of above ground biomass.	3	Death of above ground biomass.
10	10	7		5		4		2	

H.2 IFR 1 – HIGH FLOWS

H.2.1 IFR 1 – CLASS I

FLOOD CLASS I – 1 - 7m^3/s				Recommended EC C			Alternative EC D			A Alternative EC B/C		
				Fish C/D; Inverts B; Rip veg D			Fish D; Inverts C Rip veg C			Fish C; Inverts B Rip veg C		
Com.	**Function/s (what does it have to do)**	**Description (what is the flood characteristic that does that)**	**Season**	**No of events**	**Frequency**	**Reasoning**	**No of events**	**Frequency**	**Reasoning**	**No of events**	**Frequency**	**Reasoning**
Inverts	Flush out fines and algae. Inundate brushside marginal vegetation thereby increasing the extent of the marginal vegetation habitat for breeding and emergence.		Spring Summer	5	Per year	Breeding and emergence cues. Optimisation of flow dependent invertebrate abundance and diversity.	3	Per year	Breeding and emergence cues. Optimisation of flow dependent invertebrate abundance and diversity.	5	Per year	Breeding and emergence cues. Optimisation of flow dependent invertebrate abundance and diversity.
Fish	Flush out riffle spawning areas. Create suitable spawning habitat for *B aeneus*. Riffles > 30cm area depth. Flood into vegetation for *B. aeneus* spawning. Backwater areas for larvae of both species. Allow depth > 30cm over shallow riffles for migration of *B. aeneus* and eels.	1. – 2.0 m^3/s	Summer Oct to Mar Apr	5		Higher risk of breeding failure with reduced number of events. Higher floods create suitable spawning habitat up to a point.	4	Summer Oct to Mar Apr	Higher risk of breeding failure with reduced number of events. Higher floods create suitable spawning habitat up to a point.	6	Summer Oct to Mar Apr	Higher risk of breeding failure with reduced number of events. Higher floods create suitable spawning habitat up to a point.
Rip veg	Marginal zone maintenance by inundation of marginal zone and provision of sediments and nutrients to marginal species.	Reaches and inundates lower terrace on Left Bank (elevation 0.6m) and covers upper edge of riparian zone. Activates the secondary channel on the left bank.	Spring Summer	5		Maintain the existing status of D category.				7		Improve status to a category higher; C category; by extending the extent and health of marginal vegetation in marginal zone.
Geom.	Maintenance of bed form, keep bed clean of fines in summer.	Depth: 0.4 – 0.6m Velocity: 0.43 – 0.85m^3/s	Wet	4								

H.2.2 IFR 1 – CLASS II

FLOOD CLASS II - 7 – 15m³/s				Recommended EC C			Alternative EC D			A Alternative EC B/C		
				Fish C/D; Inverts B; Rip veg D			Fish D; Inverts C Rip veg C			Fish C; Inverts B Rip veg C		
Com.	**Function/s (what does it have to do)**	**Description (what is the flood characteristic that does that)**	**Season**	**No of events**	**Frequency**	**Reasoning**	**No of events**	**Frequency**	**Reasoning**	**No of events**	**Frequency**	**Reasoning**
Inverts	Scour pools. Flush out sand from interstitial spaces renewing SIC habitat. Distribution of invertebrates longitudinally by drift.		Summer	1	Per year	Repositioning of coarse substrate cleaning fines and organics out of the channel. Inundating bankside areas where eggs may be present.	3	Per year	Repositioning of coarse substrate cleaning fines and organics out of the channel. Inundating bankside areas where eggs may be present.	1	Per year	Repositioning of coarse substrate cleaning fines and organics out of the channel. Inundating bankside areas where eggs may be present.
Fish	Larger floods have similar effects as Class I but to a greater degree. More suitable habitat for both spawning and larval rearing of both species. Allow migration over "depauperate" rapids and riffles when inundated. Backwater is flooded completely.	2 – 4.0 m^3/s	Summer Oct – Mar Apr									
Rip veg	Maintenance of the lower riparian zone by provision of water and nutrients and deposition of sediments and seeds/propogules.	Reaches higher terrace on left bank and right bank Elevation: 0.8m	Summer	3		Maintain the existing status of D category				3		Improve status to a category higher; C category; by maintaining the status of the lower riparian zone.
Geom.	Bench/Flood terrace maintenance. Flow to overtop and deposit sediments.	Depth: 0.75 – 0.9m Velocity: 1.03 – 1.24m^3/s	Wet	3								

H.2.3 IFR 1 – CLASS III

FLOOD CLASS III - 15 - 45 m³/s				Recommended EC C Fish C/D; Inverts B; Rip veg D			Alternative EC D Fish D; Inverts C Rip veg C			A Alternative EC B/C Fish C; Inverts B Rip veg C		
Com.	**Function/s (what does it have to do)**	**Description (what is the flood characteristic that does that)**	**Season**	**No of events**	**Frequency**	**Reasoning**	**No of events**	**Frequency**	**Reasoning**	**No of events**	**Frequency**	**Reasoning**
Fish	This class flood is not as important for fish as the maintenance of the habitat.		Summer	1								
Rip Veg	Maintenance of middle riparian zone by provision of water and nutrients and deposition of sediments, seeds and propogules.	Reactivate upper riparian terraces on right bank. Elevation: 1.3m	Summer	1								Improve status to a category higher; C category; by maintaining the status of the middle riparian zone.
Geom	Active channel maintenance and keep active channel open and clean to the boundaries. Maintain sediment dynamics.	Depth: 1 – 1.2m Velocity: 1.42 – 1.78 m^3/s	Wet	1						1		

H.2.4 IFR 1 – CLASS IV

FLOOD CLASS IV – 45 - 65m³/s				Recommended EC C Fish C/D; Inverts B; Rip veg D			Alternative EC D Fish D; Inverts C Rip veg C			A Alternative EC B/C Fish C; Inverts B Rip veg C		
Com.	**Function/s (what does it have to do)**	**Description (what is the flood characteristic that does that)**	**Season**	**No of events**	**Frequency**	**Reasoning**	**No of events**	**Frequency**	**Reasoning**	**No of events**	**Frequency**	**Reasoning**
Geom	Maintenance of the macro channel. Flow to overtop banks and fill the macro channel.	Depth: 1.3 – 1.5m Velocity: 1.99 – 2.42 m^3/s	Wet	1:5								

H.3 IFR 2: LOW FLOWS

H.3.1 AQUATIC INVERTEBRATES: MARGINAL VEGETATION

Species stress	Critical stress	Recommended EC D (Inverts D)				Recommended EC C (Inverts C)			
		Dry season requirements		Wet season requirements		Dry season requirements		Wet season requirements	
		Dur (%)	Comment	Dur (%)	Comment	Dur (%)	Comment	Dur (%)	Comment
1	1	80	Inundate MV stems for up to 20% of the time.	60	Provide substantial habitat for the MV community for feeding, breeding and shelter.	75	If flows are maintained in general and increased over short durations, it is likely that greater expanses of usable habitat will become available and recruitment of FD species and non- is possible. Diversity of FD and MV taxa should increase, and overall.	50	
	1.7								
3	3								
4	4							27	Provide well-oxygenated flow through MV over the majority of time through summer to provide substantial habitat for breeding, feeding, and shelter, and also to reduce algal density.
5 derived		60	Flows to inundate small areas of veg stems and to provide depth over mobile cobble substrate for 40% of the time	20	Provide well-oxygenated flow through MV over the majority of time through summer to provide substantial habitat for breeding, feeding, and shelter, and also to reduce algal density.	50	Flows to inundate small areas of veg stems and to provide depth over mobile cobble substrate for 80% of the time.		
6	6								
	8 derived			5	Only allow flow trickle (close to cessation) during extreme droughts. MV invertebrates are likely to colonise pools or GSM areas during these periods.			5	Only allow flow trickle (close to cessation) during extreme droughts. MV invertebrates are likely to colonise pools or GSM areas during these periods.
9	9	10	Flow cessation for up to 10% of time (can be continuous). This may reduce community diversity or abundance up to with resilient species remaining and possibly becoming dominant.			10	Flow cessation for up to 10% of time (can be continuous). This may reduce community diversity or abundance up to with resilient species remaining and possibly becoming dominant.		
10									

H.3.2 FISH: EURYTOPIC AND LIMNOPHILIC FISH SPECIES

Species stress	Critical stress	Recommended EC D (Fish D)				Alternative EC C (Fish C)			
		Dry season requirements		Wet season requirements		Dry season requirements		Wet season requirements	
		Dur (%)	Comment	Dur (%)	Comment	Dur (%)	Comment	Dur (%)	Comment
2	2.4	85	Some habitats limiting, reduced cover and increased predation.	50	Some habitats limiting, reduced cover and increased predation.	75	Some habitats limiting, reduced cover and increased predation.	35	Some habitats limiting, reduced cover and increased predation.
3	3.5	75	Less suitable habitat available, fish breeding less successful.	45	Less suitable habitat available, fish breeding less successful.	60	Less suitable habitat available, fish breeding less successful.	30	Less suitable habitat available, fish breeding less successful.
4	6.5	60	Even less suitable habitat, *B. aeneus*. Breeding seriously impacted.	30	Even less suitable habitat, *B. aeneus*. Breeding seriously impacted.	45	Even less suitable habitat, *B. aeneus*. Breeding seriously impacted.	20	Even less suitable habitat, *B. aeneus*. Breeding seriously impacted.
6	8	55	Little suitable habitat, no riffles for breeding.	20	Little suitable habitat, no riffles for breeding.	30	Little suitable habitat, no riffles for breeding.	10	Little suitable habitat, no riffles for breeding.
7	8.8	40	Fish confined to pools, only adults, water quality affected.	10	Fish confined to pools, only adults, water quality affected.	20	Fish confined to pools, only adults, water quality affected.	5	Fish confined to pools, only adults, water quality affected.
9	9.5	8	Only few fish surviving in stagnant pools.	8	Only few fish surviving in stagnant pools.	8	Only few fish surviving in stagnant pools.	8	Only few fish surviving in stagnant pools.
10	10	0		0		0		0	

H.4 IFR 2 – HIGH FLOWS

H.4.1 IFR 2 – CLASS I

FLOOD CLASS I - 1.5 - 3m^3/s				Recommended EC D			Alternative EC C		
				Fish D; Inverts D; Rip veg C/D			Fish C; Inverts C; Rip veg B/C		
Com.	**Function/s (what does it have to do)**	**Description (what is the flood characteristic that does that)**	**Season**	**No of events**	**Frequency**	**Reasoning**	**No of events**	**Frequency**	**Reasoning**
Inverts	Flush out fines. Cue for breeding/emergence.		Late winter	2	Per year	To maintain reasonably clear surfaces in SIC and prevent further embeddedness.	3	Per year	As for EC D, increases confidence in cueing for breeding and emergence. Improvement of general condition in pools as well as SIC and marginal vegetation.
			Late Summer	2	Per year	Cue relevant taxa for emergence or for breeding.	3	Per year	
Fish	Flush out riffle areas and create suitable spawning habitat for *Barbus aeneus*, flood vegetation for spawning habitat for B. anoplus. Create backwater areas for larval development of both species. Allow sufficient depth for migration of eels, and *B. aeneus* upstream over shallow riffle and rapids	1.5 to 2.0 m^3/s	Summer Oct to March	2		Only limited suitable habitat created, low number of events means high risk of failure and limited breeding success Few chances for migration	3		Same as for EC D, but more suitable habitat for spawning and larval rearing created, more opportunities for migration
Rip veg	Maintain marginal vegetation and marginal zone by the provision of water and nutrients to marginal vegetation.	Floods marginal zone several times a year and inundates all marginal zone species to crown level.	Spring Summer	3 - 5	Evenly in summer	Maintain existing distribution of marginal vegetation.	6		Improve water availability to the marginal zone and increase its distribution.
Geom.	Maintain present bed form.	Depth: 0.8 – 1.1m Velocity: 0. – 1.07 m/s		Wet	4				

H.4.2 IFR 2 - CLASS II

FLOOD CLASS II - 2.5 – 12m^3/s				Recommended EC D Fish D; Inverts D; Rip veg C/D			Alternative EC C Fish C; Inverts C; Rip veg B/C		
Com.	**Function/s (what does it have to do)**	**Description (what is the flood characteristic that does that)**	**Season**	**No of events**	**Frequency**	**Reasoning**	**No of events**	**Frequency**	**Reasoning**
Inverts	Inundate bankside marginal vegetation, allow flow through pools to clean bottom sediments and oxygenate. Inundate side channels. Breeding cues.								
Fish	Flush out riffle areas and create suitable spawning habitat for *Barbus aeneus*, flood vegetation for spawning habitat for *B. anoplus*. Create backwater areas for larval development of both species. Allow sufficient depth for migration of eels, and *B. aeneus* upstream over shallow riffle and rapids	2.5 to 10 m^3/s	Summer Oct to March	1		Limited suitable habitat created, increased number of events means moderate risk of failure and moderate breeding success Few chances for migration	3		Same as for Category D, but more suitable habitat for spawning and larval rearing created, more opportunities for migration
Rip veg	Maintain lower riparian vegetation zone vegetation by the provision of water and nutrients.	Floods the marginal zone and lower riparian zone and inundates the rooting zone for herbaceous and woody species.	Spring and summer	2 - 3	Evenly in summer	Inundate existing vegetation in the lower riparian zone.	3		Encourage the recovery of riparian vegetation in the lower riparian zone.

H.4.3 IFR 2 - CLASS III

FLOOD CLASS III - 12 - 30m³/s				Recommended EC D Fish D; Inverts D; Rip veg C/D			Alternative EC C Fish C; Inverts C; Rip veg B/C		
Com.	**Function/s (what does it have to do)**	**Description (what is the flood characteristic that does that)**	**Season**	**No of events**	**Frequency**	**Reasoning**	**No of events**	**Frequency**	**Reasoning**
Rip veg	Maintain middle riparian zone vegetation by the provision of water and nutrients, the removal of debris and deposit seeds and propogules.	Floods the marginal, lower and middle riparian zones and provides nutrients, water etc. to woody vegetation. Velocity: 1.99 – 2.42 m/s	Summer	1	Summer	To maintain existing riparian plants in the middle riparian zone.	1		To maintain, and encourage the recovery of new riparian plants in the middle riparian zone.
Geom.	Flood bench maintenance of present form i.e. entrain bed load sediment and deposit over banks.	Depth: 1.1 – 1.3m Velocity: 1.07 – 1.37 m/s	Wet	3			3		

H.4.4 IFR 2 - CLASS IV

FLOOD CLASS IV - 22 - 50m³/s				Recommended EC D Fish D; Inverts D; Rip veg C/D			Alternative EC C Fish C; Inverts C; Rip veg B/C		
Com.	**Function/s (what does it have to do)**	**Description (what is the flood characteristic that does that)**	**Season**	**No of events**	**Frequency**	**Reasoning**	**No of events**	**Frequency**	**Reasoning**
Geom	Channel maintenance: Keep channel area open and clean. Roll bed material. Entrain material. Scour and deposit on higher terraces	Depth: 1.3 – 1.6m Velocity: 1.37 – 1.95 m/s	Wet	1			1		

H.4.5 IFR 2 - CLASS V

FLOOD CLASS V - 50 - 130m³/s				RECOMMENDED EC D SCENARIO EVALUATION Fish D; Inverts D; Rip veg C/D			ALTERNATIVE SCENARIO EC C SCENARIO EVALUATION Fish C; Inverts C; Rip veg B/C		
Com.	**Function/s (what does it have to do)**	**Description (what is the flood characteristic that does that)**	**Season**	**No of events**	**Frequency**	**Reasoning**	**No of events**	**Frequency**	**Reasoning**
Geom	Macro channel maintenance: Fill macro channel. Deposit sediments. Scour bed and banks. Roll material.	Depth: 1.63 –2m Velocity: 1.95 – 3.06 m/s	Wet	1	Every 5 years		1	Every 5 years	

H.5 IFR 3: LOW FLOWS

H.5.1 INVERTEBRATES: FLOW DEPENDENT

Species stress	Critical stress	Recommended EC C/D (inverts C/D)				Alternative EC B/C (Inverts B/C)				Alternative EC D (Inverts D)			
		Dry season requirements		Wet season requirements		Dry season requirements		Wet season requirements		Dry season requirements		Wet season requirements	
		Dur (%)	Comment	Dur (%)	Comment	Dur (%)	Comment	Dur (%)	Comment	Dur (%)	Comment	Dur (%)	Comment
0	0.5												
1	1.2	80	Flushing of fines and algae, increased velocity over SIC for a short period.	50	Inundation of MV, provision of fast flow for FDIs.	70	Flushing of fines and algae, increased velocity over SIC for a short period.	40	Inundation of MV, provision of fast flow for sensitive FDIs, flushing of fines.			70	Short periods of fast flow for target spp, and inundation of MV.
5	5	50	Provision of adequate habitat for overwintering populations.	25	Maintenance of FD species.	60	Provide adequate flows to sustain community with sensitive FDIs.	20	Maintenance and optimisation of FD spp.	70	Provide adequate flows to maintain target spp over winter.	40	Maintenance of target spp.
8	8					30	Trickling flows mostly for oxygenation.			40	Trickling flows mostly for oxygenation.		
		20	Loss of flow during dry season may reduce diversity and allow increase of less sensitive taxa.	10	Loss of flow during droughts is sustainable for most of community.	20	Loss of flow during dry season may reduce diversity and allow increase of less sensitive taxa.	10	Loss of flow during droughts is sustainable for most of community.	20	Loss of flow during dry season may reduce diversity and allow increase of less sensitive taxa.	10	Loss of flow during droughts is sustainable for most of community.

H.5.2 FISH: EURYTOPIC AND LIMNOPHILIC FISH SPECIES

Species stress	Critical stress	Recommended EC C/D and Alternative EC D (Fish D)				Alternative EC C (Fish C)			
		Dry season requirements		Wet season requirements		Dry season requirements		Wet season requirements	
		Dur (%)	Comment	Dur (%)	Comment	Dur	Comment	Dur	Comment
0	0	90	All suitable habitats in abundance for all size classes and fish species.	60	All suitable habitats in abundance for all size classes and fish species, as well as suitable breeding and larval rearing habitat available for all species.	80	All suitable habitats in abundance for all size classes and fish species.	45	All suitable habitats in abundance for all size classes and fish species, as well as suitable breeding and larval rearing habitat available for all species
1	1	85	Some habitats limiting, reduced cover and increased predation.	50	Some habitats limiting, reduced cover and increased predation, some good spawning habitat left.	75	Some habitats limiting, reduced cover and increased predation.	40	Some habitats limiting, reduced cover and increased predation, some good spawning habitat left.
3	3	78		45		65		35	
5	5	60	Few suitable habitats for small fish, high predation, very reduced larval fish cover and habitat, fish numbers drastically reduced.	35	Few suitable habitats for small fish, high predation, very reduced larval fish cover and habitat, very limited fish spawning habitat available fish numbers drastically reduced.	45	Few suitable habitats for small fish, high predation, very reduced larval fish cover and habitat, fish numbers drastically reduced.	25	Few suitable habitats for small fish, high predation, very reduced larval fish cover and habitat, very limited fish spawning habitat available fish numbers drastically reduced.
7	9.5	5	Very little suitable habitat for all size classes, predation high, water quality problems, fish numbers very low.	30	Very little suitable habitat for all size classes, predation high, water quality problems, no fish spawning habitats, fish numbers very low.	30	Very little suitable habitat for all size classes, predation high, water quality problems, fish numbers very low.	20	Very little suitable habitat for all size classes, predation high, water quality problems, no fish spawning habitats, fish numbers very low.
9	10	5	Only refuge pools, poor water quality, numbers of fish almost nil.	10	Only refuge pools, poor water quality, numbers of fish almost nil.	5	Only refuge pools, poor water quality, numbers of fish almost nil.	10	Only refuge pools, poor water quality, numbers of fish almost nil.
10	10								

H.6 IFR 3: HIGH FLOWS

H.6.1 IFR 3 - CLASS I

FLOOD CLASS I - 2.5 – 8m³/s				Recommended EC C/D Fish D; Inverts C/D; Rip veg C			Alternative EC D Fish D; Inverts D; Rip veg D			Alternative EC B/C Fish C; Inverts B/C Rip veg B/C		
Com.	**Function/s (what does it have to do)**	**Description (what is the flood characteristic that does that)**	**Season**	**No of events**	**Frequency**	**Reasoning**	**No of events**	**Frequency**	**Reasoning**	**No of events**	**Frequency**	**Reasoning**
Inverts	2.5 - 6 m^3/s	Flush fines and algae, inundate stems to some extent. Provide cues for breeding and emergence.	Spring Summer	4	Per year	Inundation of sufficient marginal vegetation three times during the breeding season for juveniles.	3	Per year	Inundation of sufficient marginal vegetation four times during the breeding season for juveniles	6	Per year	Optimal habitat for expansion of flow dependent invertebrates communities and inundation of marginal vegetation six times during breeding season.
Fish	See IFR 2. Flush and clean spawning riffles. Stimulate spawning migrations. Create spawning habitat, > 30cm depth riffles for *B. aeneus* and flooded backwaters with vegetation for *B. anoplus*.	2 5 – 6.0m^3/s	Summer Oct – Mar	5	Per year		3	Per year		7	Per year	
Rip veg	Inundate and maintain marginal vegetation by the provision of water, nutrients and sediments to the marginal zone.	Inundate marginal vegetation within marginal zone and islands several times during spring and summer.	Spring Summer	5		Keep existing marginal zones inundated and thereby maintain its existing distribution and extent.	4		Lower frequency of elevated Class I floods will probably lead to thinning in the abundance and reduction in the marginal zone width.	6		Increased flooding will sustain existing marginal vegetation and possibly lead to the expansion in distribution by widening of the marginal cover.
Geom.	Bed form maintenance.	Depth: 0.8 – 0.9m Velocity: 0.23 – 0.31 m/s	Wet	4			4					

H.6.2 IFR 3 - CLASS II:

FLOOD CLASS II - 4 - 15m³/s				Recommended EC C/D Fish D; Inverts C/D; Rip veg C			Alternative EC D Fish D; Inverts D; Rip veg D			Alternative EC B/C Fish C; Inverts B/C Rip veg B/C		
Com.	**Function/s (what does it have to do)**	**Description (what is the flood characteristic that does that)**	**Season**	**No of events**	**Frequency**	**Reasoning**	**No of events**	**Frequency**	**Reasoning**	**No of events**	**Frequency**	**Reasoning**
Inverts	6 - 10m^3/s	Clear interstitial spaces, inundate marginal vegetation, shift small substrates and renew SIC habitat.	Nov, Dec, Feb	2	Per year	Maintenance of SIC habitat in optimal condition through summer.	1	Per year	Maintenance of SIC habitat in optimal condition through summer.	2	Per year	Maintenance of SIC habitat in optimal condition through summer.
Fish	Flood high backwater areas. Further clean out riffles. Create further suitable spawning habitat and larval rearing backwaters. Allow migration of eels and *B. aeneus* over shallow rapids and riffles.	6 - 12m^3/s	Summer Oct – Mar	1	Per year		1	Per year		2	Per year	
Rip Veg	Maintain riparian vegetation in the lower riparian zone by the provision of nutrients, water and sediments to the lower riparian zone.	Must inundate the lower riparian zone a number of times per year.	Summer	3		Resulting in the maintenance of existing riparian vegetation in the lower riparian zone.	2		Result in the reduction in cover and abundance of vegetation by reduced germination and growth.	4		Will result in an improvement in the riparian vegetation cover in the lower riparian zone by increased germination and growth of vegetation.
Geom.	Bench maintenance.	Depth: 0.9 – 1.1m Velocity: 0.13 – 0.5 m/s	Wet	3			3					

H.6.3 IFR 3 - CLASS III

FLOOD CLASS III – 14 - 20m³/s				Recommended EC C/D			Alternative EC D			Alternative EC B/C		
				Fish D; Inverts C/D; Rip veg C			Fish D; Inverts D; Rip veg D			Fish C; Inverts B/C Rip veg B/C		
Com.	**Function/s (what does it have to do)**	**Description (what is the flood characteristic that does that)**	**Season**	**No of events**	**Frequency**	**Reasoning**	**No of events**	**Frequency**	**Reasoning**	**No of events**	**Frequency**	**Reasoning**
Rip Veg	Maintain riparian vegetation in the middle riparian zone by the provision of nutrients, water and sediments to the middle riparian zone.	Must inundate the middle riparian zone once per year.	Summer	1		Resulting in the maintenance of existing riparian vegetation in the middle riparian zone.	1		Result in the reduction in cover and abundance of vegetation by reduced germination and growth.	1		Will result in an improvement in the riparian vegetation cover in the middle riparian zone by increased germination and growth of vegetation.
Geom.	Active channel maintenance.	Depth: 1.2 – 1.3m Velocity: 0.6 m/s	Wet	1			1					

H.6.4 IFR 3 - CLASS IV

FLOOD CLASS IV – 20 - 40m³/s				Recommended EC C/D			Alternative EC D			Alternative EC B/C		
				Fish D; Inverts C/D; Rip veg C			Fish D; Inverts D; Rip veg D			Fish C; Inverts B/C Rip veg B/C		
Com.	**Function/s (what does it have to do)**	**Description (what is the flood characteristic that does that)**	**Season**	**No of events**	**Frequency**	**Reasoning**	**No of events**	**Frequency**	**Reasoning**	**No of events**	**Frequency**	**Reasoning**
Geom.	Macro channel maintenance.	Depth: 1.3 – 1.5m	Wet	1			1					

H.7 IFR 4: LOW FLOWS

H.7.1 INVERTEBRATES: FLOW DEPENDENT

Species stress	Critical stress	Recommended EC C/D (inverts C/D)				Alternative EC B/C (inverts B/C)				Alternative EC D (inverts D)			
		Dry season requirements		Wet season requirements		Dry season requirements		Wet season requirements		Dry season requirements		Wet season requirements	
		Dur (%)	Comment	Dur (%)	Comment	Dur (%)	Comment	Dur (%)	Comment	Dur (%)	Comment	Dur (%)	Comment
0													
0	0.2			75	Provide optimal habitat for the few sensitive FDIs for a short period during summer.			60	Provide optimal flow conditions for FDIs for up to 40% of the time.				
3	3					85	Good flows for 15% of the time to flush fines and renew SIC habitat.	50	Provide slightly elevated flows to maintain good quality habitat.			75	Optimal flows for 15% of the time to provide life stage cues to inverts.
4	4	90	Reasonable flow conditions to sustain overwintering populations.	60	Reasonable flow conditions for 2/3 of the time to bolster early summer FD communities.	80	Reasonable flow conditions to sustain overwintering populations, particularly for sensitive FDIs.	40	Reasonable flow conditions for fair period of summer to provide for requirements of all life stages.			65	Reasonable flow conditions for 2/3 of the time to bolster early summer FD communities.
5	5												
6	6									95	FD community may be affected in terms of abundance but will likely remain intact in terms of diversity.		
8	8	60	FD invertebrates will diminish in numbers but most will remain present due to trickling flows.	20	FD invertebrates are likely to survive trickling flows for a short period of time. Preferably not continuous.	40	FD invertebrates will diminish in numbers but will remain present due to trickling flows.	10	FD invertebrates are likely to survive trickling flows for a short period of time. Preferably not continuous.	75	If flows greater than trickling for > 25% of the time, majority of community will survive.	30	FD invertebrates are likely to survive trickling flows for a short period of time. Preferably not continuous.
9	9	5	Community should withstand cessation of flow, and loss of connectivity for short periods.	5	Community should withstand no flow and loss of connectivity for short periods	5	Community should withstand no flow and loss of connectivity for short periods.	5	Community should withstand no flow and loss of connectivity for short periods.	5	Community should withstand no flow and loss of connectivity for short periods.	5	Community should withstand no flow and loss of connectivity for short periods.

H.7.2 FISH: EURYTOPIC AND LIMNOPHILIC FISH SPECIES

Species stress	Critical stress	Recommended EC C/D and Alternative EC D (Fish D)				Alternative EC C (Fish C)			
		Dry season requirements		Wet season requirements		Dry season requirements		Wet season requirements	
		Dur (%)	Comment	Dur (%)	Comment	Dur (%)	Comment	Dur (%)	Comment
0	0	98		80		95		65	
1	4	90	All habitats are abundant, except for breeding and larval rearing habitat for *B. aeneus* becoming limited. Fish abundance is slightly reduced.	60	All habitats are abundant, except for breeding and larval rearing habitat for *B. aeneus* becoming limited. Fish abundance is slightly reduced.	80	All habitats are abundant, except for breeding and larval rearing habitat for *B. aeneus* becoming limited. Fish abundance is slightly reduced.	45	All habitats are abundant, except for breeding and larval rearing habitat for *B. aeneus* becoming limited. Fish abundance is slightly reduced.
2									
3									
4									
5	5.8	85	Fast flowing habitats very reduced, breeding of *B. aeneus* very limited, unsuccessful. Slow deep and slow shallow habitat is mostly abundant and survival is moderate.	40	Fast flowing habitats very reduced, breeding of *B. aeneus* very limited, unsuccessful. Slow deep and slow shallow habitat is mostly abundant and survival is moderate.	70	Fast flowing habitats very reduced, breeding of *B. aeneus* very limited, unsuccessful. Slow deep and slow shallow habitat is mostly abundant and survival is moderate.	25	Fast flowing habitats very reduced, breeding of *B. aeneus* very limited, unsuccessful. Slow deep and slow shallow habitat is mostly abundant and survival is moderate.
6	7.9	50	No breeding for *B. aeneus* as there is no habitat. The loss of cover leads to high mortality and low fish abundance.	20	No breeding for *B. aeneus* as there is no habitat. The loss of cover leads to high mortality and low fish abundance.	30	No breeding for *B. aeneus* as there is no habitat. The loss of cover leads to high mortality and low fish abundance.	15	No breeding for *B. aeneus* as there is no habitat. The loss of cover leads to high mortality and low fish abundance.
7									
8	8.7	10	Fish are confined to deep pools, but with no marginal vegetation and little undercut banks there is a high mortality. Water quality starts impacting on the survival of fish which leads to low abundance.	10	Fish are confined to deep pools, but with no marginal vegetation and little undercut banks there is a high mortality. Water quality starts impacting on the survival of fish which leads to low abundance.	10	Fish are confined to deep pools, but with no marginal vegetation and little undercut banks there is a high mortality. Water quality starts impacting on the survival of fish which leads to low abundance.	10	Fish are confined to deep pools, but with no marginal vegetation and little undercut banks there is a high mortality. Water quality starts impacting on the survival of fish which leads to low abundance.
9	10	5		5		5		5	
10	10								

H.8 IFR 4: HIGH FLOWS

H.8.1 IFR 4 - CLASS I

FLOOD CLASS I – 3 - 10m^3/s				Recommended EC C/D Fish D; Inverts C/D; Rip veg C			Alternative EC D Fish D; Inverts D; Rip veg D			Alternative EC B/C Fish C; Inverts B/C Rip veg B/C		
Com.	**Function/s (what does it have to do)**	**Description (what is the flood characteristic that does that)**	**Season**	**No of events**	**Frequency**	**Reasoning**	**No of events**	**Frequency**	**Reasoning**	**No of events**	**Frequency**	**Reasoning**
Inverts	3 - 6m^3/s Flush fines and clear riffles. Inundate marginal vegetation. Provide breeding and emerging cues.		Spring Summer	4	Per year	Optimal habitats for the expansion of flow dependent invertebrates communities of sufficient marginal vegetation four times during the wet season.	3	Per year	Optimal habitats for the expansion of flow dependent invertebrate communities. Inundation of sufficient vegetation three times during the wet season.	6	Per year	Optimal habitats for the expansion of flow dependent invertebrate communities inundation of marginal vegetation to provide sufficient habitat six times during the wet season.
Fish	See IFR 3 and: Large silt deposits need to be flushed out of the spawning habitat – riffles. Vegetated backwaters need to be inundated for *B. anoplus* spawning and larval rearing habitat for both fish species. Stimulate migration for spawning.	3 - 10m^3/s	Summer Oct – Mar	4	Per year	Suitable spawning habitat available twice in a season reduced larval rearing.	2	Per year	Suitable spawning habitat available twice in a season reduced larval rearing.	4	Per year	Increased spawning opportunities and better larval rearing four times a season.
Rip Veg	Maintenance of the marginal vegetation by the supply of water, nutrients and sediments to the marginal zone.	4 - 10 m^3/s Inundate the full marginal zone on banks and islands several times during spring and summer.	Spring Summer	5		Maintain existing marginal vegetation by the inundation of all areas currently colonised.	4		Will provide for a thinning and reduction in the current abundance and distribution of marginal vegetation.	6		Will ensure for the expansion of the marginal vegetation by more frequent and abundant of marginal vegetation requirements and ensure the improvement of the species composition.
Geom.	Bench maintenance.	Depth: 0.9 – 1.1 Velocity: 0.13 – 0.5 m/s	Wet	5			4			6		

H.8.2 IFR 4 – CLASS II

FLOOD CLASS II – 6 - 14m³/s				Recommended EC C/D			Alternative EC D			Alternative EC B/C		
				Fish D; Inverts C/D; Rip veg C			Fish D; Inverts D; Rip veg D			Fish C; Inverts B/C; Rip veg B/C		
Com.	**Function/s (what does it have to do)**	**Description (what is the flood characteristic that does that)**	**Season**	**No of events**	**Frequency**	**Reasoning**	**No of events**	**Frequency**	**Reasoning**	**No of events**	**Frequency**	**Reasoning**
Inverts	Clean or scour pools, clean interstitial spaces.	6 - 12m³/s	Summer	2	Per year	As for the B/C category.	1	Per year	Clean the habitat of accumulated material to provide good habitat for flow dependent invertebrates. Inundate vegetation to supply breeding habitat for invertebrates.	2	Per year	Clean the habitats twice a year of accumulated material to provide good habitat for flow dependent invertebrates. Inundate vegetation to supply breeding habitat.
Geom.	Bench maintenance.	Depth: 0.8 – 1.1m Velocity: 0.3 – 0.6 m/s	Wet	4	Per year							

H.8.3 IFR 4 – CLASS III

FLOOD CLASS III - 10 - 40m³/s				RECOMMENDED EC C/D SCENARIO EVALUATION			ALTERNATIVE SCENARIO EC D SCENARIO EVALUATION			ALTERNATIVE SCENARIO EC B/C SCENARIO EVALUATION		
				Fish D; Inverts C/D; Rip veg C			Fish D; Inverts D; Rip veg D			Fish C; Inverts B/C; Rip veg B/C		
Com.	**Function/s (what does it have to do)**	**Description (what is the flood characteristic that does that)**	**Season**	**No of events**	**Frequency**	**Reasoning**	**No of events**	**Frequency**	**Reasoning**	**No of events**	**Frequency**	**Reasoning**
Fish	Larger floods are needed to flood out active channel. Vegetated backwaters for larval rearing. This flood will have the same functions as flood class I but will be more effective.	10 - 15m³/s	Summer	1	Per year	Optimal larval rearing once a season and migration will be at an optimum.	2	Per year	Optimal larval rearing once a season and migration will be at an optimum.	2	Per year	Optimal larval rearing once a season and migration at an optimum.
Rip Veg	Maintenance of riparian vegetation in the lower riparian zone, by the provision of water, nutrients and sediments and the deposition of seeds and propogules.	10 - 40 m³/s Inundate the lower riparian zone during summer months.	Summer	3		Maintain riparian vegetation by the provision of requirements for all areas currently occupied with riparian vegetation.	1		Will ensure for a reduction in the abundance and extent of riparian vegetation in this zone.	1		Will result in an improvement in the abundance, extent and composition of riparian vegetation in this zone.
Geom.	Bench maintenance.	Depth: 1.2 – 1.6m Velocity: 0.6 – 0.9 m/s	Wet	2	Per year		2	Per year		2	Per year	

H.8.4 IFR 4 – CLASS IV

FLOOD CLASS IV – 40 - 80m³/s				Recommended EC C/D Fish D; Inverts C/D; Rip veg C			Alternative EC D Fish D; Inverts D; Rip veg D			Alternative EC B/C Fish C; Inverts B/C; Rip veg B/C		
Com.	**Function/s (what does it have to do)**	**Description (what is the flood characteristic that does that)**	**Season**	**No of events**	**Frequency**	**Reasoning**	**No of events**	**Frequency**	**Reasoning**	**No of events**	**Frequency**	**Reasoning**
Rip Veg	Maintenance of riparian vegetation in the middle riparian zone by the provision of water nutrients, sediments and propogules. Removal of debris.	40 -80 m^3/s Needs to cover the middle riparian zone during summer.	Summer	1		Maintain riparian vegetation by the provision of requirements for all areas currently occupied with riparian vegetation.	1		Will ensure for a reduction in the abundance and extent of riparian vegetation in this zone.	1		Will result in an improvement in the abundance, extent and composition of riparian vegetation in this zone.
Geom.	Channel maintenance.	Depth: 1.6 – 1.9m Velocity: 0.9 – 1.25 m/s	Wet	1	Per year		1	Per year		1	Per year	

H.8.5 IFR 4 – CLASS V

FLOOD CLASS V - 75 - 130m³/s				Recommended EC C/D Fish D; Inverts C/D; Rip veg C			Alternative EC D Fish D; Inverts D Rip veg D			Alternative EC B/C Fish C; Inverts B/C Rip veg B/C		
Com.	**Function/s (what does it have to do)**	**Description (what is the flood characteristic that does that)**	**Season**	**No of events**	**Frequency**	**Reasoning**	**No of events**	**Frequency**	**Reasoning**	**No of events**	**Frequency**	**Reasoning**
Geom.	Macro channel maintenance.	Depth: 1.9 – 2.2m Velocity: 1.25 – 1.68m/s	Wet	1	Every 5 years		1	Every 5 years				

APPENDIX I

River hydraulics

Dr A Birkhead
Streamflow Solutions

TABLE OF CONTENTS

I.1 INTRODUCTION I-2
I.2 DATA COLLECTION I-2
I.3 MODELLING I-2
I.4 RESULTS I-3
I.4.1 Cross-sectional profiles I-3
I.4.2 Rating data and functions I-5
I.5 DIGITAL TERRAIN MODEL FOR IFR SITE 2 ON THE BLACK KEI RIVER I-8
I.5.1 Tabulated modelled hydraulic data I-9
I.6 CONFIDENCE IN THE HYDRAULIC CHARACTERISATIONS I-24
I.7 REFERENCE I-24

LIST OF FIGURES

Figure I.1 Cross-sectional profile for IFR Site 1 on the Klipplaat River I-3
Figure I.2 Cross-sectional profile for IFR Site 2 on the Black Kei River I-4
Figure I.3 Cross-sectional profile for IFR Site 3 on the Black Kei River I-4
Figure I.4 Cross-sectional profile for IFR Site 4 on the White Kei River I-5
Figure I.5 Measured and modelled rating data and function for the cross-sectional profile at IFR Site 1 on the Klipplaat River I-5
Figure I.6 Measured and modelled rating data and function for the cross-sectional profile at IFR Site 2 on the Black Kei River I-6
Figure I.7 Measured and modelled rating data and function for the cross-sectional profile at IFR Site 3 on the Black Kei River I-7
Figure I.8 Measured and modelled rating data and function for the cross-sectional profile at IFR Site 4 on the White Kei River I-7
Figure I.9 DTM (10cm contours) of IFR Site 2 on the Black Kei River, showing the inundated area at a discharge of 0.17m^3/s. The flow direction is right to left, modelled area is 15m x 18m, inundated areas deeper than 0.3m are indicated in darker blue, and vegetation survey points are also shown. I-8

LIST OF TABLES

Table I.1 Hydraulic data collected at IFR Sites I-2
Table I.2 Measured water surface and regional channel slopes I-2
Table I.3 Hydraulic data used to extend the measured rating data I-3
Table I.4 Regression coefficients in equation 1 .... I-3
Table I.5 Tabulated hydraulic data for IFR Site 1 on the Klipplaat River I-9
Table I.6 Tabulated hydraulic data for IFR Site 2 on the Black Kei River I-13
Table I.7 Tabulated hydraulic data for IFR Site 3 on the Black Kei River I-16
Table I.8 Tabulated hydraulic data for IFR Site 4 on the White Kei River I-18
Table I.9 Confidence in the hydraulic characterisations I-24

I.1 INTRODUCTION

The role of hydraulics and procedure for generating hydraulic information has been documented for the Comprehensive and Intermediate levels of determination (DWAF, 1999), and should be consulted for detailed explanation. The purpose of this report is to provide the hydraulic data collected for this study, and results of the analyses.

I.2 DATA COLLECTION

The measured discharges and flow depths are provided in Table I.1, together with the dates when the data were collected.

Table I.1 Hydraulic data collected at IFR Sites

River	Site no.	Date	Discharge Q (m^3/s)	Max. flow depth, y (m)
Klipplaat	1	15/07/2003	0.24	0.26
		19/08/2003	5.0	0.68
Black Kei	2	19/08/2003	0.17	0.43
		15/07/2003	0.36	0.51
		21/08/2003	2.1	0.77
		20/08/2003	8.2	1.00
	3	14/07/2003	0.16	0.43
		22/08/2003	3.8	0.89
White Kei	4	15/07/2003	1.07	0.61

I.3 MODELLING

The observed rating data at the IFR Sites have been extended using Manning=s resistance relationship. The surveyed water surface and regional (1:50 000 topographical) channel slopes are given in Table I.1, and these have been used in conjunction with estimates of Manning=s resistance coefficient (Table I.2) to synthesize rating data for discharges higher than those measured. Continuous rating functions of the form given by equation 1 have been fitted to the measured and modelled data.

$$Q = ay^b + c \qquad \text{equation 1}$$

where y is the flow depth (m), Q is the discharge (m^3/s), and a, b and c are regression coefficients, listed in Table I.4.

Table I.2 Measured water surface and regional channel slopes

River	Site no.	Discharge Q (m^3/s)	Surveyed water surface gradient	Regional (1:50 000) channel slope
Klipplaat	1	0.24 5.0	0.013(16) 0.040(35)	0.012
Black Kei	2	0.17 0.36 2.1 8.2	 0.038(40), 0.026(73)	0.0027
	3	0.16 3.8	0.011(65), 0.011(90)	0.0034
White Kei	4	1.07	0.0022(29), 0.038(40)	0.0037

() distance over which water surface gradient is surveyed (m).

Table I.3 Hydraulic data used to extend the measured rating data

River	Site no.	Discharge *Q* (m³/s)	Manning's resistance, *n*	Max. flow depth, *y* (m)	Energy slope, *S*	Ave. velocity *v* (m/s)
Klipplaat	1	53	0.05	1.40	0.020	2.21
Black Kei	2	129	0.05	2.00	0.030	3.06
	3	31	0.05	1.50	0.0030	0.83
White Kei	4	20	0.10	1.30	0.011	0.72

Italic – modelled

Table I.4 Regression coefficients in equation 1

River	Site no.	Discharge Q (m³/s)	Rating coefficients		
			a	*b*	*c*
Klipplaat	1	All	0.411	0.310	0.000
Black Kei	2	Q <= 3.6 Q > 3.6	0.641 0.621	0.216 0.240	0.000 0.000
	3	All	0.599	0.268	0.000
White Kei	4	All	0.654	0.230	0.000

In addition to the hydraulic characterisations based on cross-sectional profiles, the river at IFR Site on the Black Kei River was surveyed to provide a digital terrain model (DTM) for habitat modelling over a larger area (refer to Fig. I.9)

I.4 RESULTS

I.4.1 Cross-sectional profiles

Figure I.1 Cross-sectional profile for IFR Site 1 on the Klipplaat River

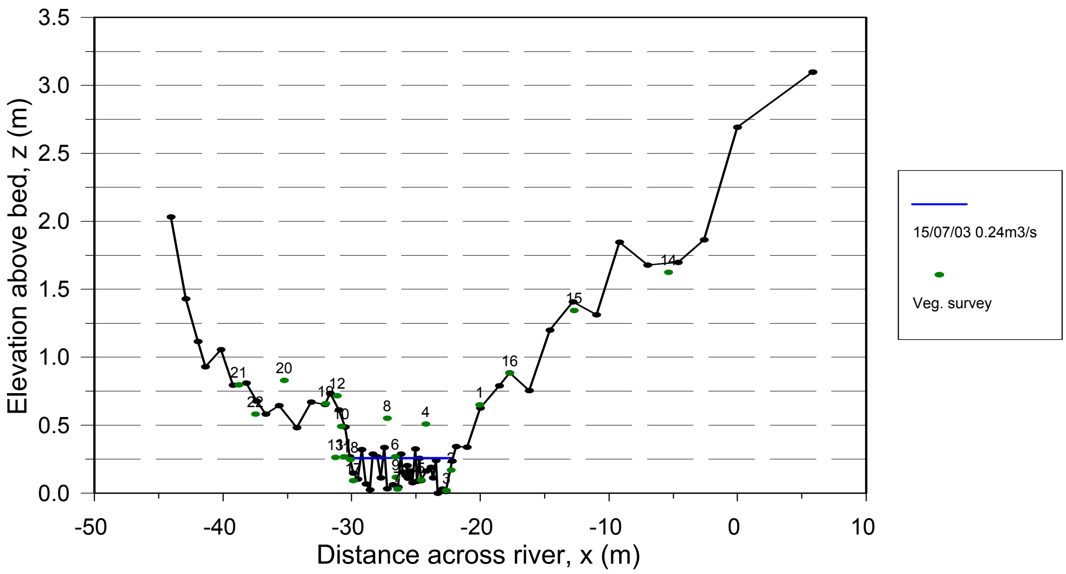


Figure I.2 Cross-sectional profile for IFR Site 2 on the Black Kei River

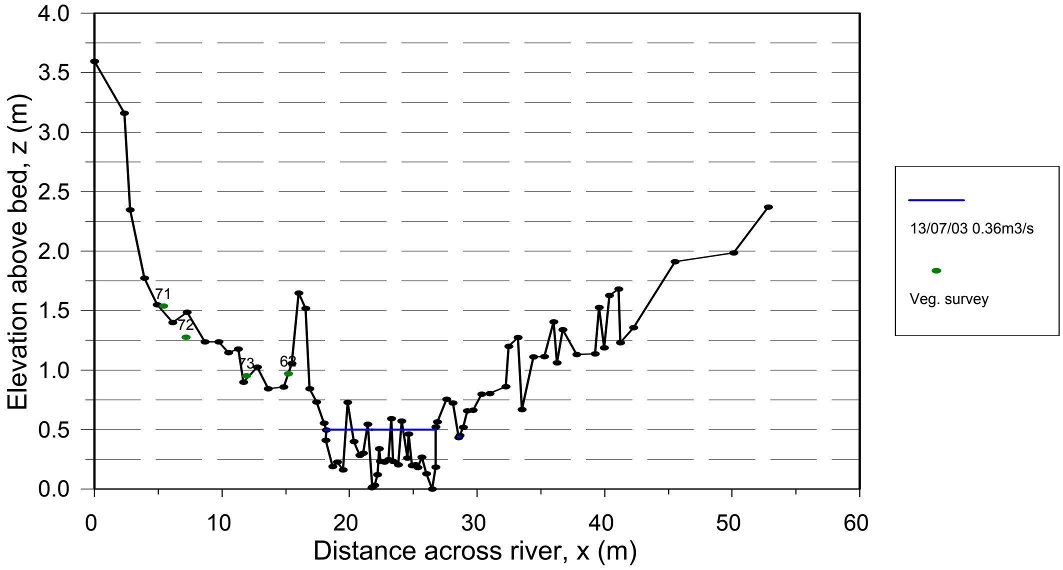


Figure I.3 Cross-sectional profile for IFR Site 3 on the Black Kei River

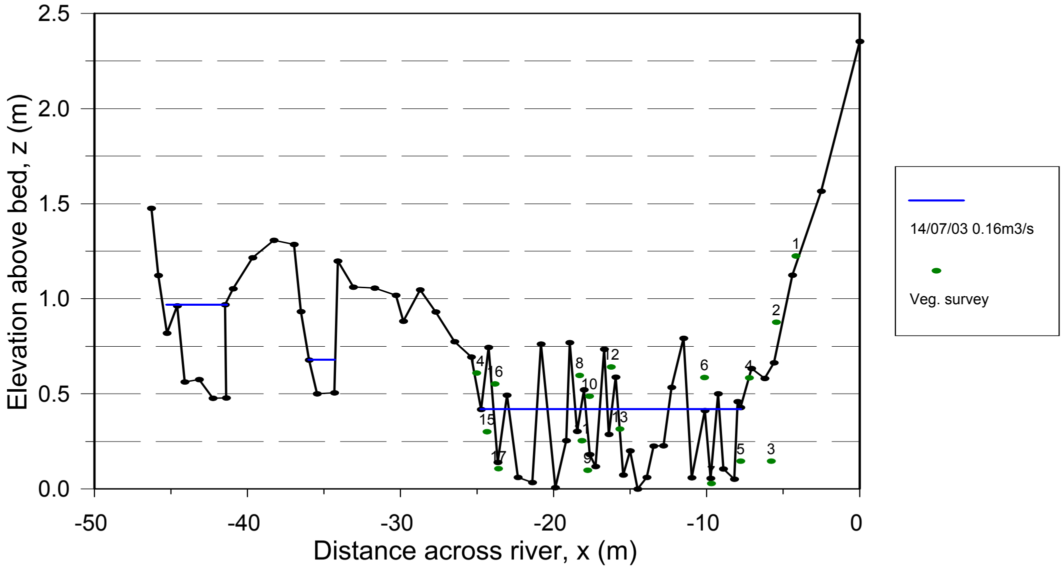
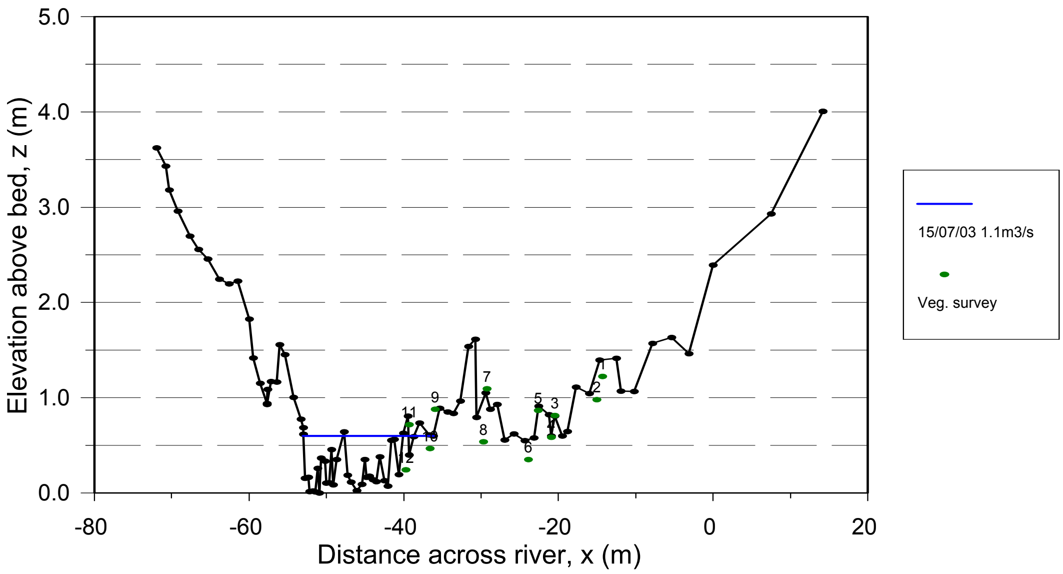


Figure I.4 Cross-sectional profile for IFR Site 4 on the White Kei River



I.4.2 Rating data and functions

Figure I.5 Measured and modelled rating data and function for the cross-sectional profile at IFR Site 1 on the Klipplaat River

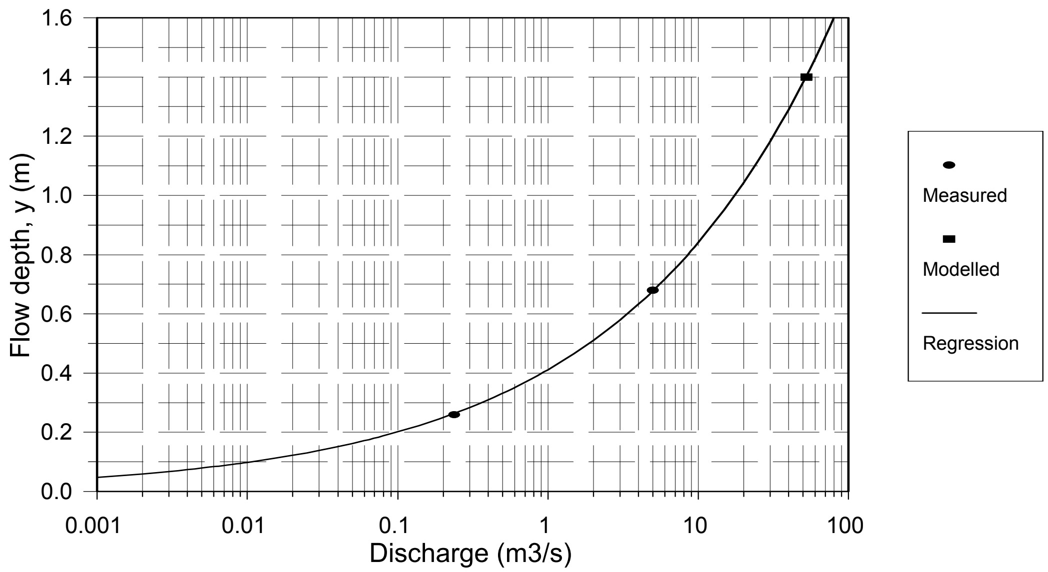


Figure I.6 Measured and modelled rating data and function for the cross-sectional profile at IFR Site 2 on the Black Kei River

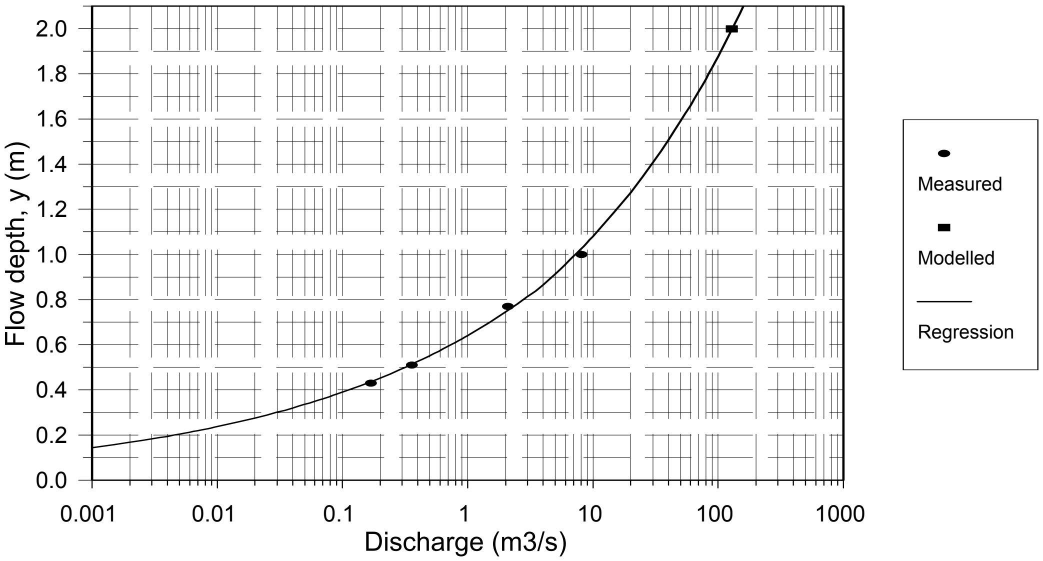


Figure I.7 Measured and modelled rating data and function for the cross-sectional profile at IFR Site 3 on the Black Kei River

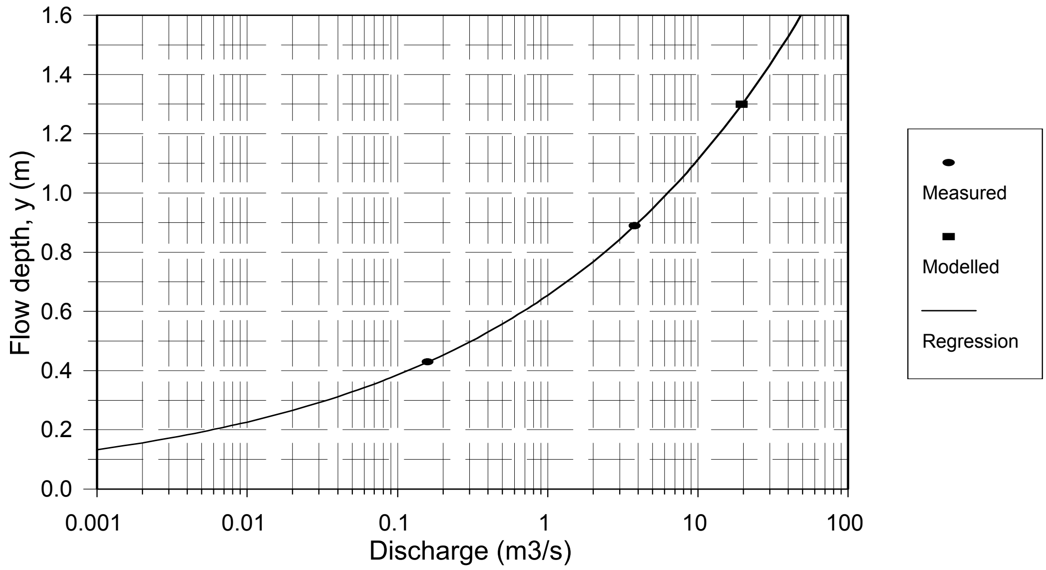
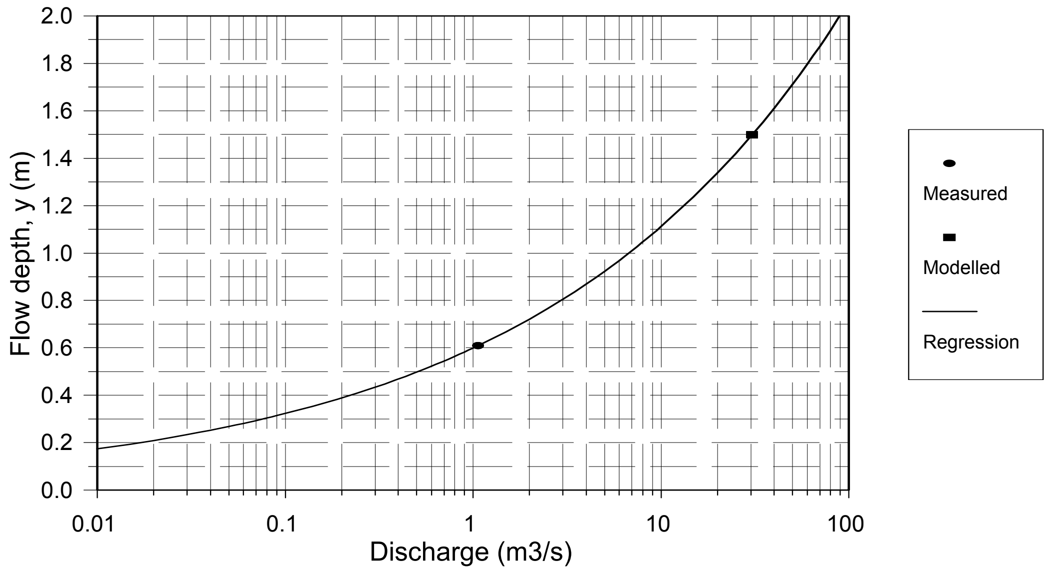
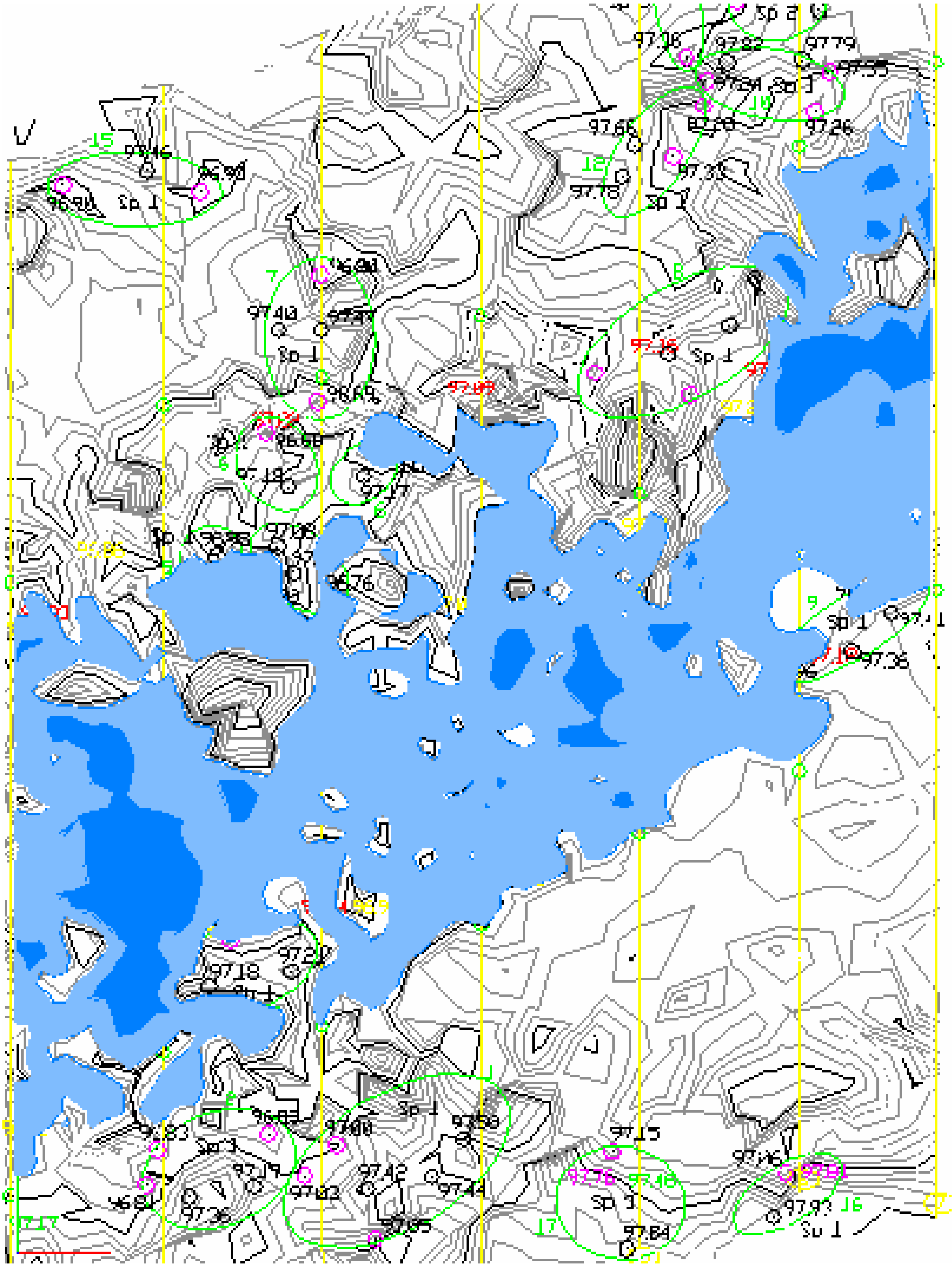


Figure I.8 Measured and modelled rating data and function for the cross-sectional profile at IFR Site 4 on the White Kei River



I.5 DIGITAL TERRAIN MODEL FOR IFR SITE 2 ON THE BLACK KEI RIVER

Figure I.9 DTM (10cm contours) of IFR Site 2 on the Black Kei River, showing the inundated area at a discharge of 0.17m³/s. The flow direction is right to left, modelled area is 15m x 18m, inundated areas deeper than 0.3m are indicated in darker blue, and vegetation survey points are also shown.



I.5.1 Tabulated modelled hydraulic data

The data in shaded rows of the tables that follow signify measured rating data.

Table I.5 Tabulated hydraulic data for IFR Site 1 on the Klipplaat River

Flow depth (m)	Discharge (m^3/s)	Av. flow depth (m)	Area (m^2)	Width (m)	Perimeter (m)	Av. velocity (m/s)
0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.01	0.00	0.00	0.00	0.11	0.12	0.01
0.02	0.00	0.01	0.00	0.31	0.33	0.02
0.03	0.00	0.01	0.01	0.62	0.65	0.03
0.04	0.00	0.02	0.01	0.89	0.93	0.04
0.05	0.00	0.02	0.03	1.24	1.30	0.04
0.06	0.00	0.02	0.04	1.71	1.80	0.05
0.07	0.00	0.03	0.06	2.00	2.11	0.06
0.08	0.01	0.04	0.08	2.07	2.21	0.06
0.09	0.01	0.05	0.10	2.16	2.33	0.07
0.10	0.01	0.05	0.12	2.31	2.52	0.09
0.11	0.01	0.06	0.15	2.53	2.80	0.10
0.12	0.02	0.06	0.17	2.89	3.22	0.11
0.13	0.02	0.06	0.20	3.27	3.68	0.12
0.14	0.03	0.06	0.24	3.76	4.24	0.13
0.15	0.04	0.07	0.28	4.25	4.81	0.14
0.16	0.05	0.07	0.32	4.67	5.30	0.15
0.17	0.06	0.07	0.37	5.04	5.75	0.16
0.18	0.07	0.08	0.42	5.40	6.19	0.16
0.19	0.08	0.08	0.48	5.76	6.62	0.17
0.20	0.10	0.09	0.54	6.01	6.94	0.18
0.21	0.11	0.10	0.60	6.21	7.22	0.19
0.22	0.13	0.10	0.66	6.41	7.47	0.20
0.23	0.15	0.11	0.73	6.60	7.73	0.21
0.24	0.18	0.12	0.80	6.79	7.99	0.22
0.25	0.20	0.12	0.86	6.97	8.22	0.23
0.26	0.23	0.13	0.94	7.14	8.45	0.24
0.27	0.26	0.14	1.01	7.31	8.66	0.26
0.28	0.29	0.14	1.08	7.62	9.01	0.27
0.29	0.32	0.15	1.16	7.90	9.34	0.28
0.30	0.36	0.15	1.24	8.01	9.47	0.29
0.31	0.40	0.16	1.32	8.12	9.61	0.30
0.32	0.45	0.17	1.40	8.22	9.75	0.32
0.33	0.49	0.18	1.48	8.31	9.85	0.33
0.34	0.54	0.19	1.57	8.37	9.93	0.35
0.35	0.60	0.18	1.66	9.29	10.85	0.36
0.36	0.65	0.19	1.75	9.34	10.91	0.37
0.37	0.71	0.20	1.84	9.39	10.96	0.39
0.38	0.78	0.21	1.94	9.44	11.02	0.40
0.39	0.84	0.21	2.03	9.50	11.08	0.42
0.40	0.92	0.22	2.13	9.55	11.13	0.43
0.41	0.99	0.23	2.22	9.60	11.19	0.45
0.42	1.07	0.24	2.32	9.65	11.25	0.46
0.43	1.16	0.25	2.42	9.71	11.30	0.48
0.44	1.25	0.26	2.52	9.76	11.36	0.50
0.45	1.34	0.27	2.61	9.81	11.42	0.51
0.46	1.44	0.27	2.71	9.87	11.48	0.53
0.47	1.54	0.28	2.81	9.92	11.53	0.55
0.48	1.65	0.29	2.91	9.97	11.59	0.57
0.49	1.76	0.30	3.01	10.15	11.77	0.59
0.50	1.88	0.30	3.11	10.37	11.99	0.60
0.51	2.01	0.30	3.22	10.58	12.21	0.62

Flow depth (m)	Discharge (m^3/s)	Av. flow depth (m)	Area (m^2)	Width (m)	Perimeter (m)	Av. velocity (m/s)
0.52	2.14	0.31	3.32	10.80	12.44	0.64
0.53	2.27	0.31	3.43	11.02	12.66	0.66
0.54	2.41	0.32	3.54	11.24	12.88	0.68
0.55	2.56	0.32	3.66	11.46	13.11	0.70
0.56	2.71	0.32	3.77	11.68	13.33	0.72
0.57	2.87	0.33	3.89	11.90	13.55	0.74
0.58	3.04	0.33	4.01	12.12	13.78	0.76
0.59	3.21	0.33	4.13	12.48	14.14	0.78
0.60	3.39	0.33	4.26	12.93	14.60	0.80
0.61	3.57	0.33	4.39	13.39	15.06	0.81
0.62	3.77	0.33	4.53	13.86	15.54	0.83
0.63	3.97	0.33	4.67	14.34	16.02	0.85
0.64	4.17	0.32	4.82	14.87	16.56	0.87
0.65	4.39	0.32	4.97	15.30	16.99	0.88
0.66	4.61	0.32	5.12	15.93	17.63	0.90
0.67	4.84	0.31	5.29	16.92	18.62	0.91
0.68	5.07	0.32	5.46	17.26	18.96	0.93
0.69	5.32	0.32	5.63	17.51	19.22	0.94
0.70	5.57	0.33	5.81	17.77	19.48	0.96
0.71	5.83	0.33	5.99	18.02	19.73	0.97
0.72	6.10	0.34	6.17	18.28	19.99	0.99
0.73	6.38	0.34	6.35	18.53	20.25	1.00
0.74	6.67	0.35	6.54	18.75	20.47	1.02
0.75	6.96	0.36	6.73	18.90	20.63	1.03
0.76	7.26	0.36	6.92	19.13	20.86	1.05
0.77	7.58	0.37	7.11	19.44	21.16	1.07
0.78	7.90	0.37	7.31	19.74	21.47	1.08
0.79	8.23	0.37	7.51	20.04	21.78	1.10
0.80	8.57	0.37	7.71	20.61	22.35	1.11
0.81	8.92	0.37	7.92	21.58	23.33	1.13
0.82	9.28	0.37	8.14	21.99	23.74	1.14
0.83	9.65	0.38	8.36	22.26	24.01	1.15
0.84	10.03	0.38	8.58	22.53	24.29	1.17
0.85	10.42	0.39	8.81	22.80	24.56	1.18
0.86	10.82	0.39	9.04	23.07	24.83	1.20
0.87	11.23	0.40	9.27	23.34	25.11	1.21
0.88	11.66	0.40	9.51	23.61	25.38	1.23
0.89	12.09	0.41	9.74	23.84	25.61	1.24
0.90	12.53	0.42	9.98	23.91	25.69	1.26
0.91	12.99	0.43	10.22	23.98	25.76	1.27
0.92	13.45	0.43	10.46	24.05	25.83	1.29
0.93	13.93	0.44	10.70	24.12	25.91	1.30
0.94	14.42	0.45	10.94	24.29	26.07	1.32
0.95	14.92	0.46	11.19	24.49	26.28	1.33
0.96	15.43	0.46	11.43	24.69	26.49	1.35
0.97	15.96	0.47	11.68	24.89	26.69	1.37
0.98	16.50	0.48	11.93	25.09	26.90	1.38
0.99	17.04	0.48	12.18	25.29	27.10	1.40
1.00	17.61	0.49	12.44	25.49	27.31	1.42
1.01	18.18	0.49	12.69	25.69	27.51	1.43
1.02	18.77	0.50	12.95	25.89	27.72	1.45
1.03	19.37	0.51	13.21	26.09	27.92	1.47
1.04	19.98	0.51	13.47	26.29	28.13	1.48
1.05	20.61	0.52	13.74	26.49	28.33	1.50
1.06	21.25	0.53	14.00	26.67	28.51	1.52
1.07	21.90	0.53	14.27	26.74	28.58	1.53
1.08	22.57	0.54	14.54	26.80	28.65	1.55
1.09	23.25	0.55	14.81	26.87	28.73	1.57
1.10	23.94	0.56	15.08	26.94	28.80	1.59

Flow depth (m)	Discharge (m^3/s)	Av. flow depth (m)	Area (m^2)	Width (m)	Perimeter (m)	Av. velocity (m/s)
1.11	24.65	0.57	15.34	27.01	28.87	1.61
1.12	25.38	0.58	15.62	27.08	28.94	1.63
1.13	26.12	0.59	15.89	27.14	29.01	1.64
1.14	26.87	0.59	16.16	27.21	29.07	1.66
1.15	27.64	0.60	16.43	27.27	29.14	1.68
1.16	28.42	0.61	16.70	27.34	29.21	1.70
1.17	29.22	0.62	16.98	27.40	29.28	1.72
1.18	30.03	0.63	17.25	27.46	29.34	1.74
1.19	30.86	0.64	17.53	27.53	29.41	1.76
1.20	31.70	0.65	17.80	27.59	29.48	1.78
1.21	32.56	0.65	18.08	27.70	29.59	1.80
1.22	33.44	0.66	18.36	27.82	29.71	1.82
1.23	34.33	0.67	18.63	27.94	29.83	1.84
1.24	35.24	0.67	18.91	28.05	29.95	1.86
1.25	36.16	0.68	19.20	28.17	30.07	1.88
1.26	37.11	0.69	19.48	28.28	30.18	1.91
1.27	38.06	0.70	19.76	28.40	30.30	1.93
1.28	39.04	0.70	20.05	28.52	30.42	1.95
1.29	40.03	0.71	20.33	28.63	30.54	1.97
1.30	41.04	0.72	20.62	28.75	30.66	1.99
1.31	42.07	0.72	20.91	28.87	30.78	2.01
1.32	43.11	0.73	21.20	29.16	31.08	2.03
1.33	44.18	0.73	21.49	29.50	31.42	2.06
1.34	45.26	0.73	21.79	29.84	31.76	2.08
1.35	46.36	0.73	22.09	30.18	32.11	2.10
1.36	47.47	0.73	22.39	30.52	32.45	2.12
1.37	48.61	0.74	22.70	30.86	32.79	2.14
1.38	49.76	0.74	23.01	31.20	33.14	2.16
1.39	50.93	0.74	23.32	31.54	33.48	2.18
1.40	52.13	0.74	23.64	31.88	33.82	2.21
1.41	53.34	0.74	23.96	32.16	34.11	2.23
1.42	54.57	0.75	24.28	32.22	34.18	2.25
1.43	55.82	0.76	24.60	32.29	34.24	2.27
1.44	57.08	0.77	24.93	32.34	34.30	2.29
1.45	58.37	0.78	25.25	32.39	34.36	2.31
1.46	59.68	0.79	25.57	32.45	34.41	2.33
1.47	61.01	0.80	25.90	32.50	34.47	2.36
1.48	62.36	0.81	26.22	32.55	34.53	2.38
1.49	63.73	0.81	26.55	32.60	34.58	2.40
1.50	65.12	0.82	26.88	32.66	34.64	2.42
1.51	66.53	0.83	27.20	32.71	34.70	2.45
1.52	67.96	0.84	27.53	32.76	34.75	2.47
1.53	69.41	0.85	27.86	32.81	34.81	2.49
1.54	70.89	0.86	28.19	32.87	34.87	2.51
1.55	72.38	0.87	28.52	32.92	34.92	2.54
1.56	73.90	0.87	28.85	32.97	34.98	2.56
1.57	75.44	0.88	29.18	33.03	35.04	2.59
1.58	77.00	0.89	29.51	33.08	35.09	2.61
1.59	78.58	0.90	29.84	33.13	35.15	2.63
1.60	80.19	0.91	30.17	33.18	35.21	2.66
1.61	81.82	0.92	30.50	33.24	35.26	2.68
1.62	83.47	0.93	30.83	33.29	35.32	2.71
1.63	85.14	0.93	31.17	33.34	35.38	2.73
1.64	86.84	0.94	31.50	33.40	35.43	2.76
1.65	88.56	0.95	31.83	33.45	35.49	2.78
1.66	90.30	0.96	32.17	33.50	35.55	2.81
1.67	92.07	0.97	32.50	33.55	35.60	2.83
1.68	93.86	0.98	32.84	33.61	35.66	2.86
1.69	95.67	0.95	33.18	34.97	37.02	2.88

Flow depth (m)	Discharge (m^3/s)	Av. flow depth (m)	Area (m^2)	Width (m)	Perimeter (m)	Av. velocity (m/s)
1.70	97.51	0.92	33.54	36.35	38.41	2.91
1.71	99.37	0.92	33.90	36.66	38.73	2.93
1.72	101.26	0.93	34.27	36.97	39.04	2.95
1.73	103.17	0.93	34.64	37.27	39.35	2.98
1.74	105.11	0.93	35.02	37.58	39.66	3.00
1.75	107.07	0.93	35.40	37.89	39.97	3.02
1.76	109.06	0.94	35.78	38.19	40.28	3.05
1.77	111.07	0.94	36.16	38.50	40.60	3.07
1.78	113.10	0.94	36.55	38.81	40.91	3.09
1.79	115.17	0.94	36.94	39.12	41.22	3.12
1.80	117.25	0.95	37.33	39.42	41.53	3.14
1.81	119.37	0.95	37.72	39.73	41.84	3.16
1.82	121.51	0.95	38.12	40.04	42.16	3.19
1.83	123.68	0.95	38.52	40.34	42.47	3.21
1.84	125.87	0.96	38.93	40.65	42.78	3.23
1.85	128.09	0.96	39.34	40.91	43.04	3.26
1.86	130.34	0.97	39.75	41.05	43.18	3.28
1.87	132.61	0.98	40.16	41.15	43.29	3.30
1.88	134.91	0.98	40.57	41.20	43.35	3.33
1.89	137.24	0.99	40.98	41.26	43.40	3.35
1.90	139.60	1.00	41.40	41.31	43.46	3.37
1.91	141.98	1.01	41.81	41.36	43.51	3.40
1.92	144.39	1.02	42.22	41.41	43.57	3.42
1.93	146.83	1.03	42.64	41.46	43.62	3.44
1.94	149.30	1.04	43.05	41.51	43.67	3.47
1.95	151.80	1.05	43.47	41.56	43.73	3.49
1.96	154.32	1.05	43.88	41.61	43.78	3.52
1.97	156.88	1.06	44.30	41.66	43.84	3.54
1.98	159.46	1.07	44.72	41.71	43.89	3.57
1.99	162.07	1.08	45.13	41.76	43.95	3.59
2.00	164.72	1.09	45.55	41.81	44.00	3.62

Table I.6 Tabulated hydraulic data for IFR Site 2 on the Black Kei River

Flow depth (m)	Discharge (m^3/s)	Av. flow depth (m)	Area (m^2)	Width (m)	Perimeter (m)	Av. velocity (m/s)
0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.01	0.00	0.00	0.00	0.05	0.05	0.00
0.02	0.00	0.01	0.00	0.12	0.24	0.00
0.03	0.00	0.01	0.00	0.27	0.40	0.00
0.04	0.00	0.02	0.01	0.37	0.50	0.00
0.05	0.00	0.02	0.01	0.45	0.60	0.00
0.06	0.00	0.03	0.02	0.53	0.69	0.00
0.07	0.00	0.03	0.02	0.61	0.78	0.00
0.08	0.00	0.04	0.03	0.69	0.87	0.00
0.09	0.00	0.05	0.03	0.77	0.96	0.00
0.10	0.00	0.05	0.04	0.85	1.06	0.00
0.11	0.00	0.06	0.05	0.93	1.15	0.01
0.12	0.00	0.06	0.06	1.01	1.24	0.01
0.13	0.00	0.07	0.07	1.08	1.32	0.01
0.14	0.00	0.07	0.08	1.13	1.39	0.01
0.15	0.00	0.08	0.09	1.18	1.46	0.01
0.16	0.00	0.09	0.11	1.24	1.53	0.02
0.17	0.00	0.09	0.12	1.35	1.66	0.02
0.18	0.00	0.09	0.13	1.47	1.81	0.02
0.19	0.00	0.09	0.15	1.69	2.05	0.02
0.20	0.00	0.08	0.17	2.03	2.43	0.03
0.21	0.01	0.07	0.19	2.69	3.12	0.03
0.22	0.01	0.07	0.22	3.13	3.60	0.03
0.23	0.01	0.07	0.25	3.60	4.11	0.03
0.24	0.01	0.07	0.29	4.19	4.76	0.04
0.25	0.01	0.08	0.34	4.46	5.08	0.04
0.26	0.02	0.08	0.38	4.61	5.28	0.04
0.27	0.02	0.09	0.43	4.77	5.50	0.04
0.28	0.02	0.10	0.48	4.87	5.67	0.05
0.29	0.03	0.10	0.53	5.08	5.94	0.05
0.30	0.03	0.11	0.58	5.39	6.31	0.05
0.31	0.03	0.11	0.63	5.58	6.57	0.05
0.32	0.04	0.12	0.69	5.74	6.79	0.06
0.33	0.05	0.13	0.75	5.89	7.02	0.06
0.34	0.05	0.13	0.81	6.05	7.24	0.07
0.35	0.06	0.14	0.87	6.19	7.44	0.07
0.36	0.07	0.15	0.93	6.34	7.64	0.07
0.37	0.08	0.15	1.00	6.48	7.84	0.08
0.38	0.09	0.16	1.06	6.62	8.03	0.08
0.39	0.10	0.17	1.13	6.76	8.23	0.09
0.40	0.11	0.17	1.20	6.90	8.43	0.09
0.41	0.13	0.18	1.27	7.02	8.61	0.10
0.42	0.14	0.19	1.34	7.11	8.77	0.11
0.43	0.16	0.20	1.41	7.19	8.93	0.11
0.44	0.18	0.20	1.48	7.31	9.12	0.12
0.45	0.19	0.21	1.56	7.47	9.35	0.12
0.46	0.22	0.21	1.63	7.61	9.57	0.13
0.47	0.24	0.22	1.71	7.75	9.78	0.14
0.48	0.26	0.23	1.79	7.88	9.97	0.15
0.49	0.29	0.23	1.87	8.01	10.17	0.15
0.50	0.32	0.24	1.95	8.15	10.37	0.16
0.51	0.35	0.24	2.03	8.31	10.59	0.17
0.52	0.38	0.25	2.11	8.47	10.81	0.18
0.53	0.41	0.25	2.20	8.64	11.02	0.19
0.54	0.45	0.26	2.29	8.81	11.24	0.20

Flow depth (m)	Discharge (m^3/s)	Av. flow depth (m)	Area (m^2)	Width (m)	Perimeter (m)	Av. velocity (m/s)
0.55	0.49	0.26	2.37	8.99	11.46	0.21
0.56	0.54	0.27	2.47	9.14	11.65	0.22
0.57	0.58	0.27	2.56	9.31	11.85	0.23
0.58	0.63	0.28	2.65	9.45	12.03	0.24
0.59	0.68	0.29	2.75	9.59	12.20	0.25
0.60	0.74	0.29	2.84	9.73	12.35	0.26
0.61	0.79	0.30	2.94	9.86	12.50	0.27
0.62	0.86	0.30	3.04	9.99	12.65	0.28
0.63	0.92	0.31	3.14	10.13	12.80	0.29
0.64	0.99	0.32	3.24	10.26	12.95	0.31
0.65	1.07	0.32	3.35	10.39	13.09	0.32
0.66	1.14	0.33	3.45	10.59	13.31	0.33
0.67	1.23	0.32	3.56	11.10	13.84	0.34
0.68	1.31	0.33	3.67	11.29	14.04	0.36
0.69	1.41	0.33	3.79	11.47	14.25	0.37
0.70	1.50	0.33	3.90	11.65	14.46	0.39
0.71	1.61	0.34	4.02	11.84	14.66	0.40
0.72	1.71	0.34	4.14	12.02	14.87	0.41
0.73	1.83	0.35	4.26	12.28	15.15	0.43
0.74	1.94	0.35	4.38	12.60	15.49	0.44
0.75	2.07	0.35	4.51	12.92	15.82	0.46
0.76	2.20	0.35	4.64	13.14	16.05	0.47
0.77	2.34	0.36	4.77	13.26	16.18	0.49
0.78	2.48	0.37	4.91	13.39	16.32	0.51
0.79	2.63	0.37	5.04	13.51	16.45	0.52
0.80	2.79	0.38	5.18	13.73	16.68	0.54
0.81	2.95	0.37	5.32	14.41	17.37	0.56
0.82	3.13	0.37	5.46	14.71	17.68	0.57
0.83	3.31	0.37	5.61	15.01	17.99	0.59
0.84	3.50	0.38	5.76	15.31	18.29	0.61
0.85	3.70	0.37	5.92	16.09	19.09	0.62
0.86	3.88	0.36	6.09	17.11	20.13	0.64
0.87	4.07	0.36	6.26	17.30	20.33	0.65
0.88	4.27	0.37	6.43	17.41	20.47	0.66
0.89	4.48	0.38	6.61	17.53	20.61	0.68
0.90	4.69	0.38	6.78	17.66	20.76	0.69
0.91	4.91	0.39	6.96	17.87	21.01	0.71
0.92	5.14	0.39	7.14	18.09	21.25	0.72
0.93	5.38	0.40	7.32	18.31	21.49	0.73
0.94	5.63	0.41	7.51	18.52	21.74	0.75
0.95	5.88	0.41	7.69	18.74	21.98	0.76
0.96	6.14	0.42	7.88	18.96	22.22	0.78
0.97	6.41	0.42	8.07	19.17	22.46	0.79
0.98	6.69	0.43	8.27	19.39	22.71	0.81
0.99	6.98	0.43	8.46	19.60	22.95	0.83
1.00	7.28	0.44	8.66	19.82	23.19	0.84
1.01	7.59	0.44	8.86	20.04	23.44	0.86
1.02	7.91	0.45	9.06	20.25	23.68	0.87
1.03	8.23	0.45	9.26	20.42	23.87	0.89
1.04	8.57	0.46	9.47	20.50	23.98	0.91
1.05	8.92	0.47	9.67	20.59	24.08	0.92
1.06	9.28	0.48	9.88	20.66	24.19	0.94
1.07	9.65	0.49	10.08	20.74	24.30	0.96
1.08	10.03	0.49	10.29	20.83	24.42	0.97
1.09	10.42	0.50	10.50	20.91	24.54	0.99
1.10	10.83	0.51	10.71	21.00	24.66	1.01
1.11	11.25	0.52	10.92	21.08	24.78	1.03
1.12	11.67	0.51	11.14	22.03	25.77	1.05

Flow depth (m)	Discharge (m^3/s)	Av. flow depth (m)	Area (m^2)	Width (m)	Perimeter (m)	Av. velocity (m/s)
1.13	12.11	0.51	11.36	22.12	25.89	1.07
1.14	12.57	0.49	11.59	23.68	27.49	1.08
1.15	13.03	0.50	11.83	23.87	27.71	1.10
1.16	13.51	0.50	12.07	24.37	28.25	1.12
1.17	14.00	0.50	12.31	24.87	28.80	1.14
1.18	14.51	0.50	12.57	25.32	29.28	1.15
1.19	15.03	0.50	12.82	25.54	29.54	1.17
1.20	15.56	0.51	13.08	25.79	29.83	1.19
1.21	16.11	0.51	13.34	26.11	30.20	1.21
1.22	16.67	0.51	13.60	26.43	30.56	1.23
1.23	17.25	0.52	13.86	26.76	30.93	1.24
1.24	17.84	0.50	14.14	28.22	32.44	1.26
1.25	18.45	0.50	14.42	28.60	32.87	1.28
1.26	19.07	0.51	14.71	28.98	33.30	1.30
1.27	19.71	0.51	15.00	29.37	33.73	1.31
1.28	20.36	0.51	15.29	29.71	34.12	1.33
1.29	21.03	0.52	15.59	29.99	34.45	1.35
1.30	21.72	0.52	15.89	30.28	34.78	1.37
1.31	22.43	0.53	16.20	30.56	35.10	1.38
1.32	23.15	0.54	16.51	30.85	35.43	1.40
1.33	23.89	0.54	16.82	31.13	35.76	1.42
1.34	24.64	0.55	17.13	31.42	36.09	1.44
1.35	25.42	0.55	17.44	31.64	36.35	1.46
1.36	26.21	0.56	17.76	31.86	36.61	1.48
1.37	27.03	0.56	18.08	32.05	36.84	1.49
1.38	27.86	0.57	18.40	32.25	37.07	1.51
1.39	28.71	0.58	18.73	32.44	37.31	1.53
1.40	29.58	0.58	19.05	32.63	37.54	1.55
1.41	30.47	0.59	19.38	33.03	37.98	1.57
1.42	31.38	0.59	19.71	33.40	38.38	1.59
1.43	32.31	0.59	20.05	33.77	38.78	1.61
1.44	33.26	0.60	20.39	34.14	39.18	1.63
1.45	34.24	0.60	20.73	34.50	39.58	1.65
1.46	35.23	0.60	21.08	34.87	39.99	1.67
1.47	36.25	0.61	21.43	35.24	40.39	1.69
1.48	37.29	0.61	21.78	35.61	40.79	1.71
1.49	38.35	0.62	22.14	35.92	41.14	1.73
1.50	39.43	0.62	22.50	36.11	41.35	1.75
1.51	40.54	0.63	22.86	36.29	41.57	1.77
1.52	41.67	0.64	23.23	36.48	41.79	1.79
1.53	42.82	0.64	23.59	36.70	42.04	1.82
1.54	44.00	0.65	23.96	36.90	42.26	1.84
1.55	45.20	0.66	24.33	37.11	42.48	1.86
1.56	46.43	0.66	24.70	37.28	42.68	1.88
1.57	47.68	0.67	25.08	37.45	42.86	1.90
1.58	48.96	0.68	25.45	37.62	43.05	1.92
1.59	50.27	0.68	25.83	37.79	43.24	1.95
1.60	51.60	0.69	26.21	37.95	43.42	1.97
1.61	52.95	0.70	26.59	38.12	43.61	1.99
1.62	54.34	0.70	26.97	38.29	43.80	2.01
1.63	55.75	0.71	27.35	38.47	44.00	2.04
1.64	57.19	0.72	27.74	38.76	44.30	2.06
1.65	58.65	0.72	28.13	39.04	44.59	2.09
1.66	60.15	0.73	28.52	39.28	44.84	2.11
1.67	61.67	0.73	28.91	39.52	45.10	2.13
1.68	63.23	0.74	29.31	39.76	45.35	2.16
1.69	64.81	0.74	29.71	39.92	45.51	2.18
1.70	66.42	0.75	30.11	40.02	45.62	2.21

Flow depth (m)	Discharge (m^3/s)	Av. flow depth (m)	Area (m^2)	Width (m)	Perimeter (m)	Av. velocity (m/s)
1.71	68.07	0.76	30.51	40.12	45.72	2.23
1.72	69.74	0.77	30.91	40.23	45.83	2.26
1.73	71.45	0.78	31.31	40.33	45.93	2.28
1.74	73.18	0.78	31.72	40.44	46.04	2.31
1.75	74.95	0.79	32.12	40.54	46.15	2.33
1.76	76.75	0.80	32.53	40.64	46.25	2.36
1.77	78.58	0.81	32.93	40.75	46.36	2.39
1.78	80.45	0.82	33.34	40.84	46.45	2.41
1.79	82.35	0.82	33.75	40.92	46.53	2.44
1.80	84.29	0.83	34.16	40.99	46.61	2.47
1.81	86.25	0.84	34.57	41.07	46.69	2.49
1.82	88.26	0.85	34.98	41.15	46.78	2.52
1.83	90.29	0.86	35.39	41.23	46.86	2.55
1.84	92.37	0.87	35.81	41.31	46.94	2.58
1.85	94.48	0.88	36.22	41.39	47.02	2.61
1.86	96.62	0.88	36.64	41.47	47.10	2.64
1.87	98.81	0.89	37.05	41.54	47.19	2.67
1.88	101.03	0.90	37.47	41.62	47.27	2.70
1.89	103.29	0.91	37.88	41.70	47.35	2.73
1.90	105.58	0.92	38.30	41.78	47.43	2.76
1.91	107.92	0.92	38.72	41.86	47.51	2.79
1.92	110.29	0.92	39.14	42.44	48.09	2.82
1.93	112.70	0.92	39.57	43.07	48.73	2.85
1.94	115.16	0.92	40.00	43.70	49.36	2.88
1.95	117.65	0.91	40.44	44.33	49.99	2.91
1.96	120.19	0.91	40.89	44.96	50.63	2.94
1.97	122.76	0.91	41.34	45.59	51.26	2.97
1.98	125.38	0.90	41.80	46.22	51.90	3.00
1.99	128.04	0.91	42.26	46.64	52.31	3.03
2.00	130.74	0.91	42.73	46.73	52.41	3.06

Table I.7 Tabulated hydraulic data for IFR Site 3 on the Black Kei River

Flow depth (m)	Discharge (m^3/s)	Av. flow depth (m)	Area (m^2)	Width (m)	Perimeter (m)	Av. velocity (m/s)
0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.01	0.00	0.00	0.00	0.14	0.14	0.00
0.02	0.00	0.01	0.00	0.30	0.31	0.00
0.03	0.00	0.01	0.01	0.46	0.48	0.00
0.04	0.00	0.02	0.01	0.80	0.83	0.00
0.05	0.00	0.02	0.02	1.31	1.35	0.00
0.06	0.00	0.02	0.04	1.92	1.98	0.00
0.07	0.00	0.03	0.06	2.30	2.39	0.00
0.08	0.00	0.03	0.08	2.64	2.77	0.00
0.09	0.00	0.04	0.11	2.99	3.18	0.00
0.10	0.00	0.04	0.14	3.35	3.58	0.00
0.11	0.00	0.05	0.18	3.67	3.94	0.00
0.12	0.00	0.06	0.22	3.91	4.22	0.00
0.13	0.00	0.06	0.26	4.21	4.58	0.00
0.14	0.00	0.07	0.30	4.51	4.93	0.00
0.15	0.00	0.07	0.35	4.83	5.32	0.00
0.16	0.00	0.08	0.40	5.16	5.70	0.01
0.17	0.00	0.08	0.45	5.49	6.09	0.01
0.18	0.00	0.09	0.51	5.81	6.47	0.01
0.19	0.00	0.09	0.57	6.09	6.82	0.01
0.20	0.01	0.10	0.63	6.37	7.16	0.01
0.21	0.01	0.11	0.70	6.60	7.45	0.01
0.22	0.01	0.11	0.76	6.82	7.73	0.01

Flow depth (m)	Discharge (m^3/s)	Av. flow depth (m)	Area (m^2)	Width (m)	Perimeter (m)	Av. velocity (m/s)
0.23	0.01	0.11	0.83	7.65	8.62	0.01
0.24	0.01	0.12	0.91	7.86	8.88	0.01
0.25	0.02	0.12	0.99	8.06	9.15	0.02
0.26	0.02	0.13	1.07	8.26	9.41	0.02
0.27	0.02	0.14	1.16	8.44	9.66	0.02
0.28	0.03	0.14	1.24	8.63	9.91	0.02
0.29	0.03	0.15	1.33	8.82	10.16	0.02
0.30	0.03	0.16	1.42	9.02	10.44	0.02
0.31	0.04	0.16	1.51	9.24	10.74	0.03
0.32	0.04	0.17	1.60	9.48	11.05	0.03
0.33	0.05	0.17	1.70	9.71	11.37	0.03
0.34	0.06	0.18	1.80	9.95	11.68	0.03
0.35	0.07	0.19	1.90	10.18	12.00	0.03
0.36	0.07	0.19	2.00	10.42	12.31	0.04
0.37	0.08	0.20	2.11	10.66	12.63	0.04
0.38	0.09	0.20	2.21	10.89	12.95	0.04
0.39	0.11	0.21	2.32	11.13	13.26	0.05
0.40	0.12	0.21	2.44	11.36	13.58	0.05
0.41	0.13	0.22	2.55	11.60	13.89	0.05
0.42	0.15	0.23	2.67	11.81	14.18	0.05
0.43	0.16	0.23	2.79	12.06	14.51	0.06
0.44	0.18	0.23	2.91	12.40	14.93	0.06
0.45	0.20	0.24	3.03	12.74	15.35	0.06
0.46	0.22	0.24	3.16	13.07	15.76	0.07
0.47	0.24	0.25	3.30	13.34	16.10	0.07
0.48	0.26	0.24	3.43	14.30	17.14	0.08
0.49	0.29	0.24	3.58	14.88	17.80	0.08
0.50	0.31	0.25	3.73	15.21	18.22	0.08
0.51	0.34	0.23	3.89	16.67	19.76	0.09
0.52	0.37	0.24	4.06	17.01	20.18	0.09
0.53	0.40	0.24	4.23	17.32	20.56	0.09
0.54	0.43	0.25	4.40	17.63	20.95	0.10
0.55	0.47	0.26	4.58	17.94	21.33	0.10
0.56	0.51	0.26	4.76	18.25	21.72	0.11
0.57	0.55	0.26	4.95	19.06	22.60	0.11
0.58	0.59	0.26	5.14	19.83	23.46	0.12
0.59	0.64	0.26	5.34	20.25	23.95	0.12
0.60	0.69	0.27	5.55	20.71	24.48	0.12
0.61	0.74	0.27	5.76	21.16	25.01	0.13
0.62	0.79	0.28	5.97	21.62	25.54	0.13
0.63	0.85	0.28	6.19	22.08	26.07	0.14
0.64	0.91	0.29	6.41	22.40	26.46	0.14
0.65	0.97	0.29	6.64	22.65	26.78	0.15
0.66	1.04	0.30	6.87	22.90	27.10	0.15
0.67	1.11	0.31	7.10	23.13	27.39	0.16
0.68	1.18	0.31	7.33	23.33	27.67	0.16
0.69	1.26	0.32	7.56	23.53	27.94	0.17
0.70	1.34	0.33	7.80	23.79	28.27	0.17
0.71	1.43	0.33	8.04	24.10	28.65	0.18
0.72	1.52	0.34	8.28	24.41	29.03	0.18
0.73	1.61	0.34	8.53	24.72	29.41	0.19
0.74	1.71	0.35	8.78	25.02	29.78	0.19
0.75	1.81	0.36	9.03	25.31	30.11	0.20
0.76	1.92	0.36	9.28	25.58	30.44	0.21
0.77	2.03	0.37	9.54	25.83	30.74	0.21
0.78	2.15	0.38	9.80	26.05	30.99	0.22
0.79	2.27	0.38	10.06	26.23	31.20	0.23
0.80	2.40	0.39	10.32	26.38	31.38	0.23

Flow depth (m)	Discharge (m^3/s)	Av. flow depth (m)	Area (m^2)	Width (m)	Perimeter (m)	Av. velocity (m/s)
0.81	2.53	0.40	10.59	26.52	31.55	0.24
0.82	2.67	0.41	10.85	26.66	31.72	0.25
0.83	2.82	0.41	11.12	26.86	31.95	0.25
0.84	2.97	0.42	11.39	27.07	32.19	0.26
0.85	3.13	0.43	11.66	27.28	32.42	0.27
0.86	3.29	0.43	11.94	27.48	32.66	0.28
0.87	3.46	0.44	12.21	27.69	32.90	0.28
0.88	3.63	0.45	12.49	27.89	33.13	0.29
0.89	3.82	0.45	12.77	28.17	33.44	0.30
0.90	4.01	0.46	13.05	28.48	33.78	0.31
0.91	4.20	0.46	13.34	28.78	34.12	0.32
0.92	4.41	0.47	13.63	29.09	34.46	0.32
0.93	4.62	0.47	13.92	29.40	34.80	0.33
0.94	4.84	0.48	14.22	29.71	35.15	0.34
0.95	5.07	0.48	14.52	30.02	35.49	0.35
0.96	5.31	0.49	14.82	30.32	35.83	0.36
0.97	5.55	0.49	15.12	30.59	36.13	0.37
0.98	5.80	0.50	15.43	30.90	36.46	0.38
0.99	6.07	0.50	15.74	31.21	36.79	0.39
1.00	6.34	0.51	16.05	31.52	37.12	0.39
1.01	6.62	0.51	16.37	31.83	37.45	0.40
1.02	6.91	0.52	16.69	32.18	37.81	0.41
1.03	7.21	0.52	17.02	32.81	38.46	0.42
1.04	7.51	0.52	17.35	33.44	39.11	0.43
1.05	7.83	0.52	17.68	34.06	39.75	0.44
1.06	8.16	0.51	18.03	35.30	41.00	0.45
1.07	8.50	0.51	18.39	36.07	41.79	0.46
1.08	8.85	0.52	18.75	36.28	42.01	0.47
1.09	9.22	0.52	19.11	36.49	42.24	0.48
1.10	9.59	0.53	19.48	36.71	42.47	0.49
1.11	9.97	0.54	19.85	36.92	42.70	0.50
1.12	10.37	0.54	20.22	37.13	42.93	0.51
1.13	10.78	0.55	20.59	37.35	43.16	0.52
1.14	11.20	0.56	20.97	37.57	43.40	0.53
1.15	11.63	0.56	21.34	37.79	43.64	0.55
1.16	12.08	0.57	21.72	38.01	43.88	0.56
1.17	12.54	0.58	22.10	38.24	44.12	0.57
1.18	13.01	0.58	22.49	38.46	44.36	0.58

Table I.8 Tabulated hydraulic data for IFR Site 4 on the White Kei River

Flow depth (m)	Discharge (m^3/s)	Av. flow depth (m)	Area (m^2)	Width (m)	Perimeter (m)	Av. velocity (m/s)
0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.01	0.00	0.00	0.00	0.02	0.03	0.00
0.02	0.00	0.00	0.00	0.43	0.45	0.00
0.03	0.00	0.01	0.01	0.90	0.94	0.00
0.04	0.00	0.02	0.02	1.11	1.17	0.00
0.05	0.00	0.02	0.03	1.33	1.41	0.00
0.06	0.00	0.03	0.05	1.54	1.64	0.00
0.07	0.00	0.04	0.06	1.75	1.88	0.01
0.08	0.00	0.04	0.08	2.04	2.18	0.01
0.09	0.00	0.04	0.10	2.34	2.52	0.01
0.10	0.00	0.05	0.13	2.61	2.82	0.01
0.11	0.00	0.05	0.16	3.20	3.44	0.01
0.12	0.00	0.05	0.19	3.53	3.82	0.01
0.13	0.00	0.06	0.23	4.01	4.35	0.01
0.14	0.00	0.06	0.27	4.45	4.84	0.02

Flow depth (m)	Discharge (m^3/s)	Av. flow depth (m)	Area (m^2)	Width (m)	Perimeter (m)	Av. velocity (m/s)
0.15	0.01	0.07	0.32	4.77	5.21	0.02
0.16	0.01	0.07	0.37	5.23	5.73	0.02
0.17	0.01	0.07	0.42	5.94	6.49	0.02
0.18	0.01	0.07	0.48	6.54	7.15	0.02
0.19	0.01	0.08	0.55	6.74	7.40	0.03
0.20	0.02	0.09	0.62	6.91	7.63	0.03
0.21	0.02	0.10	0.69	7.09	7.88	0.03
0.22	0.02	0.10	0.76	7.28	8.13	0.03
0.23	0.03	0.11	0.83	7.46	8.38	0.03
0.24	0.03	0.12	0.91	7.65	8.63	0.04
0.25	0.04	0.13	0.99	7.83	8.88	0.04
0.26	0.04	0.13	1.07	8.01	9.13	0.04
0.27	0.05	0.14	1.15	8.18	9.35	0.04
0.28	0.06	0.15	1.23	8.34	9.57	0.05
0.29	0.07	0.15	1.31	8.50	9.79	0.05
0.30	0.08	0.16	1.40	8.67	10.01	0.05
0.31	0.09	0.17	1.49	8.83	10.23	0.06
0.32	0.10	0.18	1.58	8.99	10.45	0.06
0.33	0.11	0.18	1.67	9.16	10.67	0.06
0.34	0.12	0.19	1.76	9.41	10.97	0.07
0.35	0.13	0.19	1.86	9.72	11.33	0.07
0.36	0.15	0.19	1.95	10.03	11.69	0.08
0.37	0.17	0.20	2.06	10.28	11.98	0.08
0.38	0.18	0.21	2.16	10.42	12.16	0.08
0.39	0.20	0.22	2.26	10.53	12.30	0.09
0.40	0.22	0.22	2.37	10.64	12.45	0.09
0.41	0.24	0.23	2.48	10.78	12.63	0.10
0.42	0.27	0.24	2.59	10.92	12.80	0.10
0.43	0.29	0.24	2.70	11.05	12.98	0.11
0.44	0.32	0.25	2.81	11.19	13.16	0.11
0.45	0.34	0.26	2.92	11.33	13.34	0.12
0.46	0.37	0.26	3.03	11.46	13.51	0.12
0.47	0.40	0.27	3.15	11.59	13.67	0.13
0.48	0.44	0.28	3.27	11.71	13.82	0.13
0.49	0.47	0.29	3.38	11.84	13.98	0.14
0.50	0.51	0.29	3.50	11.96	14.13	0.15
0.51	0.55	0.30	3.62	12.09	14.29	0.15
0.52	0.59	0.31	3.74	12.21	14.44	0.16
0.53	0.63	0.31	3.87	12.34	14.60	0.16
0.54	0.68	0.32	3.99	12.46	14.75	0.17
0.55	0.73	0.33	4.12	12.58	14.91	0.18
0.56	0.78	0.32	4.25	13.48	15.83	0.18
0.57	0.83	0.30	4.39	14.57	16.95	0.19
0.58	0.89	0.29	4.54	15.45	17.86	0.20
0.59	0.95	0.29	4.69	15.99	18.42	0.20
0.60	1.01	0.29	4.86	16.59	19.05	0.21
0.61	1.07	0.28	5.03	17.79	20.29	0.21
0.62	1.14	0.28	5.21	18.73	21.27	0.22
0.63	1.21	0.28	5.40	19.28	21.86	0.22
0.64	1.28	0.28	5.60	19.81	22.43	0.23
0.65	1.36	0.29	5.80	20.27	22.93	0.23
0.66	1.44	0.29	6.00	20.63	23.33	0.24
0.67	1.52	0.30	6.21	20.99	23.73	0.24
0.68	1.61	0.30	6.42	21.35	24.12	0.25
0.69	1.70	0.31	6.64	21.72	24.52	0.26
0.70	1.79	0.31	6.86	22.11	24.94	0.26
0.71	1.89	0.31	7.08	22.50	25.36	0.27
0.72	1.99	0.32	7.31	22.89	25.78	0.27

Flow depth (m)	Discharge (m^3/s)	Av. flow depth (m)	Area (m^2)	Width (m)	Perimeter (m)	Av. velocity (m/s)
0.73	2.09	0.32	7.54	23.29	26.20	0.28
0.74	2.20	0.33	7.77	23.62	26.56	0.28
0.75	2.31	0.34	8.01	23.86	26.83	0.29
0.76	2.43	0.34	8.25	24.10	27.09	0.29
0.77	2.55	0.35	8.49	24.35	27.36	0.30
0.78	2.68	0.36	8.74	24.59	27.63	0.31
0.79	2.81	0.36	8.98	24.85	27.91	0.31
0.80	2.94	0.37	9.23	25.12	28.21	0.32
0.81	3.08	0.37	9.49	25.39	28.52	0.33
0.82	3.23	0.38	9.74	25.59	28.74	0.33
0.83	3.38	0.39	10.00	25.89	29.06	0.34
0.84	3.53	0.39	10.26	26.30	29.49	0.34
0.85	3.69	0.39	10.53	27.29	30.50	0.35
0.86	3.86	0.39	10.80	28.02	31.25	0.36
0.87	4.03	0.39	11.09	28.70	31.94	0.36
0.88	4.20	0.39	11.38	29.39	32.66	0.37
0.89	4.38	0.39	11.68	30.27	33.56	0.38
0.90	4.57	0.39	11.98	30.96	34.27	0.38
0.91	4.76	0.39	12.29	31.56	34.89	0.39
0.92	4.96	0.39	12.61	32.04	35.38	0.39
0.93	5.16	0.40	12.93	32.46	35.83	0.40
0.94	5.37	0.41	13.26	32.74	36.14	0.41
0.95	5.59	0.41	13.59	33.02	36.45	0.41
0.96	5.81	0.42	13.92	33.31	36.78	0.42
0.97	6.04	0.42	14.26	33.57	37.08	0.42
0.98	6.28	0.43	14.59	33.80	37.35	0.43
0.99	6.52	0.44	14.93	34.03	37.62	0.44
1.00	6.77	0.45	15.27	34.26	37.89	0.44
1.01	7.02	0.45	15.62	34.48	38.15	0.45
1.02	7.29	0.46	15.96	34.70	38.40	0.46
1.03	7.56	0.47	16.31	34.91	38.65	0.46
1.04	7.84	0.47	16.66	35.12	38.91	0.47
1.05	8.12	0.48	17.01	35.42	39.25	0.48
1.06	8.41	0.48	17.37	35.88	39.75	0.48
1.07	8.71	0.47	17.73	37.69	41.60	0.49
1.08	9.02	0.47	18.12	38.52	42.47	0.50
1.09	9.34	0.47	18.50	39.02	43.01	0.50
1.10	9.66	0.48	18.90	39.51	43.52	0.51
1.11	9.99	0.48	19.29	39.99	44.03	0.52
1.12	10.33	0.49	19.70	40.29	44.35	0.52
1.13	10.68	0.50	20.10	40.49	44.58	0.53
1.14	11.04	0.50	20.51	40.70	44.81	0.54
1.15	11.40	0.51	20.91	40.91	45.03	0.55
1.16	11.78	0.52	21.32	41.11	45.26	0.55
1.17	12.16	0.52	21.74	41.80	45.97	0.56
1.18	12.55	0.52	22.16	42.24	46.43	0.57
1.19	12.95	0.53	22.58	42.43	46.65	0.57
1.20	13.36	0.54	23.01	42.62	46.86	0.58
1.21	13.78	0.55	23.43	42.81	47.08	0.59
1.22	14.21	0.55	23.86	43.00	47.29	0.60
1.23	14.65	0.56	24.29	43.19	47.50	0.60
1.24	15.10	0.57	24.73	43.38	47.72	0.61
1.25	15.56	0.58	25.16	43.57	47.93	0.62
1.26	16.03	0.58	25.60	43.76	48.14	0.63
1.27	16.51	0.59	26.04	43.95	48.36	0.63
1.28	17.00	0.60	26.48	44.14	48.57	0.64
1.29	17.50	0.61	26.92	44.33	48.78	0.65
1.30	18.02	0.61	27.36	44.52	49.00	0.66

Flow depth (m)	Discharge (m^3/s)	Av. flow depth (m)	Area (m^2)	Width (m)	Perimeter (m)	Av. velocity (m/s)
1.31	18.54	0.62	27.81	44.71	49.21	0.67
1.32	19.07	0.63	28.26	44.90	49.43	0.67
1.33	19.62	0.64	28.71	45.09	49.64	0.68
1.34	20.17	0.64	29.16	45.28	49.85	0.69
1.35	20.74	0.65	29.61	45.47	50.07	0.70
1.36	21.32	0.66	30.07	45.66	50.28	0.71
1.37	21.91	0.67	30.53	45.85	50.49	0.72
1.38	22.51	0.67	30.99	46.04	50.71	0.73
1.39	23.13	0.68	31.45	46.23	50.92	0.74
1.40	23.75	0.68	31.91	46.94	51.65	0.74
1.41	24.39	0.67	32.39	48.17	52.90	0.75
1.42	25.05	0.67	32.87	48.84	53.60	0.76
1.43	25.71	0.68	33.36	48.95	53.73	0.77
1.44	26.39	0.69	33.85	49.06	53.87	0.78
1.45	27.08	0.70	34.34	49.18	54.00	0.79
1.46	27.78	0.71	34.84	49.32	54.16	0.80
1.47	28.50	0.71	35.33	49.54	54.40	0.81
1.48	29.23	0.72	35.83	49.85	54.74	0.82
1.49	29.97	0.72	36.33	50.17	55.08	0.83
1.50	30.73	0.73	36.83	50.49	55.42	0.83
1.51	31.50	0.73	37.34	50.81	55.76	0.84
1.52	32.29	0.74	37.85	51.12	56.10	0.85
1.53	33.09	0.75	38.36	51.44	56.44	0.86
1.54	33.90	0.75	38.88	51.77	56.79	0.87
1.55	34.73	0.75	39.40	52.19	57.23	0.88
1.56	35.57	0.76	39.92	52.59	57.65	0.89
1.57	36.43	0.76	40.45	52.93	58.01	0.90
1.58	37.30	0.77	40.98	53.46	58.56	0.91
1.59	38.19	0.77	41.52	54.19	59.30	0.92
1.60	39.10	0.77	42.06	54.91	60.04	0.93
1.61	40.02	0.77	42.62	55.64	60.77	0.94
1.62	40.95	0.77	43.17	56.30	61.45	0.95
1.63	41.90	0.77	43.74	56.90	62.06	0.96
1.64	42.87	0.78	44.31	57.17	62.33	0.97
1.65	43.85	0.78	44.88	57.22	62.38	0.98
1.66	44.85	0.79	45.46	57.26	62.43	0.99
1.67	45.87	0.80	46.03	57.31	62.48	1.00
1.68	46.90	0.81	46.60	57.36	62.53	1.01
1.69	47.95	0.82	47.18	57.40	62.58	1.02
1.70	49.02	0.83	47.75	57.45	62.63	1.03
1.71	50.11	0.84	48.33	57.49	62.69	1.04
1.72	51.21	0.85	48.90	57.54	62.74	1.05
1.73	52.33	0.86	49.48	57.58	62.79	1.06
1.74	53.46	0.87	50.05	57.63	62.84	1.07
1.75	54.62	0.88	50.63	57.67	62.89	1.08
1.76	55.79	0.89	51.21	57.72	62.94	1.09
1.77	56.99	0.90	51.78	57.77	62.99	1.10
1.78	58.20	0.91	52.36	57.81	63.04	1.11
1.79	59.43	0.92	52.94	57.86	63.09	1.12
1.80	60.67	0.92	53.52	57.90	63.14	1.13
1.81	61.94	0.93	54.10	57.95	63.19	1.15
1.82	63.23	0.94	54.68	57.99	63.24	1.16
1.83	64.53	0.95	55.26	58.04	63.29	1.17
1.84	65.86	0.96	55.84	58.11	63.37	1.18
1.85	67.21	0.97	56.42	58.18	63.44	1.19
1.86	68.57	0.98	57.00	58.26	63.52	1.20
1.87	69.96	0.99	57.58	58.33	63.59	1.21
1.88	71.36	1.00	58.17	58.40	63.67	1.23

Flow depth (m)	Discharge (m^3/s)	Av. flow depth (m)	Area (m^2)	Width (m)	Perimeter (m)	Av. velocity (m/s)
1.89	72.79	1.00	58.75	58.47	63.74	1.24
1.90	74.24	1.01	59.34	58.54	63.81	1.25
1.91	75.71	1.02	59.92	58.61	63.89	1.26
1.92	77.20	1.03	60.51	58.69	63.96	1.28
1.93	78.71	1.04	61.10	58.76	64.04	1.29
1.94	80.24	1.05	61.68	58.83	64.11	1.30
1.95	81.79	1.06	62.27	58.90	64.19	1.31
1.96	83.37	1.07	62.86	58.97	64.26	1.33
1.97	84.97	1.07	63.45	59.04	64.33	1.34
1.98	86.59	1.08	64.04	59.12	64.41	1.35
1.99	88.23	1.09	64.64	59.19	64.48	1.37
2.00	89.90	1.10	65.23	59.26	64.56	1.38
2.01	91.58	1.11	65.82	59.33	64.63	1.39
2.02	93.30	1.12	66.41	59.40	64.71	1.40
2.03	95.03	1.13	67.01	59.47	64.78	1.42
2.04	96.79	1.14	67.60	59.54	64.86	1.43
2.05	98.57	1.14	68.20	59.62	64.93	1.45
2.06	100.38	1.15	68.80	59.69	65.00	1.46
2.07	102.21	1.16	69.39	59.76	65.08	1.47
2.08	104.06	1.17	69.99	59.83	65.15	1.49
2.09	105.94	1.18	70.59	59.90	65.23	1.50
2.10	107.85	1.19	71.19	59.97	65.30	1.51
2.11	109.78	1.20	71.79	60.05	65.38	1.53
2.12	111.73	1.20	72.39	60.12	65.45	1.54
2.13	113.71	1.21	72.99	60.19	65.52	1.56
2.14	115.71	1.22	73.59	60.26	65.60	1.57
2.15	117.74	1.23	74.20	60.33	65.67	1.59
2.16	119.80	1.24	74.80	60.40	65.75	1.60
2.17	121.88	1.25	75.40	60.48	65.82	1.62
2.18	123.99	1.26	76.01	60.55	65.90	1.63
2.19	126.13	1.26	76.62	60.62	65.97	1.65
2.20	128.29	1.27	77.22	60.98	66.34	1.66
2.21	130.48	1.26	77.84	61.64	67.00	1.68
2.22	132.70	1.26	78.46	62.30	67.66	1.69
2.23	134.94	1.26	79.08	62.84	68.21	1.71
2.24	137.21	1.26	79.71	63.12	68.49	1.72
2.25	139.51	1.27	80.34	63.35	68.72	1.74
2.26	141.84	1.28	80.98	63.45	68.82	1.75
2.27	144.20	1.28	81.61	63.55	68.93	1.77
2.28	146.58	1.29	82.25	63.66	69.03	1.78
2.29	148.99	1.30	82.89	63.76	69.13	1.80
2.30	151.44	1.31	83.52	63.86	69.24	1.81
2.31	153.91	1.32	84.16	63.96	69.34	1.83
2.32	156.41	1.32	84.80	64.06	69.45	1.84
2.33	158.94	1.33	85.45	64.17	69.55	1.86
2.34	161.50	1.34	86.09	64.27	69.65	1.88
2.35	164.09	1.35	86.73	64.37	69.76	1.89
2.36	166.71	1.36	87.37	64.47	69.86	1.91
2.37	169.36	1.36	88.02	64.57	69.97	1.92
2.38	172.04	1.37	88.67	64.67	70.07	1.94
2.39	174.75	1.38	89.31	64.78	70.17	1.96
2.40	177.50	1.39	89.96	64.92	70.32	1.97
2.41	180.27	1.39	90.61	65.13	70.53	1.99
2.42	183.08	1.40	91.26	65.34	70.74	2.01
2.43	185.92	1.40	91.92	65.55	70.95	2.02
2.44	188.79	1.41	92.58	65.76	71.16	2.04
2.45	191.69	1.41	93.23	65.97	71.38	2.06
2.46	194.63	1.42	93.89	66.19	71.59	2.07

Flow depth (m)	Discharge (m^3/s)	Av. flow depth (m)	Area (m^2)	Width (m)	Perimeter (m)	Av. velocity (m/s)
2.47	197.60	1.42	94.56	66.45	71.85	2.09
2.48	200.60	1.43	95.22	66.71	72.11	2.11
2.49	203.63	1.43	95.89	66.97	72.38	2.12
2.50	206.70	1.44	96.56	67.23	72.64	2.14
2.51	209.80	1.44	97.24	67.49	72.90	2.16
2.52	212.94	1.45	97.91	67.75	73.16	2.17
2.53	216.11	1.45	98.59	68.01	73.42	2.19
2.54	219.32	1.45	99.27	68.27	73.68	2.21
2.55	222.55	1.46	99.96	68.53	73.95	2.23
2.56	225.83	1.46	100.64	68.79	74.21	2.24
2.57	229.14	1.47	101.33	69.02	74.43	2.26
2.58	232.48	1.47	102.02	69.24	74.66	2.28
2.59	235.86	1.48	102.72	69.47	74.89	2.30
2.60	239.28	1.48	103.41	69.69	75.11	2.31
2.61	242.73	1.49	104.11	69.92	75.34	2.33
2.62	246.22	1.49	104.81	70.14	75.56	2.35
2.63	249.74	1.50	105.51	70.37	75.79	2.37
2.64	253.31	1.50	106.22	70.60	76.02	2.38
2.65	256.90	1.51	106.93	70.82	76.24	2.40
2.66	260.54	1.52	107.64	71.05	76.47	2.42
2.67	264.21	1.52	108.35	71.27	76.70	2.44
2.68	267.93	1.53	109.06	71.50	76.92	2.46
2.69	271.67	1.53	109.78	71.72	77.15	2.47
2.70	275.46	1.54	110.50	71.94	77.37	2.49
2.71	279.29	1.54	111.22	72.14	77.57	2.51
2.72	283.15	1.55	111.94	72.34	77.77	2.53
2.73	287.06	1.55	112.66	72.54	77.97	2.55
2.74	291.00	1.56	113.39	72.74	78.17	2.57
2.75	294.98	1.56	114.12	72.94	78.37	2.58
2.76	299.01	1.57	114.85	73.14	78.57	2.60
2.77	303.07	1.58	115.58	73.34	78.77	2.62
2.78	307.17	1.58	116.31	73.54	78.97	2.64
2.79	311.31	1.59	117.05	73.73	79.17	2.66
2.80	315.50	1.59	117.79	73.93	79.37	2.68
2.81	319.72	1.60	118.53	74.13	79.57	2.70
2.82	323.99	1.60	119.27	74.33	79.77	2.72
2.83	328.30	1.61	120.02	74.53	79.97	2.74
2.84	332.65	1.62	120.76	74.73	80.17	2.75
2.85	337.04	1.62	121.51	74.93	80.37	2.77
2.86	341.47	1.63	122.26	75.13	80.57	2.79
2.87	345.95	1.63	123.01	75.33	80.77	2.81
2.88	350.47	1.64	123.77	75.53	80.97	2.83
2.89	355.03	1.64	124.52	75.72	81.17	2.85
2.90	359.63	1.65	125.28	75.92	81.38	2.87
2.91	364.28	1.66	126.04	76.12	81.58	2.89
2.92	368.98	1.66	126.80	76.32	81.78	2.91
2.93	373.71	1.67	127.57	76.52	81.98	2.93
2.94	378.50	1.67	128.33	76.65	82.10	2.95
2.95	383.32	1.68	129.10	76.77	82.23	2.97
2.96	388.19	1.69	129.87	76.89	82.35	2.99
2.97	393.11	1.70	130.64	77.00	82.46	3.01
2.98	398.07	1.70	131.41	77.11	82.58	3.03
2.99	403.08	1.71	132.18	77.23	82.69	3.05
3.00	408.13	1.72	132.95	77.34	82.81	3.07

I.6 CONFIDENCE IN THE HYDRAULIC CHARACTERISATIONS

The confidence in the characterisations of the hydraulic relationships are provided in Table I.9.

Table I.9 Confidence in the hydraulic characterisations

IFR Site	Site Character	Available data	Results		Comments
			Low flows	High flows	
1	3	4	(0.15-0.23) 4	(1-65) 3	Moderately difficult site to characterise hydraulically (steep riffle). Two flows monitored at 0.24 and 5m^3/s, resulting in medium to high confidence at this site based on available data.
2	2	4	(0.15-0.32) 5	(1.5-130) 3	Difficult site to characterise hydraulically (steep rapid with large resistance elements (including boulders) and complex flow patterns. Four flows were monitored in the range 0.17 to 8.2m^3/s, resulting in medium to high confidence at this site.
3	2	2	(0.2-1.0) 2	(3-130) 3	Difficult site due to large resistance elements and non-uniform flow conditions. Single discharge value of 1.1m^3/s measured at this site, giving low to medium confidence in the hydraulic characterisations based on available data.
4	2	3	(0.3-0.9) 4	(2.5-40) 2	Difficult site to characterise hydraulically due to influence of large resistance elements, including boulders. Two flows of 0.16 and 3.8m^3/s gauged at this site, providing medium confidence.

(x-y)=range of flows for recommended Ecological Category
0=none, 1=low, 2=low/medium, 3=medium, 4=medium/high, 5=high

I.7 REFERENCE

DWAF, 1999. Resource directed measures for the protection of water resources. Volume 3: River ecosystems, Version 1.0. Department of Water Affairs and Forestry, Pretoria, South Africa. Internet address: http://www-dwaf.pwv.gov.za/Directorates/IWQS/waterlaw/index.html

APPENDIX J

ECOLOGICAL CONSEQUENCES OF OPERATIONAL FLOW SCENARIOS

Delana Louw
IWR Source-to-Sea

TABLE OF CONTENTS

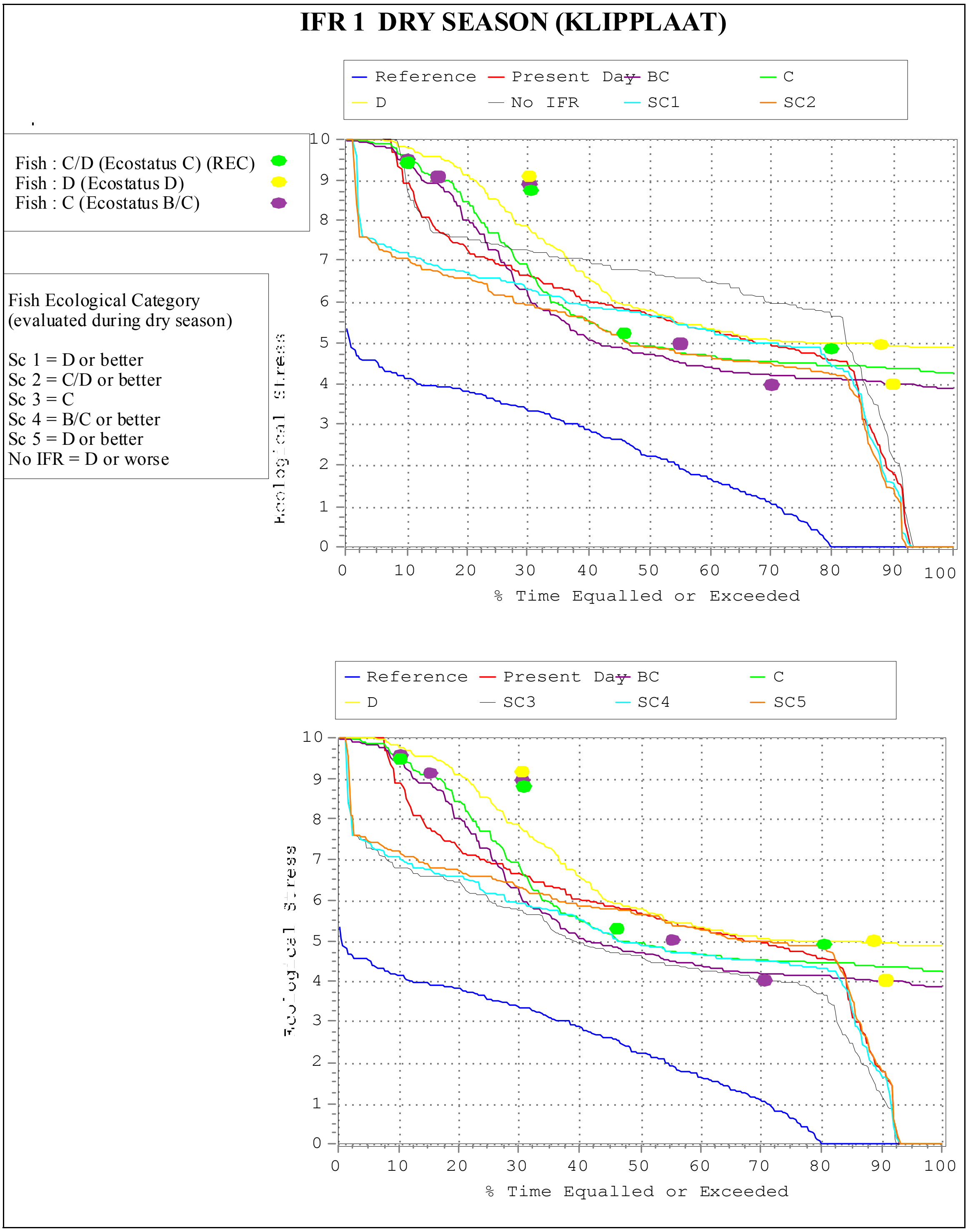
J.1 STRESS DURATION GRAPHS REPRESENTING THE VARIOUS FLOW SCENARIOS AND THE FISH AND INVERTEBRATE REQUIREMENTS. 2

J.1.1 Klipplaat River – IFR 1 2
J.1.2 Black Kei river – IFR 2 6
J.1.3 Black Kei River – IFR 3 10
J.1.4 White Kei River – IFR 4 14

J.2 REFERENCES 18

J.1 STRESS DURATION GRAPHS REPRESENTING THE VARIOUS FLOW SCENARIOS AND THE FISH AND INVERTEBRATE REQUIREMENTS.

J.1.1 KLIPPLAAT RIVER – IFR 1

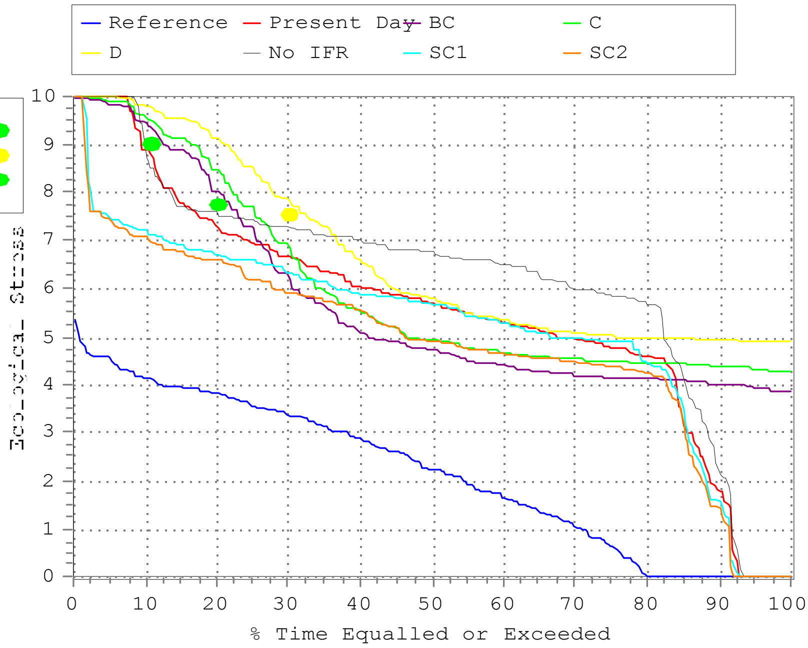


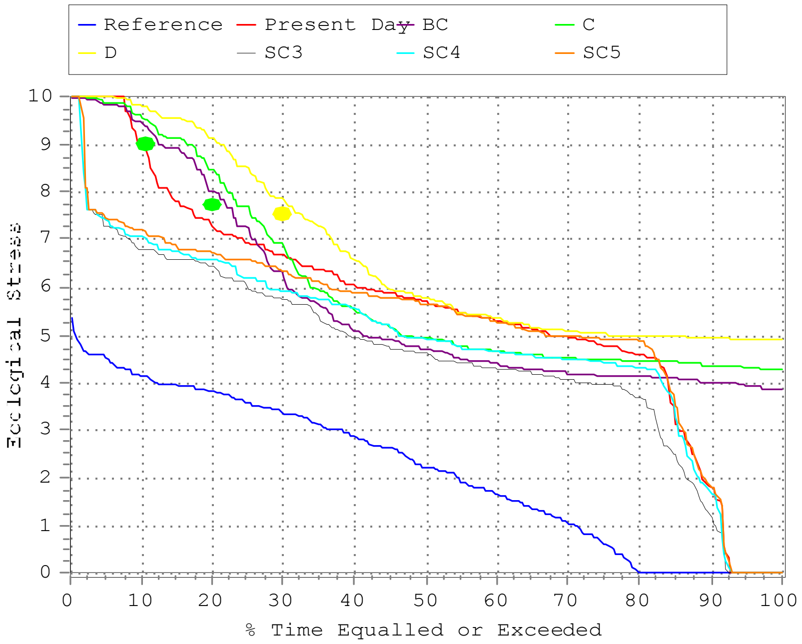
IFR 1 DRY SEASON (KLIPPLAAT)

Inverts: B (Ecostatus C) (REC)
Inverts: C (Ecostatus D)
Inverts: B (Ecostatus B/C)

Inverts Ecological Category
(evaluated during dry season)

Sc 1 = B or better
Sc 2 = B or better
Sc 3 = B or better
Sc 4 = B or better
Sc 5 = B or better
No IFR = C/D ?



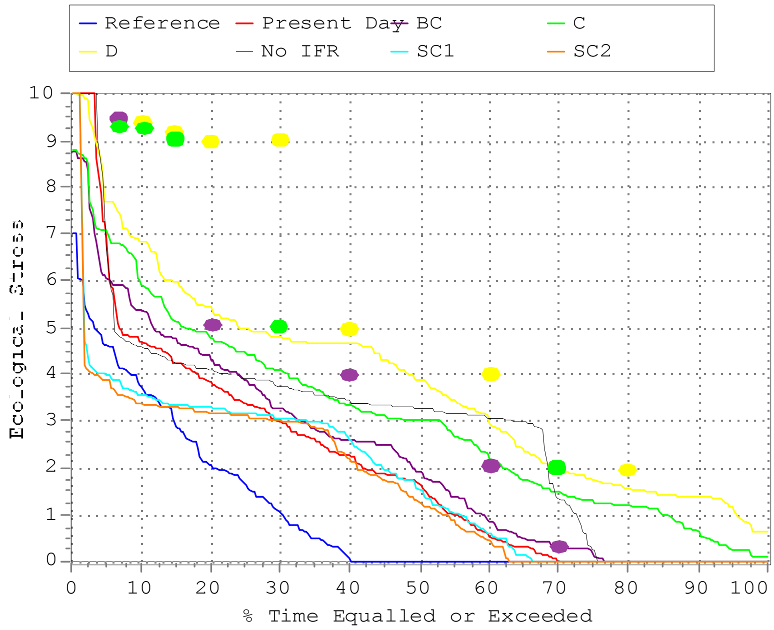


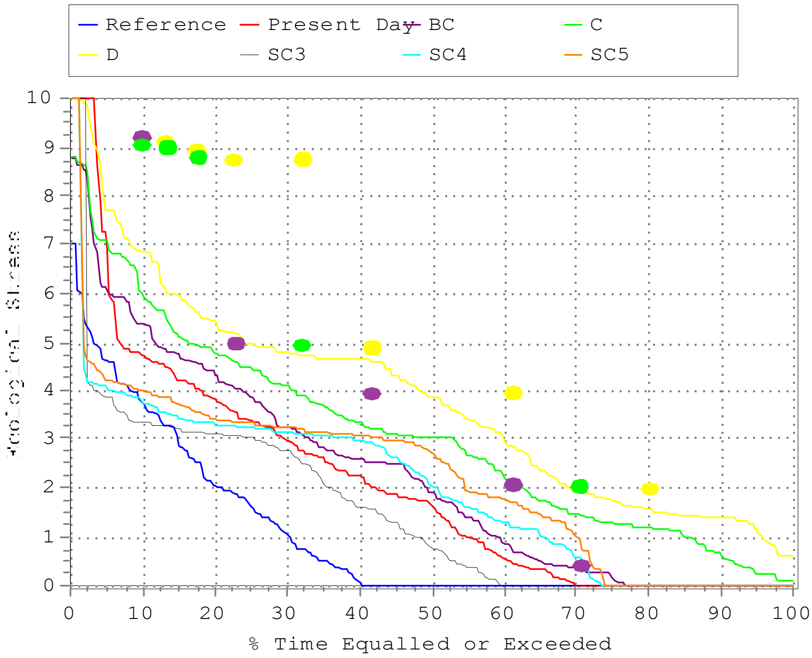
IFR 1 WET SEASON (KLIPPLAAT)

Fish : C/D (Ecostatus C) (REC)
Fish : D (Ecostatus D)
Fish : C (Ecostatus B/C)

Fish Ecological Category
(evaluated during wet season)

Sc 1 = C or better
Sc 2 = C or better
Sc 3 = C or better
Sc 4 = C or better
Sc 5 = C or better
No IFR = C



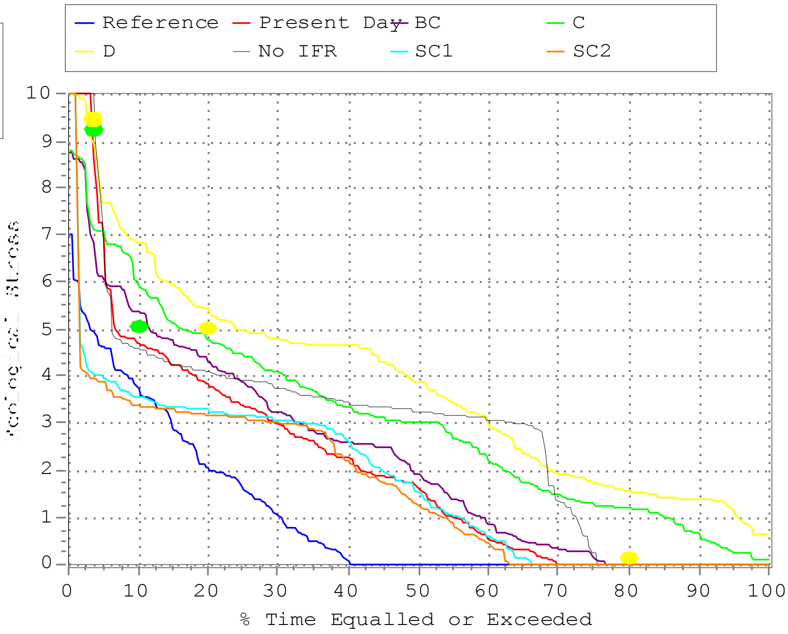


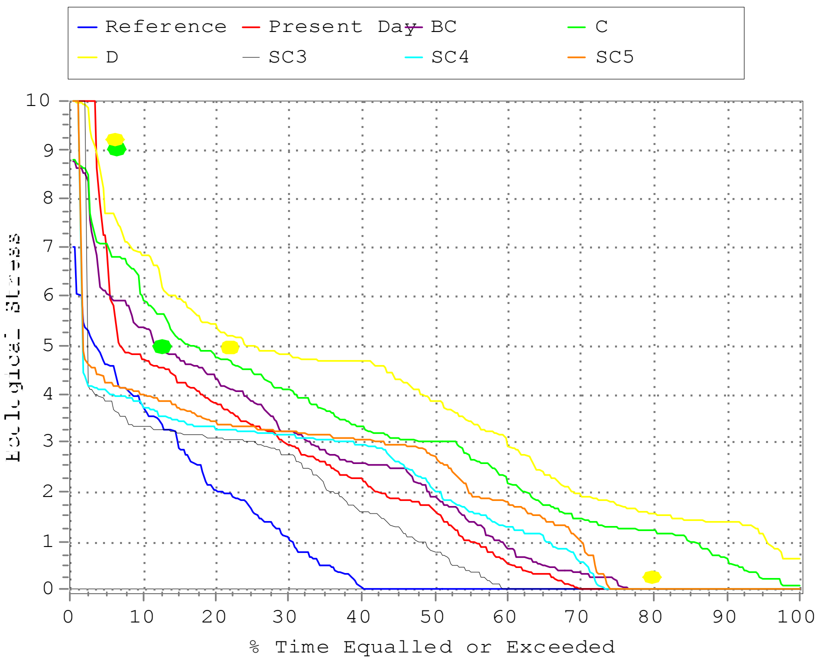
IFR 1 WET SEASON (KLIPPLAAT)

Inverts: B (Ecostatus C) (REC)
Inverts: C (Ecostatus D)
Inverts: B (Ecostatus B/C)

Inverts Ecological Category
(evaluated during wet season)

Sc 1 = B or better
Sc 2 = B or better
Sc 3 = B or better
Sc 4 = B or better
Sc 5 = B or better
No IFR = C/D ?





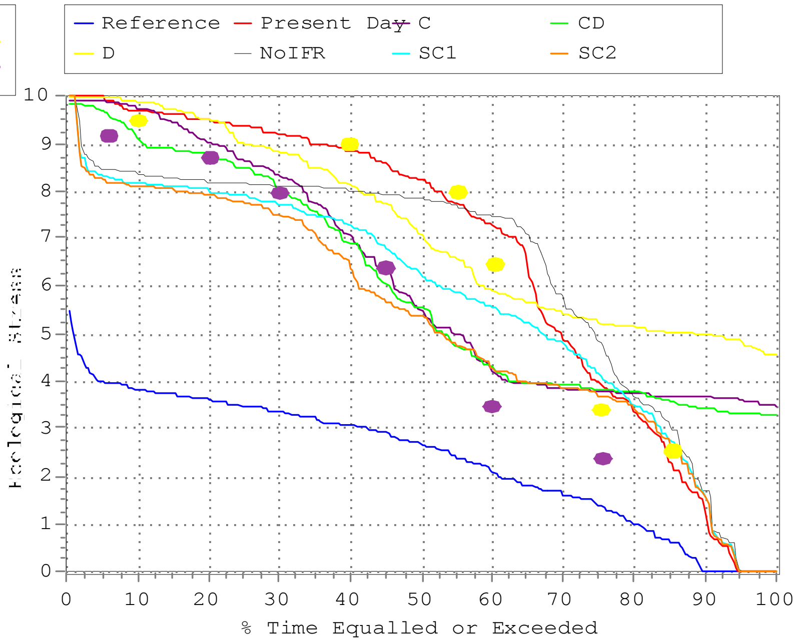
J.1.2 BLACK KEI RIVER – IFR 2

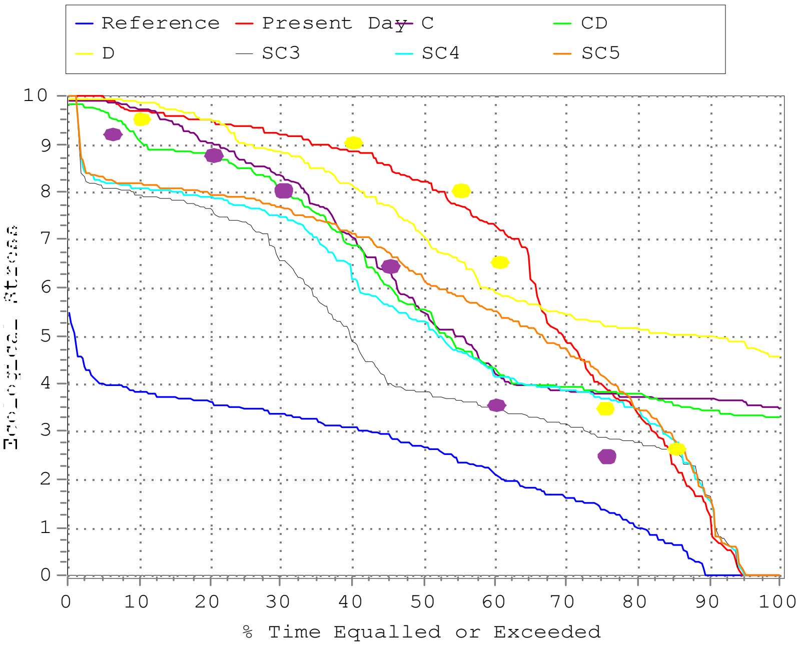
IFR 2 DRY SEASON (BLACK KEI)

Fish : D (Ecostatus D) (REC)
Fish : C (Ecostatus C)

Fish Ecological Category
(evaluated during dry season)

Sc 1 = D or C/D
Sc 2 = C/D or better
Sc 3 = C or better
Sc 4 = D or better
Sc 5 = D or better
No IFR = D



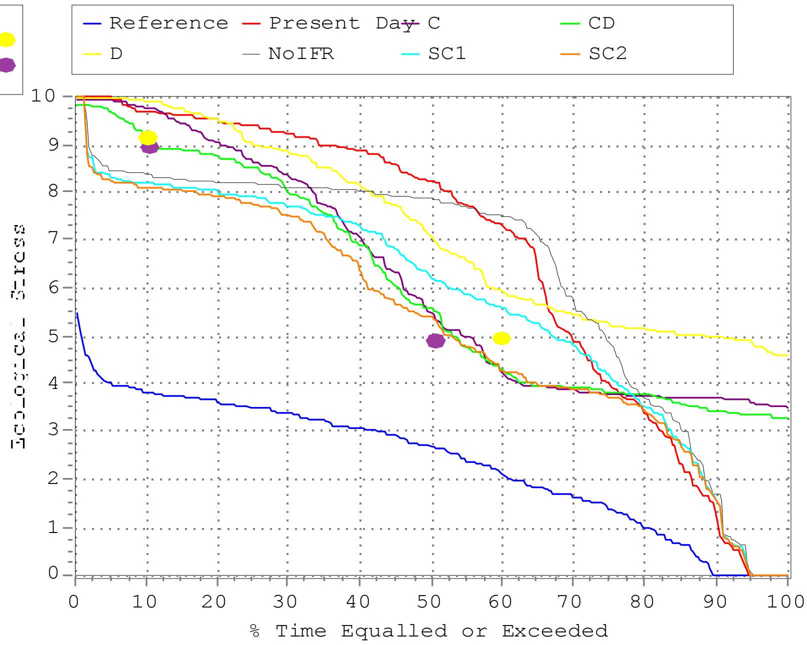


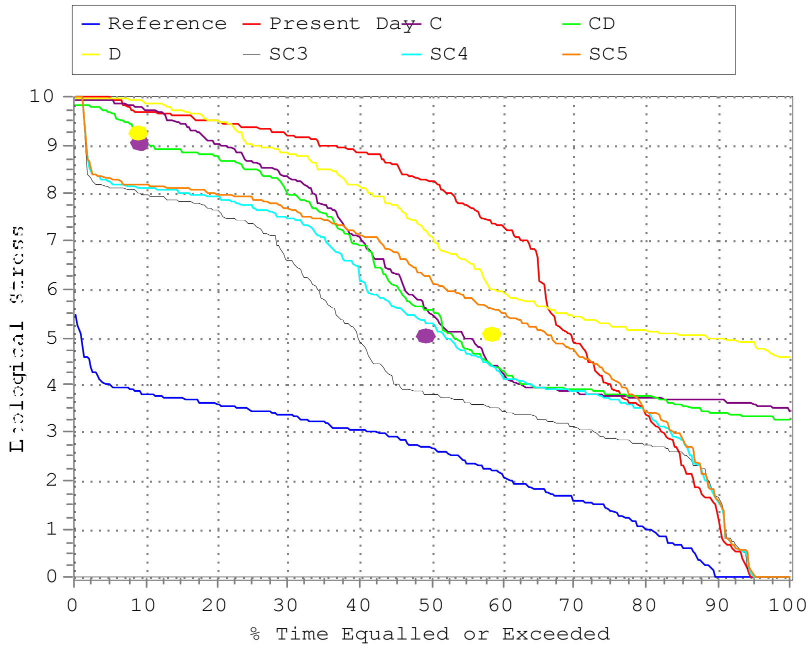
IFR 2 DRY SEASON (BLACK KEI)

Inverts: D (Ecostatus D) (REC)
Inverts: C (Ecostatus C)

Inverts Ecological Category
(evaluated during dry season)

Sc 1 = D
Sc 2 = D or better
Sc 3 = C or better
Sc 4 = D of better
Sc 5 = D
No IFR = D/E



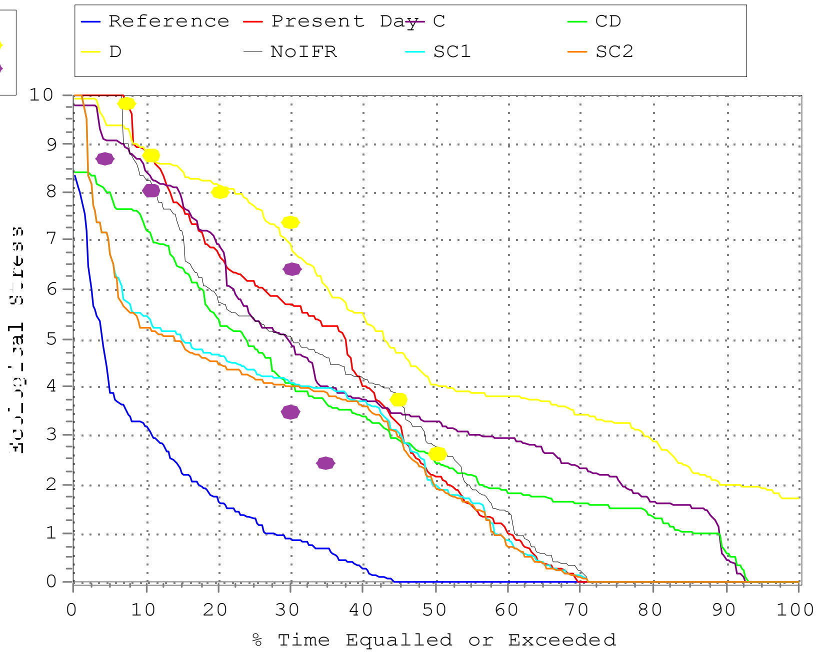


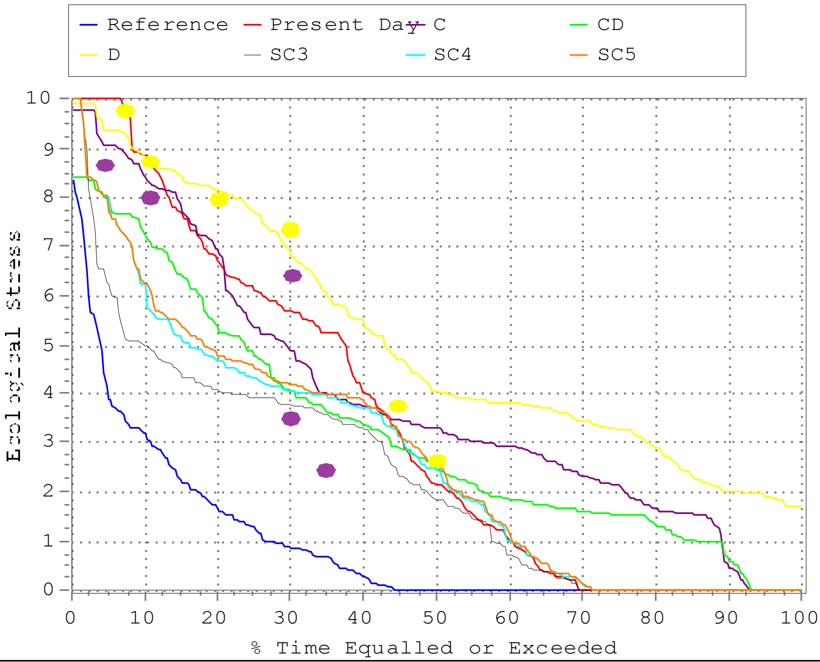
IFR 2 WET SEASON (BLACK KEI)

Fish : D (Ecostatus D) (REC)
Fish : C (Ecostatus C)

Fish Ecological Category
(evaluated during wet season)

Sc 1 = C/D or better
Sc 2 = C/D or better
Sc 3 = C/D or better
Sc 4 = D or better
Sc 5 = D or better
No IFR = D or better



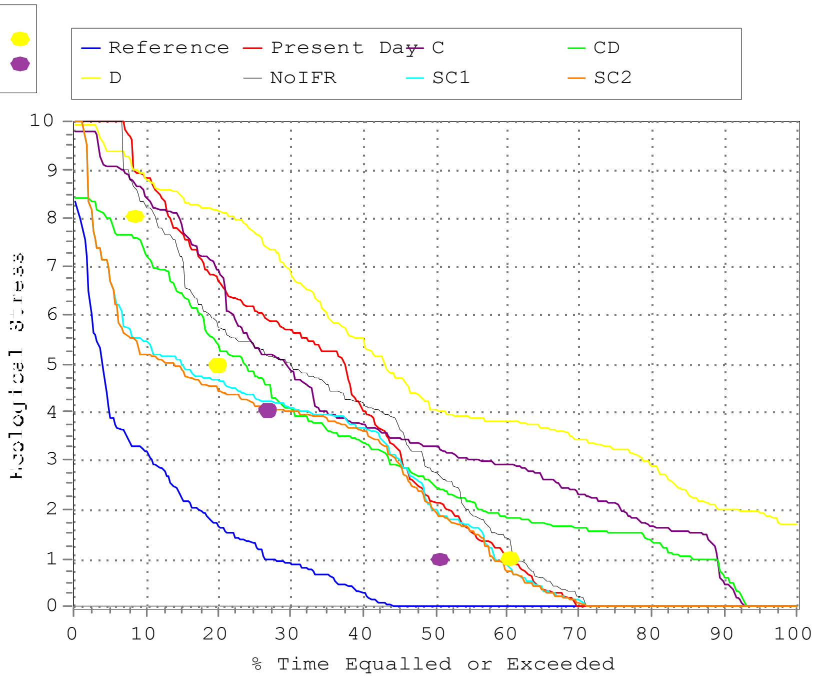


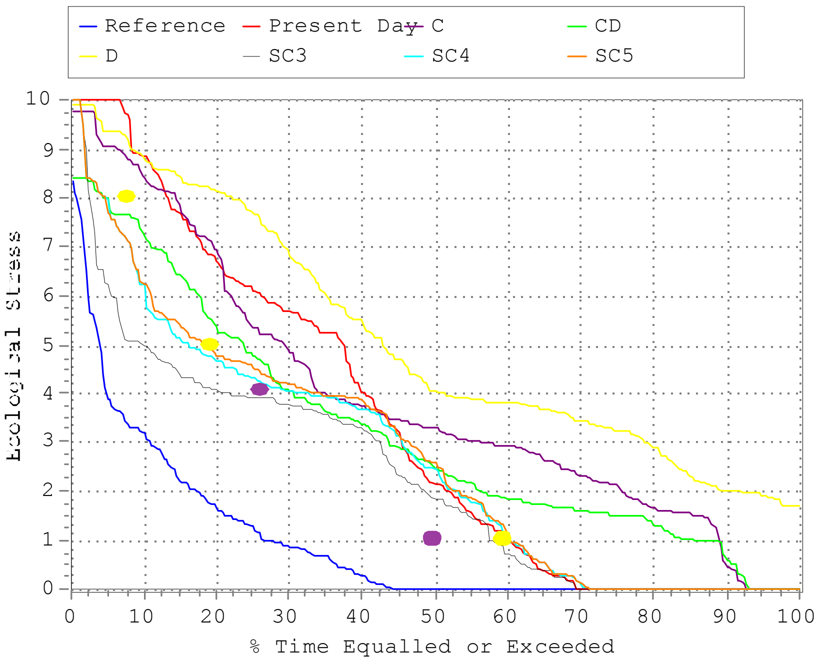
IFR 2 WET SEASON (BLACK KEI)

Inverts: D (Ecostatus D) (REC)
Inverts: C (Ecostatus C)

Inverts Ecological Category
(evaluated during wet season)

Sc 1 = C/D or better
Sc 2 = C/D or better
Sc 3 = C or better
Sc 4 = D
Sc 5 = D
No IFR = D

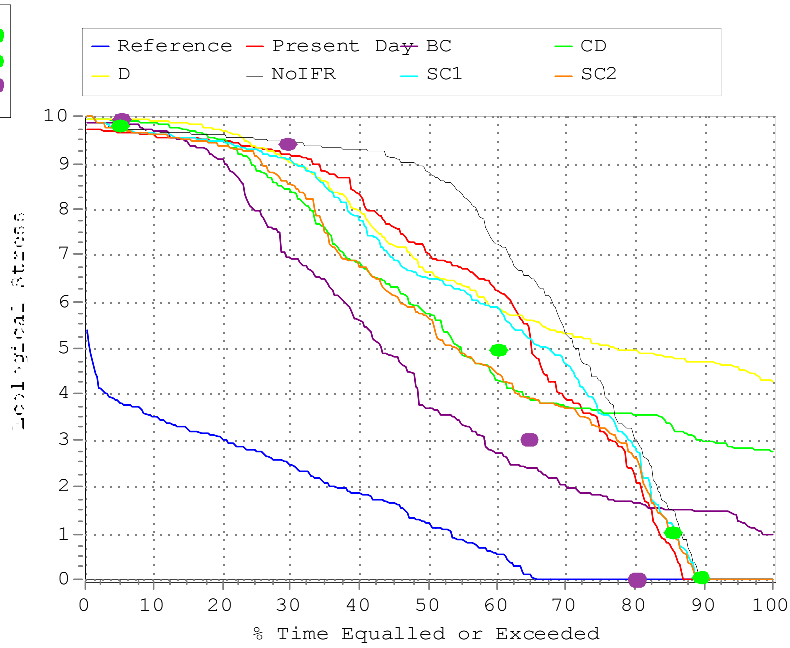




J.1.3 BLACK KEI RIVER – IFR 3

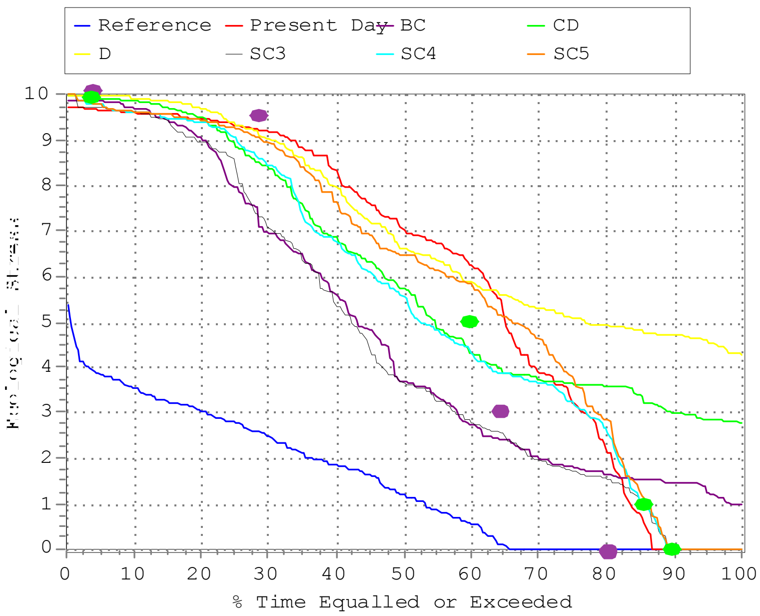
IFR 3 DRY SEASON (BLACK KEI)

Fish : D (Ecostatus C/D) (REC)
Fish : D (Ecostatus D)
Fish : C (Ecostatus B/C)



Fish Ecological Category
(evaluated during dry season)

Sc 1 = D
Sc 2 = D or better
Sc 3 = C
Sc 4 = D or better
Sc 5 = D
No IFR = D or worse

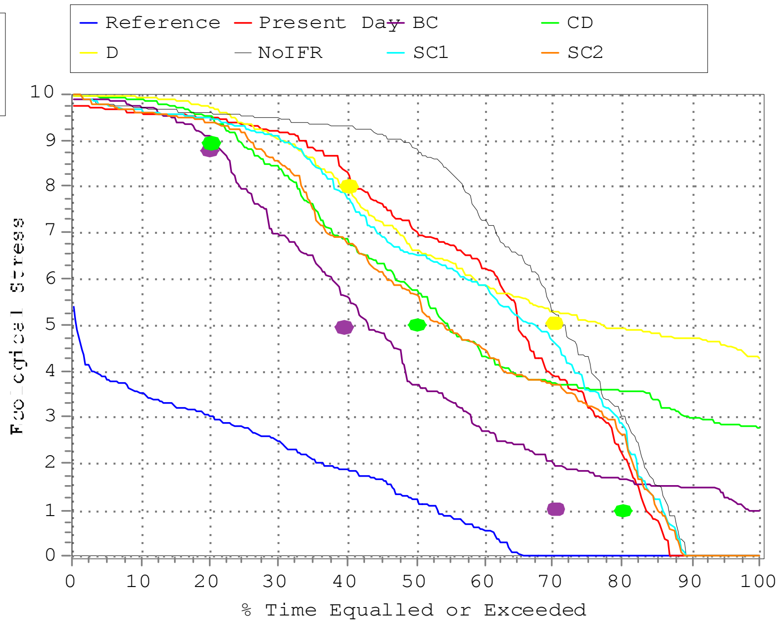


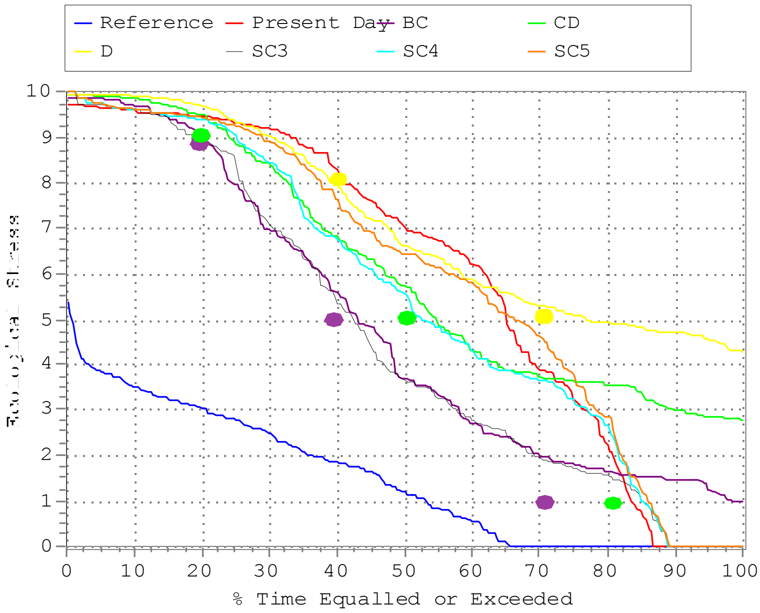
IFR 3 DRY SEASON (BLACK KEI)

Inverts: C/D (Ecostatus C/D) (REC)
Inverts: D (Ecostatus D)
Inverts: B (Ecostatus B/C)

Inverts Ecological Category
(evaluated during dry season)

Sc 1 = D
Sc 2 = C/D
Sc 3 = B/C
Sc 4 = C/D
Sc 5 = D
No IFR = D or worse



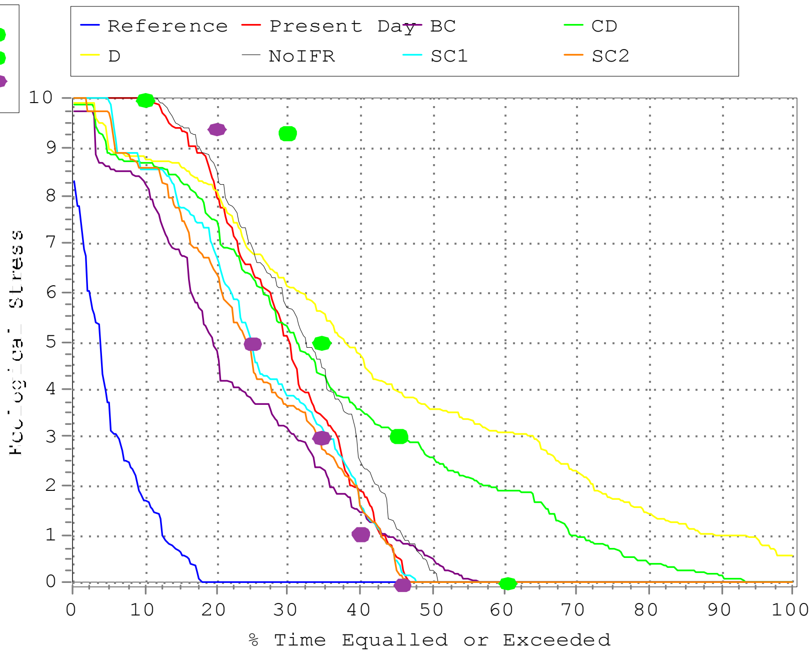


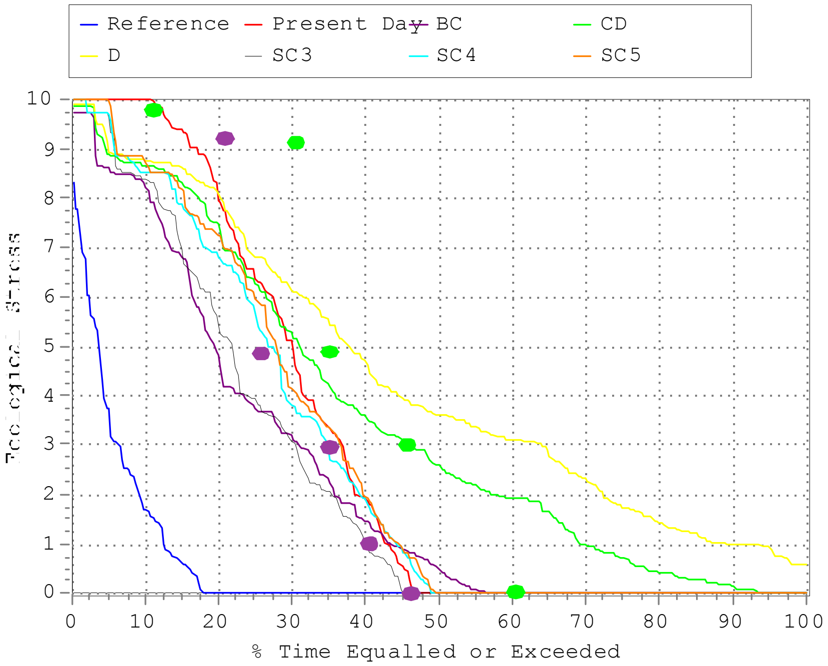
IFR 3 WET SEASON (BLACK KEI)

Fish : D (Ecostatus C/D) (REC)
Fish : D (Ecostatus D)
Fish : C (Ecostatus B/C)

Fish Ecological Category
(evaluated during wet season)

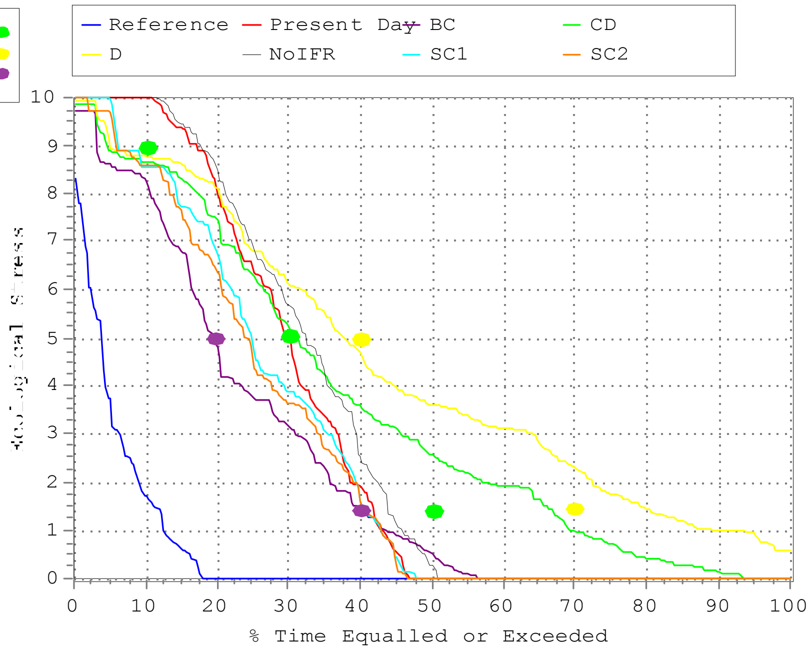
Sc 1 = C
Sc 2 = C
Sc 3 = C
Sc 4 = C
Sc 5 = C
No IFR = D





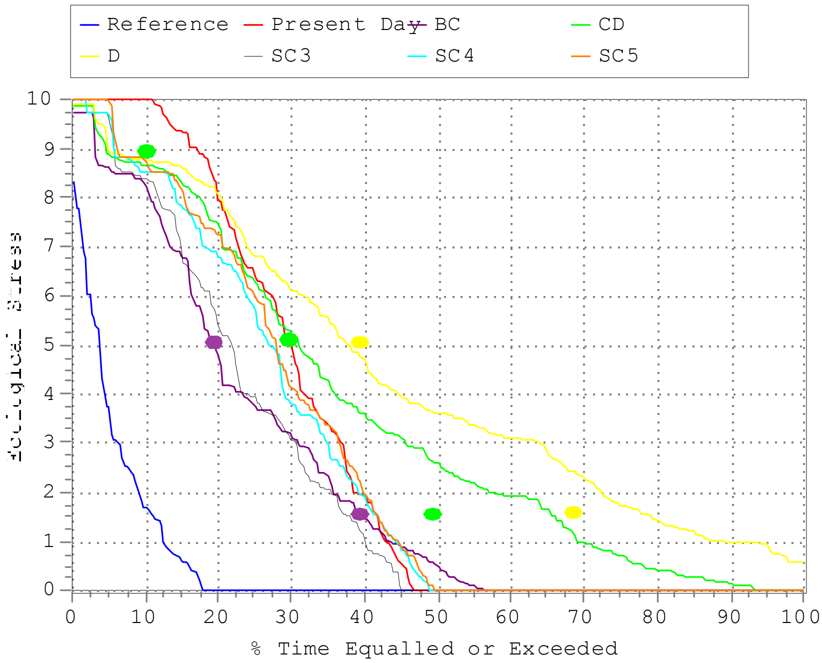
IFR 3 WET SEASON (BLACK KEI)

Inverts: C/D (Ecostatus C/D) (REC)
Inverts: D (Ecostatus D)
Inverts: B (Ecostatus B/C)



Inverts Ecological Category
(evaluated during dry season)

Sc 1 = C/D or better
Sc 2 = C/D or better
Sc 3 = B/C
Sc 4 = C/D of better
Sc 5 = C/D
No IFR = worse than a D



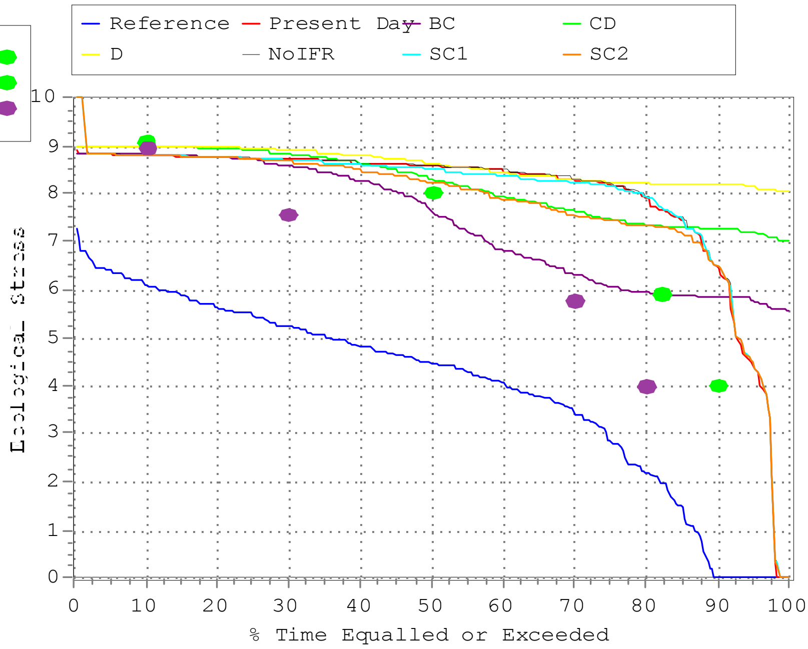
J.1.4 WHITE KEI RIVER – IFR 4

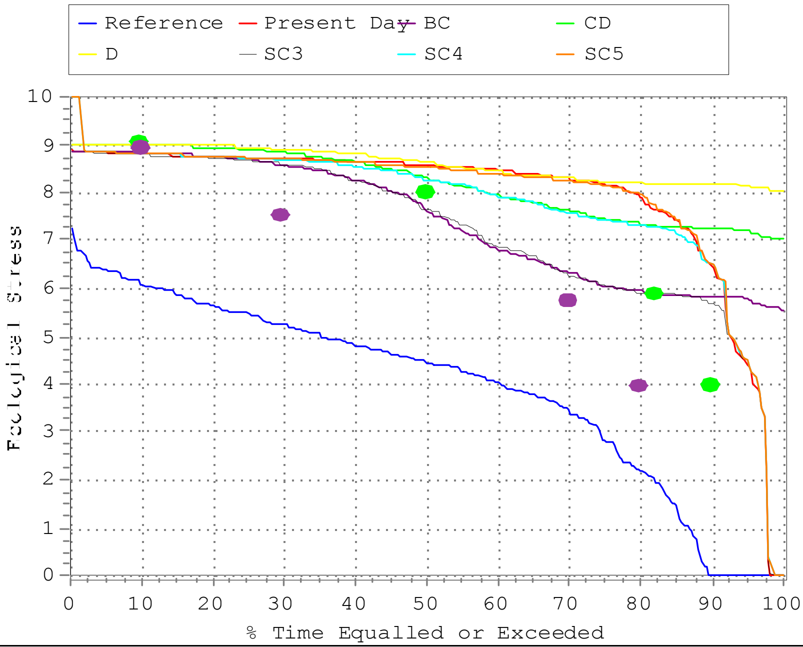
IFR 4 DRY SEASON (WHITE KEI)

Fish : D (Ecostatus C/D) (REC)
Fish : D (Ecostatus D)
Fish : C (Ecostatus B/C)

Fish Ecological Category
(evaluated during dry season)

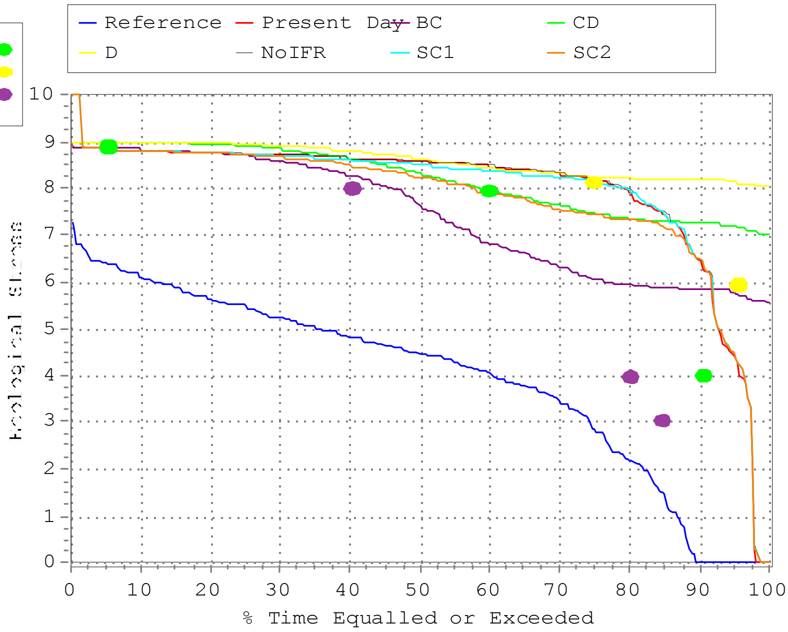
Sc 1 = D
Sc 2 = D
Sc 3 = D
Sc 4 = D or worse
Sc 5 = D or worse
No IFR = D





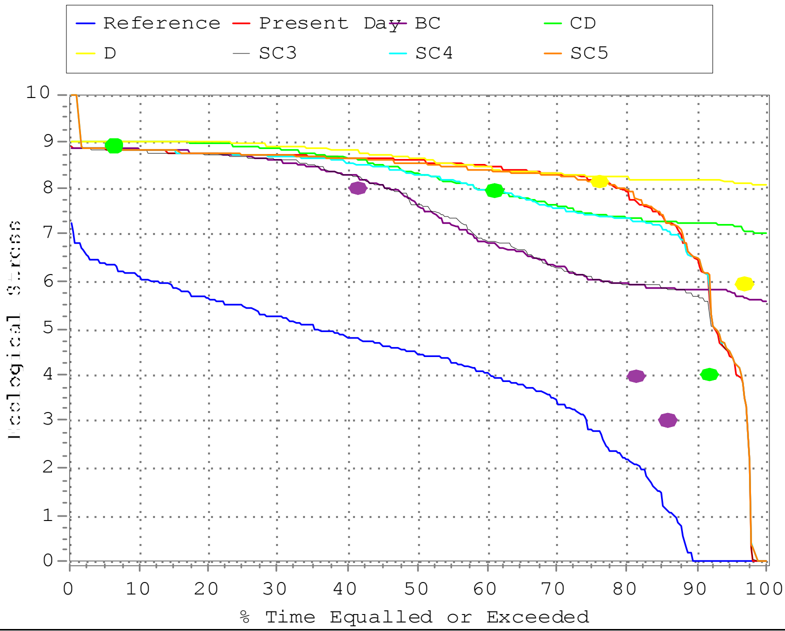
IFR 4 DRY SEASON (WHITE KEI)

Inverts: C/D (Ecostatus C/D) (REC)
Inverts: D (Ecostatus D)
Inverts: B/C (Ecostatus B/C)



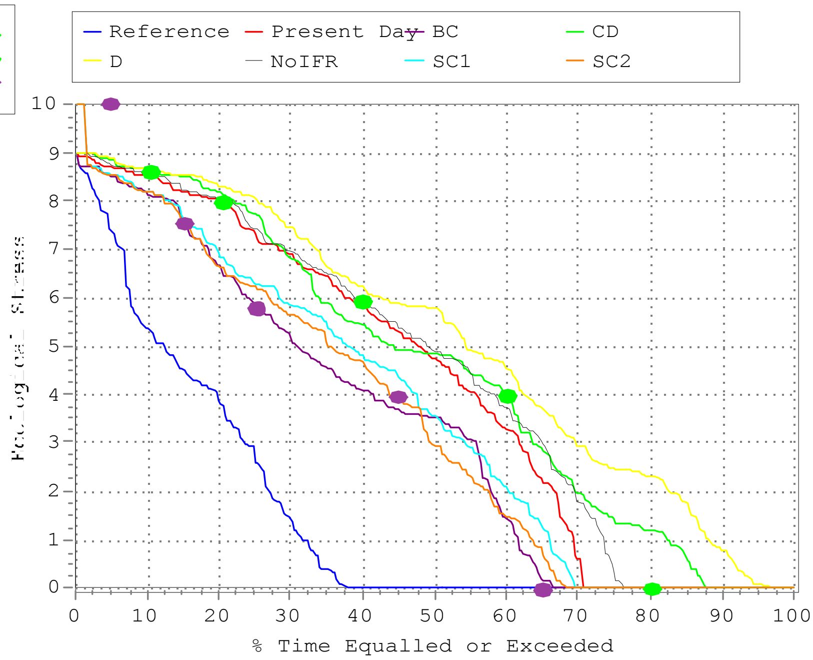
Inverts Ecological Category
(evaluated during dry season)

Sc 1 = D
Sc 2 = C/D
Sc 3 = B/C
Sc 4 = C/D
Sc 5 = D
No IFR = D



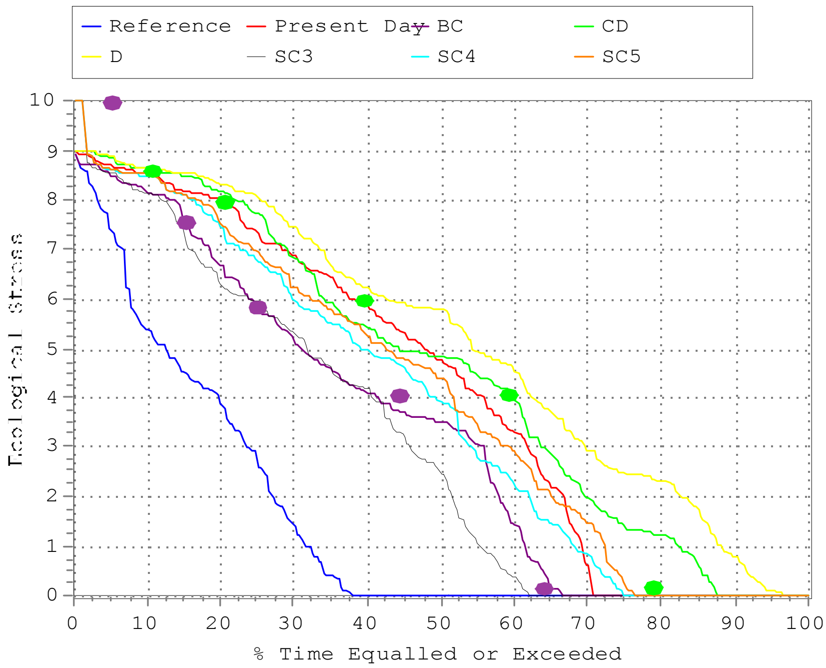
IFR 4 WET SEASON (WHITE KEI)

Fish : D (Ecostatus C/D) (REC)
Fish : D (Ecostatus D)
Fish : C (Ecostatus B/C)



Fish Ecological Category
(evaluated during wet season)

Sc 1 = D
Sc 2 = D
Sc 3 = D
Sc 4 = D or worse
Sc 5 = D or worse
No IFR = D

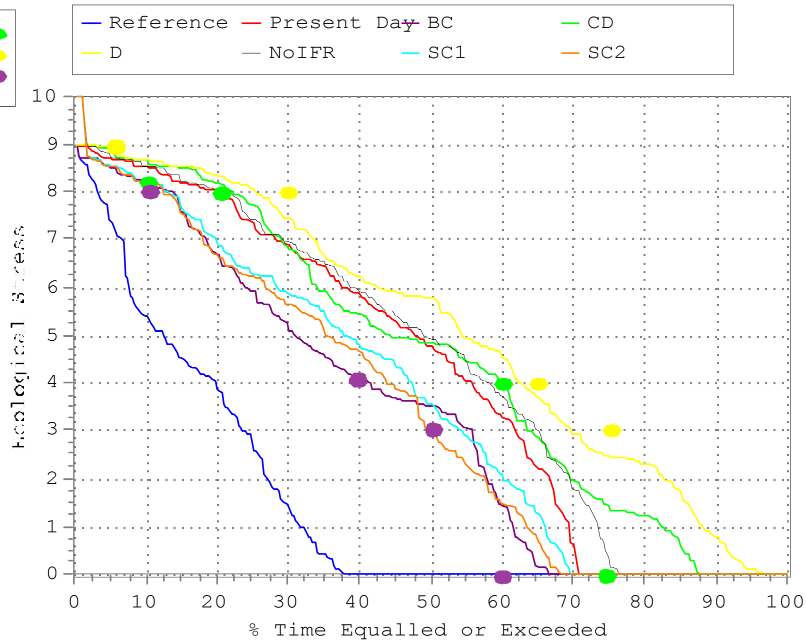


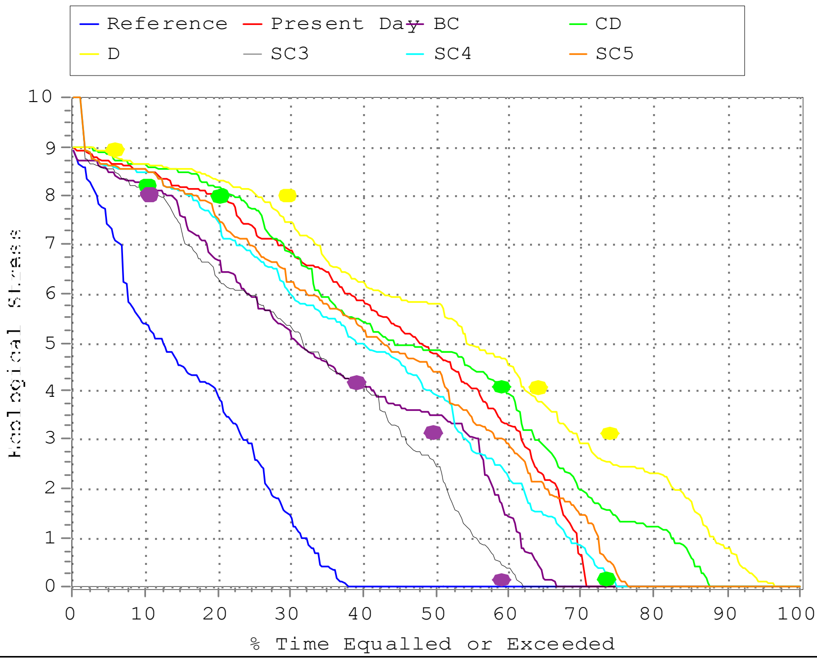
IFR 4 WET SEASON (WHITE KEI)

Inverts: C/D (Ecostatus C/D) (REC)
Inverts: D (Ecostatus D)
Inverts:B/C (Ecostatus B/C)

Inverts Ecological Category
(evaluated during wet season)

Sc 1 = B/C
Sc 2 = B/C
Sc 3 = B/C
Sc 4 = C (C/D or between)
Sc 5 = C (C/D or between)
No IFR = C/D





J.2 REFERENCES

O'Keeffe J.H., Hughes D.A. and Tharme R.E. 2002. Linking ecological responses to altered flows, for use in environmental flow assessments: The Flow Stressor-Response method. Proceedings of the International Association of Theoretical and Applied Limnology, 28, 84-92.

APPENDIX K

Notes on the operation of the Upper Kei Water Supply System

Ninham Shand (Pty) Ltd
Cape Town

TABLE OF CONTENTS

K.1 INTRODUCTION K-2
K.2 DESCRIPTION OF THE UPPER KEI RIVER SYSTEM DAMS K-2
K2.1 Doring Dam K-2
K2.2 Lubisi Dam K-3
K2.3 Xonxa Dam K-3
K2.4 Waterdown Dam K-4
K2.5 Bushmanskrantz Dam K-4
K2.6 Oxkraal Dam K-4
K2.7 Bongola Dam K-4
K2.8 Limietskloof Dam K-5
K2.9 Thrift Dam K-5
K.3 DESCRIPTION OF EXISTING SCHEMES K-5
K.4 HYDROLOGY K-7
K.5 WATER REQUIREMENTS AND RETURN FLOWS K-7
K5.1 Domestic Requirements K-7
K5.2 Irrigation Water Requirements K-7
K5.3 Forestry Water Requirements K-10
K5.4 Return Flows K-10
K.6 FUTURE SCHEMES K-10
K.7 REFERENCES K-12

LIST OF FIGURES

Figure K.1 The Upper Kei basin 11

LIST OF TABLES

Table K.1 Characteristics of Upper Kei River System Dams 2
Table K.2 Irrigation Requirements for Doorn River Irrigation Scheme 3
Table K.3 Irrigation Requirements for Qamata Irrigation Scheme 3
Table K.4 Irrigation Requirements for Xonxa Irrigation Scheme 3
Table K. 5 Percentage Distribution Irrigation Requirements for Limietskloof Dam 5
Table K. 6 Percentage Distribution of Irrigation Requirements for Thrift Dam 5
Table K.7 Existing Water Supply Schemes 6
Table K.8 Naturalised and Present Day MAR at Rivers 7
Table K.9 Monthly releases out of Waterdown Dam for Domestic/Industrial Purposes for 2002 ... 7
Table K.10 Seasonal Distribution of Queenstown water requirements 7
Table K. 11 Percentage Irrigation Releases out of Waterdown Dam and Oxkraal 8
Table K.12 Releases out of Waterdown Dam for Irrigation Purposes 9
Table K.13 Releases out of Oxkraal Dam for Irrigation Purposes 9
Table K.14 Annual Water Requirements for Forestry 10

K.1 INTRODUCTION

This document briefly outlines the existing water supply system in the Upper Kei Basin and lists the recent releases from the Waterdown and Oxkraal Dams. It gives brief descriptions of the hydrology of the Upper Kei Basin and the water requirements. Most of the information presented has been obtained from the Upper Kei Basin Study (UKBS, 1993) or the Queenstown Regional Water Supply Feasibility Study (QRWSFS, 1995) and updated from recent statistics.

K.2 DESCRIPTION OF THE UPPER KEI RIVER SYSTEM DAMS

The Upper Kei Basin is regulated by nine storage dams. These are listed in Table K.1, together with their corresponding characteristics, as were presented in the *UKBS* and updated in the *QRWSFS*. Also listed are the firm yields based on the 1992 *UKBS* assessment of the hydrology of the basin. Brief descriptions of the individual dams and any applicable operating rules are given below. Figure K.1 shows the Upper Kei Basin with the dams and the different irrigation schemes.

Table K.1 Characteristics of Upper Kei River System Dams

Dam	River	MAP	Naturalized Cumulative MAR	Present Day Cumulative MAR (1995)	Original Storage Capacity	Firm Yield (1992)	Predicted Yield (2010)
		(mm)	(Mm^3)	(Mm^3)	(Mm^3)	(Mm^3)	(m)
Doring River Dam	Doring	581	10.8	8.8	23.44	3.38	3.35
Lubisi Dam	Indwe	573	51.4	42.4	157.00	28.52	28.47
Xonxa Dam	White Kei	569	47.9	42.9	157.60	27.56	26.47
Waterdown Dam	Klipplaat	634	51.1	39.4	38.61	17.66	17.63
Bushmanskrantz Dam	Oxkraal	592	4.9	4.7	4.72	2.07	2.06
Oxkraal Dam	Oxkraal	490	19.8	12.9	17.8	6.18	5.71
Bongola Dam	Bonkolo	539	3.4	2.6	7.19	0.65	0.61
Limietskloof Dam	Tributary of Black Kei	426	1.5	0.6	0.88	0.13	0.12
Thrift Dam	Black Kei	520	5.0	3.3	2.90	0.58	0.58

The table shows the estimated yields under 1992 conditions and the yields for the projected (2010) conditions. Reductions in yield normally occur because of increased water use in the catchment upstream of the dam, or as a result of loss of storage capacity caused by sedimentation accumulation. It can be seen from Table K.1 that very little reduction in yield is expected in the dams of the Upper Kei Basin, except for Oxkraal Dam where the yield is expected to decrease by about 10% (UKBS, 1993) over the period to 2010 as a result of sedimentation.

K2.1 Doring Dam

The Doring Dam on the Doring River, immediately south of the Indwe River, was completed in 1969. It had an original storage capacity of $23.44Mm^3$ and a firm yield of $3.38Mm^3/a$. Water in the Doring River is allocated both for irrigation on lands downstream of the dam and to the town of Indwe for domestic and industrial use. The irrigation allocations are based on a release quota at the dam of 6 100 $m^3/ha/a$ including river losses and the allocation to the town of Indwe is $0.78Mm^3/a$ (QRWSFS, 1993). There are no operating rules for the Doring River Dam; water is released for irrigation and urban use as and when required.

No recent statistics for Doring River Dam releases have been obtained, but Table K.2 lists the annual distribution of irrigation water use, that was used for the QRWSFS.

Table K.2 Irrigation Requirements for Doorn River Irrigation Scheme

Doorn River Scheme	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
%	8	9.9	10.9	11.5	10.7	8.0	8.6	6.3	5.8	5.9	6.5	7.9	100
Allocated Mm^3	0.25	0.31	0.34	0.36	0.34	0.25	0.29	0.20	0.18	0.18	0.20	0.25	3.15

K2.2 Lubisi Dam

The Lubisi Dam, a reinforced concrete arch dam on the Indwe River (a tributary of the White Kei River), was completed in 1968. The dam had an original gross storage capacity of 157.0Mm^3, and was built to provide water for the Qamata Irrigation Scheme (refer to Appendix K1). Irrigation water is released into the river below the dam and abstracted at the Lanti diversion weir 9.5km downstream of the dam. There are no definite operating rules for the dam. Water is released as needed.

No recent statistics for Lubisi River Dam releases have been obtained, but Table K3 lists the monthly irrigation water use, that was used for the QRWSFS.

Table K.3 Irrigation Requirements for Qamata Irrigation Scheme

Qamata Irrigation Scheme	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
%	9.2	11	11	9.9	6.7	5.5	8	9.2	8.6	6.1	6.8	8	100
Allocated Mm^3	1.5	1.8	1.8	1.62	1.1	0.9	1.3	1.5	1.4	1	1.1	1.3	16.4

K2.3 Xonxa Dam

The Xonxa Dam, completed in 1972, is a rockfill dam on the White Kei River, some 30km east of Queenstown. The scheme was originally intended to serve some 4 900 ha of irrigation development, but at the time of the QRWSFS only supplied about 1643ha of irrigated land. The only consumers supplied from the Xonxa Dam are the irrigators on the Xonxa Irrigation Scheme. Irrigation water is released into the White Kei River and abstracted at diversion weirs or by pumping from the river into storage reservoirs. It has been estimated that river distribution losses between the dam and the lowest irrigation lands could amount to about 1.58Mm^3/a and that the water requirements are 14.84Mm^3/a. At the time of the QRWSFS report, water was released from Xonxa Dam as required.

Water can be released to the river through intakes at five different levels in the 20m deep dam. The outlet capacity is 10m^3/s when the dam is full (20m water depth). The rate of flow is controlled by a sleeve valve.

According to DWAF records, no water has been released from Xonxa Dam since 1995. Table K.4 shows the monthly irrigation requirement that was assumed for the QRWSFS.

Table K.4 Irrigation Requirements for Xonxa Irrigation Scheme

Xonxa Irrigation Scheme	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
%	7.3	9.4	10.3	11.8	12.1	10	7.9	6.2	5.7	6	6.3	6.9	100
Water Requirement at time of QRWSFS (Mm^3)	1.08	1.39	1.53	1.75	1.79	1.48	1.17	0.92	0.85	0.89	0.93	1.02	14.8

K2.4 Waterdown Dam

The dam is situated on the Klipplaat River about 46km south of Queenstown and was completed in 1957. It supplies water for irrigation, domestic and industrial use. Water for irrigation is released from the dam into the river channel to supply irrigators along the Klipplaat River to its confluence with the Black Kei and along the Black Kei to its confluence with the White Kei. The allocation from Waterdown Dam to the domestic and industrial consumers is conveyed by a system of pipelines.

Water is released from Waterdown Dam for irrigation downstream of the confluences of the Klipplaat and Black Kei Rivers and Klaas Smits and Black Kei Rivers. There are significant losses in these river reaches. Analyses of different operating rules have been carried out over the years. The operators of Waterdown Dam attempt to provide irrigation releases in excess of the irrigation allocation in order to offset the river conveyance losses between the dam and the irrigation lands. The actual releases from the dam are achieved by releasing between 1.03 and 1.16Mm^3 of water from the dam over a period of 9 to 10 days with discharge rates starting at about 2m^3/s and gradually reducing over the period (QRWSFS, 1992). Water can be released to the river through intakes at four different levels in the 35m deep dam. The outlet capacity is about 5m^3/s when the dam is full.

Table K.4 shows the monthly irrigation releases from Waterdown Dam since 1995. Releases have been decreasing significantly since 2000.

K2.5 Bushmanskrantz Dam

The Bushmanskrantz Dam, on the upper Oxkraal River, is a rockfill dam that was completed in 1983. It had an original gross storage capacity of 4.72Mm^3 and a firm yield of 2.07Mm^3/a. The primary purpose of the dam is irrigation. It supplies water via a pipeline to irrigate lands downstream of the dam. There are no specific operating rules for the dam and water has been released as and when required. According to DWAF records, no water has been released from Bushmanskrantz Dam since 1995.

Water can be released from the 30m deep dam to the river through a 700mm diameter outlet pipe fitted with a 400mm diameter sleeve valve at about 2m^3/s.

K2.6 Oxkraal Dam

The Oxkraal Dam is situated on the Oxkraal River about 3 km west of Sada. It was completed in 1989 and had an original storage capacity of 17.8Mm^3. The yield (refer to Table K.1) is expected to decrease by about 10% from 1992 to 2010 as result of sedimentation.

Water can be released to the river through intakes at four different levels in the 22m deep dam. The outlet capacity is about 11m^3/s when the dam is full.

At the time of the QRWSFS study the lands downstream of the Oxkraal Dam had not been developed. The only water that had been released from Oxkraal Dam was a temporary supply of 1.69Mm^3/a for use on the Klipplaat Scheme (refer to Appendix K1). As can be seen from Table K.5, 1999, 2001 to 2003 releases of the order of 4 to 5Mm^3/a were made from Oxkraal Dam. Table K.5 also lists the monthly irrigation releases.

K2.7 Bongola Dam

The Bongola Dam is situated on the Bonkolo River, a tributary of the Komani River, about 4km east of Queenstown. It was built in 1908 and raised by 1.2m in 1935, to provide water to Queenstown and eZibeleni. The firm yield of the Bongolo Dam is 0.65Mm^3/a and is intended solely for consumers supplied by the Queenstown Water Supply Scheme (refer to Appendix K1). Water is conveyed from the dam to Berry Reservoir by pipeline and then treated and distributed.

K2.8 Limietskloof Dam

Limietskloof Dam is situated on a tributary of the Black Kei River. The dam was completed in 1975. This dam, as well as Thrift Dam and other small dams were built to provide water for the Ntabethemba and associated irrigation schemes (refer to Appendix A). According to DWAF records, no water has been released from Limietskloof Dam since 1995. Table 2.5 shows the monthly percentage distribution of irrigation requirements that was used for the QRWSFS.

Table K.5 Percentage Distribution Irrigation Requirements for Limietskloof Dam

Limietskloof Dam	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
%	6.6	10.7	13	13.2	14.8	18	9.3	4.8	2.2	2.4	2	3

The combined yield of the dams of the Ntabethemba and associated irrigation schemes is considerably less than the scheduled 3.93Mm^3/a and unscheduled 5.88 Mm^3/a water requirement of this scheme at the time of the QRWSFS.

K2.9 Thrift Dam

Thrift Dam is situated on the upper reaches of the Black Kei River and was completed in 1974. As mentioned in 2.8, this dam, as well as the Limietskloof Dam and other small dams were built to provide water for the Ntabethemba and associated irrigation schemes (refer to Appendix A). According to DWAF records, no water has been released from Thrift Dam since 1995. Table K.6 shows the monthly percentage distribution of irrigation requirements that were used for the QRWSFS.

Table K.6 Percentage Distribution of Irrigation Requirements for Thrift Dam

Thrift Dam	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
%	10.1	9.2	10.3	9.7	16.5	20.8	7.7	3.3	1.5	3.9	3.2	3.8

As mentioned above, the combined yield of the dams of the Ntabethemba and associated irrigation schemes is considerably less than the scheduled 3.93Mm^3/a and unscheduled 5.88Mm^3/a water requirement of this scheme at the time of the QRWSFS.

K.3 DESCRIPTION OF EXISTING SCHEMES

The existing schemes in the Upper Kei Basin are:

- Upper Klipplaat Irrigation Scheme
- Klipplaat River Government Water Scheme
- Queenstown Water Supply Scheme
- Sada-Whittlesea Water Supply Scheme
- Doorn River Government Water Scheme
- Klaas Smits River Irrigation Scheme
- Zweledinga Irrigation Scheme
- Oxkraal Irrigation Scheme
- Ntabethemba and Associated Irrigation Schemes
- Qamata Irrigation Scheme
- Xonxa Irrigation Scheme
- Cacadu Rural Water Supply Scheme

These schemes are described in more detail in Appendix K1. Table K7 lists the schemes, the consumers supplied, the annual allocation of irrigation/domestic water, the receiving river, and estimated return flows.

Table K.7 Existing Water Supply Schemes

River	Scheme name	Consumer supplied		Storage dams	Receiving River	Water requirement (Mm^3/a)	Return Flows (Mm^3/a)
		Domestic	Irrigation				
Klipplaat	Upper Klipplaat Irrigation Scheme	-	Lands along the Klipplaat River	-		7.15	0.72
Klipplaat	Klipplaat River Irrigation Scheme	Sada-Whittlesea Queenstown eZibeleni	Lands along Klipplaat and Black Kei to confluence with White Kei River Lands along Shiloh Irrigation Scheme Lands along Lower Black Kei	Waterdown Dam	Klipplaat	13.8	1.38
	Queenstown Water Supply Scheme	Queenstown eZibeleni	-	Allocation from Waterdown Dam Bongolo Dam Berry Reservoir	-pipeline-	Allocation: 8.25	6.19
	Sada-Whittlesea Water Supply Scheme	Sada-Whittlesea	-	Allocation from Waterdown Dam	-pipeline-	Allocation: 4.2	3.15
White Kei	Doorn River Government Scheme	Indwe	Lands along Doring and Indwe Rivers	Doring River Dam	Indwe	3.81	0.38
Klaas Smits	Klaas Smits River Irrigation Scheme	-	Lands along the Klaas Smits River and its tributaries	-		16.43	1.64
Oxkraal	Zweledinga Irrigation Scheme	Villages on Upper Oxkraal River	Lands along the Upper Oxkraal River	Bushmanskrantz Dam	-pipeline-	1.5	0.15
Oxkraal	Oxkraal Irrigation Scheme	-	Lands along the Lower Oxkraal River	Oxkraal Dam Shiloh Dam	Oxkraal	3.4	0.34
Upper Black Kei	Ntabethemba and Associated Irrigation Scheme	-	Lands along the Upper Black Kei River	Thrift Dam Limietskloof Dam Thibet Park Diversion Tentergate Dam Mitford Dam Glenbrock Dam	Black Kei	3.93 (scheduled) 5.88 (unscheduled)	0.39 (scheduled) 0.59 (unscheduled)
Indwe	Qamata Irrigation Scheme	Qamata Villages	Lands along the Indwe River downstream of Lanti Weir	Lubisi Dam	Indwe	16.7	1.67
White Kei	Xonxa Irrigation Scheme	-	Lands along the White Kei River downstream of Xonxa Dam	Xonxa Dam	White Kei	14.84	1.48
Cacadu (tributary of White Kei)	Cacadu Irrigation Scheme	Lady Frere (Cacadu) Transkei Rural Villages in the Cacadu River Valley	-	Macubeni Dam	-pipeline-	2	0.2

K.4 HYDROLOGY

The hydrology of the Upper Kei Basin was investigated in detail as part of the UKBS (1993) and updated/improved in the QRWSFS (1995). The UKBS (1993) used a calibrated Pitman rainfall/runoff model at selected flow-gauging stations to generate 70 years of monthly flow sequences representing naturalised, present day (1992) and future development conditions. The runoff sequences were then extended from 1989 to 1993 in the QRWSFS, thus extending the monthly sequences to cover 74 years.

The principal sources of water in the Upper Kei River System are the Klipplaat, Black Kei, Klaas Smits and White Kei Rivers. The naturalised and the estimated present day mean annual runoff at selected points in the rivers is shown in Table K.8, the naturalised and the estimated present day MAR at the dams is listed in Table K.1. These estimates will be refined when the system modelling is carried out.

Table K.8 Naturalised and Present Day MAR at Rivers

River	Naturalised MAR (Mm^3/a)	Present Day MAR (1995) (Mm^3/a)
Black Kei at confluence with Klaas Smits	109	60
Klaas Smits at confluence with Black Kei	60	38
White Kei at confluence with Black Kei	149	72
Black Kei at confluence with White Kei	226	152
Great Kei at confluence of Black and White Kei	375	224
Great Kei at estuary	931	554

K.5 WATER REQUIREMENTS AND RETURN FLOWS

K5.1 Domestic Requirements

Queenstown and Sada-Whittlesea are the largest water users. The population growth rate assumed in QRWSFS was 3.5% per annum for Queenstown. The more recent demographic studies for development of the National Water Resources Strategy shows that growth rates are about 1% per annum.

Monthly releases out of Waterdown Dam for Domestic and Industrial Purposes to Queenstown, Whittlesea and Shiloh Bede Township via the Queenstown Pipeline for 2002 are shown in Table K.9. There has been a general trend in the seasonal distribution of the Queenstown demand and this is shown in Table K.9.

Table K.9 Monthly releases out of Waterdown Dam for Domestic/Industrial Purposes for 2002

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
Mm^3	0.500	0.520	0.452	0.551	0.533	0.581	0.663	0.539	0.520	0.480	0.499	0.253	6.091

Table K.10 Seasonal Distribution of Queenstown water requirements

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
%	9.3	9.0	10.0	9.1	8.0	7.9	7.6	7.5	7.5	7.2	8.3	8.6

K5.2 Irrigation Water Requirements

Irrigation of crops is the main water use activity in the Upper Kei Basin. Table K.7 lists the annual water requirements for the different water supply schemes in the Upper Kei Basin. Future development is expected to be limited to Doorn River, Oxkraal and Ntabethemba Irrigation schemes. The QRWSFS assumed that there would be very little futher increase in irrigation after 2010. From the study it could be seen that water requirements for irrigation are expected to only increase marginally from 111Mm^3/a to 118Mm^3/a between 1990-2045 for all the irrigation schemes. Table K.11 below lists the monthly distribution in percent of irrigation water released from Waterdown Dam and Oxkraal Dam. Table K.12 and Table K.13 lists the monthly distribution for the years 1995 to 2002 in more detail. According to DWAF records, no releases for these years have been made for Bushmanskrantz, Thrift, Limietskloof or Xonxa Dam.

Table K. 11 Percentage Irrigation Releases out of Waterdown Dam and Oxkraal

%	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Waterdown Dam	8.7	10.1	11.1	12.4	13.5	10.0	8.9	6.0	4.2	3.9	4.7	6.7
Oxkraal Dam	10.7	11.4	11.4	12.9	10.7	9.3	7.9	5.7	5.0	4.3	3.6	7.1

Table K.12 Releases out of Waterdown Dam for Irrigation Purposes

Month	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	TOTAL
%Release	**8.7%**	**10.1%**	**11.1%**	**12.4%**	**13.5%**	**10.0%**	**8.9%**	**6.0%**	**4.2%**	**3.9%**	**4.7%**	**6.7%**	**100.0%**
Release (Mm^3) 1995													13.878
Release (Mm^3) 1996	1.207	1.402	1.534	2.002	2.181	1.621	1.443	0.965	0.681	0.632	0.762	1.086	16.213
Release (Mm^3) 1997	1.411	1.638	1.792	2.217	2.414	1.795	1.598	1.068	0.754	0.700	0.844	1.203	17.950
Release (Mm^3) 1998	1.562	1.813	1.983	1.652	1.799	1.338	1.191	0.796	0.562	0.522	0.629	0.896	13.378
Release (Mm^3) 1999	1.164	1.351	1.478	1.617	1.761	1.309	1.165	0.779	0.550	0.511	0.615	0.877	13.092
Release (Mm^3) 2000	1.139	1.322	1.447	0.743	0.809	0.602	0.535	0.358	0.253	0.235	0.283	0.403	6.016
Release (Mm^3) 2001	0.523	0.608	0.665	0.144	0.157	0.117	0.104	0.069	0.049	0.046	0.055	0.078	1.167
Release (Mm^3) 2002	0.102	0.118	0.129	0.112	0.122	0.091	0.081	0.054	0.038	0.035	0.043	0.061	0.909
Release (Mm^3) 2003	0.079	0.092	0.100										

Table K.13 Releases out of Oxkraal Dam for Irrigation Purposes

Month	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	TOTAL
% Release	**10.7%**	**11.4%**	**11.4%**	**12.9%**	**10.7%**	**9.3%**	**7.9%**	**5.7%**	**5.0%**	**4.3%**	**3.6%**	**7.1%**	**100.0%**
Release (Mm^3) 1995													0.000
Release (Mm^3) 1996	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Release (Mm^3) 1997	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Release (Mm^3) 1998	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Release (Mm^3) 1999	0.000	0.000	0.000	0.677	0.561	0.488	0.414	0.299	0.262	0.226	0.189	0.372	5.246
Release (Mm^3) 2000	0.561	0.598	0.598	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Release (Mm^3) 2001	0.000	0.000	0.000	0.519	0.430	0.374	0.318	0.229	0.201	0.173	0.145	0.285	4.019
Release (Mm^3) 2002	0.430	0.458	0.458	0.651	0.540	0.469	0.399	0.288	0.252	0.217	0.182	0.358	5.047
Release (Mm^3) 2003	0.540	0.575	0.575										

K5.3 Forestry Water Requirements

There is little indigenous forest in the Upper Kei Basin. Only 15.8 km^2 of the Basin is covered by commercial timber plantations and most of this occurs along the Amatola mountain range near the headwaters of the Klipplaat River (QRWSFS, 1993). The mean yearly water requirements are listed in Table K.14.

Table K.14 Annual Water Requirements for Forestry

River Catchment	Afforested Area (ha)	Water Requirement (Mm^3/a)
Upper Klipplaat River	474	0.28
Middle Klipplaat River	20	0.01
Lower Klipplaat River	7	-
Doring River	32	0.02
Upper Oxkraal river	146	0.09
Lower Oxkraal river	1	-
Upper White Kei River	45	0.03
Cacadu River	96	0.06
Total	**821**	**0.49**

K5.4 Return Flows

The only assumed source of effluent return flow is from Queenstown's sewage treatment works. This effluent return flow is discharged into the Komani River. The QRWSFS estimated the return flow at 75% of the total demand. Table K.7 lists the return flows from Queenstown assuming the total allocation of Waterdown and Bongola Dams is used.

No data on the irrigation return flow has been reported in the QRWSFS, but for the Mzimbvubu to Keiskamma WMA Water Resources Situation Assessment (DWAF, 2001) the return flows were assumed to be 10% of the total irrigation requirements in the Upper Kei Basin. The total irrigation requirements were used in the study to obtain an indication of the volume of the return flows generated. Table K.7 lists the irrigation return flows of the different schemes.

K.6 FUTURE SCHEMES

In the previous study, the QRWSFS, a comprehensive review of potential schemes to augment the water supply to Queenstown has been presented. The conclusion was that the most favourable scheme would be the construction of a pipeline to Queenstown from the under-utilised Xonxa Dam. Since then it has become apparent that contrary to the assumptions made at the time, some of the dams in the system can be used for other purposes than irrigation. These dams are the Oxkraal Dam, the Thrift Dam and the Limietskloof Dam. In this study, the Lukhanji Regional Water Supply Feasibility Study, two of the factors that will be investigated are firstly, revised operating rules of the existing schemes and secondly future augmentation schemes.

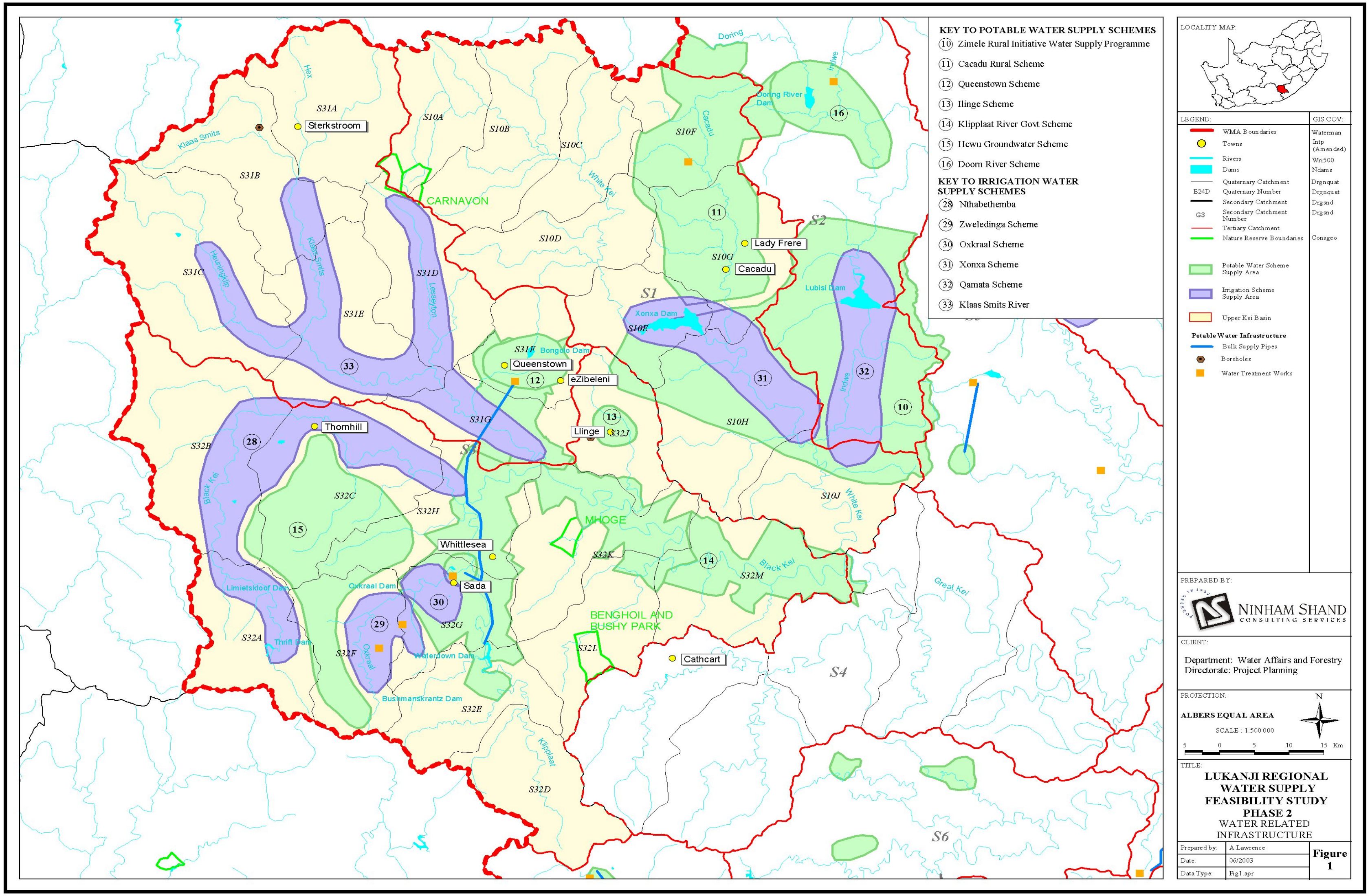


Figure K.1 The Upper Kei basin

K.7 REFERENCES

DEPARTMENT OF WATER AFFAIRS AND FORESTRY. 2001. **Mzimvubu to Keiskamma Water Management Area: Water Resources Situation Assessment.** Prepared by Ninham Shand in association with Jakoet & Associates.

KEI BASIN CONSULTING ENGINEERS. 1993. **Upper Kei Basin Study**, **Vol4,** prepared for the Department of Water Affairs and Forestry, the Ciskei Department of Public Works and the Transkei Department of Agriculture and Forestry.

KEI BASIN CONSULTING ENGINEERS. 1995. **Queenstown Regional Water Supply Scheme : Feasibility Study: Appendix 5: System Modelling** prepared for the Department of Water Affairs and Forestry.

APPENDIX K1

K1.1 Description of Existing Water Supply Schemes in the Upper Kei Basin

The schemes existing in the Upper Kei Basin are described briefly below and listed in Table 1. Table 1 also shows the consumers supplied by each scheme, the storage dams associated with each of the schemes, the receiving rivers as well as the requirements and amount of water released for 2002. Table 2 indicates the water releases for the individual dams.

K1.2 Upper Klipplaat Irrigation Scheme

The upper Klipplaat Irrigation Scheme supplies water to the irrigated lands upstream of the Waterdown Dam. Lands of 1457 ha are irrigated in this region, using predominantly sprinkler irrigation. Water for irrigation is abstracted from the Klipplaat River by pumping into small storage dams. (Upper Kei Basin Study, Vol4, 1993)

K1.3 Klipplaat River Government Water Scheme

The main water consumers supplied from Waterdown Dam are the irrigators downstream of the dam along the Klipplaat and Kei Rivers and the urban centers of Queenstown, eZibeleni and Sada-Whittlesea.

Irrigation:
Water for this scheme is supplied by Waterdown Dam. Water is released from the dam into the river channel to supply scheduled irrigated area of 1924 ha along the Klipplaat River to its confluence with the Black Kei, and along the Black Kei to its confluence with the White Kei. The water for the 412ha Shiloh irrigation scheme near Sada-Whittlesea is diverted at a weir on the Klipplaat River and conveyed via an earth canal to the farming units. The remainder of the irrigators extract water directly from the river channel.

K1.4 Queenstown Water Supply Scheme

The Queenstown Water Supply Scheme comprises of domestic and industrial Water supply to Queenstown and eZibeleni. The principal sources of water for this scheme are the Waterdown Dam on the Klipplaat River and the Bongolo Dam on the Bonkolo River. The allocation to Queenstown from the Waterdown Dam for domestic and industrial use is 8.25 Mm^3/a. Water is conveyed from both the Waterdown and Bongolo Dams by pipeline to the Berry Reservoir in Queenstown. The water is then treated and pumped to various reservoirs.

K1.5 Sada-Whittlesea Water Supply Scheme

The Sada-Whittlesea Scheme utilises water allocated from the Waterdown Dam to supply the towns of Sada and Whittlesea. The allocation from Waterdown Dam is 4.2 Mm^3/a. The water supply is drawn from the main Waterdown-Queenstown pipeline via a metered offtake. It is then conveyed via pipeline to the Sada Water Treatment Works and pumped to various reservoirs in the area.

K1.6 Doorn River Government Water Scheme

Water from the Doring River Dam is allocated both for irrigation purposes and for domestic and industrial use.

Irrigation:
The scheme is intended to provide water to a scheduled area of 513ha of irrigation downstream of the dam. Currently, only 182ha of land have been developed. The irrigation allocations are based on a release quota at the dam of 6100m^3/ha/a including river losses. The irrigation allocation is 3.14Mm^3/a.

Domestic:
The allocation of the town of Indwe for domestic and industrial use is 0.78Mm^3/a.

K1.7 Klaas Smits River Irrigation Scheme

Klaas Smits River Irrigation Scheme comprises of all the irrigated lands along the Klaas Smits River and its tributaries. Irrigation water is drawn from the rivers and from numerous boreholes adjacent to the river. Comparison of the available resources (about 9.2Mm^3/a) and the water requirements of the irrigated areas (16.4Mm^3/a) indicate that resources of the Klaas Smits catchment are unable to meet demands (Upper Kei Basin Study, Vol4, 1993)

K1.8 Zweledinga Irrigation Scheme

This scheme utilises water from the Bushmanskrantz Dam on the upper Oxkraal River to irrigate a total area of 259 ha of irrigation development on the east bank of the Oxkraal River, downstream of the dam. Water is conveyed from the dam through a 17km long, 700mm diameter asbestos cement gravity pipeline down the Oxkraal River valley. Branch offtakes along the main pipeline convey water to the various irrigation areas.

K1.9 Oxkraal Irrigation Scheme

The Oxkraal Irrigation Scheme comprises of the Oxkraal and Shiloh Dams and the lands that are intended to be irrigated downstream of these dams. These lands have not been developed by 1995 (Upper Kei Basin Study, 1993). Since 1999, between 4 and 5.25Mm^3/a of water has been released from the Oxkraal Dam for irrigation purposes.

K1.10 Ntabethemba and Associated Irrigation Schemes

The Ntabethemba scheme is a partially developed irrigation project situated in the valley of the Black Kei River in the Hewu Region. The scheme was originally described to comprise of 497ha, and irrigated lands have been developed in the Black Kei River catchment upstream of the confluence of the Black Kei and Klipplaat Rivers along the river system. Water is being pumped from the Black Kei River to the individual areas.

The Associated Irrigation Schemes are: (Upper Kei Basin Study, Vol.4, 1993):

- 180ha developed at Thrift in the upper Kei River valley. Water is supplied from Thrift Dam. These lands are now fallow.
- 50ha have been developed at Limietskloof. Water is supplied from Limietskloof Dam. These lands are now fallow.
- 565ha of irrigation have been developed by farmers along the Black Kei River between Thornhill and the confluence with the Klipplaat River; these lands are irrigated by pumping water from the Black Kei River.

The combined yield of the dams and low flows are substantially less than the scheduled 3.93Mm^3/a and the unscheduled water requirements of 5.88Mm3/a. The existing water supply infrastructure is therefore inadequate to meet the demands of existing irrigation developments.

K1.11 Qamata Irrigation Scheme

The Qamata Scheme utilises water from the Lubisi Dam to irrigate an originally targeted area of 3 574ha. Currently, only 1 959ha were irrigated. Irrigation water, released into the river below the dam, is abstracted at the Lanti diversion weir, 9.5km downstream of the dam. The water is then conveyed to the irrigation developments via a 28.5km long canal to the in-field flood irrigation system. For the upper 19.5 km of its length the main distribution canal has a design capacity of 2.55m3/s, thereafter the design capacity gradually decreases to 0.7m3/s at the end of the system (Upper Kei Basin Study, Vol.4, 1993).

K1.12 Xonxa Irrigation Scheme

The Xonxa Irrigation Scheme supplies water from the Xonxa Dam to the 1 643ha of irrigated lands along the banks of the White Kei River downstream of Xonxa Dam. The scheme was originally intended to serve some 4 900 ha of irrigation development. The water is abstracted from the White Kei River at diversion weirs or by pumping water from the river into storage reservoirs. The water requirements are 14.84Mm^3/a. It was also estimated that the river distribution losses between the dam and the lowest irrigated lands could amount to 1.58Mm^3/a (Upper Kei Basin Study, Vol 4, 1993).

K1.13 Cacadu Rural Water Supply Scheme

The Cacadu Rural Water Supply Scheme utilises water from the Macubeni Dam to supply water to about eight rural villages and the town Cacadu. The scheme was originally intended to supply water to 36 rural villages. Water is conveyed by pipeline to a water treatment located 600m downstream of the dam and then conveyed via a system of pipelines and storage reservoirs to the rural settlements.

Table K1.1 Existing Water Supply Schemes

Scheme name	Consumers supplied		Storage dams	Receiving river	Water requirement (Mm3/a)
	Domestic	Irrigation			
Upper Klipplaat Irrigation Scheme	-	Lands along the Klipplaat River	-		7.15
Klipplaat River Irrigation Scheme	Sada-Whittlesea Queenstown eZibeleni	Lands along Klipplaat and Black Kei to confluence with White Kei River Lands along Shiloh Irrigation Scheme Lands along Lower Black Kei	Waterdown Dam	Klipplaat	13.8
Queenstown Water Supply Scheme	Queenstown eZibeleni	-	Allocation from Waterdown Dam Bongolo Dam Berry Reservoir	-pipeline-	Allocation: 8.25
Sada-Whittlesea Water Supply Scheme	Sada-Whittlesea	-	Allocation from Waterdown Dam	-pipeline-	Allocation: 4.2
Doorn River Government Scheme	Indwe	Lands along Doring and Indwe Rivers	Doring River Dam	Indwe	3.81
Klaas Smits River Irrigation Scheme	-	Lands along the Klaas Smits River and its tributaries	-		16.43
Zweledinga Irrigation Scheme	Villages on Upper Oxkraal River	Lands along the Upper Oxkraal River	Bushmanskrantz Dam	-pipeline-	1.5
Oxkraal Irrigation Scheme	-	Lands along the Lower Oxkraal River	Oxkraal Dam Shiloh Dam	Oxkraal	3.4
Ntabethemba and Associated Irrigation Scheme	-	Lands along the Upper Black Kei River	Thrift Dam Limietskloof Dam Thibet Park Diversion Tentergate Dam Mitford Dam Glenbrock Dam	Black Kei	3.93 (scheduled) 5.88 (unscheduled)
Qamata Irrigation Scheme	Qamata Villages	Lands along the Indwe River downstream of Lanti Weir	Lubisi Dam	Indwe	16.7
Xonxa Irrigation Scheme	-	Lands along the White Kei River downstream of Xonxa Dam	Xonxa Dam	White Kei	14.84
Cacadu Irrigation Scheme	Lady Frere (Cacadu) Transkei Rural Villages in the Cacadu River Valley	-	Macubeni Dam	-pipeline-	2

Table K1.2 Releases out of dams for Irrigation Purposes

Releases out of Waterdown Dam, Oxkraal Dam, Bushmanskrantz Dam, Thrift Dam, Limietskloof Dam and Xonxa Dam for irrigation purposes						
Date	**Waterdown Dam**	**Oxkraal Dam**	**Bushmanskrantz Dam**	**Thrift Dam**	**Limietskloof Dam**	**Xonxa Dam**
	m^3	**m^3**	**m^3**	**m^3**	**m^3**	**m^3**
	Irrigation releases	**Domestic releases**	**Irrigation releases**	**Irrigation releases**	**Irrigation releases**	**Irrigation releases**
1995	13,878,107	7,702,279	0	0	0	21,580,386
1996	16,213,041	7,375,715	0	0	0	23,588,756
1997	17,950,038	7,704,849	0	0	0	25,654,887
1998	13,377,882	8,851,051	0	0	0	22,228,933
1999	13,092,498	8,302,161	5,245,838	0	0	26,640,497
2000	6,015,923	6,411,962	0	0		12,427.885
2001	1,166,752	6,205,334	4,019,448	0	0	11,391,534
2002	908,956	6,413,534	5,047,416	0	0	12,369,906
2003	181,896	2,712,612	4,324,749	0	0	7,219,257
Total	**82,785,093**		**18,637,451**	**0**	**0**	**163,102,041**

K1.14 REFERENCE

KEI BASIN CONSULTING ENGINEERS. 1993. Upper Kei Basin Study, Vol4, prepared for the Department of Water Affairs and Forestry, the Ciskei Department of Public Works and the Transkei Department of Agriculture and Forestry.