Resource Directed Measures

REPORT NO. RDM/K000/02/CON/0607, VOLUME 2

RESERVE DETERMINATION STUDIES FOR SELECTED SURFACE WATER, GROUNDWATER, ESTUARIES AND WETLANDS IN THE OUTENIQUA CATCHMENT: TECHNICAL COMPONENT – KNYSNA AND SWARTVLEI

Riverine RDM Report, Volume 2: Appendices

FINAL

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DOCUMENT INDEX

Reports as part of this project:

Report number	Report title
RDM/K000/00/CON/0107	INCEPTION REPORT (K10-K50, K60G)
RDM/K000/00/CON/00/0207	PROJECT CLOSURE REPORT (K10-K50, K60G)
RDM/K000/00/CON/00/0307	EXECUTIVE SUMMARY REPORT (K10-K50, K60G)
RDM/K000/05/CON/0407	SOCIO-ECONOMIC REPORT (K10-K50, K60G)
RDM/K000/02/CON/0507	GROUNDWATER RDM REPORT (K10-K50, K60G)
RDM/K000/02/CON/0607	WETLAND RDM REPORT (K10-K50, K60G)
RDM/K000/02/CON/0707	PRELIMINARY PROCESS REPORT: INTEGRATION
RDM/K000/02/CON/0807	ECOLOGICAL INPUT: WATER RESOURCE CLASSIFICATION (K10-K50, K60G)
RDM/K000/02/CON/0907	MAIN REPORT: OUTENIQUA RESERVE STUDY (K10-K50, K60G)
RDM/K10 – K30, K40E/00/CON/0107	INCEPTION REPORT: RESERVE DETERMINATION STUDIES FOR SELECTED SURFACE WATER, GROUNDWATER, ESTUARIES AND WETLANDS IN THE OUTENIQUA (GROOT BRAK AND OTHER WATER RESOURCES, EXCLUDING WETLANDS) CATCHMENT: ECOLOGICAL WATER REQUIREMENTS STUDY
RDM/K10 – K30, K40E/00/CON/0207	DELINEATION REPORT: RESERVE DETERMINATION STUDIES FOR SELECTED SURFACE WATER, GROUNDWATER, ESTUARIES AND WETLANDS IN THE OUTENIQUA (GROOT BRAK AND OTHER WATER RESOURCES, EXCLUDING WETLANDS) CATCHMENT: ECOLOGICAL WATER REQUIREMENTS STUDY
RDM/K10 – K30, K40E/00/CON/0307	ESTUARINE RDM REPORT: GROOT BRAK ASSESSMENT
RDM/K10 – K30, K40E/00/CON/0407	ESTUARINE RDM REPORT: GOUKAMMA ASSESSMENT
RDM/K10 – K30, K40E/00/CON/0507	ESTUARINE RDM REPORT: MAALGATE, GWAING AND KAAIMANS ASSESSMENT
RDM/K10 – K30, K40E/00/CON/0607	ESTUARINE RDM REPORT: ECOLOGICAL SPECIFICATIONS AND MONITORING FOR GROOT BRAK
RDM/K10 – K30, K40E/00/CON/0707	RIVERINE RDM REPORT: ASSESSMENT
RDM/K10 – K30, K40E/00/CON/0807	RIVERINE RDM REPORT: ECOLOGICAL SPECIFICATIONS AND MONITORING
RDM/K10 – K30, K40E/00/CON/0907	SCENARIO REPORT: RIVERS AND ESTUARIES
RDM/K40 – K50/00/CON/0107	INCEPTION REPORT
RDM/K40 – K50/00/CON/0207	DELINEATION REPORT
RDM/K40 - K50/00/CON/0307, VOLUME 1	ESTUARINE RDM REPORT, VOLUME 1: KNYSNA ESTUARY - MAIN REPORT
RDM/K40 - K50/00/CON/0307, VOLUME 2	ESTUARINE RDM REPORT, VOLUME 2: KNYSNA ESTUARY – ABIOTIC COMPONENT SPECIALIST APPENDICES
RDM/K40 - K50/00/CON/0307, VOLUME 3	ESTUARINE RDM REPORT, VOLUME 3: KNYSNA ESTUARY – BIOTIC COMPONENT SPECIALIST APPENDICES
RDM/K40 – K50/00/CON/0407	ESTUARINE RDM REPORT: SWARTVLEI
RDM/K40 – K50/00/CON/0507	RDM REPORT: ECOLOGICAL SPECIFICATIONS AND MONITORING
RDM/K40 – K50/00/CON/0607, VOLUME 1	RIVERINE RDM REPORT, VOLUME 1: ASSESSMENT
RDM/K40 – K50/00/CON/0607, VOLUME 2	**RIVERINE RDM REPORT, VOLUME 2: APPENDICES**

Bold indicates this report.

APPROVAL

TITLE:	Resource Directed Measures: Reserve Determination studies for selected surface water, groundwater, estuaries and wetlands in the Outeniqua catchment: Ecological Water Requirements Study. Riverine RDM Report, Volume 2: Appendices.
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Following the South African General Election, which took place on 22 April 2009, numerous reconfigurations of government departments were announced by the newly elected President of South Africa. These reconfigurations included the movement of the Forestry section of the Department of Water Affairs and Forestry (DWAF) to the Department of Agriculture (now known as the Department of Agriculture, Fisheries and Forestry). The DWAF was subsequently renamed as the Department of Water Affairs (DWA) in May 2009. Following this, all reports relating to the Outeniqua Intermediate Reserve Study that were completed prior to the announcement of the Departmental name changes, but not yet signed off by the Department will still refer to DWAF throughout the body of the report, except for the front three pages which will indicate the new DWA logo and name.

REPORT CONTRIBUTORS

The information in this report was authored by the multi-disciplinary group of specialists involved. Contributions were provided as follows:

- Delana Louw: EWR coordinator, EcoClassification process, application of the Index of Habitat Integrity
- Dr Andrew Birkhead: EcoHydraulics
- Dr Anton Bok: Fish
- Prof Denis Hughes: EcoHydrology
- Shael Koekemoer: Diatoms
- Shileen Louw: Data capturing
- James Mackenzie: Riparian vegetation
- Stephen Mallory: Systems modelling
- Mark Rountree: Fluvial geomorphology
- Dr Patsy Scherman: Water quality
- Dr Mandy Uys: Macroinvertebrates

The following persons participated as trainees:

- Pearl Gola: Water quality
- Prudence Ngwenya: Water quality
- Ntsiki Majiza: Aquatic macroinvertebrates
- Ntombi Myeko: Geomorphology

PREFACE

This report consists of the Specialist Appendices which is a supplementary document to the Riverine RDM Report: Assessment (RDM/K40 – K50/00/CON/0607, VOLUME 1). The suite of EcoStatus models and component assessment models applied to this study is provided electronically.

Note that specialist appendices are provided as additional information that is not included in Volume 1 of the RDM Rivers report for reference purposes. Information is provided according to specific reporting templates, with raw data submitted to the client in CD format at the end of the study.

Information was collected during a site visit in April – May 2007. Surveys and analyses were conducted according to the DWA-approved suite of EcoStatus models and methods, routinely used in EWR assessments. References are shown below:

- Hydrological Assessment Index (HAI): Kleynhans *et al*. (2005).
- Physico-chemical Assessment Index (PAI): Kleynhans *et al*. (2005); DWAF (2008).
- Geomorphological Assessment Index (GAI): Rountree and du Preez (in prep).
- Fish Response Assessment Index (FRAI): Kleynhans (2007).
- Macroinvertebrate Assessment Index (MIRAI): Thirion (2007).
- Riparian Vegetation Assessment index (VEGRAI): Kleynhans *et al*. (2007a).
- Instream Habitat integrity (IHI): Kleynhans *et al*. (2009). The new IHI method was undertaken during this study (amongst many others) to pilot test the model. This was not budgeted for and no report will be provided. The manual which is now available provides the necessary explanations in detail. The IHI models used to assess the different EWR sites will be provided electronically.

An outline of the specialist appendices is provided below.

APPENDIX A	River Hydraulics Specialist Report (AL Birkhead)
APPENDIX B	Hydrology Specialist Report (DA Hughes)
APPENDIX C	Geomorphology Specialist Report (M Rountree)
APPENDIX D	Water Quality Specialist Report (PA Scherman)
APPENDIX E	Fish Specialist Report (A Bok)
APPENDIX F	Macroinvertebrate Specialist Report (M Uys)
APPENDIX G	Riparian Vegetation Specialist Report (J Mackenzie)
APPENDIX H	Diatom Specialist Report (S Koekemoer and JC Taylor)
APPENDIX I	Water Resources Scenario Analysis (S Mallory)

TABLE OF CONTENTS

APPENDIX F: MACROINVERTEBRATES

APPENDIX G: RIPARIAN VEGETATION

LIST OF FIGURES

APPENDIX G

APPENDIX I

LIST OF TABLES

APPENDIX B

APPENDIX D

APPENDIX G

APPENDIX H

APPENDIX I

ACRONYMS

AEC	Alternative Ecological Category
ASPT	Average Score Per Taxon
CD: RDM	Chief Directorate: Resource Directed Measures
CES	Coastal and Environmental Services
COD	Chemical Oxygen Demand
D:RQS	Directorate: Resource Quality Services
DO	Dissolved Oxygen
DRM	Desktop Reserve Model
DWA	Department of Water Affairs
DWAF	Department of Water Affairs and Forestry
DWAF	Department of Water Affairs and Forestry
Eald	Elevation above local datum
EC	Ecological Category
EC	Electrical Conductivity
EIS	Ecological Importance and Sensitivity
EPA	Environmental Protection Agency
EWR	Ecological Water Requirements
EWR	Ecological Water Requirements
F0.1	Fast Depth >0.1m (Flow)
FBR	Fast Bedrock (flow)
FCS	Fast flow over coarse sediments including bedrock
FD	Fast deep (Fish habitat)
FDI	Flow dependent macroinvertebrate
FFCS	Fast Flow over Coarse Sediments
FFS	Fast flow over fine sediments
FRAI	Fish Response Assessment Index
FROC	Fish Frequency of occurrence
FS	Fast shallow fish habitat
FSA	Full Supply Area
FSC	Full Supply Capacity
FV	Fast vegetation (flow)
GAI	Geomorphological Assessment Index
GSM	Gravel, sand, mud habitat
HAI	Hydrological Assessment Index
HFSR	Habitat Flow Stressor Response
IHI	Index of Habitat Integrity
IIHI	Instream Index of Habitat Integrity
Integ	Integrated
IPC	Iron Peg in Concrete
LB	Left Bank
Maint	Maintenance
MAR	Mean Annual Runoff
MCM	Million Cubic Meters
MIRAI	Macro Invertebrate Response Assessment Index
MRK	Mark
MRU	Management Resource Unit
MV	Marginal Vegetation
MVI	Marginal vegetation macroinvertebrate
MVIC	Marginal vegetation in Current
MVOC	Marginal Vegetation out of Current
NRHP	National River Health Programme
OCWSS	Outeniqua Coast Water Situation Study
PAI	Physico-chemical Assessment Index
PAI	Physico-Chemical Driver Assessment Index
PES	Present Ecological State
PES	Present Ecological State
Quat	Quaternary catchment
RB	Right Bank
RC	Reference Condition
RC	Reference Condition

REC	Recommended Ecological Category
REC	Recommended Ecological Category
RHP	River Health Programme
RIHI	Riparian Index of Habitat Integrity
Rip Veg	Riparian vegetation
RU	Resource Unit
SAIAB	South African Institute of Aquatic Biodiversity
SANParks	South African National Parks
SASS5	South African Scoring System version 5
SBR	Slow Bedrock (flow)
SCI	Socio-cultural Importance
SCS	Slow flow over coarse sediments including bedrock
SD	Slow Deep (Fish habitat)
SFS	Slow flow over fine sediments
SIC	Stones-in-current habitat
SOC	Stones-out-of-current habitat
SPI	Specific Pollution sensitivity Index
SS	Slow Shallow (Fish habitat)
SSR	Small semi-rheophilic fish species
SV	Slow vegetation (flow)
TDS	Total Dissolved Solids
TEACHA	Tool for Ecological Aquatic Chemical Habitat Assessment
TIN	Total Inorganic Nitrogen
ToR	Terms of Reference
TSS	Total Suspended Solids
TSS	Total Suspended Solids
VEGRAI	Riparian Vegetation Response Assessment Index
WL	Water Level
WMA	Water Management Area
WMS	Water Management System
WQS	Water Quality Sub-Unit

APPENDIX A: RIVER HYDRAULICS SPECIALIST REPORT
AL BIRKHEAD, Streamflow Solutions

A1 INTRODUCTION AND AIMS OF THIS REPORT

The role of hydraulics and procedure for generating hydraulic information for Ecological Reserve studies have been documented for the Comprehensive and Intermediate levels of determination (DWAF, 1999), with subsequent periodic updates (Birkhead, 2002; Jordanova *et al.*, 2004; Hirschowitz *et al.*, 2007). This report provides the hydraulic information (data collection, analysis and results) for selected river sites within the Outeniqua system.

A1.1 METHODOLOGY

The application of holistic methods for ecological flow determination (refer to Tharme, 1996) requires environmental flow requirements to be expressed as discharge rates (including its temporal characteristics) through assessments of the presence of suitable habitat for certain biota at different flows. The interface between the way in which flow requirements are assessed and expressed is through the results of hydraulic measurements, analyses and hydraulic modelling of sites along rivers. The primary product of these hydraulic analyses are relationships between discharge and the following determinants, which have been found over the course of numerous flow assessments, to be the most useful: depth (maximum and average), velocity (average), wetted perimeter, and width of the water surface. The discharge-depth (or rating) relationship is fundamental to hydraulic analysis, and is generally derived from a combination of measured and synthesized data (refer to Rowlston *et al.,* 2000 and Birkhead, 2002 for descriptions of procedures for deriving hydraulic information for use in environmental flow requirements (or Reserves) in South Africa). Once the rating relationship for a river section has been developed, the relationships between discharge and the other hydraulic parameters (listed above) may readily be computed using the cross-sectional geometry, and are generally provided in tabular format using look-up tables (see Section A4.3).

The cross-sectional profile plots and look-up tables comprise the "standard hydraulic data" used in Reserve determinations in South Africa at the Rapid III, Intermediate and Comprehensive levels. Ecologists use these standard hydraulic data with the aid of site assessments, photographs and to determine the quantity and quality of hydraulic habitat at different flows. Substantial experience and interpretation are required to provide assessments of site-based and reach-based habitat requirements for the various biotic components, using cross-sectional surveys and the results of one-dimensional hydraulic analyses (biological habitat refers to the integration of the different components defining habitat (e.g. hydraulic, substrate and cover attributes for fish). Procedures have been developed for using standard hydraulic information as the basis for quantifying hydraulic habitat for fish (refer to Jordanova *et al.,* 2004 for an explanation of the method). The method allows the assessment of abundance of different habitat types to be applied more consistently in Reserve determinations, and has been applied in this study.

A2 DATA COLLECTION

Fixed stations were installed at the EWR sites using a local datum (Table A1).

Table A1 Fixed survey stations at EWR sites

River	Site no.	Station	Hz (decimal degrees) rel. to cross-section (0°)	Eald[1] (m)
Knysna	1	1.1 (MRK[2]) LB	NA	100.00
		1.2 (Bridge)	101.73	101.73
		1.3 (Bridge)	101.66	101.66
Gouna	2	2.1 (IPC[3]) LB	NA	100.00
		2.2 (MRK) RB	0.00	98.83
		2.3 (MRK) LB	167.05	100.21
		2.4 (MRK) LB	209.62	100.36
Diep	3	3.1 (IPC) LB	NA	100.00
		3.1 (MRK) LB	115.58	101.26
		3.2 (MRK) LB	0.00	100.37
		3.3 (MRK) LB	7.25	100.98
Karatara	4	4.1 (MRK) RB	NA	100.00
		4.2 (MRK) RB	78.52	100.51

1 Elevation above local datum 2 Mark (painted) 3 Iron Peg in Concrete

The measured discharge and flow depth are provided in Table A2, together with the date when the data were collected.

Table A2 Hydraulic data collected at EWR sites

River	Site no.	Date	Discharge Q (m^3/s)	Stage ald z (m)	Max. flow depth y (m)
				Cross-section A/B	
Knysna	1	23/4/07	0.19	99.21	0.43
		17/8/07	1.26	99.31	0.53
		16/8/07	2.70	99.46	0.68
		5/07	23	100.28	1.50
		2/8/06	40	101.12	2.34
		2/8/06	338	104.97	6.19
Gouna	2	23/4/07	0.12	98.97	0.30
		12/11/07	0.17	98.53	0.33
		2/8/06	215	98.53	5.50
Diep	3	24/4/07	0.098	98.12	0.31
		17/8/07	0.11	98.18	0.37
		22/5/07	0.91	98.42	0.61
		8/06	120	101.71	3.90
Karatara	4	24/4/07	0.035	98.72	0.19
		17/8/07	0.10	98.87	0.34
		20/5/07	3.7	99.39	0.86
		2/8/06	78	102.93	4.40

A3 MODELLING

Gauging stations are located at the EWR sites on the Knysna, Diep and Karatara Rivers (K5H002, K4H003 and K4H002, respectively). These rivers, together with the Gouna, experienced high floods due to heavy rainfall in this area in August 2006 (Table A2) and flood levels (strand lines) were identified and surveyed during site selection (April 2007). Unfortunately, the floods exceeded the capacities at both the Knysna and Karatara gauging stations, and the discharge tables were extended to estimate flood peaks. The peak flood discharge for the Gouna (EWR 2) site was estimated by correlating catchment area with peak discharge for the three sites with operational gauges, giving regression coefficient R^2 = 0.9. Use has been made of measured rating data to define the rating relationships - made possible for the high-flow range by correlating strand lines with discharge measurements from the local gauging stations. This alleviates the need to apply a resistance equation to synthesize rating data – this is preferable, given the bedrock pool-rapid morphology (i.e. stage-discharge largely influenced by structural hydraulic controls and not bed resistance).

Continuous rating functions of the form given by equation A1 have been fitted to the measured data (but modified using a resistance equation where unrealistic implied resistance values occur). The rating relationships are plotted in Figure A5 to Figure A8 for EWR sites 1 to 4, respectively.

$Q = ay^b + c$ equation A1

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 A4.

Table A3 Surveyed water surface slopes

River	Site no.	Discharge (m^3/s)	Water surface slope
Knysna	1	**0.19**	**0.020(8.3); 0.025(67)**
Gouna	2	**0.12**	**0.001(31); 0.017(77)**
Diep	3	**0.098**	**0.001(6); 0.020(90)**

(x) Distance over which slope surveyed (m)

Table A4 Regression coefficients in equation A1

River	Site no.	Discharge Q (m^3/s)	Rating coefficients			
			a	*b*	*c* relative to	
					Bed	local datum
Knysna	1	Q < 2.94 Q ∃ 2.94	0.550 0.450	0.173 0.310	0.000 0.101	98.78 98.88
Gouna	2	All	0.700	0.385	0.000	97.81
Diep	3	Q < 0.91 Q ∃ 0.91	0.557 0.450	0.310 0.441	0.070 0.179	98.60 98.71
Karatara	4	Q < 3.80 Q ∃ 3.80	0.592 0.249	0.288 0.643	0.000 0.282	98.67 98.95

A4 RESULTS

A4.1 CROSS-SECTIONAL PROFILES

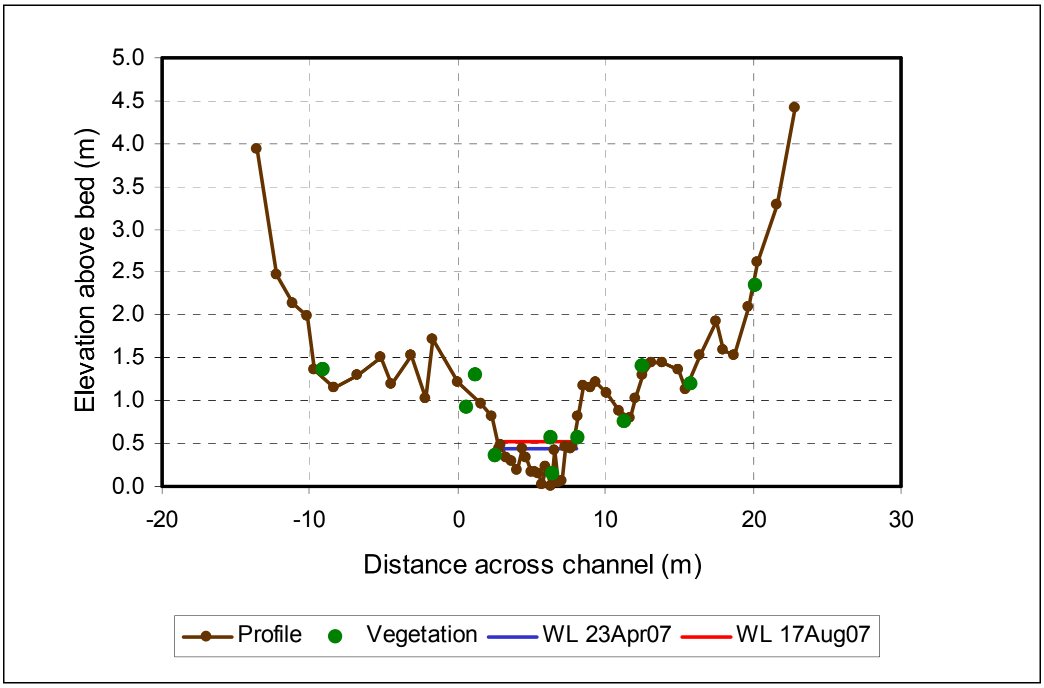

Figure A1 Cross-sectional profile for EWR 1 on the Knysna River (bedrock pool-rapid), showing water levels surveyed on 23/4/2007 and 17/8/2007 (discharges of 0.19 and 1.26m^3/s, respectively) and the position of vegetation surveyed along the cross-section (indicated by markers)

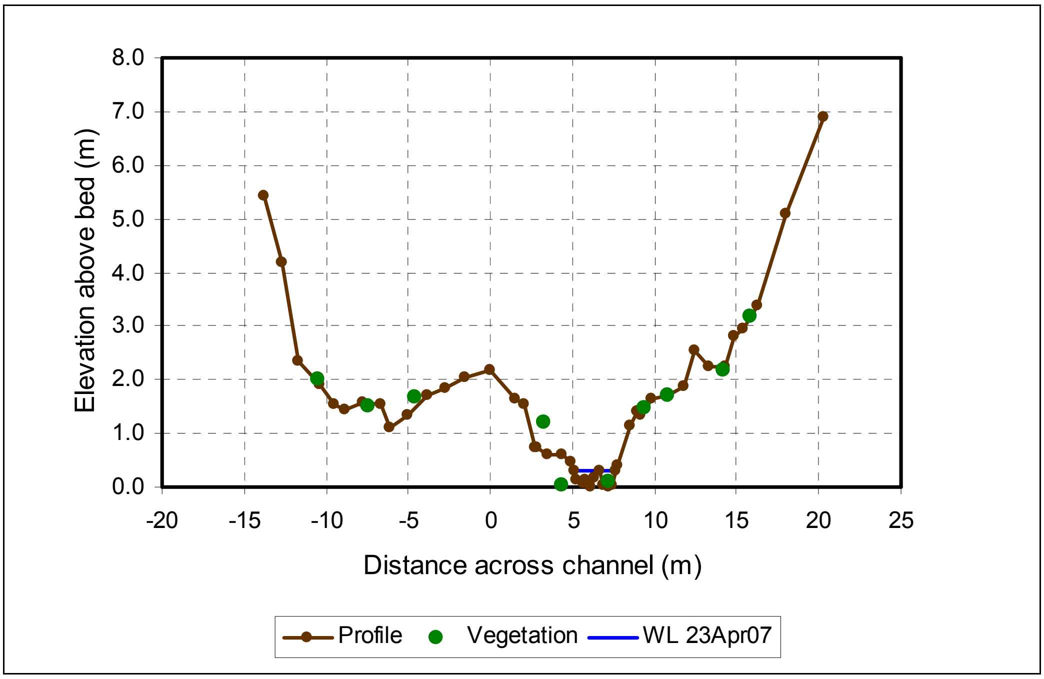

Figure A2 Cross-sectional profile for EWR 2 on the Gouna River (mixed pool-riffle) surveyed on 23/04/2007 (discharge of 0.12m^3/s) and the position of vegetation surveyed along the cross-section (indicated by markers)

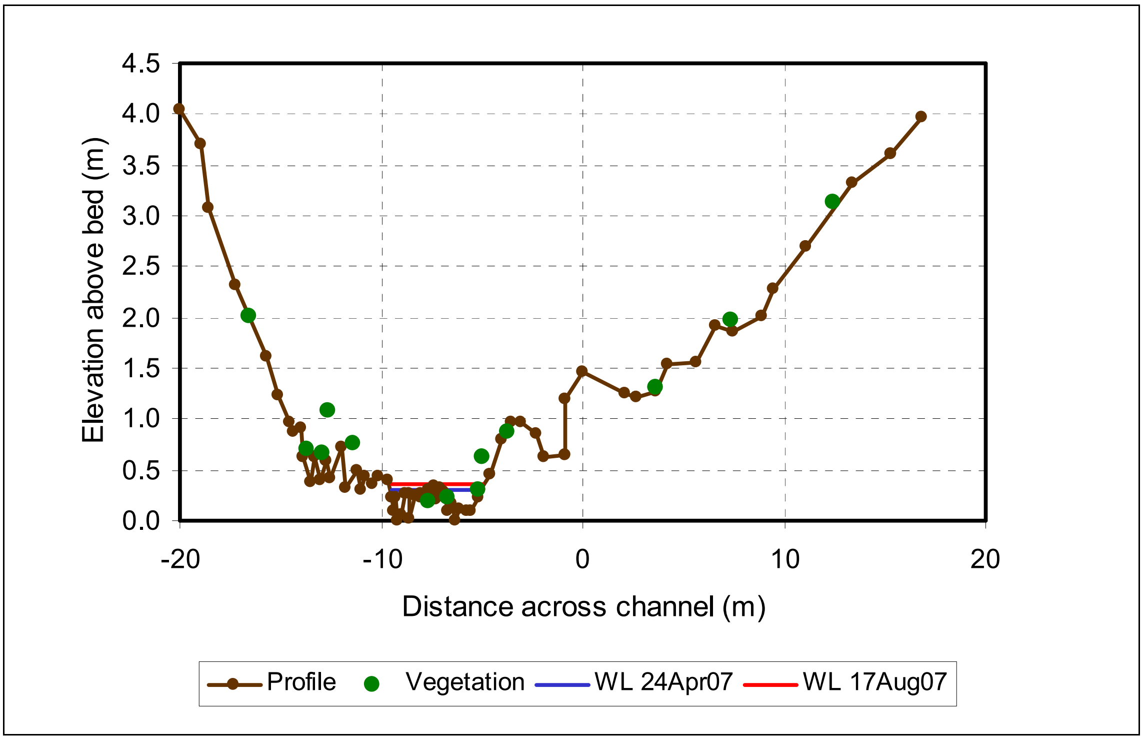

Figure A3 **Cross-sectional profile for EWR 3 on the Diep River (bedrock pool-rapid), showing water levels surveyed on 24/4/2007 and 17/8/2007 (discharges of 0.098 and 0.11m^3/s, respectively) and the position of vegetation surveyed along the cross-section (indicated by markers)**

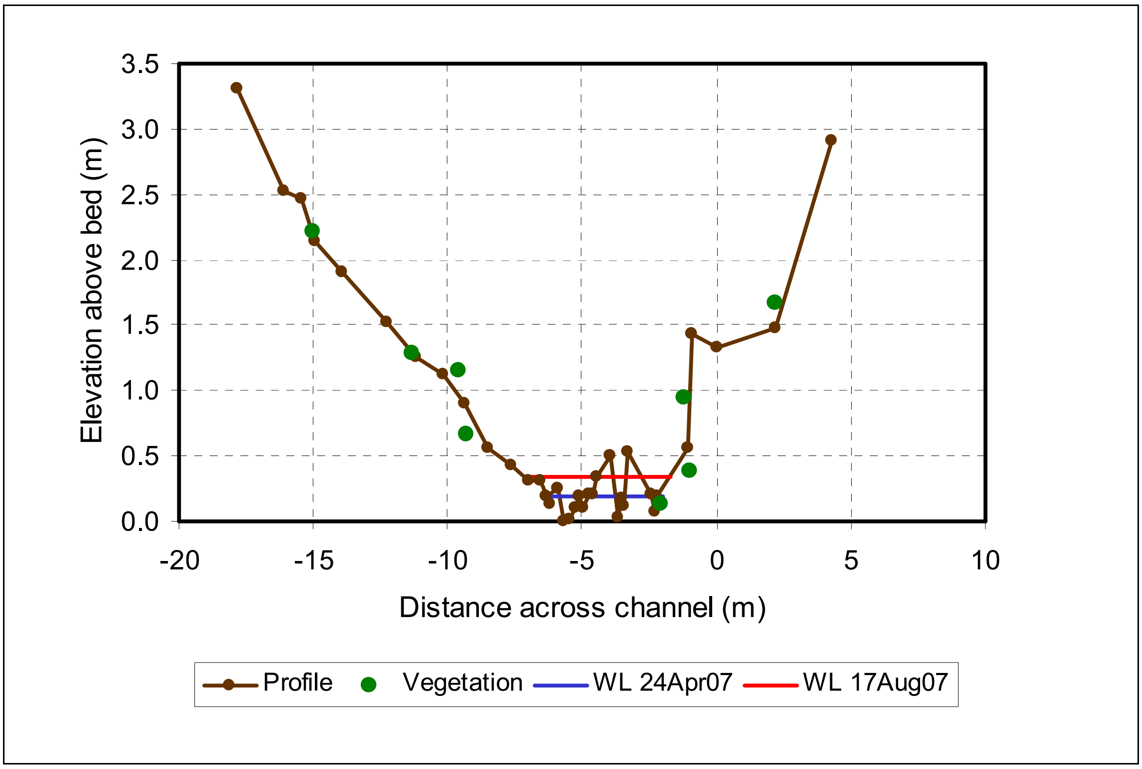

Figure A4 **Cross-sectional profile for EWR 3 on the Karatara River (bedrock pool-rapid), showing water levels surveyed on 24/04/2007 and 17/08/2007 (discharges of 0.035 and 0.10m^3/s, respectively) and the position of vegetation surveyed along the cross-section (indicated by markers)**

A4.2 RATING FUNCTIONS

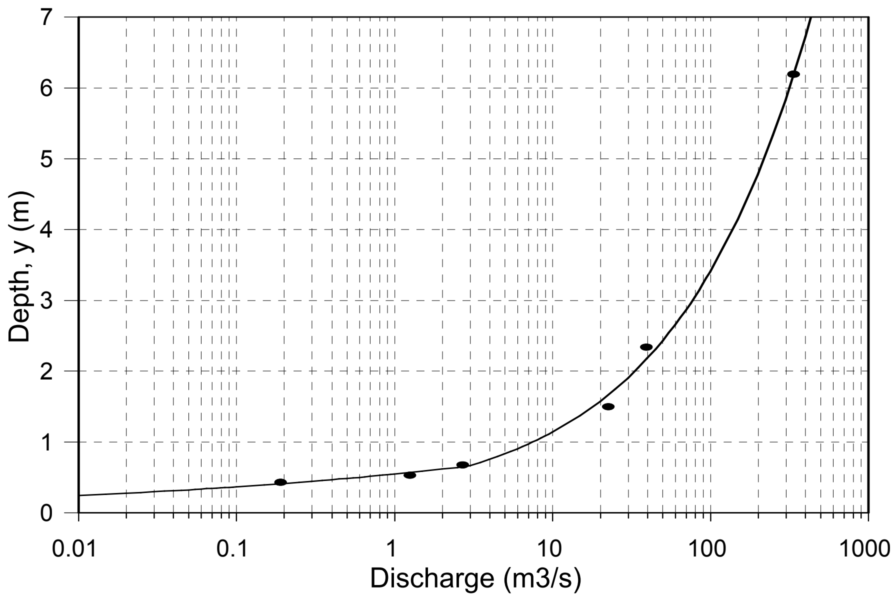

Figure A0.1 Measured and modelled rating data points and function for the cross-sectional profile at EWR 1 on the Knysna River

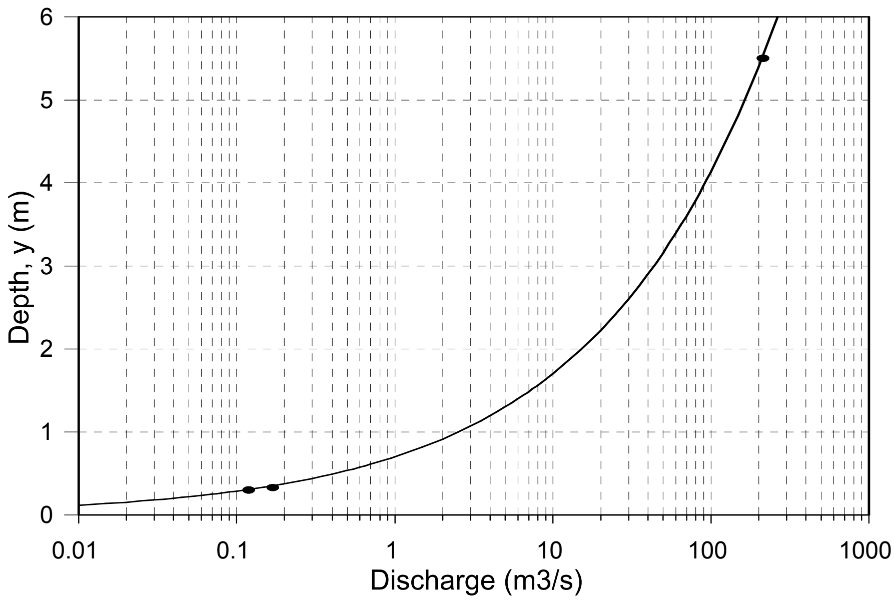

Figure A0.2 Measured and modelled rating data points and function for the cross-sectional profiles at EWR 2 on the Gouna River

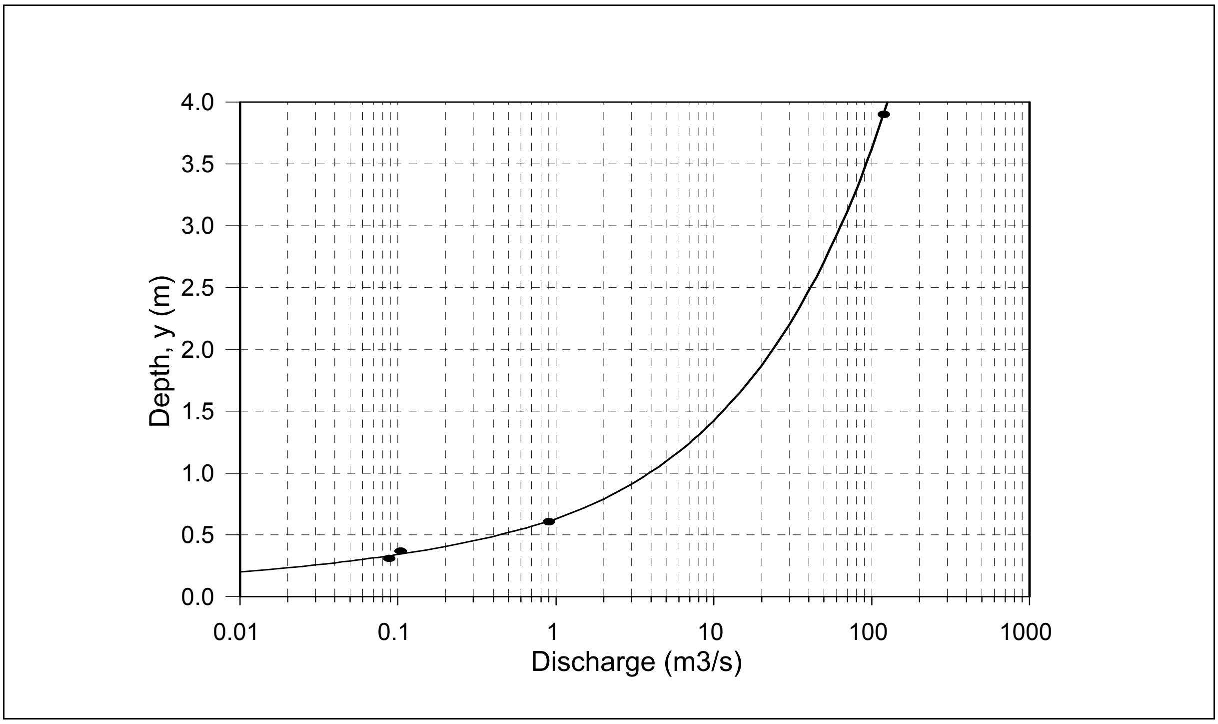

Figure A0.3 Measured and modelled rating data points and function for the cross-sectional profiles at EWR 3 on the Diep River

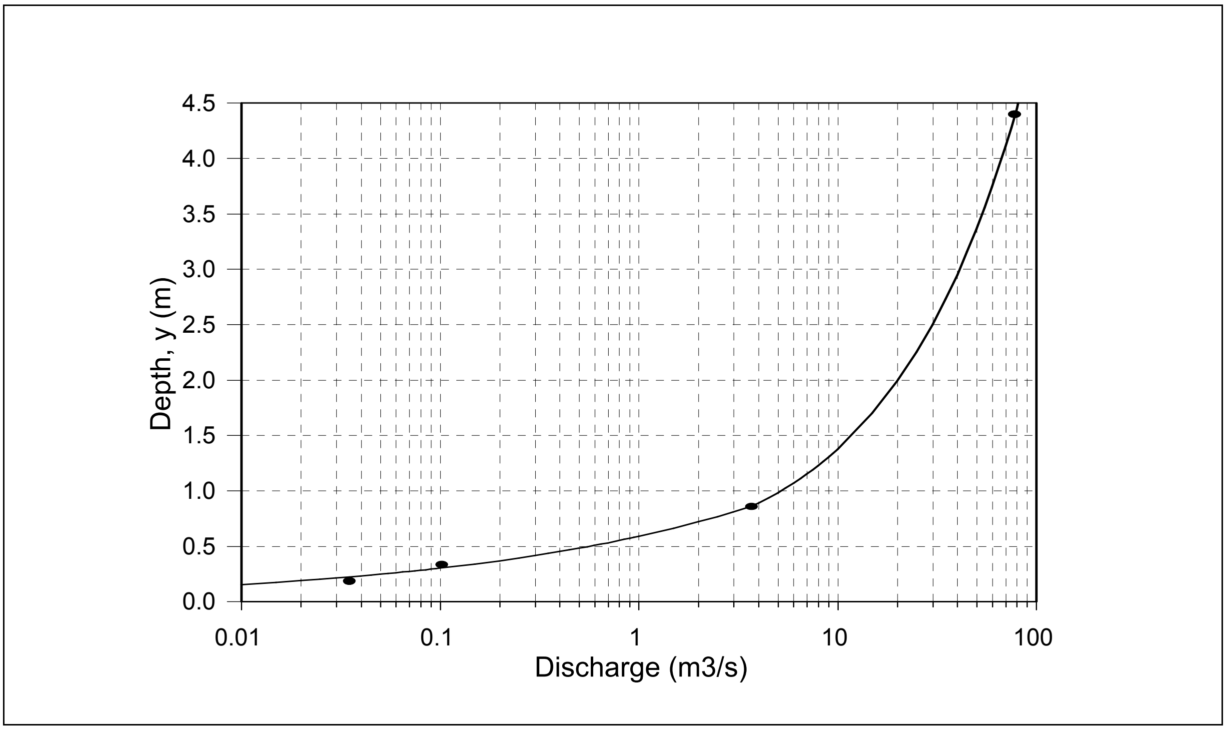

Figure A0.4 Measured and modelled rating data points and function for the cross-sectional profiles at EWR 4 on the Karatara River

A4.3 Tabulated modelled hydraulic data

Table A5 Modelled hydraulic and habitat-type data for EWR 1 on the Knysna River

Maxdepth (m)	Avdepth (m)	Discharge (m^3/s)	Width (m)	Perim (m)	AvVel (m/s)	Vel98% (m/s)	Composition Fish Habitat Types (%)					Composition Invertebrate Habitat Types (%)							
							SS[1]	SD[2]	FS[3]	FD[4]	F0.1[5]	SCS[6]	FCS[7]	SFS[8]	FFS[9]	SBR[10]	FBR[11]	SV[12]	FV[13]
0.02	0.01	0.000	0.0	0.1	0.00	0.00	0	0	0	0	0	0	90	0	10	0	0	0	0
0.04	0.02	0.000	0.1	0.2	0.00	0.00	0	0	0	0	0	0	90	0	10	0	0	0	0
0.06	0.02	0.000	0.4	0.5	0.00	0.00	0	0	0	0	0	0	90	0	10	0	0	0	0
0.08	0.03	0.000	0.6	0.7	0.00	0.00	0	0	0	0	0	0	90	0	10	0	0	0	0
0.10	0.04	0.000	0.7	0.9	0.00	0.01	0	0	0	0	0	0	90	0	10	0	0	0	0
0.12	0.05	0.000	0.9	1.1	0.00	0.01	0	0	0	0	0	0	90	0	10	0	0	0	0
0.14	0.07	0.000	1.0	1.3	0.01	0.02	0	0	0	0	0	0	90	0	10	0	0	0	0
0.16	**0.07**	**0.001**	**1.3**	**1.6**	**0.01**	**0.03**	**0**	**0**	**0**	**0**	**0**	**0**	**90**	**0**	**10**	0	0	**0**	**0**
0.18	0.07	0.002	1.7	2.1	0.01	0.05	0	0	0	0	0	0	90	0	10	0	0	0	0
0.20	0.08	0.003	1.9	2.4	0.02	0.07	0	0	0	0	0	0	90	0	10	0	0	0	0
0.22	0.09	0.005	2.2	2.7	0.03	0.09	0	0	0	0	0	0	90	0	10	0	0	0	0
0.24	0.10	0.008	2.4	2.9	0.03	0.12	0	0	0	0	0	0	90	0	10	0	0	0	0
0.26	0.11	0.013	2.6	3.2	0.04	0.16	0	0	0	0	0	0	90	0	10	0	0	0	0
0.28	0.13	0.020	2.8	3.4	0.06	0.21	0	0	0	0	0	0	90	0	10	0	0	0	0
0.30	0.14	0.030	3.0	3.6	0.07	0.27	0	1	0	1	0	1	89	0	10	0	0	0	0
0.32	0.14	0.044	3.3	4.0	0.09	0.33	0	3	0	3	0	4	87	0	10	0	0	0	0
0.34	0.15	0.062	3.6	4.3	0.12	0.41	0	5	0	5	0	7	81	1	9	0	0	0	2
0.36	0.16	0.086	3.7	4.6	0.14	0.49	1	8	1	8	1	10	75	1	8	0	0	1	4
0.38	0.17	0.12	3.9	4.8	0.17	0.59	2	12	2	12	2	14	69	2	7	0	0	1	7
0.40	0.19	0.16	4.1	5.0	0.21	0.71	4	18	4	18	4	19	61	2	7	0	0	3	8
0.42	**0.20**	**0.19**	**4.2**	**5.2**	**0.23**	**0.77**	**6**	**22**	**6**	**22**	**6**	**23**	**56**	**3**	**6**	0	0	**4**	**9**
0.44	0.21	0.28	4.5	5.5	0.29	0.96	9	32	9	32	9	33	45	4	5	0	0	6	9
0.46	0.21	0.36	4.9	5.9	0.35	1.12	13	38	13	38	13	38	37	4	4	0	0	8	8
0.48	0.22	0.46	5.1	6.2	0.40	1.26	19	44	19	44	19	43	31	5	3	0	0	10	8
0.50	0.24	0.58	5.2	6.2	0.47	1.43	24	51	24	51	24	46	26	5	3	0	0	13	7
0.52	0.25	0.72	5.2	6.3	0.54	1.61	29	57	29	57	29	49	22	6	2	0	0	15	7
0.54	0.27	0.90	5.3	6.4	0.62	1.79	33	64	33	64	33	51	18	6	2	0	0	18	6
0.56	0.29	1.11	5.3	6.4	0.72	2.02	37	71	37	71	37	52	15	5	2	0	0	20	6
0.58	0.31	1.36	5.4	6.5	0.82	2.22	42	77	42	77	42	53	12	6	1	0	0	23	5
0.60	0.32	1.65	5.4	6.5	0.94	2.43	47	81	47	81	47	54	9	6	1	0	0	25	4
0.62	0.34	2.00	5.5	6.6	1.07	2.56	54	85	54	85	54	54	8	6	1	0	0	27	4

Maxdepth (m)	Avdepth (m)	Discharge (m^3/s)	Width (m)	Perim (m)	AvVel (m/s)	Vel98% (m/s)	Composition Fish Habitat Types (%)					Composition Invertebrate Habitat Types (%)							
							SS[1]	SD[2]	FS[3]	FD[4]	F0.1[5]	SCS[6]	FCS[7]	SFS[8]	FFS[9]	SBR[10]	FBR[11]	SV[12]	FV[13]
0.64	0.36	2.40	5.5	6.7	1.21	2.78	58	87	58	87	58	54	6	6	1	0	0	30	3
0.66	**0.38**	**2.87**	**5.6**	**6.7**	**1.37**	**3.01**	**62**	**88**	**62**	**88**	**62**	**54**	**5**	**6**	**1**	0	0	**32**	**3**
0.68	0.39	3.12	5.6	6.8	1.41	3.15	64	88	64	88	64	52	5	5	1	0	0	34	3
0.70	0.41	3.34	5.7	6.9	1.44	3.17	66	88	66	88	66	51	4	6	0	0	0	36	3
0.72	0.43	3.57	5.7	6.9	1.47	3.17	69	89	69	89	69	50	4	6	0	0	0	37	3
0.74	0.44	3.80	5.8	7.0	1.49	3.15	75	90	75	90	75	48	3	6	0	0	0	40	2
0.76	0.46	4.04	5.8	7.0	1.52	3.17	78	91	78	91	78	47	3	6	0	0	0	41	3
0.78	0.48	4.29	5.8	7.1	1.54	3.21	83	91	83	91	83	46	3	5	0	0	0	42	3
0.80	0.48	4.54	6.0	7.3	1.57	3.25	82	89	82	89	82	46	3	5	0	0	0	43	3
0.82	0.48	4.80	6.3	7.6	1.59	3.28	80	86	80	86	80	46	3	5	0	0	0	43	3
0.84	0.48	5.07	6.6	7.9	1.61	3.31	77	83	77	83	77	47	3	5	0	0	0	42	3
0.86	0.48	5.35	6.9	8.2	1.63	3.36	73	80	73	80	73	47	3	5	0	0	0	42	3
0.88	0.48	5.64	7.2	8.6	1.65	3.34	72	79	72	79	72	48	3	6	0	0	0	42	3
0.90	0.48	5.93	7.5	8.8	1.66	3.38	69	78	69	78	69	45	3	5	0	0	0	44	3
0.92	0.48	6.23	7.7	9.1	1.67	3.41	68	80	68	80	68	43	2	5	0	0	0	48	2
0.94	0.49	6.53	7.9	9.3	1.68	3.39	68	81	68	81	68	41	2	5	0	0	0	50	2
0.96	0.50	6.85	8.1	9.6	1.70	3.46	66	81	66	81	66	39	2	5	0	0	0	52	3
0.98	0.50	7.17	8.4	9.8	1.70	3.45	64	82	64	82	64	38	2	4	0	0	0	54	3
1.00	0.51	7.50	8.6	10.1	1.71	3.43	63	83	63	83	63	35	2	4	0	0	0	56	3
1.02	0.51	7.83	8.9	10.4	1.72	3.47	61	83	61	83	61	34	2	4	0	0	0	57	3
1.04	0.51	8.18	9.2	10.7	1.73	3.42	62	84	62	84	62	33	1	4	0	0	0	60	2
1.06	0.52	8.53	9.5	11.0	1.73	3.49	59	83	59	83	59	32	1	4	0	0	0	61	2
1.08	0.52	8.89	9.8	11.4	1.74	3.50	58	83	58	83	58	31	1	4	0	0	0	62	2
1.10	0.52	9.25	10.1	11.7	1.74	3.52	57	82	57	82	57	30	1	3	0	0	0	63	2
1.12	0.53	9.62	10.5	12.1	1.74	3.52	58	82	58	82	58	29	1	3	0	0	0	64	2
1.14	0.53	10.00	10.8	12.5	1.75	3.48	60	83	60	83	60	28	1	3	0	0	0	65	2
1.16	0.52	10.39	11.5	13.2	1.75	3.52	58	81	58	81	58	29	1	3	0	0	0	65	2
1.18	0.49	10.79	12.7	14.4	1.74	3.52	54	75	54	75	54	31	1	4	0	0	0	62	2
1.20	0.48	11.19	13.6	15.4	1.73	3.55	52	71	52	71	52	32	2	4	0	0	0	58	4
1.22	0.46	11.60	14.6	16.4	1.72	3.53	50	68	50	68	50	33	2	4	0	0	0	58	3
1.24	0.46	12.01	15.3	17.2	1.71	3.50	49	67	49	67	49	34	2	4	0	0	0	57	3
1.26	0.46	12.44	16.1	18.0	1.69	3.43	48	72	48	72	48	36	2	4	0	0	0	55	3
1.28	0.46	12.87	16.8	18.7	1.68	3.44	47	72	47	72	47	37	2	4	0	0	0	54	3
1.30	0.46	13.31	17.5	19.5	1.66	3.40	47	74	47	74	47	37	2	4	0	0	0	53	3
1.32	0.46	13.75	18.2	20.3	1.64	3.38	46	75	46	75	46	38	2	4	0	0	0	53	3
1.34	0.46	14.21	19.0	21.0	1.62	3.31	46	76	46	76	46	38	3	5	0	0	0	51	4
1.36	0.46	14.67	19.7	21.8	1.60	3.32	46	78	46	78	46	39	3	5	0	0	0	50	4
1.38	0.47	15.13	20.5	22.6	1.59	3.30	45	76	45	76	45	40	3	5	0	0	0	49	4
1.40	0.47	15.61	21.2	23.4	1.57	3.12	46	80	46	80	46	40	3	5	0	0	0	48	4

Maxdepth (m)	Avdepth (m)	Discharge (m^3/s)	Width (m)	Perim (m)	AvVel (m/s)	Vel98% (m/s)	Composition Fish Habitat Types (%)					Composition Invertebrate Habitat Types (%)							
							SS[1]	SD[2]	FS[3]	FD[4]	F0.1[5]	SCS[6]	FCS[7]	SFS[8]	FFS[9]	SBR[10]	FBR[11]	SV[12]	FV[13]
1.42	0.47	16.09	22.0	24.3	1.55	3.14	45	79	45	79	45	40	3	5	0	0	0	48	4
1.44	0.48	16.58	22.8	25.1	1.53	3.17	44	77	44	77	44	42	3	5	0	0	0	48	3
1.46	0.47	17.08	24.1	26.4	1.51	3.12	46	76	46	76	46	43	3	5	0	0	0	46	3
1.48	0.48	17.58	24.6	26.9	1.49	3.12	48	78	48	78	48	44	3	5	0	0	0	45	3
1.50	0.49	18.09	25.0	27.4	1.47	3.09	50	79	50	79	50	44	3	5	0	0	0	45	3
1.52	0.51	18.61	25.3	27.7	1.45	3.03	53	80	53	80	53	44	3	5	0	0	0	44	3
1.54	0.52	19.14	25.7	28.2	1.44	2.99	55	84	55	84	55	45	3	5	0	0	0	44	3
1.56	0.53	19.67	26.2	28.7	1.42	2.95	57	86	57	86	57	45	3	5	0	0	0	43	3
1.58	0.54	20.21	26.7	29.2	1.41	2.95	59	87	59	87	59	47	3	6	0	0	0	42	3
1.60	0.55	20.76	26.9	29.5	1.39	2.90	62	88	62	88	62	47	3	6	0	0	0	42	3
1.62	0.57	21.32	27.1	29.7	1.38	2.91	62	86	62	86	62	47	3	6	0	0	0	41	3
1.64	0.58	21.88	27.3	30.0	1.37	2.87	64	88	64	88	64	47	3	6	0	0	0	41	3
1.66	0.60	22.45	27.5	30.2	1.36	2.87	67	86	67	86	67	47	3	6	0	0	0	40	3
1.68	**0.62**	**23.03**	**27.8**	**30.5**	**1.35**	**2.78**	**70**	**89**	**70**	**89**	**70**	**47**	**4**	**6**	**0**	0	0	**40**	**3**
1.70	0.63	23.61	28.0	30.7	1.34	2.74	72	91	72	91	72	47	4	6	0	0	0	40	3
1.72	0.65	24.20	28.2	31.0	1.33	2.81	73	89	73	89	73	48	4	6	0	0	0	39	3
1.74	0.66	24.80	28.3	31.1	1.32	2.80	72	90	72	90	72	48	4	6	0	0	0	39	3
1.76	0.68	25.41	28.5	31.3	1.31	2.74	76	89	76	89	76	48	4	6	0	0	0	39	3
1.78	0.70	26.02	28.6	31.5	1.31	2.73	77	90	77	90	77	48	4	6	0	0	0	39	3
1.80	0.71	26.64	28.7	31.6	1.30	2.73	79	91	79	91	79	48	4	6	0	0	0	39	3
1.82	0.73	27.27	28.9	31.8	1.30	2.70	82	91	82	91	82	49	4	6	0	0	0	38	3
1.84	0.75	27.91	29.0	31.9	1.29	2.75	81	90	81	90	81	48	4	6	0	0	0	38	3
1.86	0.76	28.55	29.1	32.1	1.29	2.71	82	90	82	90	82	49	4	6	0	0	0	38	3
1.88	0.78	29.20	29.3	32.3	1.28	2.67	84	91	84	91	84	49	4	6	0	0	0	38	3
1.90	0.80	29.86	29.4	32.4	1.28	2.68	85	91	85	91	85	49	4	6	0	0	0	38	3
1.92	0.81	30.52	29.5	32.6	1.27	2.70	84	90	84	90	84	50	4	6	0	0	0	38	3
1.94	0.83	31.20	29.6	32.7	1.27	2.72	85	91	85	91	85	50	4	6	0	0	0	37	3
1.96	0.85	31.88	29.7	32.8	1.27	2.70	85	91	85	91	85	50	4	6	0	0	0	37	3
1.98	0.87	32.56	29.7	32.8	1.26	2.69	85	91	85	91	85	50	4	6	0	0	0	37	3
2.00	0.88	33.26	29.9	33.0	1.26	2.63	86	91	86	91	86	50	4	6	0	0	0	37	3

1 Slow Shallow 2 Slow Deep 3 Fast Shallow 4 Fast Deep 5 Fast Depth>0.1m 6 Slow Coarse Sediment
7 Fast Coarse Sediment 8 Slow Fine Sediment 9 Fast Fine Sediment 10 Slow Bedrock 11 Fast Bedrock 12 Slow Vegetation 13 Fast Vegetation
Bold = measured 23/4/2007(0.19m^3/s), 17/8/2007 (1.3m^3/s), 16/8/2007 (2.7m^3/s) & 2007 (23m^3/s).

Table A6 Modelled hydraulic and habitat-type data for EWR 2 on the Gouna River

Maxdepth (m)	Avdepth (m)	Discharge (m^3/s)	Width (m)	Perim (m)	AvVel (m/s)	Vel98% (m/s)	Composition Fish Habitat Types (%)					Composition Invertebrate Habitat Types (%)							
							SS[1]	SD[2]	FS[3]	FD[4]	F0.1[5]	SCS[6]	FCS[7]	SFS[8]	FFS[9]	SBR[10]	FBR[11]	SV[12]	FV[13]
0.02	0.01	0.000	0.4	0.5	0.02	0.08	100	0	0	0	0	0	70	0	20	0	10	0	0
0.04	0.02	0.001	0.8	0.8	0.03	0.12	100	0	0	0	0	0	70	0	20	0	10	0	0
0.06	0.04	0.002	0.9	1.0	0.05	0.17	100	0	0	0	0	0	70	0	20	0	10	0	0
0.08	0.05	0.004	1.1	1.2	0.07	0.23	100	0	0	0	0	0	70	0	20	0	10	0	0
0.10	0.06	0.006	1.4	1.6	0.08	0.28	98	0	2	0	0	1	69	0	20	0	10	0	0
0.12	0.06	0.010	1.7	1.9	0.09	0.32	97	0	3	0	1	2	68	1	19	0	10	0	0
0.14	0.08	0.015	1.8	2.0	0.11	0.36	94	0	6	0	2	4	66	1	19	1	9	0	0
0.16	0.10	0.022	1.9	2.1	0.12	0.41	92	0	8	0	4	5	64	1	19	1	10	0	0
0.18	0.11	0.029	1.9	2.2	0.13	0.46	90	0	10	0	6	7	63	2	18	1	9	0	0
0.20	0.13	0.039	2.0	2.3	0.15	0.51	88	0	12	0	9	9	62	3	17	1	8	0	0
0.22	0.14	0.049	2.1	2.5	0.17	0.56	85	0	15	0	12	10	59	3	17	2	9	0	0
0.24	0.16	0.062	2.2	2.6	0.18	0.61	82	0	18	0	15	12	58	3	17	2	7	0	1
0.26	0.17	0.076	2.3	2.7	0.20	0.67	78	0	22	0	18	15	53	4	15	2	6	1	4
0.28	0.18	0.093	2.3	2.8	0.21	0.72	75	0	25	0	20	16	49	4	14	2	7	2	6
0.30	0.20	0.11	2.4	3.0	0.23	0.77	71	0	28	1	24	18	45	5	13	2	6	3	8
0.32	**0.21**	**0.13**	**2.5**	**3.0**	**0.25**	**0.82**	**67**	**0**	**27**	**6**	**28**	**20**	**40**	**6**	**11**	**3**	**5**	**5**	**10**
0.34	0.23	0.15	2.5	3.1	0.26	0.86	64	0	25	11	31	20	37	6	10	3	6	6	12
0.36	**0.24**	**0.18**	**2.6**	**3.2**	**0.28**	**0.92**	**60**	**0**	**26**	**14**	**35**	**22**	**33**	**6**	**10**	**3**	**5**	**8**	**13**
0.38	0.26	0.21	2.7	3.2	0.30	0.95	57	0	25	18	38	23	30	7	8	3	5	10	14
0.40	0.27	0.23	2.7	3.3	0.32	1.00	53	0	22	24	42	24	28	7	8	3	4	12	14
0.42	0.29	0.27	2.8	3.4	0.33	1.04	50	0	20	30	45	24	25	7	7	4	4	14	15
0.44	0.30	0.30	2.8	3.4	0.35	1.08	48	0	19	33	48	25	23	7	7	4	3	16	15
0.46	0.31	0.34	2.9	3.5	0.37	1.13	45	0	19	36	50	26	21	7	6	3	3	19	15
0.48	0.33	0.38	2.9	3.6	0.39	1.16	42	0	19	38	53	25	19	7	6	4	3	20	16
0.50	0.34	0.42	3.0	3.7	0.41	1.20	39	1	20	40	54	26	17	8	5	4	2	23	15
0.52	0.34	0.46	3.2	3.8	0.43	1.25	31	6	21	42	55	26	16	7	5	4	3	24	15
0.54	0.35	0.51	3.3	3.9	0.44	1.28	27	9	21	43	56	27	15	8	4	4	2	26	14
0.56	0.36	0.56	3.4	4.1	0.46	1.31	25	9	22	44	57	27	14	8	4	3	2	28	14
0.58	0.37	0.61	3.5	4.2	0.48	1.33	22	10	22	46	58	27	12	8	4	4	2	30	13
0.60	0.30	0.67	4.5	5.2	0.49	1.38	22	10	32	37	46	31	14	9	4	5	2	24	11
0.62	0.31	0.73	4.6	5.3	0.50	1.41	19	12	32	37	47	30	14	9	4	5	2	25	11
0.64	0.33	0.79	4.7	5.5	0.51	1.41	19	11	33	37	48	30	12	9	4	6	2	26	11
0.66	0.34	0.86	4.9	5.6	0.52	1.42	18	11	33	38	49	30	12	9	4	5	2	27	11
0.68	0.35	0.93	5.0	5.7	0.53	1.45	17	11	33	38	50	30	12	9	4	4	2	28	11
0.70	0.36	1.00	5.1	5.9	0.54	1.44	17	11	34	39	62	30	12	9	4	4	2	28	11
0.72	0.37	1.08	5.2	6.0	0.55	1.46	16	11	34	39	64	30	11	10	3	4	2	29	11

Maxdepth (m)	Avdepth (m)	Discharge (m^3/s)	Width (m)	Perim (m)	AvVel (m/s)	Vel98% (m/s)	Composition Fish Habitat Types (%)					Composition Invertebrate Habitat Types (%)							
							SS[1]	SD[2]	FS[3]	FD[4]	F0.1[5]	SCS[6]	FCS[7]	SFS[8]	FFS[9]	SBR[10]	FBR[11]	SV[12]	FV[13]
0.74	0.38	1.16	5.4	6.2	0.56	1.49	16	10	35	39	66	30	10	9	3	5	2	31	10
0.76	0.40	1.24	5.4	6.2	0.57	1.48	15	11	34	40	67	29	10	9	3	5	2	31	11
0.78	0.42	1.33	5.5	6.3	0.58	1.49	14	11	34	41	69	29	9	9	3	5	2	33	10
0.80	0.43	1.42	5.5	6.3	0.60	1.53	13	11	34	42	71	29	9	9	3	4	1	34	11
0.82	0.45	1.51	5.5	6.4	0.61	1.52	13	11	33	44	72	28	9	8	3	5	1	35	11
0.84	0.47	1.61	5.6	6.4	0.62	1.54	12	10	32	46	74	27	9	8	3	5	2	35	12
0.86	0.48	1.71	5.6	6.5	0.63	1.56	12	10	31	47	75	27	7	9	2	6	1	38	10
0.88	0.50	1.81	5.6	6.5	0.64	1.58	11	10	29	49	76	27	7	9	2	4	1	40	10
0.90	0.52	1.92	5.7	6.6	0.65	1.58	11	10	20	59	76	26	7	8	2	5	1	40	11
0.92	0.53	2.03	5.7	6.7	0.67	1.57	10	10	15	64	78	26	7	8	2	4	1	41	11
0.94	0.55	2.15	5.8	6.7	0.68	1.60	10	10	14	66	78	25	6	8	2	5	1	43	10
0.96	0.57	2.27	5.8	6.8	0.69	1.62	10	10	13	68	79	25	6	8	2	4	1	44	10
0.98	0.58	2.40	5.8	6.8	0.71	1.65	9	10	11	70	80	24	6	7	2	5	1	44	11
1.00	0.60	2.53	5.9	6.9	0.72	1.66	9	10	10	72	80	24	6	7	2	3	1	46	11
1.02	0.61	2.66	5.9	6.9	0.73	1.68	8	9	10	73	80	24	5	7	2	3	1	48	10
1.04	0.63	2.80	5.9	7.0	0.75	1.70	8	9	9	74	81	23	5	7	2	3	1	48	11
1.06	0.65	2.94	6.0	7.0	0.76	1.72	7	9	8	75	81	23	4	8	1	3	1	51	9
1.08	0.66	3.08	6.0	7.1	0.77	1.76	6	10	8	76	82	22	4	7	1	4	1	52	9
1.10	0.68	3.24	6.1	7.2	0.79	1.78	6	10	8	77	82	21	4	7	1	4	1	52	10
1.12	0.68	3.39	6.2	7.3	0.80	1.78	5	10	9	75	81	21	4	7	1	4	1	52	10
1.14	0.68	3.55	6.4	7.5	0.81	1.77	4	11	10	75	80	22	4	7	1	3	1	52	10
1.16	0.69	3.71	6.5	7.7	0.83	1.81	4	11	12	73	78	22	4	7	1	4	1	52	9
1.18	0.69	3.88	6.7	7.9	0.84	1.85	3	10	13	73	78	22	3	7	1	5	1	54	7
1.20	0.69	4.06	6.9	8.1	0.85	1.85	3	10	14	72	78	23	3	7	1	4	1	54	7
1.22	0.70	4.23	7.0	8.3	0.86	1.89	3	10	17	70	77	23	3	7	1	4	1	54	7
1.24	0.70	4.42	7.2	8.5	0.88	1.91	3	9	18	70	78	23	3	8	1	4	0	54	7
1.26	0.70	4.60	7.4	8.6	0.89	1.93	3	9	18	69	78	23	3	8	1	4	0	54	7
1.28	0.71	4.80	7.5	8.8	0.90	1.92	3	9	19	69	80	23	3	8	1	4	1	53	7
1.30	0.71	4.99	7.7	9.0	0.91	1.93	3	8	21	67	79	24	3	8	1	4	0	53	7
1.32	0.72	5.19	7.8	9.2	0.92	1.92	3	8	21	67	80	24	3	8	1	4	0	53	7
1.34	0.72	5.40	8.0	9.4	0.93	1.97	3	8	23	66	80	23	3	8	1	4	1	53	7
1.36	0.73	5.61	8.2	9.6	0.94	1.96	4	8	23	66	81	23	3	8	1	4	1	53	7
1.38	0.72	5.83	8.5	9.9	0.95	2.01	4	7	26	64	79	24	3	8	1	4	1	52	7
1.40	0.72	6.05	8.7	10.2	0.96	2.00	4	7	26	64	80	24	3	8	1	5	1	52	6
1.42	0.73	6.28	8.9	10.4	0.97	2.04	4	7	27	62	79	25	3	8	1	4	1	52	6
1.44	0.73	6.51	9.1	10.6	0.98	2.04	4	7	26	64	80	25	3	8	1	4	1	52	6
1.46	0.72	6.75	9.5	11.1	0.99	2.04	4	6	28	62	79	25	3	9	1	5	1	50	6
1.48	0.71	6.99	9.9	11.5	0.99	2.06	4	6	30	60	77	26	3	9	1	6	1	48	6
1.50	0.70	7.24	10.4	12.0	1.00	2.08	4	5	31	60	75	27	3	10	1	5	1	48	5

Maxdepth (m)	Avdepth (m)	Discharge (m^3/s)	Width (m)	Perim (m)	AvVel (m/s)	Vel98% (m/s)	Composition Fish Habitat Types (%)					Composition Invertebrate Habitat Types (%)							
							SS[1]	SD[2]	FS[3]	FD[4]	F0.1[5]	SCS[6]	FCS[7]	SFS[8]	FFS[9]	SBR[10]	FBR[11]	SV[12]	FV[13]
1.52	0.69	7.49	10.8	12.4	1.01	2.07	4	5	31	59	76	28	3	10	1	5	1	47	5
1.54	0.67	7.75	11.4	13.1	1.01	2.07	5	5	33	57	73	29	3	11	1	5	1	45	5
1.56	0.64	8.02	12.3	14.0	1.01	2.07	5	5	36	55	70	30	3	11	1	7	1	43	4
1.58	0.62	8.29	13.1	14.8	1.02	2.06	5	5	37	53	70	31	3	12	1	7	1	41	4
1.60	0.63	8.56	13.4	15.1	1.02	2.07	5	4	38	53	71	31	3	12	1	8	1	40	4
1.62	0.64	8.84	13.6	15.4	1.02	2.09	5	4	38	52	73	31	3	12	1	8	1	40	4
1.64	0.65	9.13	13.9	15.6	1.02	2.09	5	4	38	53	75	31	3	12	1	8	1	40	4
1.66	0.64	9.42	14.4	16.1	1.02	2.11	5	4	39	52	76	32	3	13	1	7	1	39	4
1.68	0.64	9.72	14.8	16.6	1.02	2.09	5	4	39	52	79	32	3	13	1	8	1	38	4
1.70	0.65	10.02	15.2	17.0	1.02	2.11	5	4	39	52	80	32	3	13	1	9	1	37	4
1.72	0.65	10.33	15.7	17.5	1.02	2.09	5	4	37	53	80	32	3	13	1	9	1	37	4
1.74	0.65	10.65	16.1	17.9	1.02	2.09	5	4	37	54	80	32	3	13	1	8	1	38	4
1.76	0.66	10.97	16.5	18.3	1.02	2.11	5	4	37	54	80	32	3	13	1	8	1	38	4
1.78	0.66	11.29	16.8	18.6	1.01	2.12	5	4	36	54	80	31	3	13	1	9	1	38	4
1.80	0.67	11.63	17.2	19.0	1.01	2.10	5	4	34	56	80	31	3	13	1	8	1	39	4
1.82	0.67	11.96	17.6	19.4	1.01	2.11	5	4	33	58	80	31	3	13	1	8	1	39	4
1.84	0.68	12.31	18.0	19.8	1.01	2.06	5	4	30	60	81	30	3	13	1	9	1	39	4
1.86	0.68	12.66	18.3	20.2	1.01	2.09	5	4	30	60	82	30	3	13	1	8	1	40	4
1.88	0.69	13.02	18.7	20.5	1.01	2.09	5	4	30	61	82	30	3	13	1	8	1	40	4
1.90	0.70	13.38	18.9	20.8	1.01	2.09	5	4	29	61	83	30	3	13	1	8	1	40	4
1.92	0.71	13.75	19.2	21.1	1.01	2.05	5	5	27	63	83	29	3	13	1	8	1	41	4
1.94	0.72	14.12	19.5	21.4	1.01	2.04	5	5	26	64	83	29	3	13	1	8	1	41	4
1.96	0.73	14.50	19.7	21.7	1.00	2.05	5	5	25	66	83	29	3	13	1	7	1	42	4
1.98	0.74	14.89	20.0	21.9	1.00	2.05	5	5	23	68	84	28	3	13	1	8	1	42	4
2.00	0.75	15.28	20.3	22.2	1.00	2.03	5	5	21	69	85	28	3	13	1	7	1	42	5

1 Slow Shallow 2 Slow Deep 3 Fast Shallow 4 Fast Deep 5 Fast Depth>0.1m 6 Slow Coarse Sediment
7 Fast Coarse Sediment 8 Slow Fine Sediment 9 Fast Fine Sediment 10 Slow Bedrock 11 Fast Bedrock 12 Slow Vegetation 13 Fast Vegetation
Bold = measured 23/4/2007(0.12m^3/s) & 12/11/2007 (0.17m^3/s).

Table A7 Modelled hydraulic and habitat-type data for EWR 3 on the Diep River

Maxdepth (m)	Avdepth (m)	Discharge (m^3/s)	Width (m)	Perim (m)	AvVel (m/s)	Vel98% (m/s)	Composition Fish Habitat Types (%)					Composition Invertebrate Habitat Types (%)							
							SS[1]	SD[2]	FS[3]	FD[4]	F0.1[5]	SCS[6]	FCS[7]	SFS[8]	FFS[9]	SBR[10]	FBR[11]	SV[12]	FV[13]
0.08	0.04	0.000	0.60	0.80	0.00	0.00	100	0	0	0	0	0	60	0	10	0	30	0	0
0.10	0.04	0.000	1.10	1.40	0.00	0.01	100	0	0	0	0	0	60	0	10	0	30	0	0
0.12	0.04	0.000	1.50	1.90	0.01	0.02	100	0	0	0	0	0	60	0	10	0	30	0	0
0.14	0.06	0.001	1.80	2.20	0.01	0.05	100	0	0	0	0	0	60	0	10	0	30	0	0
0.16	0.07	0.003	2.00	2.60	0.02	0.08	100	0	0	0	0	0	60	0	10	0	30	0	0
0.18	0.08	0.005	2.20	2.90	0.03	0.11	100	0	0	0	0	0	60	0	10	0	30	0	0
0.20	0.09	0.009	2.40	3.10	0.04	0.15	100	0	0	0	0	0	60	0	10	0	30	0	0
0.22	0.11	0.015	2.60	3.40	0.05	0.19	100	0	0	0	0	0	60	0	10	0	30	0	0
0.24	0.11	0.022	3.00	3.90	0.07	0.23	100	0	0	0	0	0	60	0	10	0	30	0	0
0.26	0.12	0.031	3.20	4.20	0.08	0.28	98	0	2	0	1	1	59	0	10	1	30	0	0
0.28	0.12	0.043	3.80	4.90	0.09	0.32	96	0	4	0	2	2	58	0	10	1	29	0	0
0.30	0.13	0.058	4.20	5.40	0.11	0.37	94	0	6	0	4	4	56	1	9	2	28	0	0
0.32	0.14	0.075	4.50	5.70	0.12	0.41	92	0	8	0	5	5	55	1	9	3	28	0	0
0.34	**0.15**	**0.10**	**4.80**	**6.00**	**0.13**	**0.46**	**90**	**0**	**10**	**1**	**6**	**6**	**53**	**1**	**9**	**3**	**28**	**0**	**0**
0.36	0.16	0.12	5.00	6.30	0.15	0.52	87	0	12	1	8	8	52	1	9	4	26	0	0
0.38	0.17	0.15	5.30	6.60	0.16	0.56	85	0	13	2	11	9	51	2	9	5	26	0	0
0.40	0.18	0.19	5.80	7.10	0.18	0.61	82	0	15	3	13	11	48	2	8	6	25	0	0
0.42	0.18	0.22	6.60	8.00	0.19	0.64	80	0	15	5	14	12	46	2	8	7	25	0	0
0.44	0.18	0.27	7.30	8.80	0.21	0.69	77	0	17	6	15	14	44	2	8	8	24	0	0
0.46	0.19	0.32	7.60	9.10	0.22	0.74	74	0	19	7	17	15	42	3	7	9	24	0	0
0.48	0.20	0.37	7.80	9.50	0.23	0.77	71	0	21	8	20	17	41	3	7	9	23	0	0
0.50	0.22	0.43	8.10	9.80	0.25	0.82	67	0	24	9	23	19	39	3	7	10	22	0	0
0.52	0.23	0.50	8.30	10.10	0.26	0.85	63	1	24	11	28	20	36	3	6	13	23	0	0
0.54	0.25	0.58	8.60	10.40	0.28	0.88	60	2	25	13	33	21	35	3	6	13	22	0	0
0.56	0.26	0.66	8.80	10.60	0.29	0.93	56	2	25	16	36	23	32	4	5	15	21	0	0
0.58	0.27	0.75	9.00	10.90	0.31	0.97	51	4	25	19	39	25	31	4	5	16	19	0	0
0.60	0.29	0.85	9.20	11.20	0.32	1.01	46	6	26	22	42	26	29	4	5	17	18	0	1
0.62	0.30	0.96	9.30	11.30	0.34	1.04	41	9	26	25	46	28	27	5	4	17	17	1	1
0.64	0.29	1.06	10.30	12.40	0.35	1.08	40	8	28	24	44	28	26	5	4	18	17	1	1
0.66	0.30	1.16	10.60	12.70	0.36	1.12	38	8	28	26	44	28	24	5	4	18	16	3	2
0.68	0.32	1.28	10.70	12.90	0.37	1.13	35	9	27	29	47	29	22	5	4	19	14	4	3
0.70	0.34	1.39	10.80	13.10	0.38	1.14	33	10	24	33	49	28	22	4	4	18	15	5	4
0.72	0.35	1.52	10.90	13.30	0.39	1.18	31	10	22	36	50	29	20	5	3	18	13	7	5
0.74	0.37	1.65	11.00	13.40	0.40	1.19	29	11	21	39	56	28	19	5	3	18	13	8	6
0.76	0.39	1.79	11.10	13.50	0.41	1.21	27	12	19	42	59	28	18	5	3	18	12	10	6
0.78	0.41	1.93	11.10	13.60	0.43	1.25	25	12	19	44	60	28	17	4	3	19	11	11	7

Maxdepth (m)	Avdepth (m)	Discharge (m^3/s)	Width (m)	Perim (m)	AvVel (m/s)	Vel98% (m/s)	Composition Fish Habitat Types (%)					Composition Invertebrate Habitat Types (%)							
							SS[1]	SD[2]	FS[3]	FD[4]	F0.1[5]	SCS[6]	FCS[7]	SFS[8]	FFS[9]	SBR[10]	FBR[11]	SV[12]	FV[13]
0.80	0.42	2.08	11.20	13.70	0.44	1.27	23	13	18	46	62	28	15	5	2	20	10	13	7
0.82	0.44	2.23	11.30	13.90	0.45	1.28	21	14	18	47	63	27	15	5	3	18	10	15	8
0.84	0.46	2.39	11.40	14.00	0.46	1.29	20	15	16	50	64	27	14	5	2	18	9	16	9
0.86	0.47	2.56	11.50	14.20	0.47	1.33	18	15	16	51	65	27	13	5	2	18	8	18	9
0.88	0.48	2.73	11.90	14.60	0.48	1.34	17	15	17	51	63	26	12	5	2	18	9	19	9
0.90	0.48	2.91	12.40	15.10	0.49	1.35	16	16	17	52	63	26	12	4	2	18	9	20	9
0.92	0.49	3.10	12.70	15.40	0.50	1.38	14	16	18	52	62	26	11	4	2	19	8	21	9
0.94	0.50	3.29	12.90	15.70	0.51	1.38	13	16	17	53	63	26	11	4	2	18	7	22	10
0.96	0.51	3.49	13.10	16.00	0.52	1.40	12	17	15	56	65	25	10	4	2	19	7	24	9
0.98	0.51	3.70	13.70	16.60	0.53	1.41	12	16	16	56	64	25	10	4	2	19	7	24	9
1.00	0.52	3.91	13.80	16.70	0.54	1.44	11	17	16	57	65	26	10	4	2	18	7	24	9
1.02	0.54	4.13	13.80	16.70	0.55	1.47	10	16	16	58	67	26	9	4	2	19	7	25	8
1.04	0.56	4.36	13.80	16.80	0.56	1.48	10	16	15	59	70	26	9	4	2	19	7	25	8
1.06	0.58	4.59	13.90	16.80	0.57	1.49	9	16	15	59	70	26	9	4	2	19	7	25	8
1.08	0.60	4.83	13.90	16.90	0.58	1.51	9	16	15	60	72	27	9	5	2	19	6	25	8
1.10	0.62	5.07	14.00	17.00	0.59	1.51	8	16	15	61	73	27	9	5	2	19	6	25	8
1.12	0.63	5.33	14.00	17.00	0.60	1.52	7	17	14	62	75	26	9	4	2	19	7	25	8
1.14	0.65	5.59	14.00	17.10	0.61	1.56	7	16	15	62	75	27	9	5	2	19	6	25	8
1.16	0.67	5.85	14.10	17.20	0.62	1.56	6	17	14	63	76	27	8	5	1	20	6	25	8
1.18	0.69	6.13	14.10	17.20	0.63	1.59	6	17	12	65	76	27	8	5	1	20	6	25	8
1.20	0.71	6.41	14.20	17.30	0.64	1.61	5	17	10	68	77	27	7	5	1	21	6	26	7
1.22	0.70	6.70	14.60	17.80	0.65	1.59	5	16	10	69	76	26	7	5	1	21	6	27	7
1.24	0.69	6.99	15.30	18.50	0.66	1.61	6	15	12	67	72	26	7	5	1	20	6	28	7
1.26	0.68	7.30	16.00	19.20	0.67	1.60	6	14	14	65	70	25	7	4	1	21	6	28	8
1.28	0.68	7.61	16.50	19.60	0.68	1.61	6	14	14	66	69	25	6	4	1	21	5	31	7
1.30	0.69	7.92	16.80	20.00	0.69	1.63	6	14	15	65	69	24	6	4	1	20	5	32	8
1.32	0.70	8.25	17.10	20.30	0.69	1.66	7	13	17	64	70	23	6	4	1	20	5	33	8
1.34	0.70	8.58	17.40	20.60	0.70	1.66	6	13	16	64	72	23	6	4	1	18	5	34	9
1.36	0.71	8.92	17.70	21.00	0.71	1.67	6	13	17	64	74	22	5	4	1	19	4	37	8
1.38	0.72	9.26	18.10	21.30	0.71	1.70	6	12	19	63	74	21	5	3	1	19	5	37	9
1.40	0.72	9.62	18.40	21.70	0.72	1.69	6	12	19	63	75	21	4	3	1	19	4	40	8
1.42	0.73	9.98	18.70	22.00	0.73	1.71	6	12	21	61	75	20	4	3	1	19	4	41	8
1.44	0.74	10.35	19.00	22.30	0.74	1.71	6	12	21	61	75	19	4	3	1	18	4	42	9
1.46	0.75	10.72	19.40	22.70	0.74	1.70	5	12	22	61	76	18	4	3	1	18	4	43	9
1.48	0.76	11.10	19.60	22.90	0.75	1.72	5	12	23	60	76	18	4	3	1	17	4	43	10
1.50	0.78	11.50	19.60	23.00	0.75	1.74	5	12	23	60	77	18	4	3	1	16	4	44	10
1.52	0.79	11.89	19.70	23.10	0.76	1.74	5	12	21	62	79	18	3	3	1	17	3	47	8
1.54	0.78	12.30	20.50	23.90	0.77	1.76	5	11	21	62	78	18	3	3	1	18	3	46	8
1.56	0.78	12.71	21.20	24.60	0.77	1.77	6	11	21	62	76	18	3	3	1	19	3	45	8

Maxdepth (m)	Avdepth (m)	Discharge (m^3/s)	Width (m)	Perim (m)	AvVel (m/s)	Vel98% (m/s)	Composition Fish Habitat Types (%)					Composition Invertebrate Habitat Types (%)							
							SS[1]	SD[2]	FS[3]	FD[4]	F0.1[5]	SCS[6]	FCS[7]	SFS[8]	FFS[9]	SBR[10]	FBR[11]	SV[12]	FV[13]
1.58	0.79	13.14	21.30	24.70	0.78	1.78	6	11	20	64	77	18	3	3	1	18	3	46	8
1.60	0.81	13.56	21.40	24.80	0.78	1.81	6	10	18	66	78	17	3	3	1	18	3	47	8
1.62	0.83	14.00	21.50	24.80	0.79	1.82	6	10	17	67	78	17	3	3	0	19	3	47	8
1.64	0.84	14.45	21.50	24.90	0.80	1.81	5	10	15	69	79	17	3	3	0	18	3	48	8
1.66	0.86	14.90	21.70	25.10	0.80	1.82	5	10	15	69	83	17	3	3	0	17	3	48	9
1.68	0.87	15.36	21.80	25.20	0.81	1.81	5	10	14	71	84	16	3	3	0	17	3	49	9
1.70	0.89	15.83	21.90	25.30	0.81	1.83	5	10	13	72	82	16	3	3	0	17	3	49	9
1.72	0.91	16.30	22.00	25.40	0.82	1.84	5	11	12	72	83	16	3	3	0	16	3	50	9
1.74	0.92	16.79	22.10	25.50	0.83	1.84	4	11	11	73	83	16	3	3	0	15	3	51	9
1.76	0.94	17.28	22.20	25.60	0.83	1.89	4	11	12	74	83	16	3	3	0	15	3	51	9
1.78	0.95	17.78	22.30	25.70	0.84	1.89	4	11	10	76	84	15	3	3	1	15	3	51	10
1.80	0.97	18.28	22.40	25.80	0.84	1.91	4	11	9	77	84	15	3	3	1	14	3	52	10
1.82	0.98	18.80	22.50	25.90	0.85	1.90	3	11	7	78	84	14	3	2	1	15	3	51	11
1.84	1.00	19.32	22.60	26.00	0.86	1.92	3	11	8	78	84	14	3	2	1	14	3	52	11
1.86	1.02	19.85	22.70	26.10	0.86	1.94	3	11	7	79	84	14	3	2	1	13	3	53	11
1.88	1.01	20.39	23.20	26.70	0.87	1.92	3	11	8	78	83	14	3	2	1	14	3	52	11
1.90	1.01	20.94	23.80	27.30	0.87	1.95	3	10	10	76	82	14	3	2	1	15	3	51	11
1.92	1.00	21.50	24.40	27.90	0.88	1.93	3	11	11	76	81	14	3	2	1	15	3	51	11
1.94	1.01	22.06	24.60	28.10	0.89	1.92	3	10	10	76	81	14	3	2	1	15	3	51	11
1.96	1.02	22.63	24.90	28.40	0.89	1.95	3	10	11	76	80	14	2	3	0	17	2	54	8
1.98	1.03	23.22	25.10	28.60	0.90	1.97	3	10	12	75	80	14	2	3	0	17	2	54	8
2.00	1.04	23.80	25.30	28.90	0.90	1.99	3	10	11	76	81	14	2	3	0	16	2	55	8

1 Slow Shallow 2 Slow Deep 3 Fast Shallow 4 Fast Deep 5 Fast Depth>0.1m 6 Slow Coarse Sediment
7 Fast Coarse Sediment 8 Slow Fine Sediment 9 Fast Fine Sediment 10 Slow Bedrock 11 Fast Bedrock 12 Slow Vegetation 13 Fast Vegetation
Bold = measured 24/4/2007(0.098m^3/s) & 17/8/2007 (0.11m^3/s).

Table A8 Modelled hydraulic and habitat-type data for EWR Site 4 on the Karatara River

Maxdepth (m)	Avdepth (m)	Discharge (m^3/s)	Width (m)	Perim (m)	AvVel (m/s)	Vel98% (m/s)	Composition Fish Habitat Types (%)					Composition Invertebrate Habitat Types (%)							
							SS[1]	SD[2]	FS[3]	FD[4]	F0.1[5]	SCS[6]	FCS[7]	SFS[8]	FFS[9]	SBR[10]	FBR[11]	SV[12]	FV[13]
0.02	0.01	0.000	0.20	0.20	0.00	0.01	100	0	0	0	0	0	70	0	10	0	20	0	0
0.04	0.03	0.000	0.30	0.40	0.01	0.04	100	0	0	0	0	0	70	0	10	0	20	0	0
0.06	0.04	0.000	0.40	0.50	0.02	0.08	100	0	0	0	0	0	70	0	10	0	20	0	0
0.08	0.05	0.001	0.50	0.60	0.04	0.14	100	0	0	0	0	0	70	0	10	0	20	0	0
0.10	0.06	0.002	0.60	0.80	0.06	0.20	100	0	0	0	0	0	70	0	10	0	20	0	0
0.12	0.06	0.004	0.80	1.10	0.08	0.26	99	0	1	0	0	1	69	0	10	0	20	0	0
0.14	0.07	0.007	1.10	1.40	0.10	0.34	96	0	4	0	1	3	67	0	10	1	19	0	0
0.16	0.07	0.011	1.30	1.80	0.11	0.41	93	0	7	0	2	5	65	1	9	1	19	0	0
0.18	0.08	0.016	1.50	2.30	0.13	0.47	90	0	10	0	3	7	63	1	9	2	18	0	0
0.20	0.09	0.023	1.70	2.60	0.15	0.51	88	0	12	0	4	9	61	1	9	3	17	0	0
0.22	**0.09**	**0.032**	**2.30**	**3.20**	**0.17**	**0.53**	**87**	**0**	**13**	**0**	**5**	**9**	**60**	**1**	**9**	**3**	**18**	**0**	**0**
0.24	0.09	0.044	2.60	3.60	0.18	0.58	84	0	16	0	7	12	58	2	8	3	17	0	0
0.26	0.10	0.057	2.90	3.90	0.19	0.62	81	0	19	0	9	13	56	2	8	4	17	0	0
0.28	0.12	0.074	3.10	4.20	0.21	0.67	77	0	23	0	12	16	53	2	8	5	16	0	0
0.30	**0.13**	**0.094**	**3.30**	**4.40**	**0.22**	**0.72**	**74**	**0**	**26**	**0**	**15**	**17**	**51**	**3**	**8**	**5**	**16**	**0**	**0**
0.32	0.12	0.12	4.00	5.20	0.24	0.76	70	0	28	2	17	21	47	3	8	6	15	0	0
0.34	0.14	0.15	4.30	5.50	0.25	0.79	67	0	30	2	20	22	46	4	7	7	14	0	0
0.36	0.15	0.18	4.60	5.80	0.27	0.85	64	0	33	3	23	25	42	4	7	8	14	0	0
0.38	0.16	0.22	4.90	6.20	0.28	0.91	60	0	35	4	26	27	40	4	7	9	13	0	0
0.40	0.17	0.26	5.20	6.50	0.30	0.95	57	0	37	5	28	28	38	5	6	10	13	0	0
0.42	0.18	0.30	5.50	6.90	0.31	1.01	54	0	39	7	31	31	36	5	6	10	12	0	0
0.44	0.19	0.36	5.80	7.20	0.33	1.04	52	0	39	9	36	31	35	5	6	11	12	0	0
0.46	0.20	0.42	6.10	7.60	0.35	1.08	50	0	39	11	38	33	33	6	6	12	12	0	0
0.48	0.21	0.48	6.50	7.90	0.36	1.14	47	0	40	13	40	34	31	6	6	12	11	0	0
0.50	0.21	0.56	6.80	8.30	0.38	1.21	44	0	40	15	43	36	29	7	5	13	10	0	0
0.52	0.23	0.64	7.00	8.60	0.40	1.25	42	1	38	19	45	37	28	7	5	13	10	0	0
0.54	0.24	0.73	7.30	8.80	0.42	1.31	39	2	38	21	48	39	26	7	5	14	9	0	0
0.56	0.25	0.83	7.40	9.00	0.44	1.37	37	2	38	23	50	39	25	7	5	15	9	0	0
0.58	0.27	0.93	7.50	9.10	0.46	1.44	35	2	37	26	54	41	24	8	4	15	8	0	0
0.60	0.29	1.05	7.60	9.20	0.48	1.48	33	3	33	31	58	41	24	8	4	15	8	0	0
0.62	0.31	1.17	7.60	9.20	0.50	1.56	30	4	31	35	61	42	22	8	4	15	8	1	0
0.64	0.32	1.31	7.70	9.30	0.53	1.60	28	4	30	38	64	42	20	8	4	16	8	1	1
0.66	0.34	1.46	7.70	9.40	0.55	1.64	25	5	28	42	67	44	19	8	4	15	7	2	1
0.68	0.36	1.62	7.80	9.50	0.58	1.68	22	6	26	46	69	44	17	8	3	17	7	3	1
0.70	0.38	1.79	7.80	9.60	0.61	1.74	20	6	25	48	71	45	15	8	3	18	6	4	1
0.72	0.39	1.97	7.90	9.60	0.63	1.77	17	7	23	53	73	45	15	8	3	17	6	5	2

Maxdepth (m)	Avdepth (m)	Discharge (m^3/s)	Width (m)	Perim (m)	AvVel (m/s)	Vel98% (m/s)	Composition Fish Habitat Types (%)					Composition Invertebrate Habitat Types (%)							
							SS[1]	SD[2]	FS[3]	FD[4]	F0.1[5]	SCS[6]	FCS[7]	SFS[8]	FFS[9]	SBR[10]	FBR[11]	SV[12]	FV[13]
0.74	0.41	2.17	7.90	9.70	0.66	1.82	16	8	20	57	74	46	14	8	3	16	5	6	2
0.76	0.43	2.38	8.00	9.80	0.69	1.88	14	8	18	61	75	46	12	9	2	17	5	7	2
0.78	0.45	2.61	8.10	9.90	0.73	1.91	12	8	16	64	77	46	12	9	2	17	4	8	2
0.80	0.46	2.85	8.10	9.90	0.76	1.92	10	9	13	68	79	46	11	9	2	17	4	9	2
0.82	0.48	3.10	8.20	10.00	0.79	1.98	9	9	12	71	80	46	10	9	2	17	4	10	2
0.84	0.50	3.37	8.20	10.10	0.83	1.97	8	8	9	74	82	47	9	9	2	17	3	11	2
0.86	0.51	3.66	8.30	10.20	0.86	2.04	7	8	9	76	82	47	9	8	2	18	3	11	2
0.88	0.53	3.91	8.30	10.30	0.89	2.07	6	8	9	77	83	47	8	9	1	18	3	12	2
0.90	0.55	4.11	8.40	10.30	0.90	2.05	5	9	8	78	84	46	7	9	1	19	3	13	2
0.92	0.56	4.32	8.50	10.40	0.91	2.09	5	9	9	78	83	46	7	9	1	18	3	14	2
0.94	0.58	4.53	8.50	10.50	0.92	2.09	4	9	9	78	83	46	7	9	1	17	3	15	2
0.96	0.59	4.75	8.60	10.60	0.93	2.08	4	9	9	78	84	46	6	9	1	18	2	16	2
0.98	0.61	4.97	8.70	10.70	0.94	2.06	3	9	8	79	85	44	6	9	1	18	3	17	2
1.00	0.62	5.19	8.70	10.80	0.96	2.15	3	9	10	78	84	45	6	9	1	17	2	18	2
1.02	0.64	5.42	8.80	10.90	0.97	2.15	2	9	9	79	84	44	6	9	1	18	2	18	2
1.04	0.65	5.65	8.90	11.00	0.98	2.17	2	9	9	79	85	44	6	9	1	17	2	18	3
1.06	0.67	5.88	8.90	11.10	0.99	2.16	2	10	8	80	86	44	6	9	1	16	2	19	3
1.08	0.68	6.12	9.00	11.10	1.00	2.19	2	9	10	79	85	43	6	9	1	16	2	20	3
1.10	0.70	6.36	9.10	11.20	1.01	2.20	2	9	10	79	85	43	6	8	1	16	2	21	3
1.12	0.71	6.60	9.20	11.30	1.01	2.21	2	9	10	79	86	42	5	8	1	18	2	21	3
1.14	0.72	6.85	9.30	11.50	1.02	2.20	2	9	10	80	86	42	5	8	1	17	2	22	3
1.16	0.73	7.10	9.40	11.70	1.03	2.23	2	9	11	78	84	42	5	8	1	17	2	22	3
1.18	0.74	7.35	9.60	11.80	1.04	2.24	2	8	12	78	84	41	5	8	1	17	2	23	3
1.20	0.74	7.61	9.80	12.00	1.05	2.24	2	8	13	77	83	41	5	8	1	17	2	23	3
1.22	0.75	7.87	9.90	12.20	1.05	2.24	2	8	13	77	83	41	5	8	1	16	2	24	3
1.24	0.76	8.13	10.10	12.40	1.06	2.25	2	8	14	76	83	40	4	8	1	18	2	25	2
1.26	0.77	8.40	10.20	12.50	1.07	2.27	2	8	13	77	84	40	4	8	1	17	2	25	3
1.28	0.78	8.66	10.30	12.60	1.07	2.30	2	8	14	76	84	40	4	8	1	17	2	25	3
1.30	0.80	8.94	10.40	12.70	1.08	2.30	2	8	14	76	86	40	4	8	1	16	2	26	3
1.32	0.81	9.21	10.40	12.80	1.09	2.29	2	8	14	77	86	39	4	8	1	16	2	27	3
1.34	0.80	9.49	10.80	13.20	1.09	2.29	2	7	15	75	85	39	4	8	1	17	2	26	3
1.36	0.78	9.77	11.40	13.80	1.10	2.29	3	7	18	72	82	39	4	8	1	17	2	26	3
1.38	0.77	10.05	11.90	14.40	1.10	2.29	3	7	21	69	78	39	4	9	1	17	2	25	3
1.40	0.75	10.34	12.50	15.00	1.10	2.33	3	6	24	67	75	40	4	9	1	17	2	25	2
1.42	0.74	10.63	13.10	15.50	1.10	2.34	3	6	27	64	73	40	4	9	1	17	2	25	2
1.44	0.73	10.92	13.50	16.00	1.10	2.34	3	6	28	62	73	39	4	9	1	18	2	24	3
1.46	0.73	11.21	13.90	16.40	1.10	2.33	3	6	28	62	75	39	4	9	1	18	2	24	3
1.48	0.74	11.51	14.20	16.70	1.10	2.32	4	6	30	61	77	39	4	9	1	18	2	24	3
1.50	0.75	11.81	14.30	16.90	1.10	2.33	4	6	29	62	79	39	4	9	1	18	2	24	3

Maxdepth (m)	Avdepth (m)	Discharge (m^3/s)	Width (m)	Perim (m)	AvVel (m/s)	Vel98% (m/s)	Composition Fish Habitat Types (%)					Composition Invertebrate Habitat Types (%)							
							SS[1]	SD[2]	FS[3]	FD[4]	F0.1[5]	SCS[6]	FCS[7]	SFS[8]	FFS[9]	SBR[10]	FBR[11]	SV[12]	FV[13]
1.52	0.76	12.11	14.40	17.00	1.10	2.33	4	6	28	63	83	38	4	9	1	19	2	24	3
1.54	0.78	12.42	14.60	17.10	1.10	2.32	4	6	28	63	85	37	4	9	1	19	2	25	3
1.56	0.79	12.73	14.70	17.20	1.09	2.32	4	6	27	63	86	37	4	9	1	19	2	25	3
1.58	0.81	13.04	14.80	17.40	1.09	2.30	4	6	26	65	87	37	4	9	1	19	2	25	3
1.60	0.82	13.35	14.90	17.50	1.09	2.32	4	6	25	65	87	37	4	9	1	18	2	26	3
1.62	0.83	13.67	15.00	17.60	1.09	2.31	4	6	25	66	87	36	4	9	1	19	2	26	3
1.64	0.85	13.99	15.20	17.70	1.09	2.33	4	6	25	66	86	36	4	9	1	19	2	26	3
1.66	0.86	14.31	15.30	17.90	1.09	2.33	4	6	23	67	86	36	4	9	1	18	2	27	3
1.68	0.87	14.63	15.40	18.00	1.09	2.34	4	6	21	69	87	36	4	9	1	18	2	27	3
1.70	0.89	14.96	15.50	18.10	1.09	2.33	4	6	19	72	87	35	4	9	1	19	2	27	3
1.72	0.90	15.29	15.60	18.20	1.09	2.33	4	6	17	73	87	35	4	9	1	18	2	28	3
1.74	0.91	15.62	15.80	18.40	1.09	2.33	3	6	15	75	87	35	3	9	1	19	2	29	2
1.76	0.92	15.96	15.90	18.50	1.09	2.33	3	6	14	76	87	35	3	9	1	19	2	29	2
1.78	0.94	16.29	16.00	18.60	1.09	2.33	3	6	13	78	87	35	3	9	1	18	2	29	3
1.80	0.95	16.63	16.10	18.80	1.09	2.33	3	6	11	79	87	34	3	9	1	19	2	29	3
1.82	0.96	16.97	16.20	18.90	1.09	2.33	3	6	11	80	87	34	3	9	1	19	2	29	3
1.84	0.98	17.32	16.40	19.00	1.08	2.33	3	6	10	80	87	34	3	9	1	19	2	29	3
1.86	0.99	17.67	16.50	19.10	1.08	2.34	3	7	10	80	87	34	3	9	1	18	2	30	3
1.88	1.00	18.02	16.60	19.30	1.08	2.34	3	7	10	80	87	34	3	9	1	18	2	30	3
1.90	1.02	18.37	16.70	19.40	1.08	2.31	2	7	9	81	87	33	3	9	1	19	2	30	3
1.92	1.03	18.72	16.80	19.50	1.08	2.34	2	7	10	81	87	33	3	9	1	18	2	31	3
1.94	1.04	19.08	16.90	19.60	1.08	2.31	2	8	9	81	87	33	3	9	1	18	2	31	3
1.96	1.05	19.44	17.10	19.80	1.08	2.33	2	8	9	81	87	33	3	9	1	18	2	31	3
1.98	1.07	19.80	17.20	19.90	1.08	2.31	2	8	8	82	87	33	3	9	1	18	2	31	3
2.00	1.08	20.16	17.30	20.00	1.08	2.34	2	8	9	81	87	33	3	9	1	17	2	32	3

1 Slow Shallow   2 Slow Deep   3 Fast Shallow   4 Fast Deep   5 Fast Depth>0.1m   6 Slow Coarse Sediment
7 Fast Coarse Sediment   8 Slow Fine Sediment   9 Fast Fine Sediment   10 Slow Bedrock   11 Fast Bedrock   12 Slow Vegetation   13 Fast Vegetation
Bold = measured 24/4/2007(0.035m^3/s) & 17/8/2007 (0.10m^3/s).

A5 SITE SUITABILITY AND CONFIDENCE IN THE HYDRAULIC CHARACTERISATIONS

The confidence in the characterisations of the hydraulic relationships is provided in Table A9. “Site character” refers to the suitability of the site for hydraulic modelling, “available data” refers to the range of measured rating data, and the final column refers to the confidence in the hydraulic characterisations with reference to the ecological low and high flow recommendations.

Table A9 Site suitability and confidence in the results

<table>
<tr><th rowspan="2">Site no. and name</th><th rowspan="2">Site suitability</th><th rowspan="2">Available data</th><th colspan="2">Reference to PES or recommended EC</th></tr>
<tr><th>Low flows</th><th>High flows</th></tr>
<tr><td>1 Knysna</td><td>2 (low), 3 (high)</td><td>3 (low), 4 (high)</td><td>4</td><td>4</td></tr>
<tr><td colspan="5">Reasons for site suitability ratings:
<u>Positive attributes</u>
Location of gauging weir for determining discharges (gauge rated to 81m^3/s). Location of gauging weir with near real-time data available on the DWAF hydrology web-site. This will assist hydraulic data collection through the remote observation of current discharges in the river.
<u>Negative attributes</u>
Large nature of the bed substrate (cobbles, boulders and bedrock). This makes resistance predictions difficult at low-flows, compromising the accuracy of the stage-discharge relationship. Influence of vegetation on flow resistance at medium/high flows. Rapidly varies flow conditions (rapid with cascades) making it difficult to predict the energy slope in the absence of detailed topographical survey. Non-horizontal water surface across the inundated channel width at low-flows.
<u>EWR results</u>
Low flows: Droughts 0.094 – 0.20m^3/s; Maintenance EC C = 0.16 - 0.19m^3/s, EC B = 0.4m^3/s
High flows: class I (1-2 m^3/s), class II (2-6 m^3/s), class III (7-12 m^3/s), class IV (12-18 m^3/s - annual), class V (22-45 m^3/s - 1:2), class VI (50+ m^3/s -1:5).</td></tr>
<tr><td>2 Gouna</td><td>3 (low), 3 (high)</td><td>2 (low), 2 (high)</td><td>3</td><td>2</td></tr>
<tr><td colspan="5">Reasons for site suitability ratings:
<u>Positive attributes</u>
None.
<u>Negative attributes</u>
Influence of vegetation on flow resistance at medium-flows and above. Rapidly varied flow conditions (cross-section located immediately upstream of bedrock step), making it difficult to predict the energy slope in the absence of a detailed topographical survey. Multiple channels at medium/high-flows making it difficult to predict stage-discharge relationships in the absence of detailed topographical survey and two-dimensional hydraulic modelling. Difficult to manually determine discharge using velocity-area at medium-flows and above due to extensive vegetation across the channel floor. Low confidence in the predicted velocity distribution at medium-flows and above due to extensive vegetation. This will reduce the confidence in the modelled habitat-types incorporating velocity (e.g. velocity-depth habitat types for fish and velocity habitat-types for invertebrates).
<u>EWR results</u>
Low flows: Droughts 0.075 – 0.11m^3/s; Maintenance EC A/B = 0.31 – 0.38m^3/s, EC B/C = 0.23 - 0.31m^3/s
High flows: class I (1-3 m^3/s), class II (5-10 m^3/s), class III (10-12 m^3/s – annual), class IV (15-20 m^3/s – 1:2), class V (20-45 m^3/s - 1:4), class VI (50-60 m^3/s -1:5).</td></tr>
<tr><td>3 Diep</td><td>1 (low), 2 (high)</td><td>2 (low), 4 (high)</td><td>3</td><td>4</td></tr>
</table>

<table>
<tr><th rowspan="2">Site no. and name</th><th rowspan="2">Site suitability</th><th rowspan="2">Available data</th><th colspan="2">Reference to PES or recommended EC</th></tr>
<tr><th>Low flows</th><th>High flows</th></tr>
<tr><td colspan="5">Reasons for site suitability ratings:
<u>Positive attributes</u>
Location of gauging weir for determining discharges. Location of gauging weir with near real-time data available on the DWAF hydrology web-site. This will assist hydraulic data collection through the remote observation of current discharges in the river.
<u>Negative attributes</u>
Location of site in bedrock morphology with rapidly varied flow conditions (rapids and cascades). This makes resistance and energy slope predictions difficult, compromising the accuracy of the stage-discharge relationship in the absence of measured rating data. Influence of downstream bedrock controls at medium-flows and above. Low confidence in the predicted velocity distribution. This will reduce the confidence in the modelled habitat-types incorporating velocity (e.g. velocity-depth habitat types for fish and velocity habitat-types for invertebrates).
<u>EWR results</u>
Low flows: Droughts 0.015 – 0.030m^3/s; Maintenance EC B = 0.075 – 0.20m^3/s, EC C = 0.06 – 0.075m^3/s
High flows: class I (0.2-1 m^3/s), class II (1-2 m^3/s), class III (3-8 m^3/s), class IV (12-20 m^3/s – 1:3), class V (25-40 m^3/s - 1:4-5), class VI (60+ m^3/s -1:5+).</td></tr>
<tr><td>4 Karatara</td><td>2 (low), 3 (high)</td><td>3 (low), 3 (high)</td><td>3</td><td>3</td></tr>
<tr><td colspan="5">Reasons for site suitability ratings:
<u>Positive attributes</u>
Location of gauging weir for determining low and medium discharges (gauge rated to 35m3/s). Location of gauging weir with near real-time data available on the DWAF hydrology web-site. This will assist hydraulic data collection through the remote observation of current discharges in the river.
<u>Negative attributes</u>
Location of site in bedrock channel with large roughness elements (boulders) and rapidly varied flow conditions (rapids and cascades). This makes resistance and energy slope predictions difficult, compromising the accuracy of the stage-discharge relationship in the absence of measured rating data. Low confidence in the predicted velocity distribution at low/medium/high lows. This will reduce the confidence in the modelled habitat-types incorporating velocity (e.g. velocity-depth habitat types for fish and velocity habitat-types for invertebrates).
<u>EWR results</u>
Low flows: Droughts 0.017 – 0.020m^3/s; Maintenance EC A/B = 0.058 – 0.10m^3/s, EC B/C = 0.032 – 0.058m^3/s
High flows: class I (0.3-0.5 m^3/s), class II (1-4 m^3/s), class III (6-10 m^3/s – 1:2), class IV (10-15 m^3/s – 1:3), class V (18-24 m^3/s - 1:4), class VI (30+ m^3/s -1:5).</td></tr>
</table>

Confidence ratings: 0 = none, 1 = low, 2 = low/medium, 3 = medium, 4 = medium/high, high = 5

A6 REFERENCES

Birkhead AL. (2002). The procedure for generating hydraulic information for the Intermediate and Comprehensive Ecological Reserves (Quantity). Appendix in Resource Directed Measures for Protection of Water Resources: River Ecosystems - Revision of the quantity component (Louw MD and Hughes DA, eds). Prepared for the Department of Water Affairs and Forestry, South Africa.

Department of Water Affairs and Forestry, South Africa (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

Hirschowitz PM, Birkhead AL and James CS. (2007). Hydraulic modelling for ecological studies for South African Rivers, Water Research Report No. 1508/07, Pretoria, South Africa. 249pp.

Jordanova AA, Birkhead AL, James CS and Kleynhans CL, (2004). Hydraulics for determination of the ecological Reserve for rivers. Report to the Water Research Commission on the project "Hydraulic analyses for the determination of the ecological Reserve for rivers". WRC Report no. 1174/0/1.

Kleynhans, CJ. (1999). The development of a fish index to assess the biological integrity of South African rivers, Water SA, Vol. 25, No. 3, pp 265-278.

Lamouroux N, Souchon Y and Herouin, E. (1995). Predicting velocity frequency distributions in stream reaches, Water Resources Research, Vol. 31, No. 9, pp 2367-2375.

Oswood ME and Barber WE. (1982). Assessment of fish habitat in streams: Goals, constraints, and a new technique, Fishers, No. 7, pp 8-1.

Rowlston B, Jordanova AA and Birkhead AL. (2000) Hydraulics In: Environmental flow assessment for rivers: Manual for the Building Block Methodology, King, JM, Tharme, RE and de Villiers, MS, (eds), Water Research Commission report No.TT 131/00, Pretoria, South Africa.

Tharme RE. (1996). Review of international methodologies for the quantification of the instream flow requirements of rivers. Water law review. Final report for policy development. Commissioned by the Department of Water Affairs and Forestry, Pretoria. Freshwater Research Unit, University of Cape Town, Cape Town. 116pp.

APPENDIX B: HYDROLOGY SPECIALIST REPORT

DA HUGHES, IWR Rhodes University

B1 INTRODUCTION

The study area is covered by six quaternary catchments (Figure B1), the majority of which drain into either Swartvlei or the Knysna Estuary (note the WR90 error in the placement of the boundary between K50A and K50B). K40E was not included in this study. Within this area there are four EWR sites and five DWAF streamflow gauging stations (Figure B1). Of the streamflow gauging stations, three (K4H002, K4H003 and K5H002) are considered to have reasonably good records from the early 1960s to the present day. K4H001 is part of a causeway (with pipes under the road deck) over the Hoëkraal River and is not expected to measure flows very well, while the gauge on the Gouna River (K5H001) has a very short and inaccurate record.

The majority of the upstream impacts for all the sites are related to landuse changes and minor abstractions associated with the forestry industry or the limited amount of cultivation in these mountain catchments. The major effects are associated with the replacement of indigenous coastal forest and fynbos with commercial forestry plantations (pine and eucalypts).

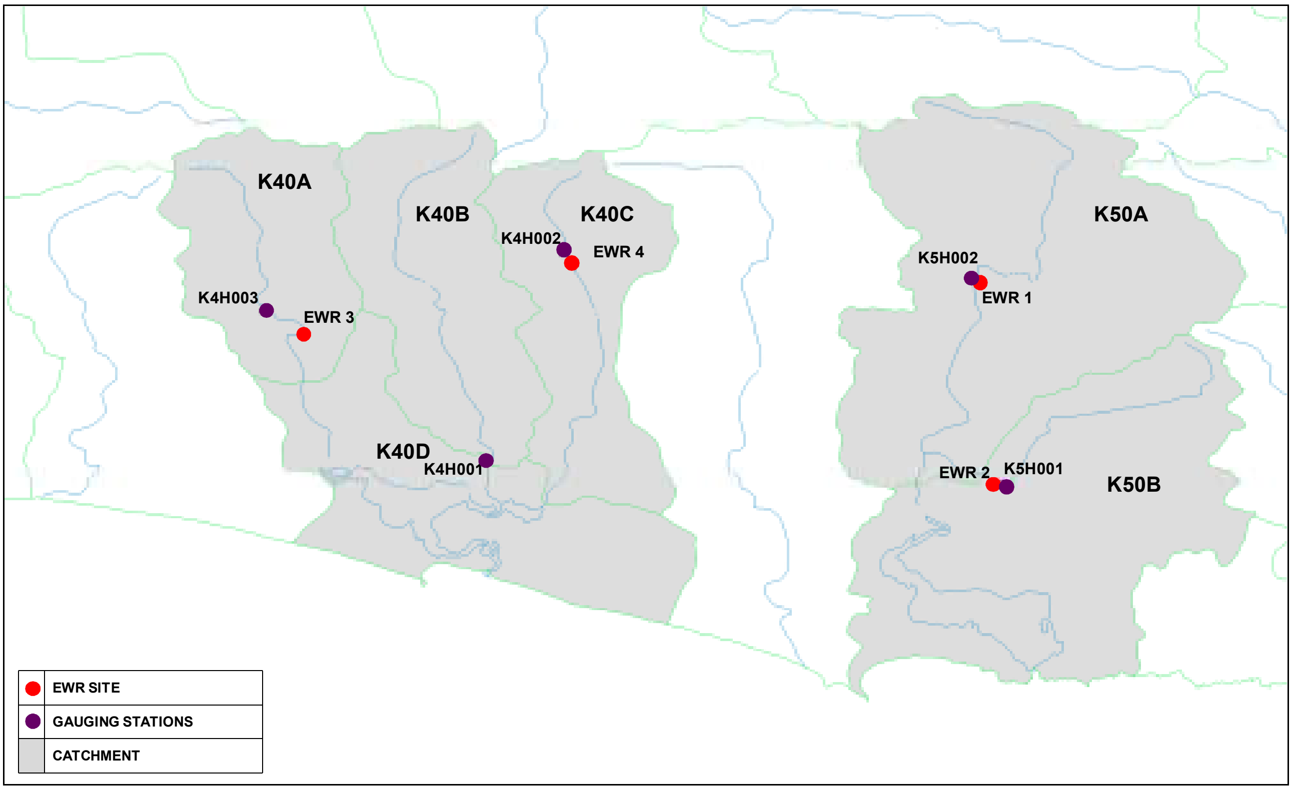

Figure B1 Study area

The catchment areas at the DWA weirs (all situated close to the EWR sites), as well as some estimates of landuse variations (from data obtained in the 1980s) are provided in Table B1.

Table B1 Catchment areas and 1980 estimates of landuse

Gauge	Catchment Area (km^2)	Landuse (% Area)			
		Indigenous Forest	Fynbos	Managed Plantations	Farming Land
K4H001	111	24.1	48.1	18.5	9.3
K4H002	22		80.9	19.1	
K4H003	71	2.9	42.1	54.3	0.7
K5H001	89	61.6	9.1	29.3	
K5H002	130	11.4	58.9	29.7	

It should be noted that the present day landuse has remained similar throughout the period of flow gauging. This means that any estimates of the natural hydrology have to be based on some process of naturalisation and will be subject to uncertainty associated with the interpretation of the effects of the landuse changes compared to the natural vegetation. The normal assumption is that commercial forestry (pines and eucalypts) will use greater amounts of water than either indigenous forest or fynbos. It is accepted that current estimates of landuse may be different to those provided in Table B1 due to more sophisticated methods of identifying landuse, as well as some changes in landuse since the early 1980s.

B2 PRESENT DAY HYDROLOGICAL IMPACTS

The natural and present day time series of monthly flows were provided by the systems modellers and these have been compared with the observed records as part of the assessment of the present day hydrological impacts. The Hydrology Assessment Index (HAI) details for the four main sites are given in Tables B2 to B5, and were assessed according to Kleynhans *et al*. (2005). A comparison of the flow duration curves is provided in Figures B2 to B5 to support some of the conclusions.

B2.1 HAI FOR EWR 1 – KNYSNA RIVER

Figure B2 illustrates that the simulated monthly flows for natural and present day are not very different to each other despite the fact that a relatively high proportion of the catchment is under managed plantations. The flows in the observed record are substantially lower than those provided by the simulated present day record, throughout most of the flow range (comparing the black and red lines in Figure B2). This indicates that the simulations are not very good, and produce an over-estimate of the present-day flows in the river. The author of this report would have expected a greater impact on low and moderate flows than has been simulated. Table B2 provides the best estimates of HAI based on these data. It is also possible that the observed flows represent present day conditions better than the simulated flows and that the natural flows are also over-estimated.
Figure B3 illustrates the seasonal distribution of rainfall and streamflow volume.

Table B2 HAI details for EWR 1

HYDROLOGY METRICS	RATING	CONFIDENCE
LOW FLOWS	2.00	3.00
ZERO FLOW DURATION	0.00	5.00
SEASONALITY	0.00	5.00
MODERATE EVENTS	2.00	4.00
EVENT HYDROLOGY(HIGH FLOWS-FLOODS)	1.00	4.00

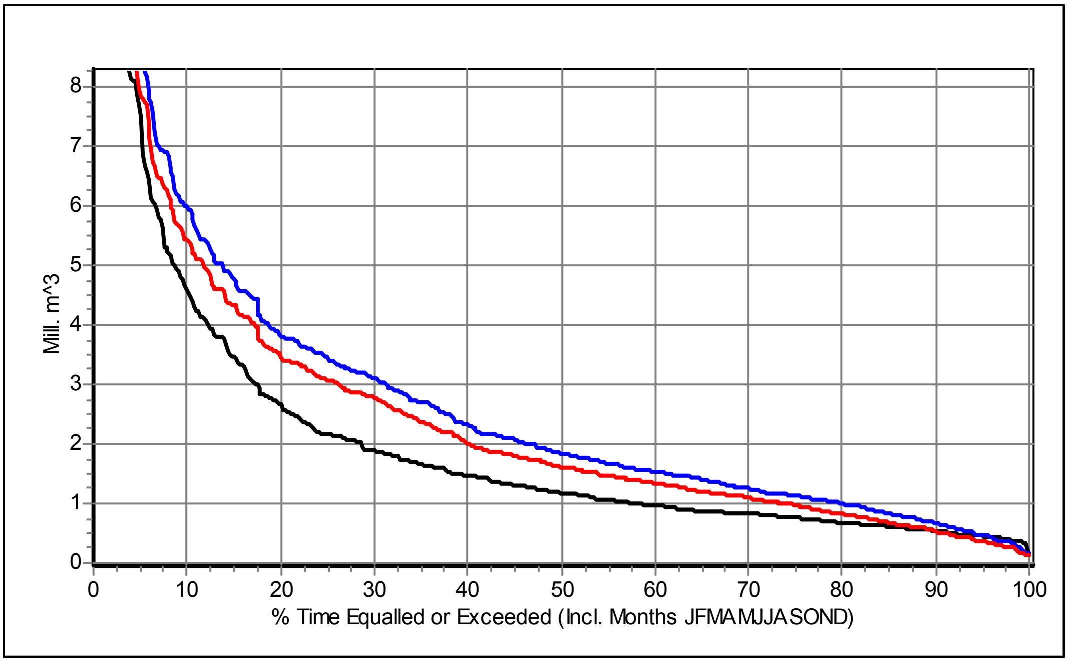

Figure B2 Annual monthly flow duration curves (data 1961 to 2004) for EWR 1 and gauge K5H002 (black=observed, blue=natural and red=present day)

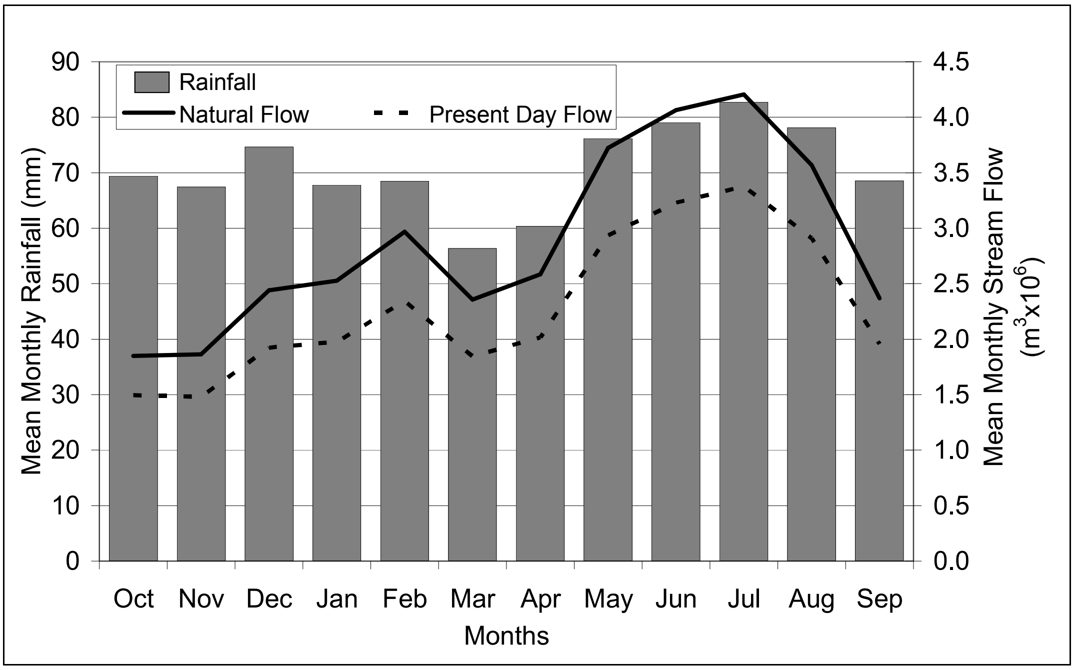

Figure B3 Seasonal distribution of rainfall (K50A) and stream flow volume (natural and present day) for EWR 1 (Knysna River)

B2.2 HAI FOR EWR 2 – GOUNA RIVER

Figure B4 indicates that the impacts are greater at this site than at EWR 1 with present day flows almost reaching zero for very short periods. This is not consistent with the simulated situation at EWR 1 and the two sites are expected to have more similar hydrological characteristics. Unfortunately, the gauged records are not accurate or long enough to provide checks. Figure B5 illustrates the seasonal distribution of rainfall and streamflow volume.

Table B3 HAI details for EWR 2

HYDROLOGY METRICS	RATING	CONFIDENCE
LOW FLOWS	3.00	3.00
ZERO FLOW DURATION	0.00	5.00
SEASONALITY	0.00	5.00
MODERATE EVENTS	2.00	4.00
EVENT HYDROLOGY(HIGH FLOWS-FLOODS)	1.00	4.00

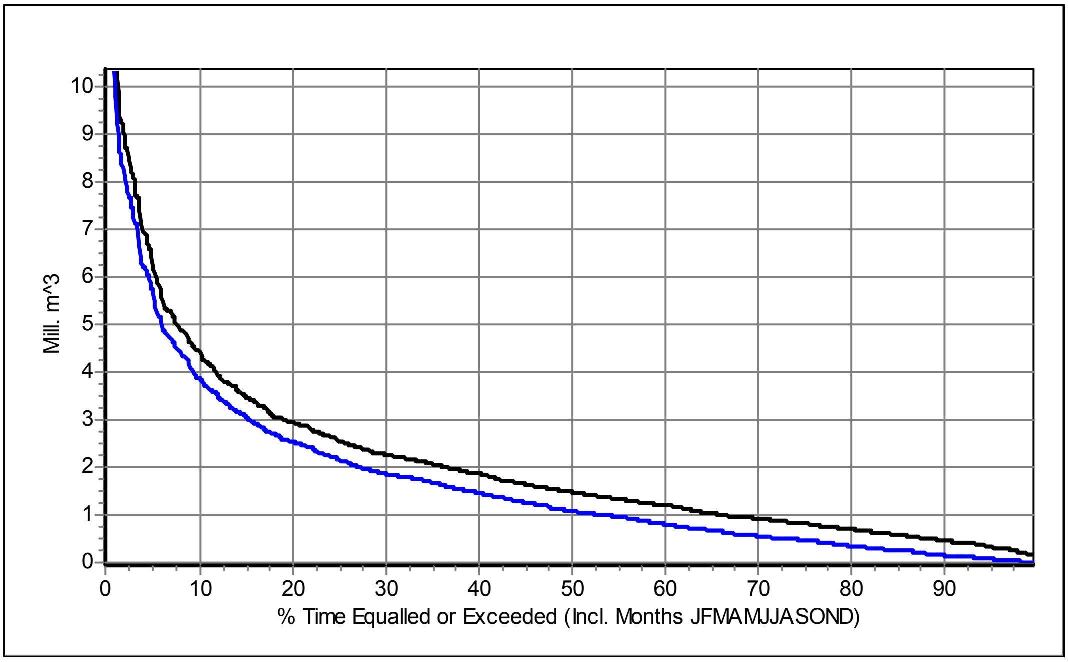

Figure B4 Annual monthly flow duration curves (data 1920 to 2004) for EWR 2 (black=natural and blue=present day)

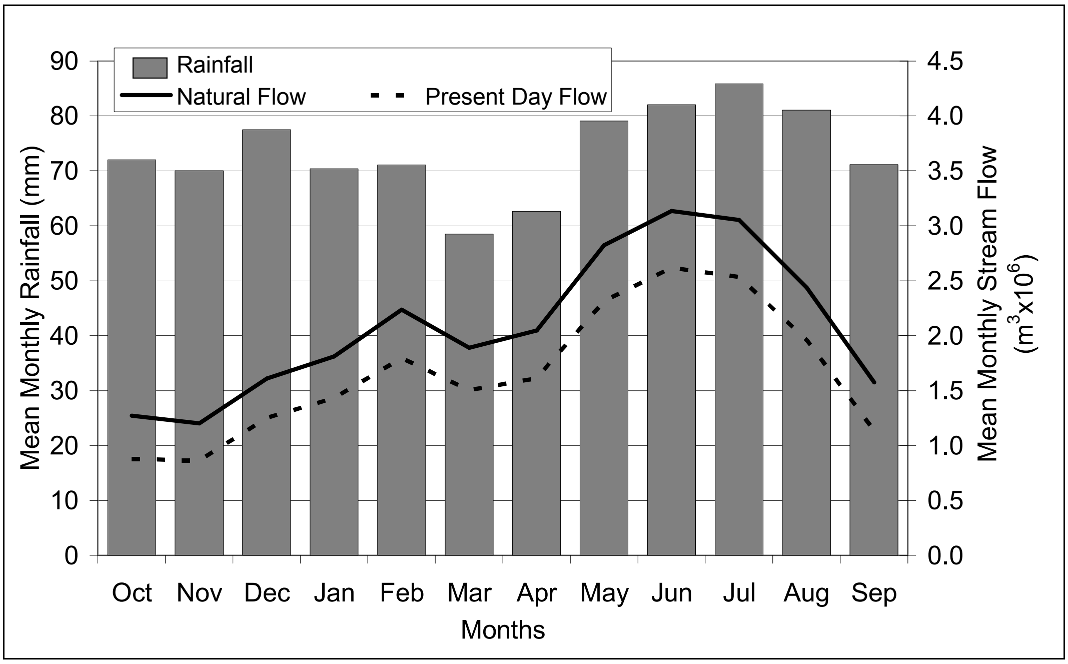

Figure B5 Seasonal distribution of rainfall (K50B) and stream flow volume (natural and present day) for EWR 2 (Gouna River)

B2.3 HAI FOR EWR 3 – DIEP RIVER

Figure B6 indicates that the simulated present day flows are very close to the observed flows. However, the simulated natural flows are much greater, especially in the moderate to high flow range. This result is not really consistent with the normally expected impacts of afforestation and this report concludes that the moderate flows (5 to 60% exceedence) have been over-simulated. Table B4 provides the estimated HAI values. Figure B7 illustrates the seasonal distribution of rainfall and streamflow volume.

Table B4 HAI details for EWR 3

HYDROLOGY METRICS	RATING	CONFIDENCE
LOW FLOWS	4.00	3.00
ZERO FLOW DURATION	0.00	5.00
SEASONALITY	0.00	5.00
MODERATE EVENTS	3.00	3.00
EVENT HYDROLOGY(HIGH FLOWS-FLOODS)	1.00	4.00

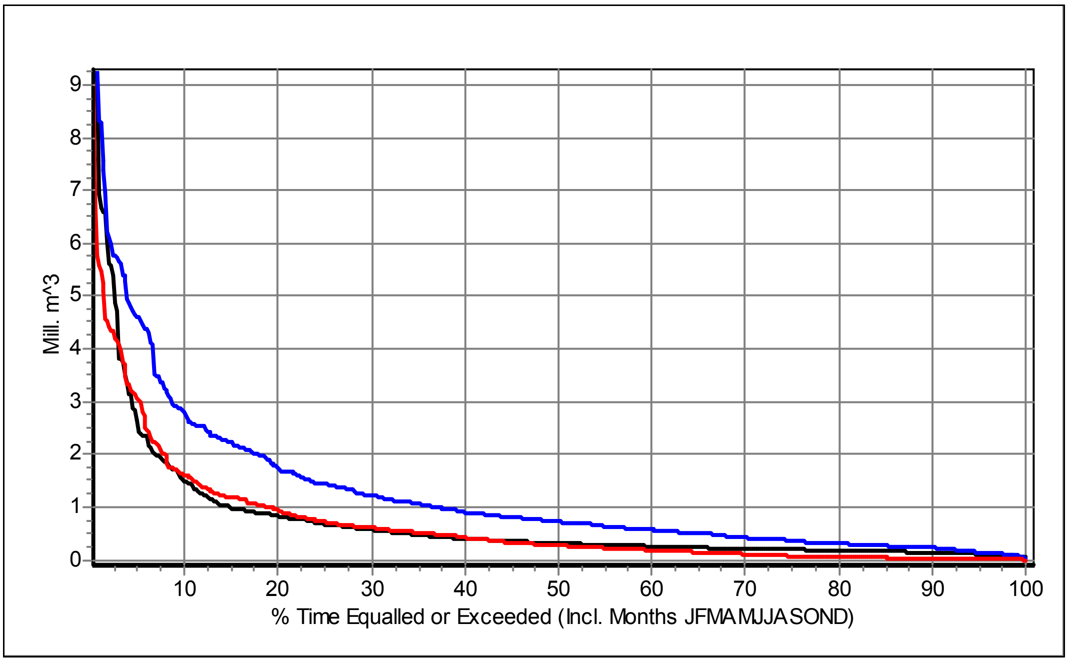

Figure B6 Annual monthly flow duration curves (data 1961 to 2004) for EWR 3 and gauge K4H003 (black=observed, blue=natural and red=present day)

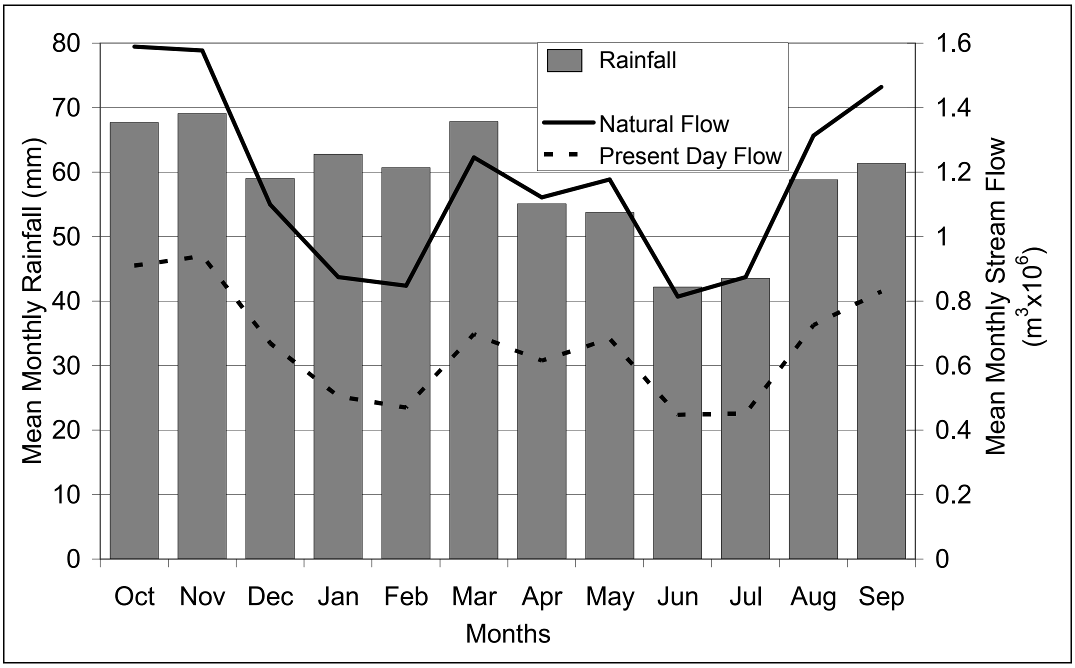

Figure B7 Seasonal distribution of rainfall (K40A) and stream flow volume (natural and present day) for EWR 3 (Diep River)

B2.4 HAI FOR EWR4 – KARATARA RIVER

The flow gauge at this site do not measure high flows very well and this is immediately apparent from Figure B8. However, as with the previous site it is likely that the differences between natural and present day flows for a large part of the flow duration curve have been over-estimated. This seems to be related to assumptions about the water use of the present day landuse. While this area does have some managed plantations, a large part of the catchment is under Fynbos, as illustrated by the Google Earth image in Figure B9, which suggests that most of the landuse changes are in the lower part of the catchment. Figure B10 illustrates the seasonal distribution of rainfall and streamflow volume.

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Table B5 HAI details for EWR 4

HYDROLOGY METRICS	RATING	CONFIDENCE
LOW FLOWS	3.00	3.00
ZERO FLOW DURATION	0.00	5.00
SEASONALITY	0.00	5.00
MODERATE EVENTS	1.00	3.00
EVENT HYDROLOGY(HIGH FLOWS-FLOODS)	0.00	3.00

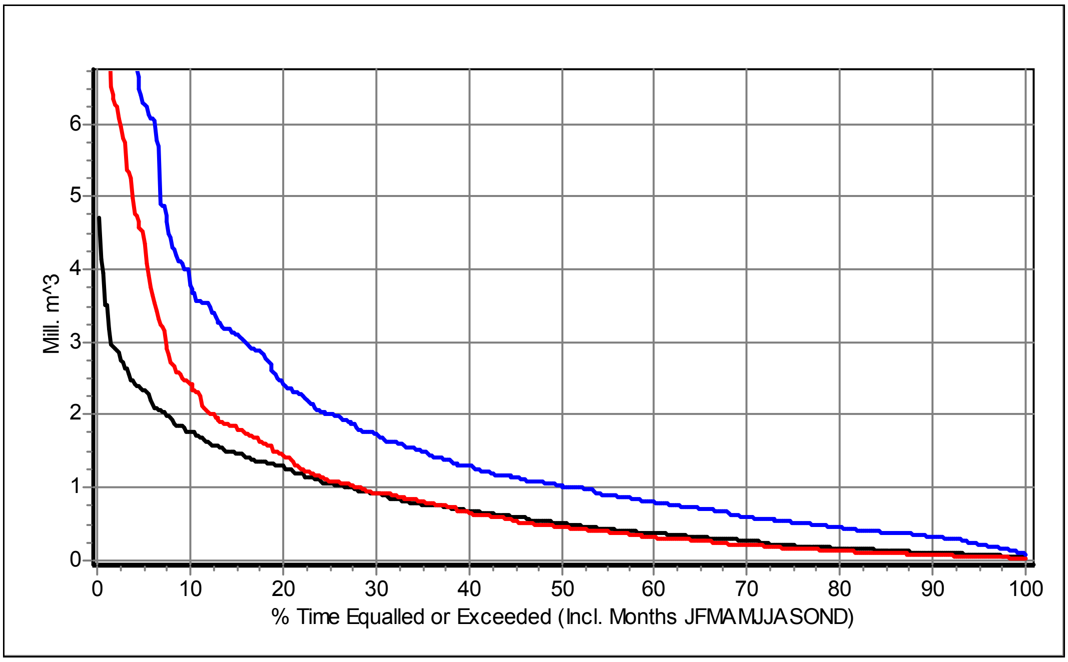


Figure B8 Annual monthly flow duration curves (data 1962 to 2004) for site 4 and gauge K4H002 (black=observed, blue=natural and red=present day)

Figure B9 Google Earth image of the Karatara catchment

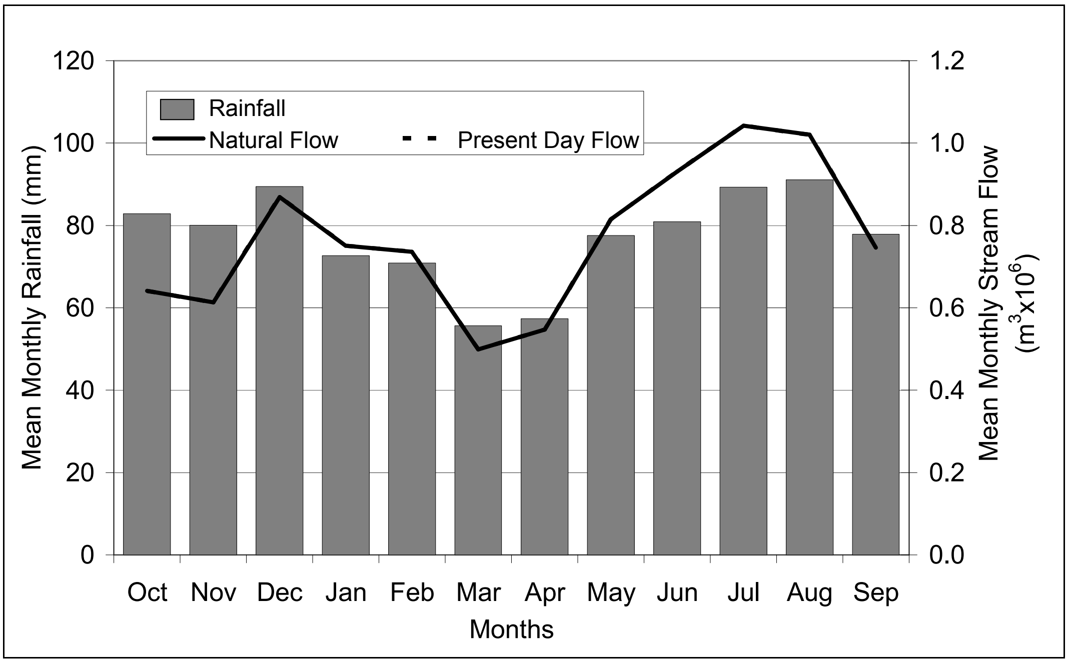


Figure B10 Seasonal distribution of rainfall (K40C) and stream flow volume (natural and present day) for EWR 4 (Karatara River)

B3 CONCLUSIONS

The available hydrological data need to be treated with caution. There appears to be a mismatch between the expected impacts of the historical landuse changes and the differences between the simulated natural and present day hydrology. Unfortunately, it is difficult to make comparisons with the WR90 database as all of these sites are located at the outlet of catchments that are smaller than the quaternary catchments of the area. One of the issues that require further investigation is the catchment average rainfall values that were used as input to the recent simulations. Estimating rainfall over these catchments is very difficult due to the presence of localized rain-shadows in the high rainfall areas of the mountains.

While in some cases the present day hydrological simulations appear to be reasonable, the natural simulations seem to be too high. This may not affect the determination of the Reserve but will have serious implications from the point of view of estimating the volume of the resource that is available for use.

APPENDIX C: GEOMORPHOLOGY SPECIALIST REPORT
M ROUNTREE, Fluvius Environmental Consultants
N MYEKO, Walter Sisulu University: Trainee

C1 EWR 1: UPPER KNYSNA (KNYSNA RIVER) - ECOCLASSIFICATION

C1.1 DATA AVAILABILITY

Historical aerial photography was not useful to the assessment as it could not detect morphological changes due to the heavily forested nature of the upper sites. However, due to the very small width of the river at this site, and the generally very good Present Ecological State (PES) condition, this does not present a limitation to the study. Field assessments, combined with catchment assessments (using Google Earth, 2007) were deemed sufficient to assess the PES and infer the likely Reference Condition (RC) of the river.

Confidence: 4

C1.2 REFERENCE CONDITIONS

The RC was similar to the current condition – and a cobble/boulder dominated section of river with narrow riparian zone and limited presence of fines was expected.
Confidence: 4

C1.3 PRESENT ECOLOGICAL STATE

The present state of the site was an A/B category.

C1.3.1 Site description

- The site was downstream of a low flow road crossing, which was downstream of a gauging weir.
- The catchment had some large forestry areas. This and associated gravel roads may have caused slightly higher sand/gravel components in the bedload.
- Sediment at the site was composed of cobbles and boulders, with some gravel present in elevated, protected positions.

C1.3.2 Morphology of the site

- The channel was a pool-rapid channel type, within an extremely confined, V-shaped valley (Figure C1).
- The west bank was a bedrock cliff; the east bank was composed of a (indigenous) forested bank.
- The east (alluvial) bank was cut due to the recent (Aug 06) flood of approximately 75 cumecs.
- More or less paired terraces on the east (unvegetated) and west banks were present probably associated with the 1:1 or 1:2 year events.

The affected components of the GAI which reduced the PES from the RC were primarily the altered sediment supply (due to increased fines) and, to a lesser extent, a change in transport capacity and sediment connectivity.

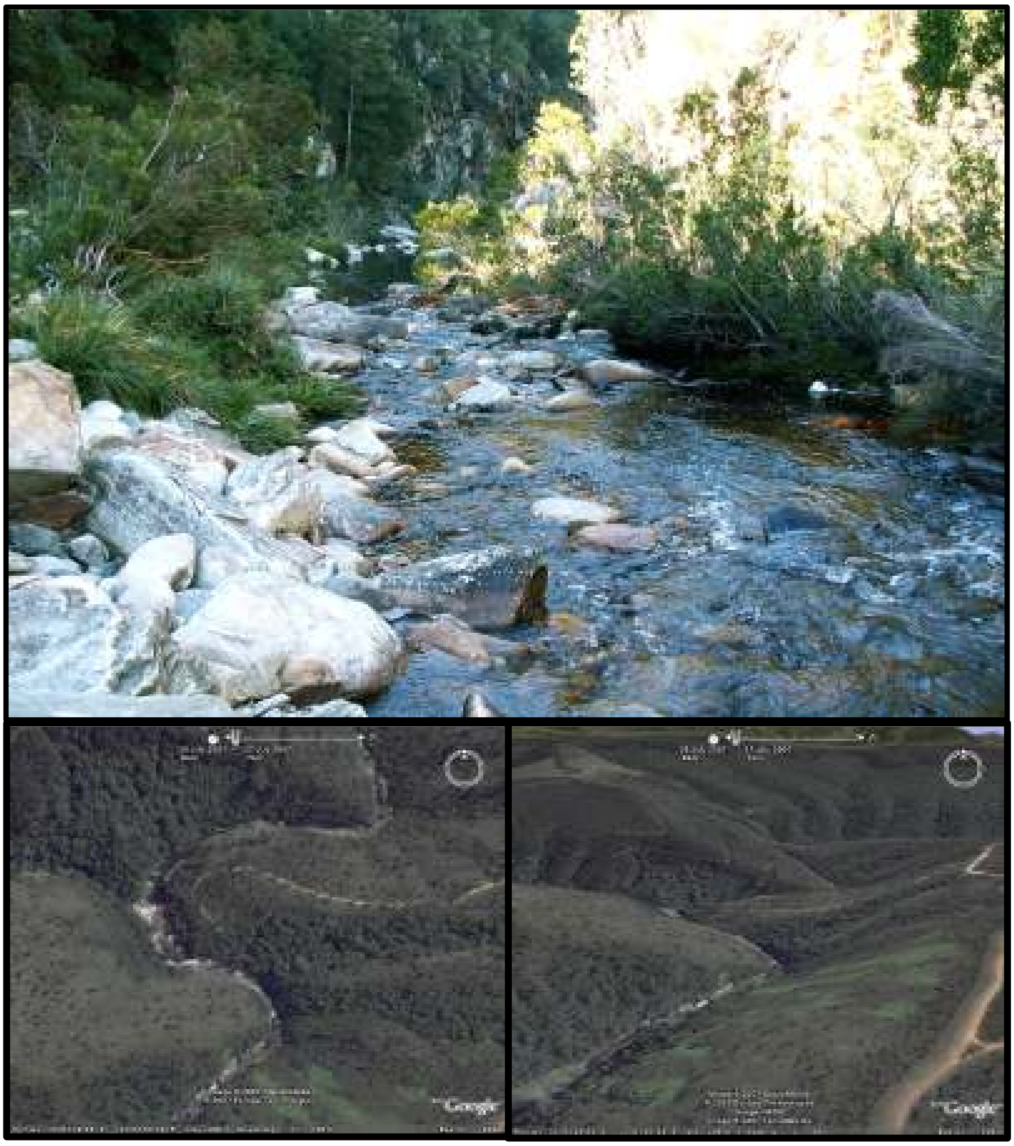


Figure C1 **View of the site (top) and direct overhead (left) and oblique (showing the topography of the valley) imagery of the site**

C1.4 REC: A/B

PES	REC[1]	Comments
A/B	A/B	The site was stable, and no additional impacts sufficient to change the category of the geomorphology were anticipated under the current scenario.

1 Recommended Ecological Ecological

C1.5 AEC: B

PES	AEC[1]	Comments
A/B	B	With a scenario of poorer forestry management and associated increased sediment inputs; removal of some riparian vegetation; increased alien vegetation and reduced low flows, a slight decrease in the current condition of the reach was expected. This decrease in condition would primarily be as a result of increased sediment (fines) supplied to the channel.

1 Alternative Ecological Category

C2 EWR 2: GOUNA (GOUNA RIVER) - ECOCLASSIFICATION

C2.1 DATA AVAILABILITY

Historical aerial photography was not useful to the assessment as it could not detect morphological changes due to the heavily forested nature of the upper sites. However, due to the very small width of the river at this site, and the generally very good PES condition, this did not present a limitation to the study. Field assessments, combined with catchment assessments (using Google Earth, 2007) were deemed sufficient to assess the PES and infer the likely RC of the river.

Confidence: 3

C2.2 REFERENCE CONDITIONS

The Reference condition was similar to the current condition.
Confidence: 3

C2.3 PRESENT ECOLOGICAL STATE

The present state of the site was an A category.

C2.3.1 Site description

- A step, deeply incised valley.
- The catchment had some large forestry areas. This and associated gravel roads may have caused slightly higher sand/gravel components in the bedload.
- Sediment at the site is composed of cobbles, boulders, gravels and fines.

C2.3.2 Morphology of the site

- The channel was a pool-rapid channel type, within a relatively confined, V-shaped valley (Figure C2).
- This was a difficult site for geomorphology because the morphological cues (terraces etc.) were heavily modified by the recent floods. There were no paired terraces, and the dense Palmiet vegetation strongly influenced roughness and sediment deposition processes. This made interpretation of the morphological cues extremely difficult.

The affected components of the GAI which have reduced, albeit slightly, the PES from the RC was the altered sediment supply (due to increased fines) and a slight change in transport capacity.

Figure C2 View of the site (top) and direct overhead (left) and oblique (showing the topography of the valley) imagery of the site

C2.4 REC: A

PES	REC	Comments
A	A	Currently very limited impacts in this river system.

C2.5 AEC: B

PES	AEC	Comments
B	B	Considering a scenario with a small dam or weir; increased abstraction, forestry and sedimentation, the site could degrade dramatically to a B category. The biggest impacts on geomorphology would be in terms of the altered transport capacity, sediment supply and system connectivity.

C3 EWR 3: UPPER DIEP (DIEP RIVER) - ECOCLASSIFICATION

C3.1 DATA AVAILABILITY

Historical aerial photography was not useful to the assessment as it could not detect morphological changes due to the heavily forested nature of the upper sites. However, due to the very small width of the river at this site, and the generally very good PES condition, this did not present a limitation to the study. Field assessments, combined with catchment assessments (using Google Earth, 2007) were deemed sufficient to assess the PES and infer the likely RC of the river.

Confidence: 3.5

C3.2 REFERENCE CONDITIONS

The Reference condition was similar to the current condition.
Confidence: 3.5

C3.3 PRESENT ECOLOGICAL STATE

The present state of the site was a B category.

C3.3.1 Site description

- A step, deeply incised valley.
- The catchment had some large forestry areas. This and associated gravel roads may have caused slightly higher sand/gravel components in the bedload.
- Sediment at the site was composed of bedrock, cobbles and boulders, with some fines deposits which may have increased due to forestry impacts.

C3.3.2 Morphology of the site

- The channel was a bedrock pool-rapid channel type, within a very confined, V-shaped valley (Figure C3)
- This site was not good from a geomorphological perspective because there were no alluvial depositional features which could be used as flood cues. All features were bedrock controlled and had no apparent or discenrable link to the current flow regime.

The affected components of the GAI which reduced the PES from the RC were primarily the altered sediment supply (due to increased fines) and to a lesser extent the slight changes in transport capacity and system connectivity.

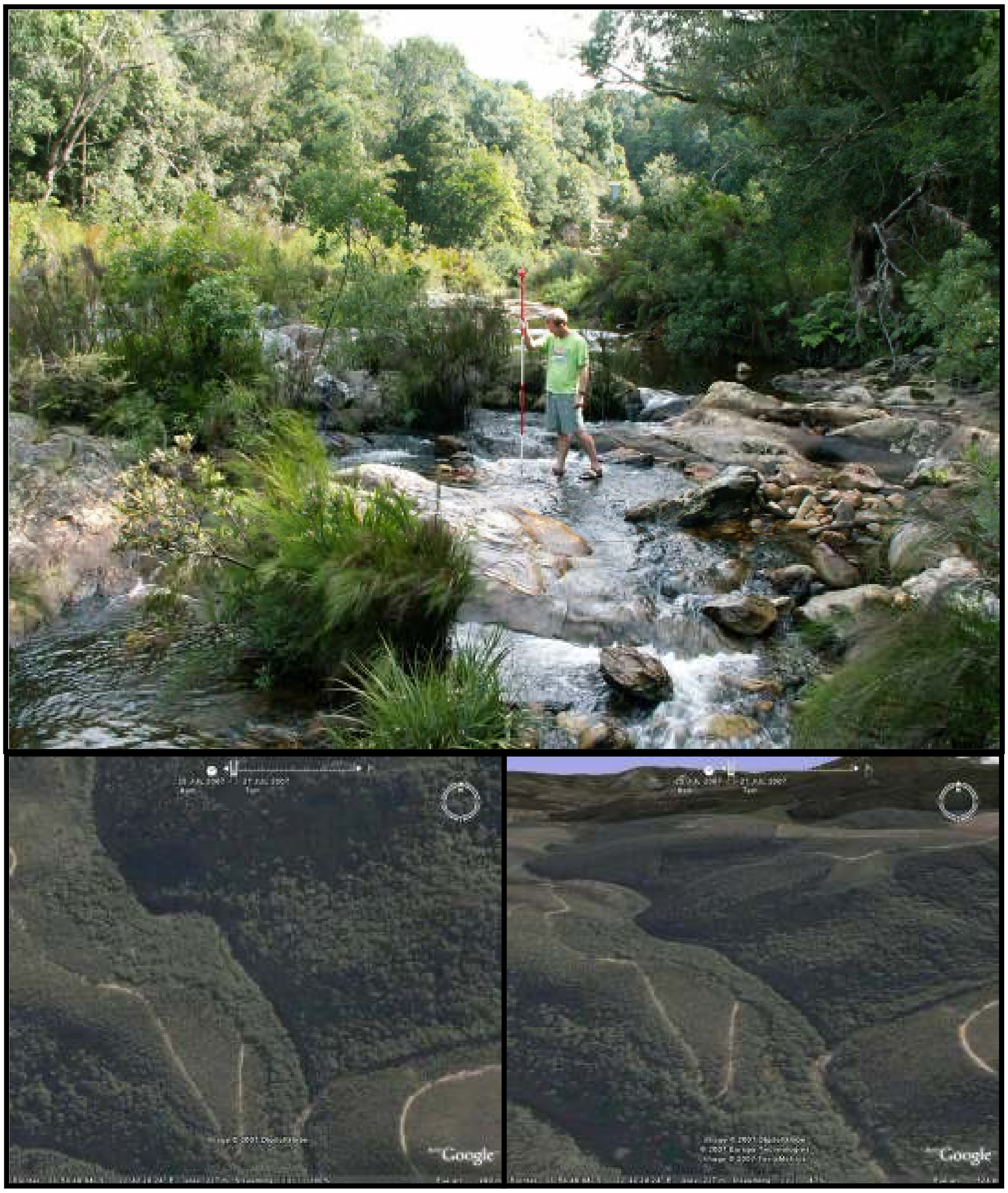


Figure C3 View of the site (top) and direct overhead (left) and oblique (showing the topography of the valley) imagery of the site

C3.4 REC: B

PES	REC	Comments
B	B	The site and reach were stable in the medium term. Although there had been an increase in fines, the reach was fairly resilent to these impacts due to the steep, high energy chanracteristics of this reach (i.e. the available sediment transport potential far exceeds available sediment supply, and thus few changes were evident despite the increased sediment loads).

C3.5 AEC: B/C

PES	AEC	Comments
B	B/C	With a scenario of poorer forestry management and associated increased sediment inputs; removal of some riparian vegetation; increased alien vegetation and reduced low flows, a slight decrease in the current condition of the reach was expected. The decrease in condition would primarily be as a result of increased sediment (fines) supplied to the channel.

C4 EWR 4: KARATARA (KARATARA RIVER) - ECOCLASSIFICATION

C4.1 DATA AVAILABILITY

Historical aerial photography was not useful to the assessment as it could not detect morphological changes due to the heavily forested nature of the upper sites. However, due to the very small width of the river at this site, and the generally very good PES condition, this did not present a limitation to the study. Field assessments, combined with catchment assessments (using Google Earth, 2007) were deemed sufficient to assess the PES and infer the likely RC of the river.

Confidence: 4

C4.2 REFERENCE CONDITIONS

The reference condition was similar to the current condition.
Confidence: 4

C4.3 PRESENT ECOLOGICAL STATE

The present state of the site was an A category.

C4.3.1 Site description

- A steep, deeply incised valley and the channel flow primarily on bedrock.
- The catchment has some large forestry areas. This and associated gravel roads may have caused slightly higher sand/gravel components in the bedload.
- Sediment at the site was composed of bedrock, cobbles and boulders.
- The site was immediately below a weir, so some coarsening of sediment was expected.

C4.3.2 Morphology of the site

- The channel was a bedrock pool-rapid channel type, within a very confined, V-shaped valley (Figure C4). One bank was bedrock at the site; the other composed of boulders and cobbles.
- This site was not good from a geomorphological perspective because there are no alluvial depositional features which could be used as flood cues.

The affected component of the GAI which slightly reduced the PES from the Reference condition was the minor altered sediment supply (due to a small increase in fines).

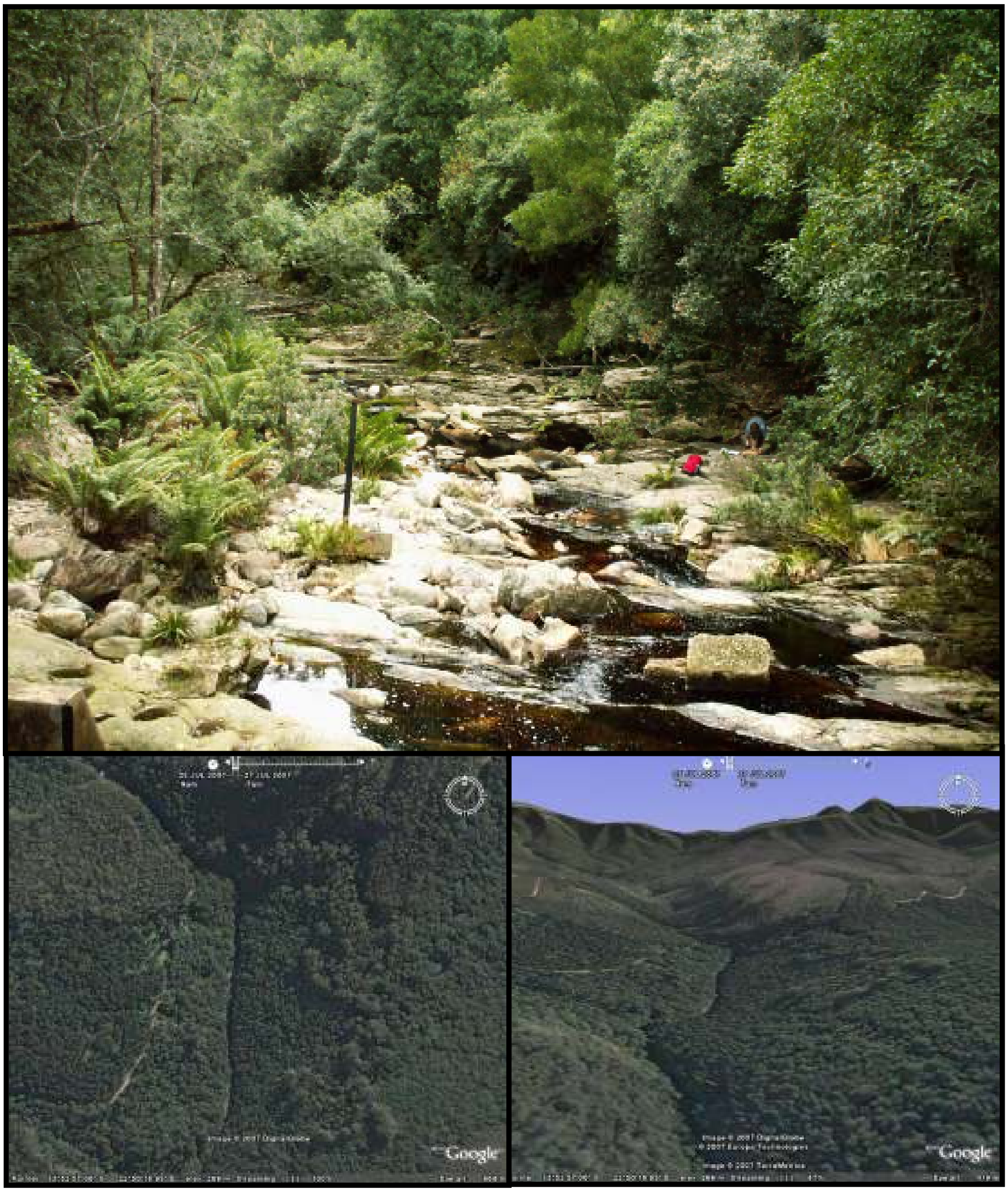


Figure C4 View of the site (top) and direct overhead (left) and oblique (showing the topography of the valley) imagery of the site

C4.4 REC: A

PES	REC	Comments
A	A	The site was stable, and no additional impacts sufficient to change the category of the geomorphology are anticipated under the current scenario.

C4.5 AEC:B/C

PES	AEC	Comments
A	B	Under this scenario a slight decrease in the current condition of the reach was expected. The decrease in condition would primarily be as a result of increased sediment (fines) supplied to the channel.

APPENDIX D: WATER QUALITY SPECIALIST REPORT

PA SCHERMAN, Scherman Colloty & Associates
P GOLA, IWR Rhodes University: Trainee
P NGWENYA, CES: Trainee

D1 INTRODUCTION

The water quality summary shown in this document is based on available data and is an assessment of water quality status for the rivers and Ecological Water Requirement (EWR) sites identified for the Outeniqua (Knysna and Swartvlei) Reserve Study.

The Knysna River, and its tributary the Gouna River, were assessed at an Intermediate level, while the Swartvlei rivers were assessed at a Rapid (III) level for the study. The approach followed for the water quality component of the Ecological Reserve generally follows the methodology for an Intermediate Reserve, although flow-concentration (Q-C) modelling was not undertaken. Q-C modelling is a recommendation for an Intermediate Reserve study, dependent on data availability and the water quality nature of the system. However, Q-C modelling is most effective for conservative variables having a strong correlation to flow, e.g. salts, and not very effective for non-conservative variables such as nutrients (i.e. those variables that undergo biological and chemical conversion, and whose concentration is altered by factors other than water volume e.g. bacterial degradation). As salts are not problematic in the study area, and little data are available for other conservative constituents, Q-C modelling was not undertaken.

The field survey was conducted at the end of May 2007. EWR sites, water quality sites (i.e. additional sites sampled during the field survey), and the position of DWA gauging weirs, are shown on Figure D1.

D1.1 CATCHMENT CONTEXT

The study area encompasses the **Knysna River** catchment between the Indian Ocean coastline in the south, and the crests of the Klein Langkloof mountains in the north, as well as the Swartvlei River system located in the south-western Cape barrier lake system. The relevant areas for the Knysna River catchment in this study are the Knysna River, with its tributary the Gouna River, as well as the Knysna Estuary and Lagoon. There are three streamflow gauging weirs in the Knysna River catchment, at the Gouna commonage (Gouna River), at the Millwood Forest (Knysna River) and at Charlesford (Knysna River) (du Plessis *et al.*, 2004).

The predominant land cover on the Knysna River catchment is exotic and indigenous vegetation. Agricultural development is confined mainly to the farms of Portland, Charlesford, Westford, Eastford, Simola and the Gouna Commonage. Irrigated food crops are cultivated at Portland, while the predominant agricultural activity is cattle grazing. There are abstractions on the Knysna River (Charlesford farm upstream of the weir) and the Gouna River (Gouna pump station) by the Knysna Municipality for water supply. The new Simola Golf and Country Estate is being built on Kaapweg, downstream of the Gouna pump station.

The **Swartvlei River** is approximately 38 km long with a total catchment area of 340 km^2. The main tributaries of the Swartvlei River are the Hoëkraal and Karatara rivers in the east and the Wolwe and Diep rivers in the west. Three rivers drain into Swartvlei Lake, i.e. the Diep, Hoëkraal and Karatara. The land-cover on the Swartvlei catchment comprises mainly bushland, forest and shrubland. Agriculture, which consists primarily of commercial forestry, improved grasslands and temporary commercial irrigation, accounts for about 40% of the land cover in the catchment, with dairy farming in the Diep River catchment. On the lower Hoëkraal there is some citrus farming, while on the Karatara the land use is dairy farming, timber processing (Geelhoutvlei), sawmill processing and forestry (DWAF, 2004). Some of sawmills have no disposal sites and could potentially have impacts on the lagoon.

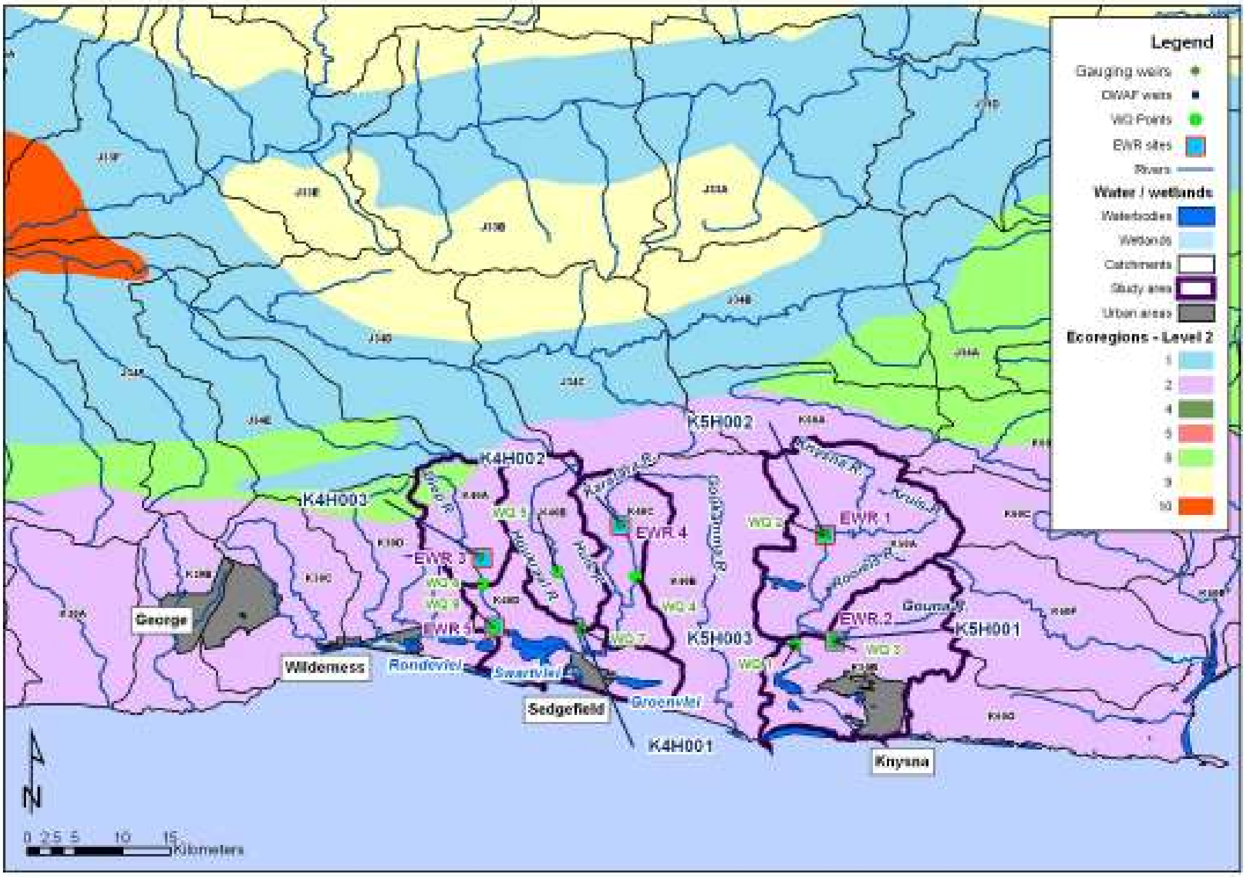


Figure D1 **Locality map showing the position of the EWR sites, additional water quality sites and gauging weirs**

D1.2 WATER QUALITY OVERVIEW

Surface water quality in quaternary catchment K50A is described as "ideal", with little information regarding surface water quality for quaternary catchment K50B. There are three main tributaries to the Swartvlei Lake. Water quality in quaternary catchment K40B (Hoëkraal River) is classified as marginal, due to a degree of elevated salinity resulting from natural sources such as geology and probable back-up from the estuarine Swartvlei Lake to the gauging weir.

The following summary is taken from the water quality report for the Outeniqua Coast Water Situation Study (OCWSS) (DWAF, 2007) and defines fitness-for-use as Ideal, Acceptable, Tolerable or Unacceptable according to the colour codes shown below.

Fitness for use range	Colour code
Ideal	**Blue**
Acceptable	**Green**
Tolerable	**Yellow**
Unacceptable	**Red**

Fitness-for-use categories can be described as follows:

- Ideal - the user of the water is not affected in any way.
- Acceptable - slight to moderate problems are encountered.
- Tolerable - moderate to severe problems are encountered.
- Unacceptable - the water cannot be used under normal circumstances.

The OCWSS report took into consideration the following user categories - domestic use, agricultural use (irrigation) and aquatic ecology - as other users were not relevant to the catchment in the study area. Variables for evaluation (chloride, electrical conductivity, nutrients (ammonium, nitrate and nitrite nitrogen, and phosphate) and pH) were selected accordingly. Data used for the assessment were 2002-2005 data from the following gauging weirs:

- Knysna River: K5H002Q01 at Milwood Forest Reserve
- Hoëkraal River: K4H001Q01 at Eastbrook
- Karatara River: K4H002Q01 at Karatara Forest Reserve
- Diep River: K4H003Q01 at Woodville Forest Reserve

Guidelines for the assessment were selected as follows for each variable:

D1.2.1 Electrical Conductivity

The agricultural guideline for irrigation was the most stringent. The ideal range in this guideline falls between 0 and 40 mS/m.

D1.2.2 pH

As rivers of the study area are naturally poorly buffered, the natural background pH was used to describe the fitness-for-use range.

D1.2.3 Nitrate and Nitrite

This concentration was consistently in the ideal range of the domestic guideline, so it was used as the fitness-for-use category.

D1.2.4 Ammonium and Phosphate

The only guidelines for ammonium and phosphate were the ecological user group.

D1.2.5 Chloride

The most stringent guideline was for agricultural irrigation.

The following tables (Tables D1 and D2) describe fitness-for-use categories using both the medians and 95th percentiles of water quality data. Note that according to the riverine ecological methods of DWAF (2008), medians are relevant to nutrients and 95th percentiles used for Cl, Electrical Conductivity and pH.

Table D1 Water quality assessment for data medians

Drainage Region	Station No	Cl	Electrical Conductivity	NH_4-N	NO_3+ NO_2-N	pH	PO_4-P
K40	K4H001	85.566	34.300	0.035	0.052	6.192	0.036
	K4H002	21.037	12.380	0.049	0.055	4.107	0.047
	K4H003	60.953	24.950	0.020	0.055	6.452	0.020
K50	K5H002	29.601	14.400	0.020	0.055	5.017	0.026

Table D2 Water quality assessment for the 95th percentiles of data analysed

Drainage Region	Station No	Cl	Electrical Conductivity	NH_4-N	NO_3+ NO_2-N	pH	PO_4-P
K40	K4H001	869.068	283.500	0.059	0.100	7.564	0.078
	K4H002	30.641	14.130	0.085	0.134	5.359	0.082
	K4H003	68.824	27.625	0.047	0.168	6.930	0.055
K50	K5H002	38.394	16.960	0.057	0.136	6.945	0.047

The data in Tables D1 and D2 indicate that potential water quality issues are focussed around phosphate levels in the rivers, although medians fall within the Acceptable to Tolerable range. Note that a more accurate assessment would have evaluated reference state levels for phosphate, and assessed the deviation or change from natural conditions. This is the approach followed in the Reserve study.

D2 METHODS AND APPROACH

D2.1 WATER QUALITY VARIABLES

The following variables were used for the assessment of water quality, according to the methods stipulated in DWAF (2008).

D2.1.1 Salts

- Sodium chloride (NaCl)
- Sodium sulphate (Na_2SO_4)
- Magnesium chloride ($MgCl_2$)
- Magnesium sulphate ($MgSO_4$)
- Calcium chloride ($CaCl_2$)
- Calcium sulphate ($CaSO_4$)
- Electrical Conductivity (EC) – used as a surrogate for aggregated salts when all ionic data are not available.

Note that salt ionic data, i.e. Ca, Na, Mg, Cl, SO_4, were run through TEACHA (Tool for Ecological Aquatic Chemical Habitat Assessment) to generate aggregated salts (see DWAF (2008) for more information). TEACHA has strict data input requirements, e.g. all salt ionic data are needed to generate aggregated salts. Where inorganic salts could not be generated using TEACHA, EC was used as a surrogate for salts after the method of DWAF (2004), outlined in salt rating tables of DWAF (2008).

D2.1.2 Nutrients

- Total inorganic nitrogen or TIN (i.e. the N portion of all nitrogen sources, e.g. NO_2+NO_3+NH_4-N)
- Phosphate (PO_4^{3-} -P)

D2.1.3 System variables

- pH
- Temperature: Although temperature is considered particularly important in the instances of thermal impacts, e.g. outputs from power stations, it is also important to consider if the EWR site is located below a dam, or if changes in flow result in extreme temperature changes in rivers.
- Dissolved oxygen (DO)
- Turbidity

As quantitative data (other than that measured in the field) were not available for Dissolved Oxygen (DO), temperature and turbidity, a qualitative assessment was conducted for these variables (as outlined in DWAF (2008)). This qualitative assessment was therefore based on specialist knowledge regarding the catchment, sizes of rivers, landuse activities and expected states of DO, temperature and turbidity. Specialist knowledge was gained by gathering literature and consulting with DWA officers and stakeholders in the area. The rating table below for DO is taken from DWAF (2008) and provides an example of how a qualitative assessment can be undertaken using environmental clues about the state of the variable being evaluated.

Rating	Deviation from reference condition	Environmental clues about the dissolved oxygen status	DO concentration (mg/L)
0	No change	Known to be a pristine river, no known problems or concerns about DO; all oxygen sensitive species are present.	> 8
1	Small change	Some man-made modifications in the catchment but no known problems or concerns about DO, most oxygen sensitive species are present.	7 – 8
2	Moderate change	Some concerns about dissolved oxygen, some oxygen sensitive species are present but mostly oxygen tolerant species.	6 – 7
3	Large change	Known problems with reduced dissolve oxygen, mostly low DO tolerant species are present.	4 – 6
4	Serious change	Major know problems with low dissolved oxygen, anoxic odours sometimes present, only very low DO tolerant species present.	2 – 4
5	Extreme change	Extreme concerns about low DO, anoxic odours present most of the time, colour of the water often dark with organic material, benthic algae replaced by grey/black bacterial films and sewage fungus, no biota present most of the time.	0 – 2

D2.1.4 Toxic substances

Toxic substances include those listed in the South African Water Quality Guidelines for Aquatic Ecosystems (DWAF, 1996), which include toxic metal ions, toxic organic substances, and/or substances selected from the chemical inventory of an effluent/discharge. The rating tables in DWAF (2008) provide values for selected toxic substances.

D2.1.5 Response indicators

The following response indicators were used in the water quality assessment:

- Fish and macroinvertebrate survey results from the study: Results are shown in Appendices E and F respectively. The results from the water quality assessment are tested against the outputs from the fish and macroinvertebrate assessments. If large disparities are noted, which are not due to habitat or flow indicators, water quality data would be re-assessed.
- Diatoms: Results and method are shown in Table D7 and Appendix H respectively
- Chlorophyll-*a* (chl-*a*): Chl-*a* provides additional information for the nutrient assessment as it indicates high nutrient levels bound up in algal growth in the water column, or more commonly, in periphyton films on the substrate. Results are shown in Table D8 and methods in Froneman (2007). Summarized methods are shown below.

D2.1.6 Phytoplankton biomass

For the determination of phytoplankton biomass at each station, triplicate 250 ml subsurface (0.5 m depth) waters sample were filtered (vacuum < 5cm Hg) through GF/F filters and extracted in 90% acetone for 24h in the dark. Chl-*a* concentrations were then determined fluorometrically (Turner 10AU fluorometer) before and after acidification (Holm-Hansen and Riemann, 1978). Results were expressed as mg chl-*a* m^{-3}.

D2.1.7 Periphyton biomass

To estimate the periphyton biomass, a fixed area (equivalent to 3.14 cm^2) of submersed pebble collected from each site was gently scrapped using a scalpel. The scrapings were then washed into a beaker using distilled water. Contents of the beaker were then gently filtered through a GF/F filter and extracted in 90% acetone for 24h in the dark. Chl-*a* concentrations were then determined fluorometrically (Turner 10AU fluorometer) before and after acidification (Holm-Hansen and Riemann 1978). Results were expressed as mg chl-*a* m^{-2}. Three replicates were prepared at each station.

D2.2 INTEGRATED WATER QUALITY CATEGORY

TEACHA is an instrument to support decision-making in the Reserve process, and is a data manipulation tool. The primary output is the recommended water quality component of the Ecological Reserve with corresponding ion data to use in the setting of Resource Quality Objectives. The use of the TEACHA software presupposes that information is available and reliable. It is not an expert system and requires the availability of expertise to check that the outcome is correct and scientifically valid, e.g. note the rules in DWAF (2008) regarding the use of the output ratings from TEACHA. It also has strict data input requirements, e.g. all salt ions have to be input or the model will not run. TEACHA was used for this assessment, with data extracted from DWA's Water Management System (WMS).

However, to arrive at an integrated water quality category, data (or ratings) from the *ecostatusfig* output screen of TEACHA were used in the Physico-Chemical Driver Assessment Index (PAI) model to generate an integrated water quality category for the site under investigation – see the PAI tables per site in Section D4.

D2.3 WATER QUALITY AND HYDROLOGY

Water quality is handled as a driver index, together with flow and geomorphology, during the Habitat Flow Stressor Response (HFSR) approach. This approach necessitates an understanding of water quality status under the present day hydrological regime, including knowledge of the relationship between water quality metrics and flow.

However, the assessment of hydrological data was used largely for the evaluation of water quality consequences under various operational flow scenarios (i.e. Step 5 of the 8-step process). The following information was used for this task:

- Physico-chemical Assessment Index (PAI) and water quality information tables produced during the EcoClassification process
- Information describing the present state for water quality at each site, including issues driving water quality (i.e. the drivers of the water quality state)
- Knowledge of land-use activities and their links to water quality
- Flow-duration tables and graphs for natural day, present day and each operational scenario
- Flow time-series for natural, present day and each operational scenario. The flow information presented for the present state is therefore linked to the PES for water quality, as defined during EcoClassification
- Water quality modelling, if available: Modelling information provides concentration-time series for selected variables, and changes in flow can be linked to changes in concentrations. This information is normally only available for variables that have a conservation relationship with flow, e.g. salts and other ions. However, metals are not generally analyzed as part of the DWA monitoring programme and Intermediate Reserve Methodology does not make provision for the initiation of monitoring.

In the absence of water quality modelling, the PAI model for the PES was adjusted according to physico-chemical changes expected under each scenario. A description of these changes was provided to the instream biota specialists, and final changes to the PAI model were made in consultation with the project team. Final adjustments were highlighted, and notes included. All PAI models and water quality tables are available electronically.

D2.4 DATA SELECTION

Fundamental to data selection is ensuring that there is suitable data to define both the Reference RC and PES of the selected river reaches. RC is derived from a site that is known to have a high biotic integrity and would be known to correspond to the description of a natural site, or one at which there is solid evidence that there is no or little significant anthropogenic impact (Palmer *et al.*, 2004). Reference data is required to determine the degree of change related to the present state of the water quality in a water resource. The latest available data from a particular monitoring point is used to represent the PES, in order to indicate present impacts.

D2.5 DATA AVAILABILITY

All DWA water quality monitoring stations in EcoRegion Level II 20.2 of catchments K40 and K50 were investigated for data to be used to describe RC and PES. The positions of the monitoring points are shown in Figure D1. There are three gauging weirs or DWA water quality stations on the Swartvlei River System and three on the Knysna River System (see Table D3 below). Data from the Charlesford site on the Knysna River is poor and could not be used for the assessment. Table D4 shows data confidence, as assessed by length of data records and numbers of variables monitored.

Note that data of a sufficient record length is required to describe water quality due to the variability and changes in concentration of water quality variables over time in a natural stream. Concentrations are determined by natural parameters such as geology and rainfall, as well as anthropogenic factors such as land use and urban discharges. Water volumes also impact those variables linked to flow, as a drop in flow results in less water for dilution. Due to this inherent variability of water quality state, summary statistics are used for data analysis, e.g. medians and percentiles.

Table D3 Knysna and Swartvlei gauging weirs

Station	Place	Latitude	Longitude	Record date
K5H001	Gouna River @ Gouna Commonage	33º 59’ 28.0”	23º 02’ 33.0”	1959-11-16 to 1984-10-22
K5H002	Knysna River @ Milwood Forest Reserve	33º 53’ 24.0”	23º 01’ 54.0”	1961-08-02 to 2006-11-28
K5H003	Knysna River @ Charlesford	33º 59’ 48.0”	23º 00’ 10.0”	2003-05-14 to 2006-11-28
K4H001	Hoëkraal River @ Eastbrook	33º 58’ 47.0”	22º 48’ 00.0”	1959-11-19 to 1993-05-17
K4H002	Karatara River @ Karatara Forest Reserve	33º 52’ 52.0”	22º 50’ 19.0”	1961-04-24 to 2006-11-28
K4H003	Diep River @ Woodville Forest Reserve	33º 54’ 42.0”	22º 42’ 21.0”	1961-05-13 to 2006-11-28

Table D4 State of water quality data assessed for the Reserve study

Station	Start and end date	Monitored variables	Data points	Frequency of monitoring	RC	PES
K4H001Q01: Hoëkraal River	69-08-18 to 2007-03-20	pH-Diss-Water (pH units)	394	Monthly	Yes	Yes
		NO_3+NO_2-N-Diss-Water (mg/L)	392	Monthly		
		NH_4-N-Diss-Water (mg/L)	383	Monthly		
		Na-Diss-Water (mg/L	389	Monthly		
		Mg-Diss-Water (mg/L	389	Monthly		
		PO_4-P-Diss-Water (mg/L)	386	Monthly		
		SO_4-Diss-Water (mg/L)	389	Monthly		
		Cl-Diss-Water (mg/L)	389	Monthly		
		K-Diss-Water (mg/L)	385	Monthly		
		Ca-Diss-Water (mg/L	389	Monthly		
K4H002Q01: Karatara River	1971-09-15 to 2007-03-20	pH-Diss-Water (pH units)	495	Monthly	Yes	Yes
		NO_3+NO_2-N-Diss-Water (mg/L)	482	Monthly		
		NH_4-N-Diss-Water (mg/L)	398	Monthly		
		Na-Diss-Water (mg/L	493	Monthly		
		Mg-Diss-Water (mg/L	493	Monthly		
		PO_4-P-Diss-Water (mg/L)	468	Monthly		
		SO_4-Diss-Water (mg/L)	489	Monthly		
		Cl-Diss-Water (mg/L)	493	Monthly		
		K-Diss-Water (mg/L)	470	Monthly		
		Ca-Diss-Water (mg/L	493	Monthly		
K4H003Q01: Diep River	1971-08-10 to 2007-03-20	pH-Diss-Water (pH units)	353	Monthly	Yes	Yes
		NO_3+NO_2-N-Diss-Water (mg/L)	352	Monthly		
		NH_4-N-Diss-Water (mg/L)	352	Monthly		
		Na-Diss-Water (mg/L	352	Monthly		
		Mg-Diss-Water (mg/L	352	Monthly		
		PO_4-P-Diss-Water (mg/L)	352	Monthly		
		SO_4-Diss-Water (mg/L)	352	Monthly		
		Cl-Diss-Water (mg/L)	352	Monthly		
		K-Diss-Water (mg/L)	346	Monthly		
		Ca-Diss-Water (mg/L	352	Monthly		
K5H001Q01: Gouna River	1971-06-29 to 1998-05-05	pH-Diss-Water (pH units)	111	Monthly	Yes	No
		NO_3+NO_2-N-Diss-Water (mg/L)	109	Monthly		
		NH_4-N-Diss-Water (mg/L)	106	Monthly		
		Na-Diss-Water (mg/L	110	Monthly		
		Mg-Diss-Water (mg/L	110	Monthly		
		PO_4-P-Diss-Water (mg/L)	107	Monthly		
		SO_4-Diss-Water (mg/L)	110	Monthly		
		Cl-Diss-Water (mg/L)	110	Monthly		
		K-Diss-Water (mg/L)	107	Monthly		
		Ca-Diss-Water (mg/L	110	Monthly		
K5H002Q01: Knysna River @ Millwood	1971-06-29 to 2007-03-20	pH-Diss-Water (pH units)	367	Monthly	Yes	Yes
		NO_3+NO_2-N-Diss-Water (mg/L)	359	Monthly		
		NH_4-N-Diss-Water (mg/L)	344	Monthly		
		Na-Diss-Water (mg/L	363	Monthly		
		Mg-Diss-Water (mg/L	363	Monthly		
		PO_4-P-Diss-Water (mg/L)	353	Monthly		
		SO_4-Diss-Water (mg/L)	362	Monthly		
		Cl-Diss-Water (mg/L)	363	Monthly		
		K-Diss-Water (mg/L)	352	Monthly		
		Ca-Diss-Water (mg/L	363	Monthly		

D3 WATER QUALITY ASSESSMENT

The EWR sites selected for the study are shown in Table D5. Additional data used for the assessment including limited water quality data (Table D6), chlorophyll-*a* samples (Table D7) and diatom samples collected during the field survey of May 2007 (Table D8). Time series graphs for selected variables are shown per EWR site in section D8 of this document.

Table D5 Knysna and Swartvlei EWR sites

EWR site number	EWR site name	GPS coordinates		EcoRegion	Geomorphic Zone	Altitude (m)	RU	Quat[1]
1	Upper Knysna	33º 53' 27.8" S	23º 01' 57.1" E	20.02	Upper Foothills	234	A	K50A
2	Gouna	33º 59' 27.3" S	23º 02' 29.2" E	20.02	Upper Foothills	108	B	K50B
3	Upper Diep	33º 54' 48.9" S	22º 42' 29" E	20.02	Upper Foothills	231	C	K40A
4	Upper Karatara	33º 52' 56.5" S	22º 50' 18.7" E	20.02	Upper Foothills	271	E	K40C

1 Quaternary catchment

Table D6 On-site water quality data collected during the 2007 field survey

Site	GPS coordinates		Temp (ºc)	EC (mS/m)	ATC (ppt)	pH
WQ 1, Charlesford on Knysna River	33º 59' 42.5" S	23º 00' 13.9" E	-	-	-	-
WQ 2, EWR 1, Knysna River	33º 53' 32.3" S	23º 01' 50.1"E	10.7	9	0.05	4.8
WQ 3, EWR 2, Gouna River	33º 59' 27.3" S	23º 02' 25.5" E	11	15	0.07	4.47
WQ 4, Karatara River, d/s EWR 4	33º 55' 50.2" S	22º 50' 15.1"E	10.7	7	0.03	4.01
WQ 5, Hoëkraal River	33º 55' 33.4" S	22º 46' 42.7" E	11.2	10	0.05	4.07
WQ 6, Diep River, d/s EWR 3	33º 56' 14.2" S	22º 42' 28.4" E	11.7	18	0.09	6.14
WQ 7, Lower Hoëkraal	33º 58' 48.2" S	22º 48' 00.0" E	14.1	42	0.14	6.1
WQ 8, EWR 5, Wolwe River	33º 58' 43.9" S	22º 43' 08.0" E	13.2	82	0.12	6.29
(EWR 5 is not being assessed)						

Table D7 Chlorophyll-*a* analysis for samples collected from the Knysna/Swartvlei study area (Froneman, 2007)

Site	Phytoplankton biomass (mg chl-*a* m^{-3})	Periphyton biomass (mg chl-*a* m^{-2})
WQ 1, Charlesford on Knysna River	0.13 (±0.01)	15.37 (±8.89)
WQ 2, EWR 1, Knysna River	0.12 (±0.02)	4.08 (±2.97)
WQ 3, EWR 2, Gouna River	0.09 (±0.01)	43.70 (±25.6)
WQ 4, Karatara River, d/s EWR 4	0.09 (±0.02)	9.91 (±6.18)
WQ 5, Hoëkraal River	0.14 (±0.01)	4.81 (± 3.87)
WQ 6, Diep River, d/s EWR 3	0.18 (±0.11)	21.25 (±9.92)
WQ 7, Lower Hoëkraal	0.47 (±0.05)	152.93 (± 188.61)
WQ 8, EWR 5, Wolwe River	0.16 (±0.09)	29.24 (±20.99)

Table D8 Diatom assessment for the Knysna/Swartvlei study area (from Appendix H)

Site	No. species	SPI[1]	Interpretation of SPI index scores
WQ 1, Charlesford on Knysna River	11	19.1	High quality
WQ 2, EWR 1, Knysna River	19	18.9	High quality
WQ 3, EWR 2, Gouna River	27	19.8	High quality
WQ 4, Karatara River, d/s EWR 4	10	19.9	High quality
WQ 5, Hoëkraal River	13	19.8	High quality
WQ 6, Diep River, d/s EWR 3	13	17.6	High quality
WQ 7, Lower Hoëkraal	25	16.2	Good quality
WQ 8, EWR 5, Wolwe River	24	18.3	High quality

1 Specific Pollution Index

D4 EWR 1: KNYSNA RIVER

The WMS database was evaluated for water quality data to be used for the assessment of the water quality component of the Ecological Reserve. Water quality station K5H002Q01 (Knysna River at Millwood) was used for both RC and PES. The earliest data set from 1977-1980, n=75, was used for RC. Figure D2 illustrates that there was good annual and monthly representivity of salt ions, nutrient and pH data over the selected data record, covering possible dry and wet years, and dry and wet months respectively (Note: the graph represents monthly and yearly data). It shows the number of samples for each month; also the number of samples for each year for the selected data period (1977-1980).

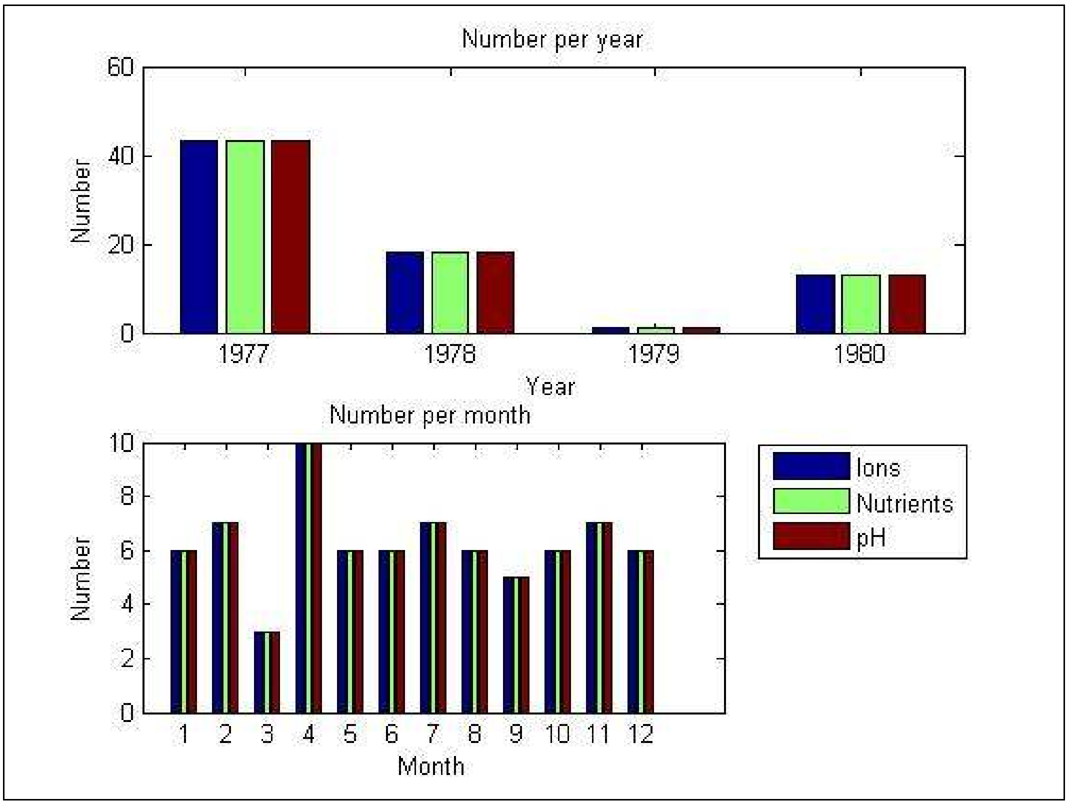


Figure D2 Data distribution graphs for RC at EWR 1

The most recent data years (i.e. 2004 - 2007) of station K5H002Q01, n = 26, were used to assess the PES for EWR 1 (Figure D3). Figure D3 also illustrates that there was good annual and monthly representivity of ion, nutrient and pH data over the selected data record, covering possible dry and wet years, and dry and wet months respectively.

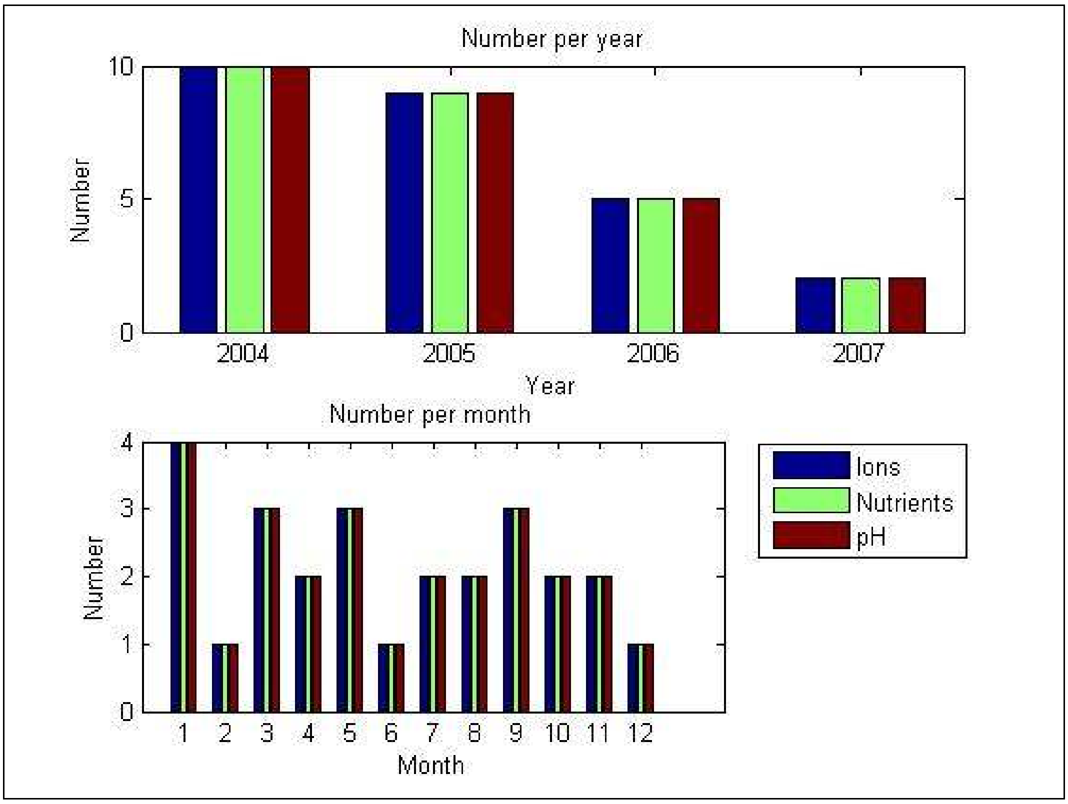


Figure D3 Data distribution graphs for PES at EWR 1

D4.1 RESULTS FOR EWR 1

The PAI table, which is completed as part of the assessment, assigns the EcoStatus rating for water quality, and is shown below as Table D9. The relationship between categories and ratings are shown below.

Table D9 Relationship between categories and ratings

Rating	Deviation from reference conditions	A- F Categories
0	No change	A
1	Small change	B
2	Moderate change	C
3	Large change	D
4	Serious change	E
5	Extreme change	F

The present state of the water quality at EWR 1 and upstream of the site was scored as an **A category** (see Table D10) due to the limited landuse other than indigenous forestry in the upstream section of the catchment. The PES for the whole Water Quality Sub-unit 1 (WQS 1) was scored as an A/B category (see Table D11), primarily due to minimal impacts on salts and nutrients from farming activities in the lower section of the WQS. Table D12 presents the water quality assessment under the AEC. Due to the data available, the assessment is of **moderate** confidence.

Table D10 PAI table for EWR 1

SCORING GUIDELINES **EWR1** Knysna River (K5H002Q01): at EWR site and upstream

PHYSICO-CHEMICAL CHANGES							
Physico-chemical Metrics	**Rank**	**%wt**	**Rating**	**Weight**	**Weighted score**	**Flow related?**	**Confidence**
pH	3	80	0.00	0.17	0.00		Confidence in the assessment is **moderate**. RC: n=75 ('77-'80); PES: n=26 ('04-'07).
SALTS	5	40	0.00	0.08	0.00		
NUTRIENTS	2	85	1.00	0.18	0.18		
TEMPERATURE	3	50	0.00	0.11	0.00		
TURBIDITY	4	70	1.00	0.15	0.15		
OXYGEN	3	50	0.00	0.11	0.00		
TOXICS	1	100	0.00	0.21	0.00		
TOTALS		475			0.33		
PHYSICO-CHEMICAL PERCENTAGE SCORE					**93.47**		
PHYSICO-CHEMICAL CATEGORY					**A**		
BOUNDARY CATEGORY							

Reasoning / Notes
Adusted to 0 as only for the site + u/s
PES better at the site + u/s, as limited land use at that point
Little change expected from natural, although possibly less shading with some forestry.
Little evidence of sedimentation seen.

Table D11 PAI table for WQS 1

SCORING GUIDELINES **EWR1** Knysna River (K5H002Q01)

PHYSICO-CHEMICAL CHANGES							
Physico-chemical Metrics	**Rank**	**%wt**	**Rating**	**Weight**	**Weighted score**	**Flow related?**	**Confidence**
pH	3	80	0.00	0.17	0.00		Confidence in the assessment is **moderate**. RC: n=75 ('77-'80); PES: n=26 ('04-'07).
SALTS	6	40	0.50	0.08	0.04		
NUTRIENTS	2	85	1.50	0.18	0.27		
TEMPERATURE	3	50	0.50	0.11	0.05		
TURBIDITY	4	70	1.00	0.15	0.15		
OXYGEN	3	50	0.50	0.11	0.05		
TOXICS	1	100	0.00	0.21	0.00		
TOTALS		475			0.56		
PHYSICO-CHEMICAL PERCENTAGE SCORE					**88.74**		
PHYSICO-CHEMICAL CATEGORY					**B**	**A/B**	
BOUNDARY CATEGORY							

Reasoning / Notes
TEACHA gives a 0 rating, but adjusted to 0.5 as the length of the river to be considered.
TEACHA seems to default to lowest category, which is a rating of a 2.
Little change expected from natural, although only a little less shading with forestry.
Little evidence of sedimentation seen.

Table D12 PAI table for AEC

SCORING GUIDELINES **EWR1** Knysna River (K5H002Q01): AEC = C

PHYSICO-CHEMICAL CHANGES							
Physico-chemical Metrics	**Rank**	**%wt**	**Rating**	**Weight**	**Weighted score**	**Flow related?**	**Confidence**
pH	3	80	0.00	0.17	0.00		Confidence in the assessment is **moderate**. RC: n=75 ('77-'80); PES: n=26 ('04-'07).
SALTS	6	40	0.00	0.08	0.00		
NUTRIENTS	2	85	2.50	0.18	0.45		
TEMPERATURE	3	50	1.00	0.11	0.11		
TURBIDITY	4	70	2.00	0.15	0.29		
OXYGEN	3	50	0.00	0.11	0.00		
TOXICS	1	100	0.00	0.21	0.00		
TOTALS		475			0.85		
PHYSICO-CHEMICAL PERCENTAGE SCORE					**83.05**		
PHYSICO-CHEMICAL CATEGORY					**B**		
BOUNDARY CATEGORY							

Reasoning / Notes
Increased nutrients with abstraction at low flows. Fires mobilize nutrients and increase TSS loads.
Less shading with increased aliens.
More sedimentation with mismanagement.

Notes on assessment:

- Chlorophyll-*a* was included as a variable to assess the nutrient status, although this assessment was based on a once-off survey.
- Diatom data was also included as a response variable and used to assess nutrient status (see Appendix H). The assessment of diatoms was also based on a once-off survey.

D5 EWR 2: GOUNA RIVER

D5.1 DATA USED FOR EWR 2

Water quality station K5H001Q01 (Gouna River @ Gouna Commonage) was assessed for available data to be used for both PES and RC. Although the data from this station was not suitable to represent the PES as there is no data beyond 1998, it was used to represent reference condition.

D5.2 REFERENCE CONDITION

The earliest data years of water quality station K5H001Q01 were used to define the reference condition of the site. The data start from 1977-1980 with 76 records (see Figure D4).

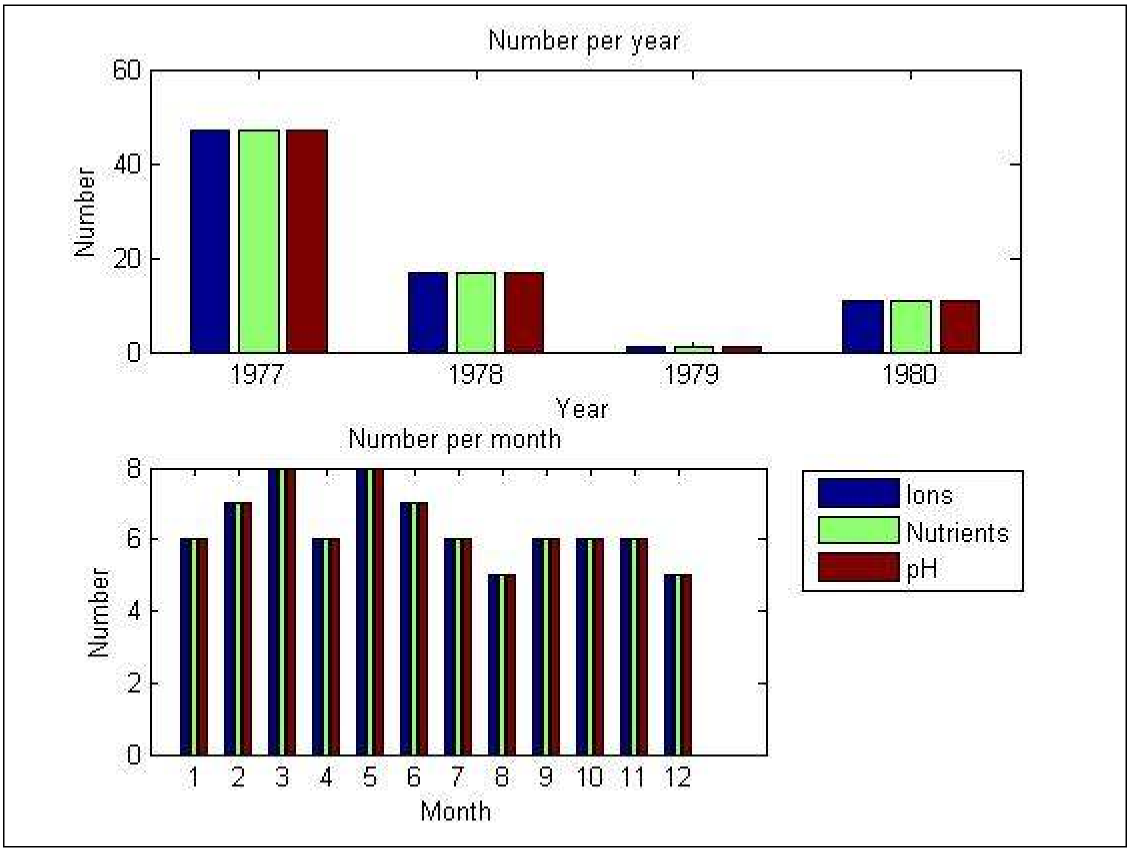


Figure D4 Data distribution graphs for RC at EWR 2

D5.3 PES

The most recent data available from water quality station K5H001Q01 were used to conduct the physico-chemical assessment for EWR 2. The selected data years start from 1981 to 1984, with 30 available records (see Figure D5).

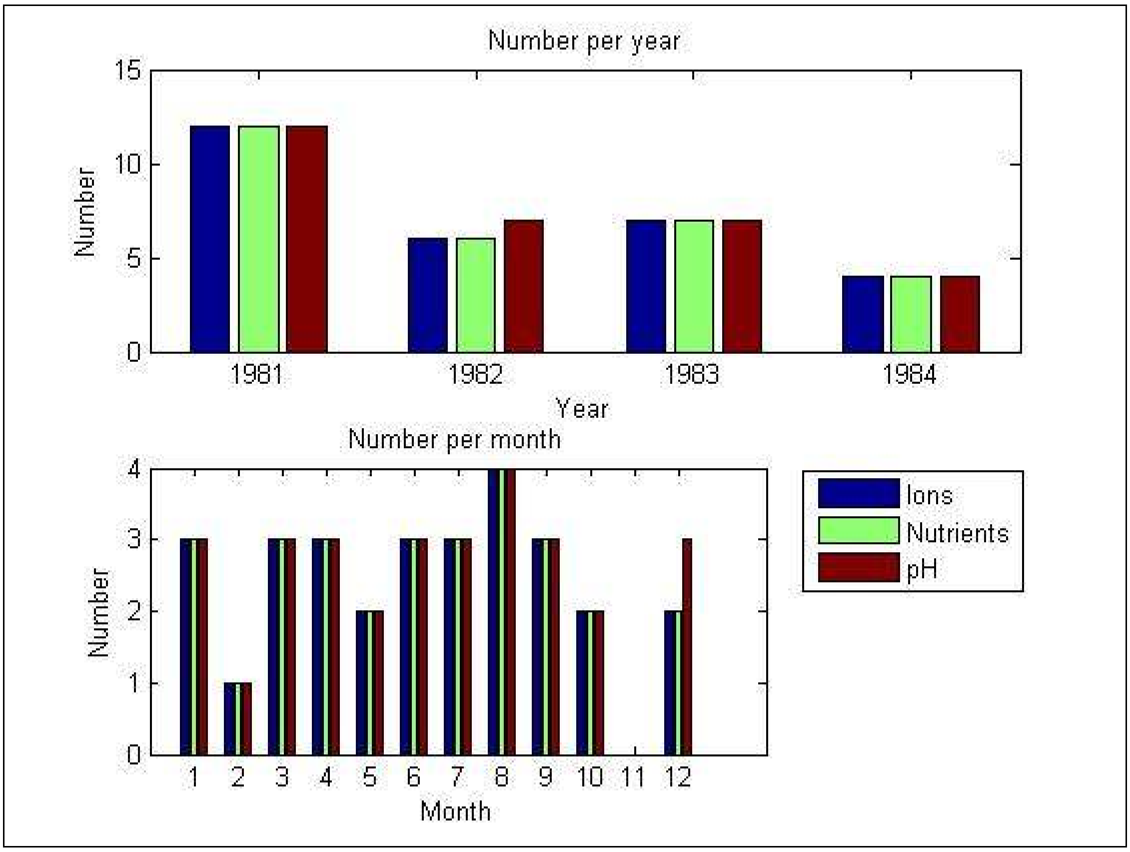


Figure D5 Data distribution graphs for PES at EWR 2

C4.6 RESULTS FOR EWR 2

The present state of the water quality at EWR 2 site above the pump station was scored as an **A category** (see Table D13) as landuse is primarily pristine forest in this area. The present state of the water quality for the whole reach was scored as a B category (see Table D14) due to sediment inputs in the downstream section. There is also evidence of elevated salts and nutrients, probably related to irrigation activities. The results of the AEC are shown as Table D15. Due to unavailable data, the assessment is of **Low** confidence.

Table D13 PAI table for EWR 2 above pump station

SCORING GUIDELINES **EWR2** Gouna River (K5H001Q01): above pump station

PHYSICO-CHEMICAL CHANGES								
Physico-chemical Metrics	**Rank**	**%wt**	**Rating**	**Weight**	**Weighted score**	**Flow related?**	**Confidence**	**Reasoning / Notes**
pH	4	50	0.00	0.12	0.00		Confidence in the assessment is **low** as no recent data for assessing PES. RC: n=76 ('77-'80); PES: n=30 ('81-'84).	TEACHA gives a rating of 1, but poor PES data
SALTS	5	40	0.50	0.09	0.05			TEACHA gives a rating of 1, but poor PES data so adjusted to 0.5
NUTRIENTS	2	80	0.50	0.19	0.09			Rating for TIN, PO4 and phyto is 0, but peri is 3 downstream of site. Adjusted to u/s site.
TEMPERATURE	4	50	0.00	0.12	0.00			Little change expected from natural - land cover mostly indigenous forestry.
TURBIDITY	3	60	0.50	0.14	0.07			Little change expected from natural
OXYGEN	4	50	0.00	0.12	0.00			
TOXICS	1	100	0.00	0.23	0.00			
TOTALS		430			0.21			
PHYSICO-CHEMICAL PERCENTAGE SCORE					**95.81**			
PHYSICO-CHEMICAL CATEGORY					**A**			
BOUNDARY CATEGORY								

Table D14 PAI table for EWR 2 for the whole reach

SCORING GUIDELINES **EWR2** Gouna River (K5H001Q01): whole reach, incl. pump station + AEC

PHYSICO-CHEMICAL CHANGES							
Physico-chemical Metrics	**Rank**	**%wt**	**Rating**	**Weight**	**Weighted score**	**Flow related?**	**Confidence**
pH	5	40	0.50	0.10	0.05		Confidence in the assessment is **low** as no recent data for assessing PES. RC: n=76 ('77-'80); PES: n=30 ('81-'84).
SALTS	5	40	0.50	0.10	0.05		
NUTRIENTS	2	80	2.00	0.20	0.39		
TEMPERATURE	5	40	0.50	0.10	0.05		
TURBIDITY	3	60	1.00	0.15	0.15		
OXYGEN	4	50	0.50	0.12	0.06		
TOXICS	1	100	0.00	0.24	0.00		
TOTALS		410			0.74		
PHYSICO-CHEMICAL PERCENTAGE SCORE					**85.12**		
PHYSICO-CHEMICAL CATEGORY					**B**		
BOUNDARY CATEGORY							

Reasoning / Notes
TEACHA gives a rating of 1, but poor PES data
TEACHA gives a rating of 1, but poor PES data so adjusted to 0.5
Rating for TIN, PO4 and phyto is 0, but peri is 3. **Note that n=1 for peri and phyto**.
Little change expected from natural - land cover mostly indigenous forestry.
Some sedimentation expected from Simola Estate development further downstream.

Table D15 PAI table for EWR 2 for the AEC

SCORING GUIDELINES **EWR2** Gouna River (K5H001Q01): AEC

PHYSICO-CHEMICAL CHANGES							
Physico-chemical Metrics	**Rank**	**%wt**	**Rating**	**Weight**	**Weighted score**	**Flow related?**	**Confidence**
pH	5	40	0.50	0.10	0.05		Confidence in the assessment is **low** as no recent data for assessing PES. RC: n=76 ('77-'80); PES: n=30 ('81-'84).
SALTS	5	40	0.50	0.10	0.05		
NUTRIENTS	2	80	2.00	0.20	0.39		
TEMPERATURE	5	40	0.50	0.10	0.05		
TURBIDITY	3	60	1.00	0.15	0.15		
OXYGEN	4	50	0.50	0.12	0.06		
TOXICS	1	100	0.00	0.24	0.00		
TOTALS		410			0.74		
PHYSICO-CHEMICAL PERCENTAGE SCORE					**85.12**		
PHYSICO-CHEMICAL CATEGORY					**B**		
BOUNDARY CATEGORY							

Reasoning / Notes
TEACHA gives a rating of 1, but poor PES data
TEACHA gives a rating of 1, but poor PES data so adjusted to 0.5
Rating for TIN, PO4 and phyto is 0, but peri is 3. **Note that n=1 for peri and phyto**.
Little change expected from natural - land cover mostly indigenous forestry.
Increased clearing may lead to increased instream sedimentation.

D6 EWR 3: Upper Diep River

D6.1 DATA USED FOR EWR 3

Water quality station K4H003Q01 (Diep River @ Woodville Forest Reserve) was assessed for available data to be used for both PES and RC. The river data from this station was suitable to represent both the PES and the RC of the site, as the data ranges from 1971 to 2007.

D6.2 REFERENCE CONDITION

The earliest data years of water quality station K4H003Q01 were used to define the reference condition of the site. The data years start from 1977 - 1980 with 58 records (see Figure D6).

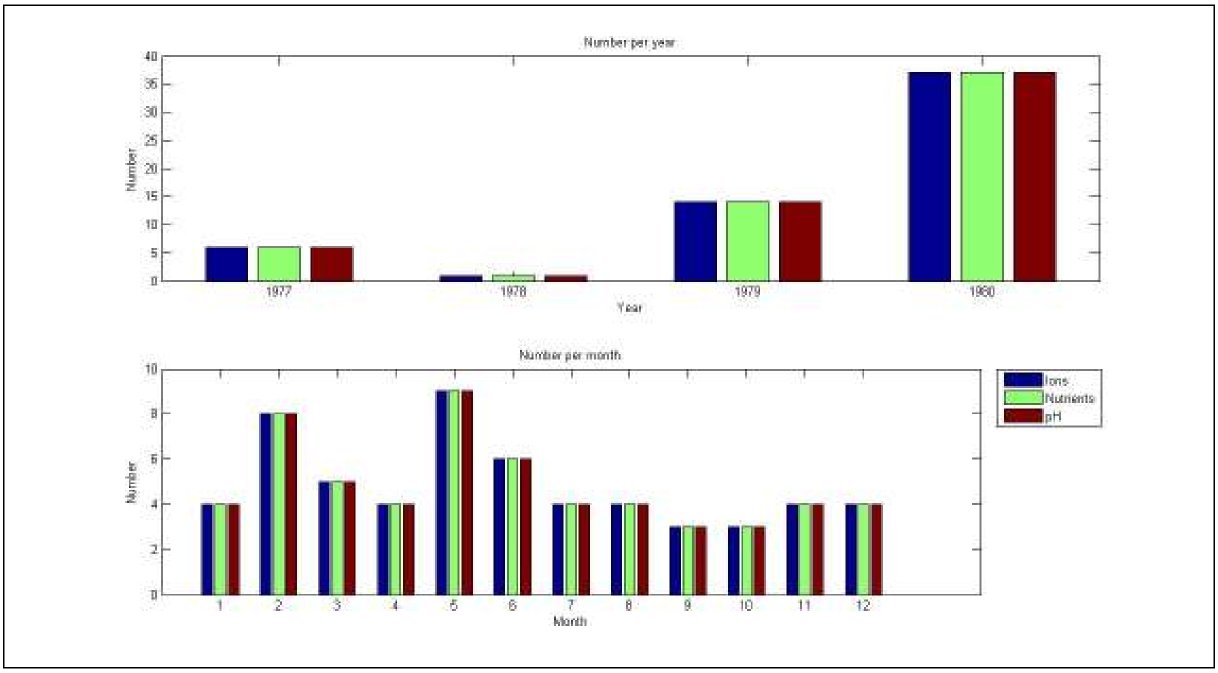


Figure D6 Data distribution graphs for Reference Condition at EWR 3

D6.3 PES

The most recent data years (i.e. 2003 - 2007) of station K4H003Q01 with 36 records were used to assess the water quality state for EWR 3 (see Figure D7). Figure D7 also illustrates that there was good annual and monthly representivity of ion, nutrient and pH data over the selected data record, covering possible dry and wet years, and dry and wet months respectively.

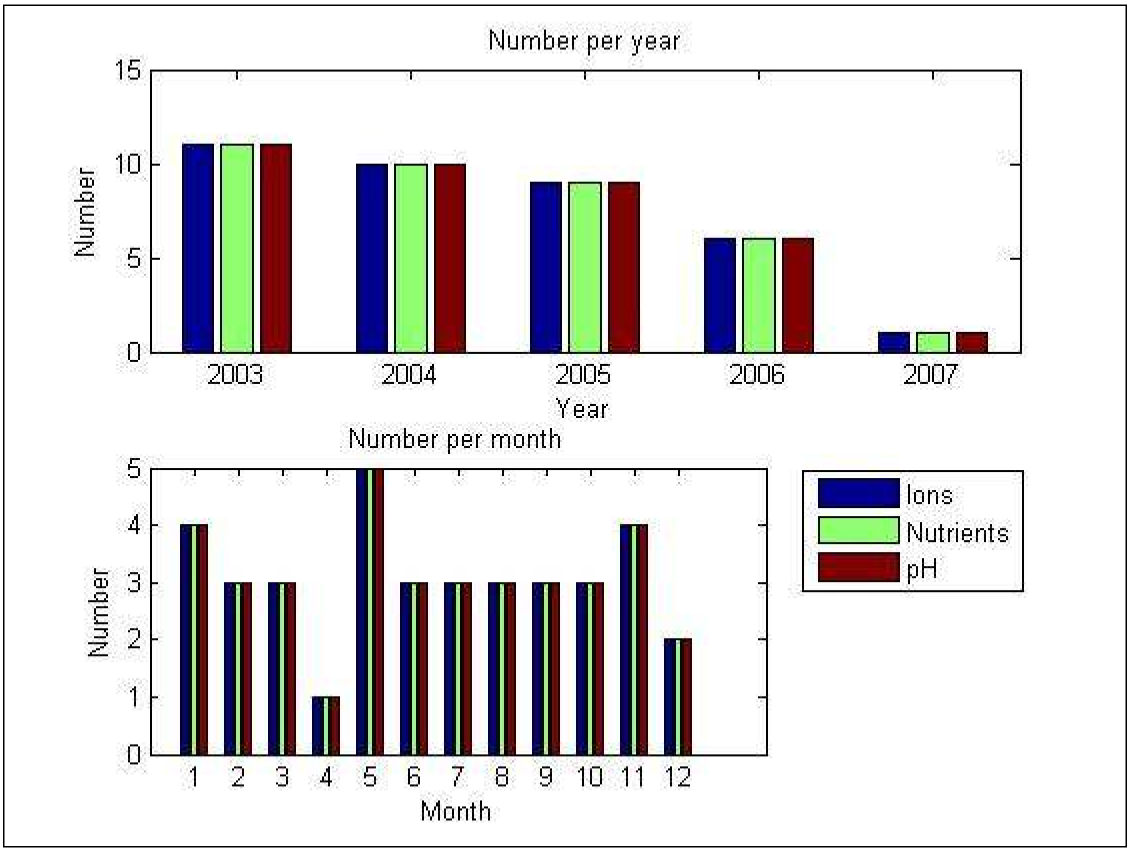


Figure D7 Data distribution graphs for PES at EWR 3

D6.4 RESULTS FOR EWR 3

The present ecological state of the water quality at this site is scored as a B category, and the assessment is of moderate-high confidence (Table D16). The AEC for this EWR site is a C category (Table D17), if more clearing for farming and more abstractions at low flows are expected. Farming related pesticide and fertilizer use may increase the impact by toxic substances, contributing to the change of the EWR site category from a B to a C category. Diatom assessment on this EWR site is based on one survey (Appendix H), with a total count of 434, with 13 species and an SPI score of 17.6 indicating high water quality.

Table D16 PAI table for EWR 3

SCORING GUIDELINES EWR3 Diep River (K4H003Q01): EWR site + WQSU

PHYSICO-CHEMICAL CHANGES								
Physico-chemical Metrics	**Rank**	**%wt**	**Rating**	**Weight**	**Weighted score**	**Flow related?**	**Confidence**	**Reasoning / Notes**
pH	3	80	1.00	0.16	0.16		Confidence in the assessment is **moderate-high (3)**. RC: n=58 ('77-'80); PES: n=37 ('03-'07).	
SALTS	6	40	0.00	0.08	0.00			
NUTRIENTS	2	90	2.00	0.18	0.35			Rating for TIN=0, PO4 and phyto=2, and peri=3 (manual assessment). **Note that n=1 for peri and phyto**.
TEMPERATURE	3	80	1.00	0.16	0.16			Little change expected from natural, although possibly less shading with forestry. Bedrock system.
TURBIDITY	5	50	0.50	0.10	0.05			Little evidence of sedimentation seen.
OXYGEN	4	70	0.50	0.14	0.07			
TOXICS	1	100	0.00	0.20	0.00			
TOTALS		510			0.78			
PHYSICO-CHEMICAL PERCENTAGE SCORE					**84.31**			
PHYSICO-CHEMICAL CATEGORY					**B**			
BOUNDARY CATEGORY								

Table D17 PAI table for EWR 3: AEC

SCORING GUIDELINES EWR3 Diep River (K4H003Q01): AEC (C category)

PHYSICO-CHEMICAL CHANGES								Reasoning / Notes
Physico-chemical Metrics	**Rank**	**%wt**	**Rating**	**Weight**	**Weighted score**	**Flow related?**	**Confidence**	
pH	3	80	1.00	0.16	0.16		Confidence in the assessment is **moderate-high (3)**. RC: n=58 ('77-'80); PES: n=37 ('03-'07).	
SALTS	6	40	0.00	0.08	0.00			
NUTRIENTS	2	90	3.00	0.18	0.53			More clearing for farming
TEMPERATURE	3	80	1.50	0.16	0.24			More abstraction + low flows. Bedrock system so expect temperature increases.
TURBIDITY	5	50	1.00	0.10	0.10			Land clearing
OXYGEN	4	70	0.50	0.14	0.07			
TOXICS	1	100	0.50	0.20	0.10			Farming-related pesticide / fertilizer use.
TOTALS		510			1.19			
PHYSICO-CHEMICAL PERCENTAGE SCORE					**76.27**			
PHYSICO-CHEMICAL CATEGORY					**C**			
BOUNDARY CATEGORY								

D7 EWR 4: Upper Karatara River

D7.1 DATA USED FOR EWR 4

Water quality station K4H002Q01 (Karatara River @ Karatara Forest Reserve) was used for both RC and PES. Data from 1976 - 1979 (n = 115) was used to define RC, and data from 2003 - 2007 (n = 37) for PES.

D7.2 REFERENCE CONDITION

The earliest data of a suitable confidence (i.e. ions, nutrients and pH) from water quality station K4H002Q01 were used to define the reference condition of the site. Data selected is from 1976 - 1979, i.e. 115 records.

Figure D8 illustrates that there was good annual and monthly representivity of salt ions, nutrient and pH data over the selected data record, covering possible dry and wet years, and dry and wet months respectively.

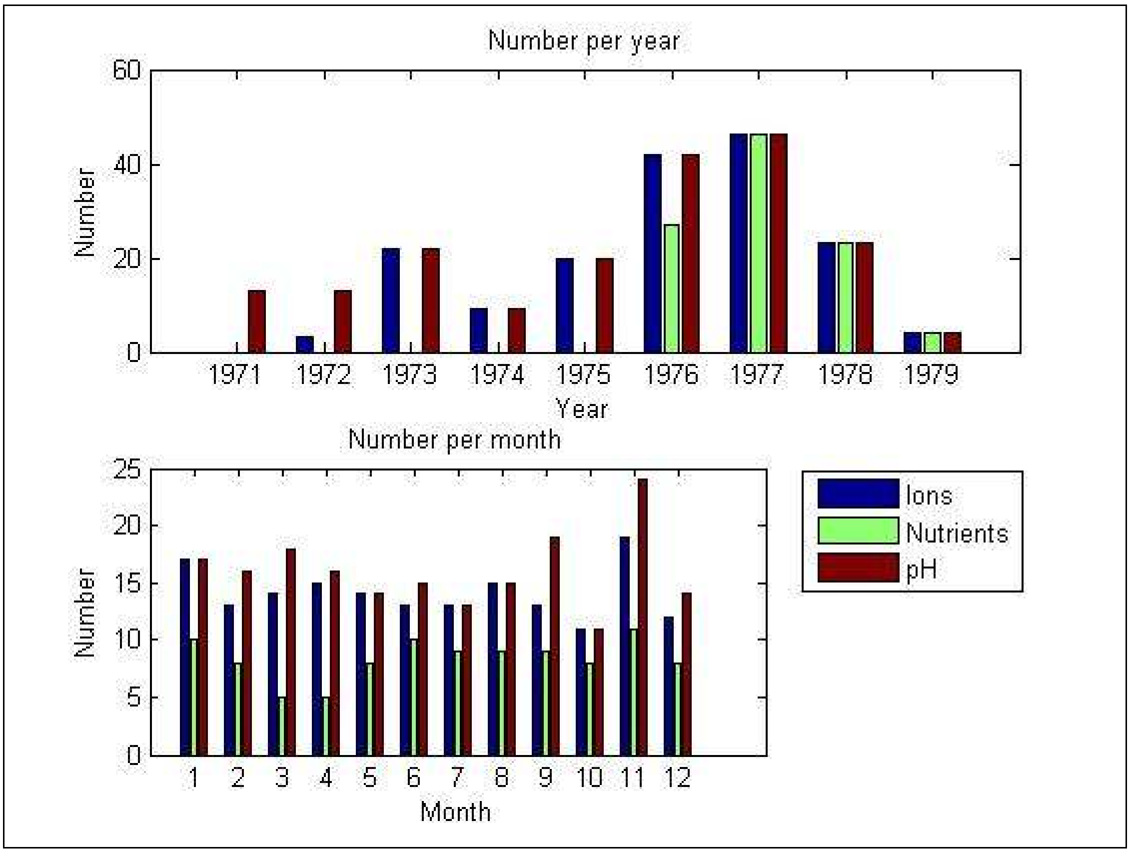


Figure D8 Data distribution graphs for RC at EWR 4

D7.3 PES

The most recent data years (i.e. 2003 - 2007) of station K4H003Q01 with 36 records were used to conduct the water quality assessment for EWR 4 (see Figure D9). Figure D9 also illustrates that there was good annual and monthly representivity of ion, nutrient and pH data over the selected data record.

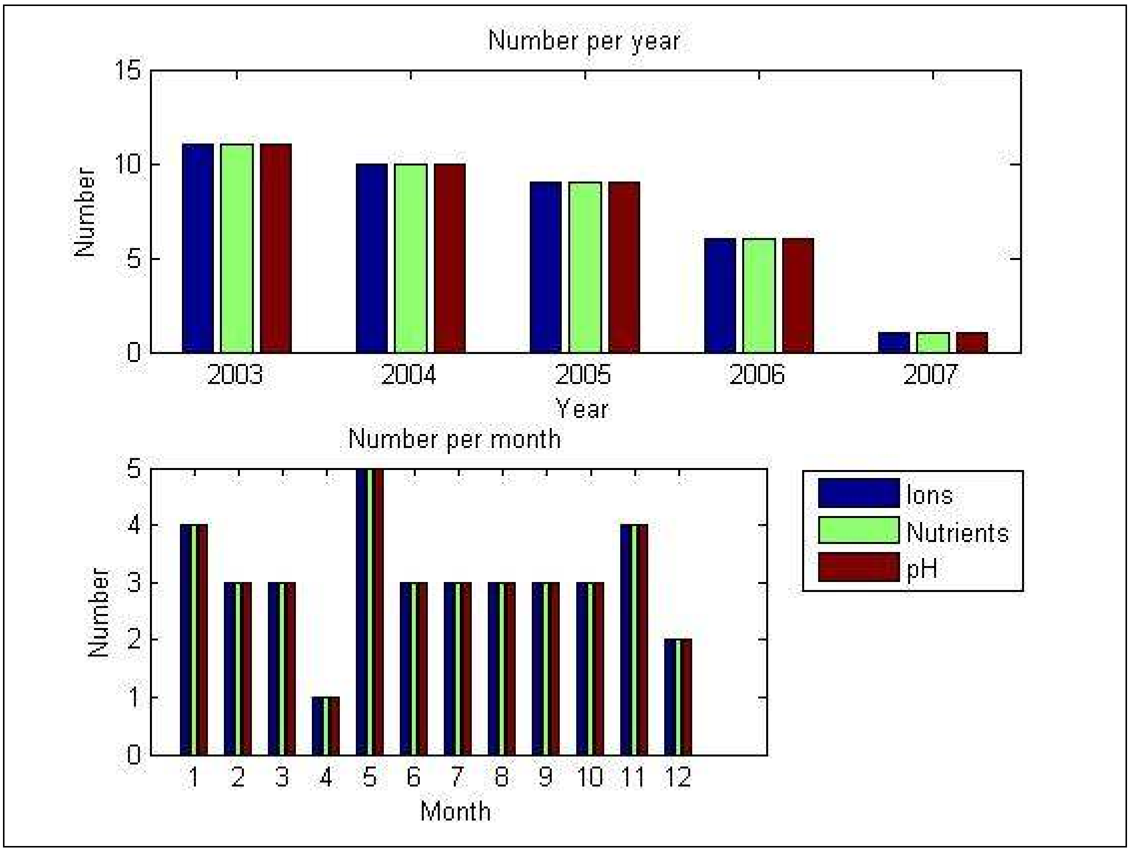


Figure D9 Data distribution graphs for PES at EWR 4

D7.4 RESULTS FOR EWR 4

The present ecological state of the water quality at this site is scored as a B category, with the assessment being of moderate confidence (Table D18). Little change from the natural state is evident, other than some nutrient loading, sedimentation and timber processing at Geelhoutvlei. Due to the more pristine nature at the site and upstream section of the river in the forest, an EC of an A is reported for the upstream section (Table D19). The alternative ecological category for this EWR site was a B category (Table D20), if more clearing for farming and farming-related pesticide and fertilizer increases.

Table D18 PAI table for EWR 4

PHYSICO-CHEMICAL CHANGES							
Physico-chemical Metrics	Rank	%wt	Rating	Weight	Weighted score	Flow related?	Confidence
pH	3	70	0.00	0.15	0.00		Confidence in the assessment is **moderate**. RC: n=115 ('76-'79); PES: n=37 ('03-'07).
SALTS	5	40	0.00	0.09	0.00		
NUTRIENTS	2	85	1.00	0.19	0.19		
TEMPERATURE	4	60	1.00	0.13	0.13		
TURBIDITY	5	40	0.50	0.09	0.04		
OXYGEN	4	60	1.00	0.13	0.13		
TOXICS	1	100	1.00	0.22	0.22		
TOTALS	455				0.71		
PHYSICO-CHEMICAL PERCENTAGE SCORE					85.71		
PHYSICO-CHEMICAL CATEGORY					B		
BOUNDARY CATEGORY							

Reasoning / Notes
Rating for TIN and phyto=0, PO4 and phyto=1, TEACHA gave a 2 rating for nutrients.
Little change expected from natural.
Little evidence of sedimentation seen. Banks stable.
Timber processing e.g. Geelhoutvlei

Table D19 PAI table for EWR 4: Site and upstream

PHYSICO-CHEMICAL CHANGES							
Physico-chemical Metrics	Rank	%wt	Rating	Weight	Weighted score	Flow related?	Confidence
pH	3	70	0.00	0.15	0.00		Confidence in the assessment is **moderate**. RC: n=115 ('76-'79); PES: n=37 ('03-'07).
SALTS	5	40	0.00	0.09	0.00		
NUTRIENTS	2	85	1.00	0.19	0.19		
TEMPERATURE	4	60	0.00	0.13	0.00		
TURBIDITY	5	40	0.50	0.09	0.04		
OXYGEN	4	60	0.00	0.13	0.00		
TOXICS	1	100	0.00	0.22	0.00		
TOTALS	455				0.23		
PHYSICO-CHEMICAL PERCENTAGE SCORE					95.38		
PHYSICO-CHEMICAL CATEGORY					A		
BOUNDARY CATEGORY							

Reasoning / Notes
Rating for TIN and phyto=0, PO4 and phyto=1, TEACHA gave a 2 rating for nutrients.
Little change expected from natural.
Little evidence of sedimentation seen. Banks stable.

Table D20 PAI table for EWR 4: AEC

PHYSICO-CHEMICAL CHANGES							
Physico-chemical Metrics	Rank	%wt	Rating	Weight	Weighted score	Flow related?	Confidence
pH	3	70	0.00	0.15	0.00		Confidence in the assessment is **moderate**. RC: n=115 ('76-'79); PES: n=37 ('03-'07).
SALTS	5	40	0.00	0.09	0.00		
NUTRIENTS	2	85	2.00	0.19	0.37		
TEMPERATURE	4	60	1.00	0.13	0.13		
TURBIDITY	5	40	2.00	0.09	0.18		
OXYGEN	4	60	0.00	0.13	0.00		
TOXICS	1	100	0.50	0.22	0.11		
TOTALS	455				0.79		
PHYSICO-CHEMICAL PERCENTAGE SCORE					84.18		
PHYSICO-CHEMICAL CATEGORY					B		
BOUNDARY CATEGORY							

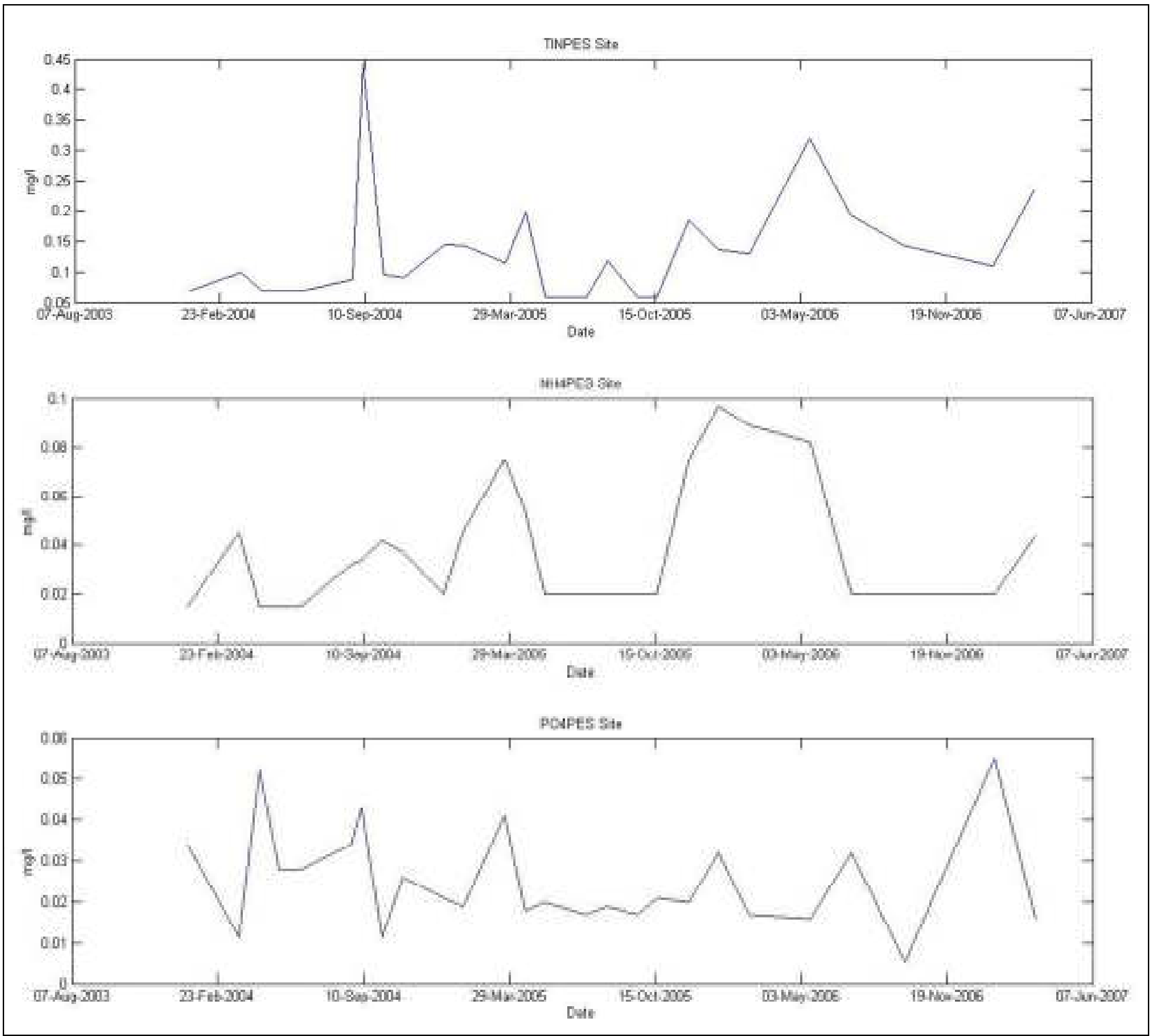
Reasoning / Notes
Increased nutrients with abstraction at low flows. Fires mobilize nutrients and increase TSS loads.
Less shading with increased aliens.
More sedimentation with mismanagement + clearing.
Farming activities

D8 GRAPHICAL REPRESENTATIONS OF WATER QUALITY DATA

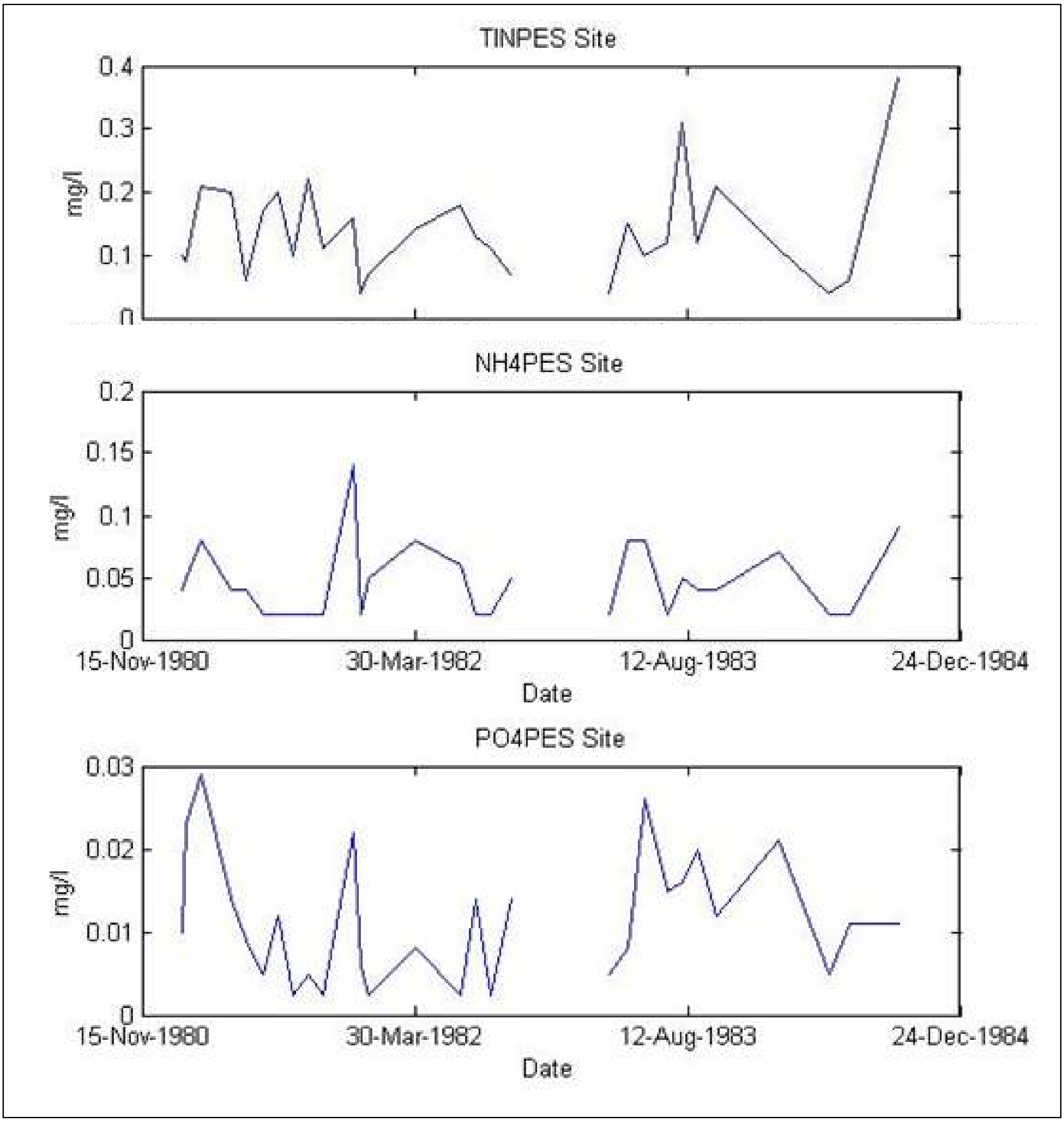
This section of the report includes graphical representations of water quality data per EWR site for nutrients under the present state, from the TEACHA output of the study. The sequence of graphs is as follows per site. Graphs of other variables, including aggregated salts, will be available on the data CD for the study.

- Total Inorganic Nitrogen (TIN)
- NH_4
- Phosphate

D8.1 EWR 1

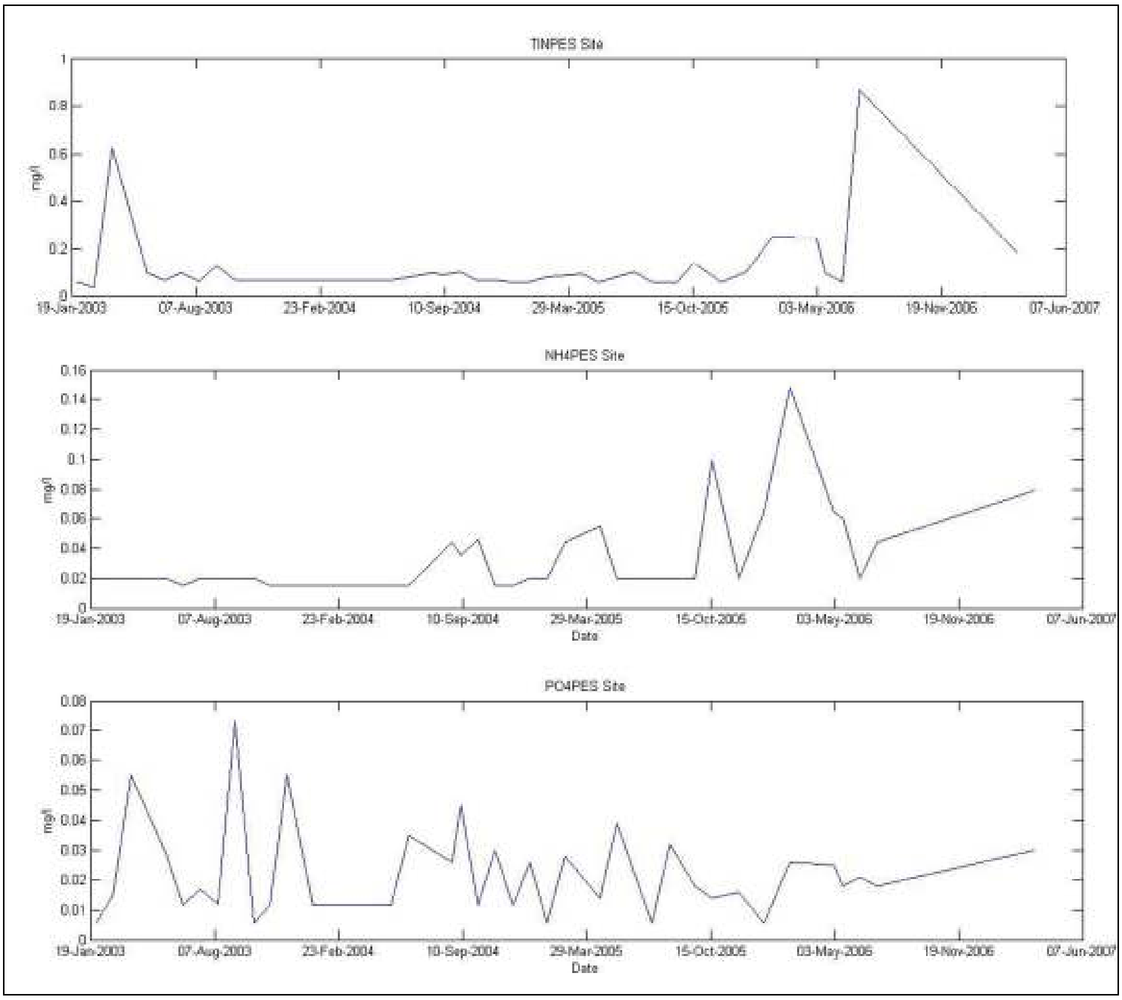


D8.2 EWR 2

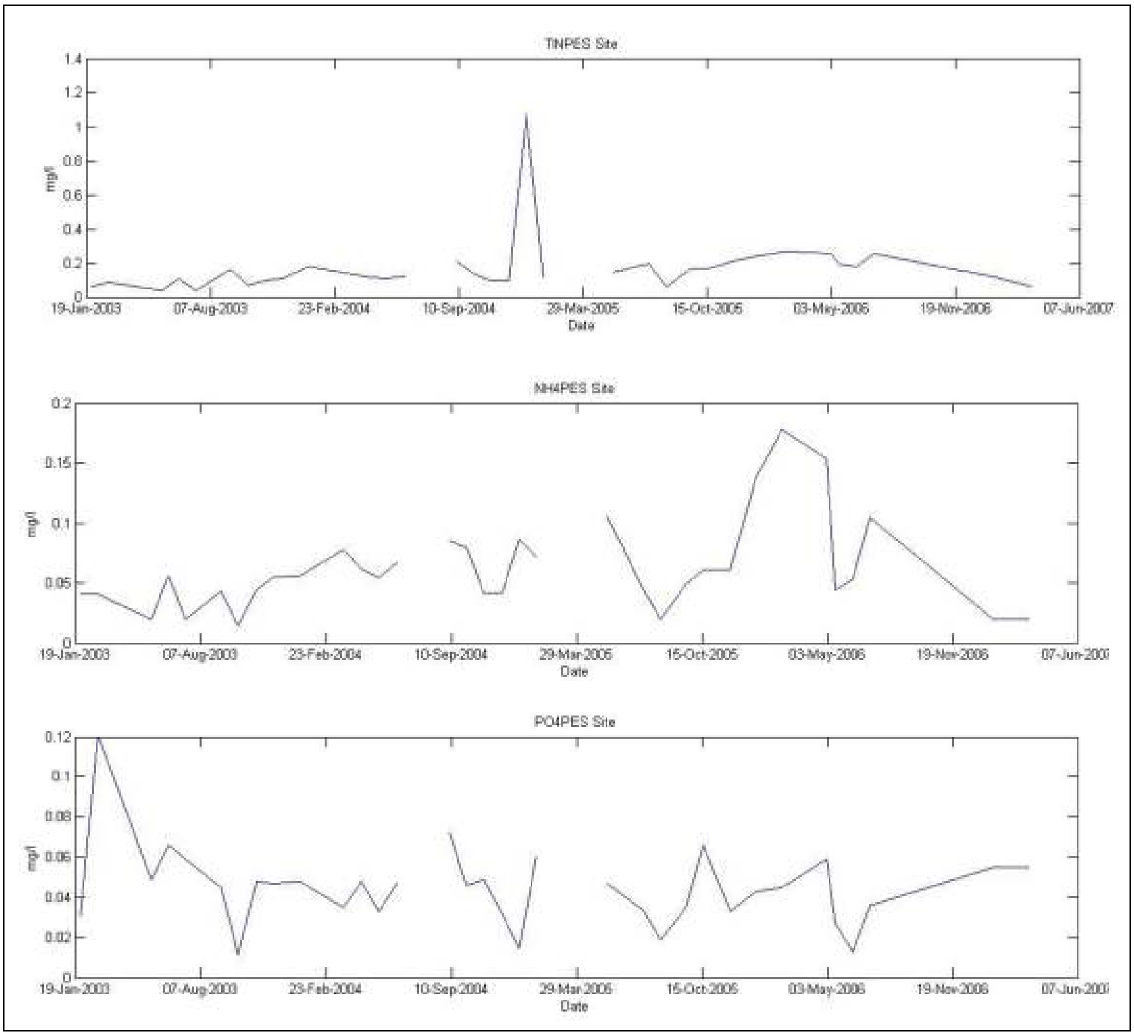


TINPES Site
mg/l
0.4
0.3
0.2
0.1
0
NH4PES Site
mg/l
0.2
0.15
0.1
0.05
0
15-Nov-1980
30-Mar-1982
12-Aug-1983
24-Dec-1984
Date
PO4PES Site
mg/l
0.03
0.02
0.01
0
15-Nov-1980
30-Mar-1982
12-Aug-1983
24-Dec-1984
Date

D8.3 EWR 3



D8.4 EWR 4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19-Jan-2003
07-Aug-2003
23-Feb-2004
10-Sep-2004
29-Mar-2005
15-Oct-2005
03-May-2006
19-Nov-2006
07-Jun-2007

D9 REFERENCES

Du Plessis JA, Allanson BR, Brown D, Harding B and Conrad J. (2004). Knysna Catchment Ecological Reserve determination study Phase 1: Situation assessment and rapid Reserve estimations. Draft 1, November 2004. ARCUS GIBB Report Number J23047A/2004/01.

Department of Water Affairs and Forestry (DWAF). (1996). South African water quality guidelines (second edition). Volume 7: Aquatic ecosystems Department of Water Affairs and Forestry, Pretoria.

Department of Water Affairs and Forestry (DWAF). (2004). Inclusion of electrical conductivity (EC) in water quality assessments within ecological Reserve determinations. Report prepared for Department of Water Affairs and Forestry, Pretoria.

Department of Water Affairs and Forestry (DWAF). (2007). Outeniqua Coast Water Situation Study. Supporting Report: Water Quality Draft Report prepared by Martin van Veelen and Dawid Maree of ILISO Consulting

Department of Water Affairs and Forestry (DWAF). (2008). Methods for determining the Water Quality component of the Ecological Reserve. Report prepared for Department of Water Affairs and Forestry, Pretoria, South Africa by P-A Scherman of Scherman Consulting

Froneman PW. (2007). Phytoplankton and periphyton biomass at selected sites within the Knysna and Swartvlei catchments. Coastal Research Group, Department of Zoology and Entomology, Rhodes University, Grahamstown. Report prepared for the Outeniqua Reserve study.

Holm-Hansen O and Riemann B. (1978). Chlorophyll-a determination: improvements in methodology. Oikios 30: 438 – 447.

Palmer CG, Muller WJ and Hughes DA. (2004). Chapter 6: Water quality in the ecological Reserve. IN: SPATSIM, an integrating framework for ecological Reserve and implementation: incorporating water quality and quantity components for rivers. Hughes DA (Ed.) WRC Report No. 1160/1/04, Water Research Commission, Pretoria.

APPENDIX E: FISH SPECIALIST REPORT
A BOK, Anton Bok Aquatic Consultants

E1 EWR 1: UPPER KNYSNA (KNYSNA RIVER) - ECOCLASSIFICATION

E1.1 SAMPLING AND SURVEY INFORMATION

One fish survey using an electric fish shocker was carried out at EWR 1 on 23 April 2007. Sampling conditions were good with low river flows. As the water was darkly stained, and no field assistant to help with netting and spotting fish, the Catch Per Unit (CPU) may be lower than expected. Sampling and data analysis was followed according to Kleynhans (2007). A summary of the site conditions during sampling is provided below. Abundance of habitat was rated as:

- 0 = absent
- 1 = rare
- 2 = sparse
- 3 = moderate
- 4 = abundant
- 5 = very abundant

E1.1.1 Fish velocity-depth classes and cover present at the site

SLOW DEEP	SLOW SHALLOW	FAST DEEP	FAST SHALLOW
40%	30%	10%	20%
Overhanging vegetation			
5	2	1	2
Undercut banks and root wads			
4	2	1	2
Substrate			
4	4	3	4
Aquatic macrophytes			
0	0	0	0
Water Column			
4	0	2	0
Remarks: Water tannin stained, visibility ca. 1 m.			

E1.1.2 Habitats sampled and effort

SAMPLING EFFORT	SLOW DEEP	SLOW SHALLOW	FAST DEEP	FAST SHALLOW
Electro shocker (min)	25 min	10 min	10 min	5 min

E1.1.3 Species sampled

SPECIES	SLOW DEEP	SLOW SHALLOW	FAST DEEP	FAST SHALLOW
P. afer	15	6	0	0

E1.2 DATA AVAILABILITY

E1.2.1 Historical Data

The Knysna River system has been relatively well-surveyed in the past and approximately twelve records are contained on the Albany Museum Fish Database for the period 1958 – 1984. No recent survey data were available from the upper reaches, and data from Charlesford weir was not applicable to EWR 1.

E1.2.2 Confidence of Data

A moderate to low confidence level (2), due to:

- Limited fishing effort of about 45 minutes.
- Sampling about 100m of river during the survey, due to time constraints.
- Extrapolation of relatively sparse catch data to the rest of the Management Resource Unit (MRU).
- The habitat at EWR 1 was also impacted to a moderate degree by the presence of a road causeway and gauging weir.

E1.3 REFERENCE CONDITION

From historical records and general fish distribution data, a total of four indigenous fish species was expected to be present in the upper Knysna River at EWR 1 (Table E1).

Table E1 Fish species expected at EWR 1 in the Knysna River

Species Expected	Found	Discussion
Pseudobarbus afer	Yes	Usually at high densities, readily seen and caught.
Sandelia capensis	No	Moderate to low densities in upper reaches (site possibly too high up in the system.) Species prefers low-gradient areas in lower reaches.
Anguilla mossambica	No	Moderate to low densities, adults not easily caught.
Anguilla marmorata	No	Low densities, not easily caught.

E1.4 PES

Although only one of potential four fish species was sampled during the survey, the habitat conditions were assessed as being very suitable, with relatively little change from the reference conditions. The good present state is supported by the high numbers and healthy population structure of the indigenous minnow (*P. afer*) found at the site. The PES was a B, with the Fish Response Assessment Index result of 86.4%

E2 EWR 1: UPPER KNYSNA (KNYSNA RIVER) – DETERMINATION OF STRESS INDICES AND EWR SCENARIOS

Section E2 provides supporting fish information for the determination of stress indices and EWR scenarios of EWR 1 (Chapter 5 and 6 of the Riverine RDM Report: Volume 1).

E2.1 FISH INDICATOR SPECIES

Pseudobarbus afer (PAFE) was used as species representing the small semi-rheophilic guild (SSR). The maximum size of PAFE is only about 10 cm, thus the depth requirements for both migration and breeding are relatively low. Preferred habitat is Slow Deep (SD) and some Slow Shallow (SS) with suitable cover. They are sensitive to poor water quality and thus, are found usually only in perennial or near-perennial streams. If conditions are suitable for the survival and breeding of *P. afer*, all other species will be catered for. The only species that prefers Fast Deep (FD) and Fast Shallow (FS) habitats, *A. mossambica*, is adaptable and utilises SD habitats.

E2.2 FISH STRESS INDEX

The abundance of fish velocity-depth classes are provided in Table E2.

Table E2 EWR 1: Habitat suitability for the SSR guild

SSR GUILD						
Depth classes	Discharges (m^3/s)					
	0.02	0.06	0.19	0.36	0.58	0.9
Fast (>0.3 m/s) Deep (> 0.3 m) (FD)	10	10	8	7	6	4
Fast (>0.3 m/s) Shallow (0.1 – 0.3 m) (FS)	10	8	4	2	2	2
Slow (<0.3 m/s) Deep (> 0.5 m) (SD)	0	0	2	2	2	2
Slow (<0.3 m/s) Shallow (0.1 – 0.3 m) (SS)	2	2	4	4	4	4
Overall habitat response	**6**	**5**	**5**	**4**	**4**	**3**

The fish stress index is provided in Table E3.

Table E3 Fish stress index

Habitat	Discharges (m^3/s)					
	0.02	0.06	0.19	0.36	0.58	0.9
SSR GUILD						
Breeding and early life-stages	1	2	3	4	5	5
Survival/Abundance	1	3	3	4	5	5
Cover	2	2	3	3	5	5
Health and condition	3	4	4	4	5	5
Water quality	2	3	4	4	5	5
Species stress: PAFE	**6.4**	**4.4**	**3.2**	**2.4**	**0**	**0**

E2.3 LOW FLOW REQUIREMENTS IN TERMS OF STRESS FOR FISH

The fish low flow requirements for the EWR scenarios are summarised in Table E4 for the SSR guild.

Table E4 Low flow requirements: SSR guild

GENERAL

Wet Season
P. afer spawns during the summer months, with a peak in spring and early summer (Oct to Dec) – thus spawning occurs during the wet season. They spawn in riffles with loose cobbles in fast flowing (>0.3 m/s) water at depths of > than 10 to 15 cm (i.e. FS habitat). Larvae require SS habitat with cover – overhanging vegetation or structure. Flow requirements are thus higher in the summer due to spawning requirements (FS and FD habitat over riffles) and higher temperatures impacting on water quality (lowered dissolved oxygen (DO) levels). Higher flow requirements are needed in the wet season due to flow depths required for spawning, egg incubation and larval rearing, as well as flow depths required to allow migration past critical shallow areas.

Dry Season
Equated to winter months. Adults require good quality water with cover (in the form of overhanging vegetation, instream structure and undercut banks) in the preferred habitat SD and some SS. Thus very low flows during dry winter months will still enable high survival, provided suitable cover and good water quality in pools are maintained, as food requirements will be reduced in low temperatures.

BUILDING BLOCK [1]	SEASON	STRESS DURATION	SPP STRESS	INTEG [2] STRESS	FLOW (m^3/s)
Drought	Dry	5%	8	8	0.01

These conditions will allow poor survival of *P. afer* in pools due to lack of food, reduced quality water, increased predation and disease, lack of connectivity between habitats, reduced access to food available in shallow habitats, scarcity of suitable cover will increase mortalities. If conditions persist for more than 5% of the time, the population could be decimated.

BUILDING BLOCK	SEASON	STRESS DURATION	SPP STRESS	INTEG STRESS	FLOW (m^3/s)
Drought	Wet	5%	8	8	0.01

Flow of 0.01 m^3/s will not allow any spawning to take place, high mortalities of adults will occur due to factors mentioned above, particularly water quality (e.g. due to iron bacteria growth) and connectivity. Species will disappear from the system if this condition continues longer than about 5% of time. A lack of breeding success and recruitment of *P. afer* could be critical as their life cycle is rapid with longevity of 3 to 4 years.

DRY SEASON REQUIREMENTS

BUILDING BLOCK	ECOSTATUS	FISH EC	STRESS DUR	SPP STRESS	INTEG STRESS	FLOW (m^3/s)
Maint[3] REC	B	B	40%	2.5	2.5	0.3

This flow will provide adequate survival of indicator species and allow good survival of other species. Most other preferred habitats will be available and although not quite optimal conditions, survival of viable populations of all fish species in most localities will be possible.

BUILDING BLOCK	ECOSTATUS	FISH EC	STRESS DUR	SP STRESS	INTEG STRESS	FLOW (m^3/s)
Maint AEC↓	C	C	40%	3.5	5	0.126

Flow will provide poor survival of *P. afer* and moderate survival of other species. Main impact will be poor recruitment and high mortalities due to the lack of FS habitat and poor quality of SD habitat available due to poor water quality and lack of suitable cover with high predation pressure.

WET SEASON REQUIREMENTS

BUILDING BLOCK	ECOSTATUS	FISH EC	STRESS DUR	SPP STRESS	INTEG STRESS	FLOW (m^3/s)
Maint REC	B	B	40%	2	2	0.4

Flow will also provide some breeding habitat although sub-optimal and breeding success will be moderate to good. This flow will provide good survival of indicator species and allow good survival of other species and viable populations to exist. Most other preferred habitats will be available, although slightly sub-optimal conditions in the form of lack of cover. Nearly all potentially available habitats in river system will be able to support viable populations of all fish species.

BUILDING BLOCK	ECOSTATUS	FISH EC	STRESS DUR	SPP STRESS	INTEG STRESS	FLOW (m^3/s)
Maint AEC↓	C	C	40	2.8	2.8	0.37

Will also provide adequate FS breeding habitat in riffle areas with moderate breeding success and survival of young, with some nursery habitats with adequate vegetative cover not available. This flow will provide moderate survival of indicator species and allow moderate to good survival of other species. Majority of sites in river will be able to support viable fish populations.

E3 EWR 2: GOUNA (GOUNA RIVER) - ECOCLASSIFICATION

E3.1 SAMPLING AND SURVEY INFORMATION

One fish survey using an electric fish shocker was carried out at EWR 2 on 23 April 2007. Sampling conditions were reasonable due to the low river flow, but sub-optimal habitat for eels and *P. afer* were present. The CPU could be lower than expected due to the water being very darkly stained and the surface covered with foam (i.e. impairing visibility), and no assistant to help with electro-fishing/netting activities. Sampling and data analysis was followed according to Kleynhans (2007). A summary of the site conditions during sampling is provided below.

E3.1.1 Fish velocity-depth classes and cover present at the site

SLOW DEEP	SLOW SHALLOW	FAST DEEP	FAST SHALLOW
60%	25%	5%	10%
Overhanging vegetation			
4	4	1	1
Undercut banks and root wads			
3	4	3	2
Substrate			
4	3	3	3
Aquatic macrophytes			
0	0	0	0
Water Column			
4	1	3	0
SD: Palmiet along edges, water darkly tannin stained, visibility ca. 60 – 80 cm. SS: Only Palmiet present along edge of river.			

E3.1.2 Habitats sampled and effort

SAMPLING EFFORT	SLOW DEEP	SLOW SHALLOW	FAST DEEP	FAST SHALLOW
Electro shocker (min)	20 min	20 min	5 min	5 min

E3.1.3 Species sampled

SPECIES	SLOW DEEP	SLOW SHALLOW	FAST DEEP	FAST SHALLOW
Sandelia capensis	18	11	0	0

E3.2 DATA AVAILABILITY

E3.2.1 Historical Data

The Gouna River system had not been adequately surveyed in the past and only two historical survey records were contained on the Albany Museum Fish Database. These were almost 50 years ago - dated 1958 for the period 1958 – 1984. One recent survey in 2006 (SAIAB database) was available for genetic material.

E3.2.2 Confidence of Data

A moderate to low confidence level (2) due to:

- Limited fishing effort of about 40 minutes and about 90 m of river during the survey due to time constraints.
- Extrapolation the relatively sparse catch data to the rest of the MRU.
- The habitat at EWR 2 was also impacted to a moderate degree by the presence of a road causeway and gauging/pumping weir and may not have been representative of MRU.

E3.3 REFERENCE CONDITION

From historical records and extrapolation of fish distribution data, a total of approximately four indigenous fish species was expected to be present in the Gouna River at EWR 2 (Table E5).

Table E5 Fish species expected at EWR 2 in the Gouna River

Species Expected	Found	Discussion
Pseudobarbus afer	No	Species readily seen and caught if present. Habitat was not optimal as the water colour was very dark, dense iron bacteria deposits were present in the backwaters.
Sandelia capensis	Yes	High numbers were found at site, and suitable habitats were available.
Anguilla mossambica	No	Occurs in low densities in marginal habitat and are not easily caught.
Anguilla marmorata	No	Occurs in low densities in marginal habitat and are not easily caught.

E3.4 PES

Although only one of potential four species was actually sampled during the survey, the habitat conditions were assessed as being suitable for fish, with relatively little change from the reference conditions. The good PES (93.8% - A EC) was supported by the high numbers and healthy population structure of the Cape kurper (*Sandelia capensis*) found at the site.

The major floods experienced in these Outeniqua rivers in mid-2006 appear not to have impacted seriously on the habitats at this locality, as shown by the presence of dense Palmiet stands in the river margins.

E4 EWR 2: GOUNA (GOUNA RIVER) – DETERMINATION OF STRESS INDICES AND EWR SCENARIOS

Section E4 provides supporting fish information for the determination of stress indices and EWR scenarios of EWR 2 (Chapter 7 and 8 of the Riverine RDM Report: Volume 1).

E4.1 FISH INDICATOR SPECIES

P. afer – Refer to Section E 2.1.1.

E4.2 FISH STRESS INDEX

The abundance of fish velocity-depth classes are provided in Table E6.

Table E6 EWR 2: Habitat suitability for the SSR guild

SSR GUILD							
Depth classes	**Discharges (m³/s)**						
	0.01	**0.03**	**0.06**	**0.12**	**0.30**	**0.51**	**0.93**
Fast (>0.3 m/s) Deep (> 0.3 m) (FD)	10	10	9	7	6	4	2
Fast (>0.3 m/s) Shallow (0.1 – 0.3 m) (FS)	8	6	6	6	4	2	0
Slow (<0.3 m/s) Deep (> 0.5 m) (SD)	0	0	0	0	0	0	0
Slow (<0.3 m/s) Shallow (0.1 – 0.3 m) (SS)	2	2	2	2	2	4	4
Overall habitat response	**5**	**5**	**4**	**4**	**3**	**3**	**2**

The fish stress index is provided in Table E7.

Table E7 Fish stress index

Habitat	**Discharges (m³/s)**					
	0.01	0.03	0.06	0.12	0.30	0.51
SSR GUILD						
Breeding and early life-stages	0.5	2	3	4	4	5
Survival/Abundance	1.5	3	3	4	4	5
Cover	3	3	4	5	5	5
Health and condition	3	4	4	4	5	5
Water quality	2	3	4	4	5	5
Species stress: PAFE	**6**	**4**	**2.8**	**1.6**	**0.8**	**0**

E4.3 LOW FLOW REQUIREMENTS IN TERMS OF STRESS FOR FISH

The fish low flow requirements for the EWR scenarios are summarised in Table E8 for the SSR guild.

Table E8 Low flow requirements: SSR guild

GENERAL

INDICATOR: *P. afer*
Wet Season and dry season: Refer to EWR 1, Table E4.

BUILDING[1] BLOCK	SEASON	STRESS DURATION	SPP STRESS	INTEG[2] STRESS	FLOW (m^3/s)
Drought	Dry	5%	3.5	6.5	0.04

These flows will allow for poor survival of *P. afer* in pools due to lack of food, reduced quality water, increased predation and disease, lack of connectivity between habitats, reduced access to food available in shallow habitats, and scarcity of suitable cover will increase mortalities. If conditions persist for more than 5% of time, the population could be decimated.

BUILDING BLOCK	SEASON	STRESS DURATION	SPP STRESS	INTEG STRESS	FLOW (m^3/s)
Drought	Wet	5%	2.3	5	0.079

A flow of 0.1m^3/s will not allow any spawning to take place, and high mortalities of adults due to factors mentioned above, particularly water quality (e.g. due to iron bacteria growth) and connectivity will occur. Species will disappear from the system if conditions continue for longer than about 5% of the time. Lack of breeding success, survival of larvae and thus recruitment of *P. afer* into the population could be critical as life cycle is rapid with longevity of 3 to 4 years.

DRY SEASON REQUIREMENTS

BUILDING BLOCK	ECOSTATUS	FISH EC	STRESS DUR	SPP STRESS	INTEG STRESS	FLOW (m^3/s)
Maint[3] REC	A/B	A	40%	1	2	0.307

This flow will provide adequate survival of indicator species and allow good survival of other species. Most other preferred habitats will be available and although sub-optimal conditions prevail, survival of viable populations of all fish species will be possible.

BUILDING BLOCK	ECOSTATUS	FISH EC	STRESS DUR	SP STRESS	INTEG STRESS	FLOW (m^3/s)
Maint AEC↓	B/C	B	40%	1.5	3	0.23

This flow will provide adequate survival of indicator species and allow good survival of other species. Most other preferred habitats will be available and although sub-optimal conditions prevail, survival of viable populations of all fish species will be possible.

WET SEASON REQUIREMENTS

BUILDING BLOCK	ECOSTATUS	FISH EC	STRESS DUR	SPP STRESS	INTEG STRESS	FLOW (m^3/s)
Maint REC	A/B	A	40%	0.3	1	0.384

Flows will provide some breeding habitat although sub-optimal and breeding success will be moderate to good. This flow will provide good survival of indicator species and allow good survival of other species and viable populations to exist in most reaches.

BUILDING BLOCK	ECOSTATUS	FISH EC	STRESS DUR	SPP STRESS	INTEG STRESS	FLOW (m^3/s)
Maint AEC↓	B/C	B	40	1	2	0.307

Flows will provide some breeding habitat although sub-optimal and breeding success will be moderate to good. This flow will provide good survival of indicator species and allow good survival of other species and viable populations to exist in most reaches.

1 Flow building block refers to drought and maintenance flows (King and Louw, 1998). Note that DROUGHTS ARE THE SAME FOR ALL CATEGORIES. This is applicable to all sites.
2 Integrated 3 Maintenance

E5 EWR 3: UPPER DIEP (DIEP RIVER) - ECOCLASSIFICATION

E5.1 SAMPLING AND SURVEY INFORMATION

One fish survey using an electric fish shocker was carried out at EWR 3 on 24 April 2007. Sampling conditions were excellent due to the low river flow, shallow pools with white sand and very clear water which allowed all fish present to be seen. Sampling and data analysis was followed according to Kleynhans (2007). A summary of the site conditions during sampling is provided below.

E5.1.1 Fish velocity-depth classes and cover present at the site

SLOW DEEP	SLOW SHALLOW	FAST DEEP	FAST SHALLOW
40%	40%	5%	15%
Overhanging vegetation			
4	3	0	1
Undercut banks and root wads			
3	3	0	2
Substrate			
2	3	3	1
Aquatic macrophytes			
1	1	0	0
Water Column			
1	0	1	0
SD: No Palmiet was present, water lightly stained, visibility ca. > 1 m. FD: Very clear water, bottom of most pools visible. FS: Bedrock usually present in FS habitats.			

E5.1.2 Habitats sampled and effort

SAMPLING EFFORT	SLOW DEEP	SLOW SHALLOW	FAST DEEP	FAST SHALLOW
Electro shocker (min)	20 min	15 min	5 min	10 min

E5.1.3 Species sampled

SPECIES	SLOW DEEP	SLOW SHALLOW	FAST DEEP	FAST SHALLOW
Micropterus salmoides	14	0	0	0

E5.2 DATA AVAILABILITY

E5.2.1 Historical Data

No records for the upper Diep River were found in the Albany Museum or the SAIAB Fish Database. SANParks surveys with the River Health study (*pers. comm.*, Ian Russel, April 2007) reported no fish in the upper Diep and only alien bass (*Micropterus* spp.) and mosquito fish (*Gambusia affinis*) in the middle reaches. FROC data was therefore used.

E5.2.2 Confidence of Data

A moderate to low confidence level (2) due to:

- Limited fishing effort of about 50 minutes and about 200 m of river during the survey due to time constraints.
- Extrapolation of relatively sparse catch data to the rest of the MRU.
- The EWR site was located downstream of a road causeway and gauging weir and may not have been representative of MRU.

E5.3 REFERENCE CONDITION

From historical records and general fish distribution data, a total of approximately four indigenous fish species was expected to be present in the Diep River at EWR 3 (Table E9).

Table E9 Fish species expected at EWR 3 in the Diep River

Species Expected	Found	Discussion
Pseudobarbus afer	No	Often occur at high densities but are readily seen and caught.
Sandelia capensis	No	High numbers are found under natural conditions.
Anguilla mossambica	No	Occurs in low densities and are not easily caught.
Anguilla marmorata	No	Occurs in low densities and are not easily caught.

E5.4 PES

Only one species of alien smallmouth bass, *M. salmoides*, was found at the site in large numbers, juveniles, sub-adults and adults. This presence of this highly effective alien predatory bass had probably exterminated the indigenous fish species *P. afer* and *S. capensis* in this locality. These native species, which should have been be present in large numbers (see above), do not have effective predator-avoidance behaviour and are very vulnerable to predation in small, shallow streams with clear water as present at this EWR site.

The major floods experienced in these Outeniqua Rivers in mid-2006 may have had a significant negative impact on fish in the upper, high gradient reaches of this river system, flushing fish downstream. This supposition was taken into account during the FRAI assessment process.

The PES (86.1% - B EC) was assessed by ignoring the impact of alien fish and assessing how the original (expected) endemic fish would have responded to habitat changes in this MRU, as assessed at the EWR site.

E6 EWR 3: UPPER DIEP (DIEP RIVER) - DETERMINATION OF STRESS INDICES AND EWR SCENARIOS

Section E6 provides supporting fish information for the determination of stress indices and EWR scenarios of EWR 3 (Chapter 9 and 10 of the Riverine RDM Report: Volume 1).

E6.1 FISH INDICATOR SPECIES

P. afer – Refer to Section E 2.1.1.

E6.2 FISH STRESS INDEX

The abundance of fish velocity-depth classes are provided in Table E10.

Table E10 EWR 3: Habitat suitability for the SSR guild

SSR GUILD					
Depth classes	Discharges (m^3/s)				
	0.009	0.03	0.075	0.19	0.37
Fast (>0.3 m/s) Deep (> 0.3 m) (FD)	10	10	10	10	8
Fast (>0.3 m/s) Shallow (0.1 – 0.3 m) (FS)	10	8	4	4	0
Slow (<0.3 m/s) Deep (> 0.5 m) (SD)	4	2	2	0	0
Slow (<0.3 m/s) Shallow (0.1 – 0.3 m) (SS)	4	4	2	2	2
Overall habitat response	**7**	**6**	**4**	**4**	**3**

The fish stress index is provided in Table E11.

Table E11 Fish stress index

Habitat	Discharges (m^3/s)				
	0.009	0.03	0.075	0.19	0.37
SSR GUILD					
Breeding and early life-stages	0.5	1	3	4	5
Survival/Abundance	1.5	2	4	4	5
Cover	1	2	4	5	5
Health and condition	2	3	4	5	5
Water quality	3	4	4	5	5
Species stress: PAFE	**6.8**	**5.2**	**2.4**	**0.8**	**0**

E6.3 LOW FLOW REQUIREMENTS IN TERMS OF STRESS FOR FISH

The fish low flow requirements for the EWR scenarios are summarised in Table E12 for the SSR guild.

Table E12 Low flow requirements: SSR guild

GENERAL

INDICATOR: *P. afer*
Wet Season and dry season: Refer to EWR 1, Table E4.

BUILDING BLOCK	SEASON	STRESS DUR	SPP STRESS	INTEG STRESS	FLOW (m^3/s)
Drought	Dry	5%	8	8	0.007

A trickle of flow will allow only poor survival of *P. afer* in pools due to lack of food, reduced quality water, increased predation and disease, lack of connectivity between habitats, reduced access to food available in inaccessible habitats, scarcity of suitable cover will increase mortalities. If conditions persist for more than 10% of the time, decimation of the population could occur.

BUILDING BLOCK	SEASON	STRESS DUR	SPP STRESS	INTEG STRESS	FLOW (m^3/s)
Drought	Wet	5%	5.8	6.8	0.018

No spawning will take place, and high mortalities of adults due to factors mentioned above will occur as particularly water quality (e.g. due to iron bacteria growth) and connectivity will be absent. Species will disappear from the system if conditions continue for longer than about 5% of the time. Lack of breeding success, survival of larvae and thus recruitment of *P. afer* into the population could be critical as their life cycle is rapid with longevity of 3 to 4 years.

DRY SEASON REQUIREMENTS

BUILDING BLOCK	ECOSTATUS	FISH EC	STRESS DUR	SPP STRESS	INTEG STRESS	FLOW (m^3/s)
Maint REC	B	B	40%	4	5	0.046

This flow will provide adequate survival of indicator species and allow good survival of other species. Most other preferred habitats will be available and although under sub-optimal conditions, survival of viable populations of all fish species will be possible.

BUILDING BLOCK	ECOSTATUS	FISH EC	STRESS DUR	SP STRESS	INTEG STRESS	FLOW (m^3/s)
Maint AEC↓	C	C	40%	5	6	0.031

Flow will provide poor survival of *P. afer* and moderate survival of other species. The main impact will be poor recruitment and high mortalities due to lack of FS habitat and poor quality of SD habitat availability due to poor water quality and lack of suitable cover with high predation pressure.

WET SEASON REQUIREMENTS

BUILDING BLOCK	ECOSTATUS	FISH EC	STRESS DUR	SPP STRESS	INTEG STRESS	FLOW (m^3/s)
Maint REC	B	B	40%	2.5	3.5	0.067

Flows will provide some breeding habitat albeit sub-optimal and breeding success will be moderate to good. This flow will provide good survival of indicator species and allow good survival of other species and viable populations to exist in most reaches.

BUILDING BLOCK	ECOSTATUS	FISH EC	STRESS DUR	SPP STRESS	INTEG STRESS	FLOW (m^3/s)
Maint AEC↓	C	C	40%	3.5	4.5	0.05

Flows will provide poor breeding habitat with poor to moderate breeding success and survival of young. This flow will provide moderate survival of indicator species and allow moderate survival of other species and viable but less frequently occurring populations to exist. Most other preferred habitats will be available and although sub-optimal as there will be a lack of cover.

E7 EWR 4: KARATARA (KARATARA RIVER) - ECOCLASSIFICATION

E7.1 SAMPLING AND SURVEY INFORMATION

One fish survey using an electric fish shocker was carried out at EWR 4 on 24 April 2007. Sampling conditions were good due to the low river flow and shallow pools. But the site was in deep shade and combined with darkly-stained water (i.e. low visibility) aquatic life was difficult to spot. Sampling and data analysis was followed according to Kleynhans (2007). A summary of the site conditions during sampling is provided below.

E7.1.1 Fish velocity-depth classes and cover present at the site

SLOW DEEP	SLOW SHALLOW	FAST DEEP	FAST SHALLOW
45%	35%	5%	15%
Overhanging vegetation			
1	1	0	0
Undercut banks and root wads			
1	1	0	0
Substrate			
2	2	2	1
Aquatic macrophytes			
0	0	0	0
Water Column			
3	0	2	0
SD: No Palmiet was present, and there was very little marginal vegetation. Water was very darkly stained with visibility ca. < 80 cm. SS: Comprised of mainly bedrock with some large rocks and boulders. FD: Very stained water, bottom of most pools not visible. FS: Bedrock usually present in FS habitats.			

E7.1.2 Habitats sampled and effort

SAMPLING EFFORT	SLOW DEEP	SLOW SHALLOW	FAST DEEP	FAST SHALLOW
Electro shocker (min)	20 min	15 min	5 min	10 min

E7.1.3 Species sampled

SPECIES	SLOW DEEP	SLOW SHALLOW	FAST DEEP	FAST SHALLOW
No fish sampled or seen	0	0	0	0

E7.2 DATA AVAILABILITY

E7.2.1 Historical Data

A total of four records for the Karatara River (1972 and 1986) were found in the Albany Museum Data Base with no records in the SAIAB Fish Database. SANParks surveys with the River Health study (*pers. comm*., Ian Russel, April 2007) included the upper Karatara River. Data from the FROC study was utilised.

E7.2.2 Confidence of Data

A low to moderate confidence level (2) due to:

- Limited fishing effort of about 40 minutes and about 80 m of river during the survey due to time constraints and the approach of a heavy thunderstorm. Further sampling at other sites within the MRU may have revealed the presence of fish.
- The presence of mainly bedrock pools with very sparse instream or riparian vegetation.
- Extrapolation of sparse catch data to the rest of the MRU.
- The EWR site was located downstream of a bridge and a high gauging weir.

E7.3 REFERENCE CONDITION

From historical records and fish distribution data extrapolated from adjacent similar systems, a total of approximately three indigenous fish species was expected to be present in the Karatara River (Table E13).

Table E13 Fish species expected at EWR 4 in the Karatara River

Species Expected	Found	Discussion
Pseudobarbus afer	No	Often occur at high densities but are readily seen and caught.
Sandelia capensis	No	High numbers are found under suitable natural conditions, but these species prefer SD habitats. The most probably occur naturally in low frequency of occurrence at EWR 4 and in the MRU.
Anguilla mossambica	No	Occurs in low densities and are not easily caught.

E7.4 PES

No fish at all were captured at EWR 4 during the survey. The major floods experienced in these Outeniqua Rivers in mid-2006 were considered to have scoured out this steep, bedrock section of the upper Karatara and reduced the FROC of fish species, particularly those with a preference for SD habitats (e.g. *S. capensis*). The fish populations were still considered to be well below “normal” pre-flood levels. This supposition was taken into account during the FRAI assessment process. The PES (82.4% - B EC) was determined by assessing the instream fish habitat and by assuming that *P. afer* and *S. capensis* (historically recorded) and the eel (*A. mossambica*), which is naturally very difficult to sample, were indeed present (in low numbers) within the MRU.

E8 EWR 4: KARATARA (KARATARA RIVER) – DETERMINATION OF STRESS INDICES AND EWR SCENARIOS

Section E8 provides supporting fish information for the determination of stress indices and EWR scenarios of EWR 4 (Chapter 11 and 12 of the Riverine RDM Report: Volume 1).

E8.1 FISH INDICATOR SPECIES

P. afer – Refer to Section E 2.1.1.

E8.2 FISH STRESS INDEX

The abundance of fish velocity-depth classes are provided in Table E14.

Table E14 EWR 3: Habitat suitability for the SSR guild

SSR GUILD					
Depth classes	Discharges (m^3/s)				
	0.004	0.01	0.032	0.094	0.15
Fast (>0.3 m/s) Deep (> 0.3 m) (FD)	10	10	8	8	8
Fast (>0.3 m/s) Shallow (0.1 – 0.3 m) (FS)	10	9	8	6	4
Slow (<0.3 m/s) Deep (> 0.5 m) (SD)	8	6	6	6	4
Slow (<0.3 m/s) Shallow (0.1 – 0.3 m) (SS)	0	0	2	2	2
Overall habitat response	**7**	**6**	**6**	**6**	**5**

The fish stress index is provided in Table E15.

Table E15 Fish stress index

Habitat	Discharges (m^3/s)				
	0.004	0.01	0.032	0.094	0.15
SMALL SEMI-RHEOPHILIC (SSR) GUILD					
Breeding and early life-stages	0	0.5	3	4	5
Survival/Abundance	1	2	3	4	5
Cover	1	2	4	5	5
Health and condition	2	3	4	5	5
Water quality	2	3	4	5	5
Species stress: PAFE	**7.6**	**5.8**	**2.8**	**0.8**	**0**

E8.3 LOW FLOW REQUIREMENTS IN TERMS OF STRESS FOR FISH

The fish low flow requirements for the EWR scenarios are summarised in Table E16 for the SSR guild.

Table E16 Low flow requirements: SSR guild

GENERAL

INDICATOR: *P. afer*
Wet Season and dry season: Refer to EWR 1, Table E4.

BUILDING BLOCK	SEASON	STRESS DURATION	SPP STRESS	INTEG STRESS	FLOW (m^3/s)
Drought	Dry	5%	5.5	6	0.0135

A trickle of flow will allow the poor survival of *P. afer* in pools due to lack of food, reduced quality water, increased predation and disease, lack of connectivity between habitats, reduced access to food available in shallow habitats, and scarcity of suitable cover will increase mortalities. If conditions persist for more than 10% of the time, the population could be decimated.

BUILDING BLOCK	SEASON	STRESS DURATION	SPP STRESS	INTEG STRESS	FLOW (m^3/s)
Drought	Wet	5%	5	5	0.017

Very minimal spawning will take place, high mortalities of eggs and larvae will occur due to lack of suitable flows and there will be poor survival of adults due to the of lack of connectivity between pools. Species will disappear from the system if these conditions continue for more than 5% of time. Lack of breeding success, survival of larvae and thus recruitment of *P. afer* into the population could be critical as their life cycle is rapid with longevity of 3 to 4 years.

DRY SEASON REQUIREMENTS

BUILDING BLOCK	ECOSTATUS	FISH EC	STRESS DUR	SPP STRESS	INTEG STRESS	FLOW (m^3/s)
Main REC	A/B	B	40%	2.8	3	0.06

This flow will provide adequate habitats, water quality and food and hence the survival of indicator species and allow good survival of other species as well. Most other preferred habitats will be available although conditions will be sub-optimal conditions. Survival of viable populations of all fish species will be possible.

BUILDING BLOCK	ECOSTATUS	FISH EC	STRESS DUR	SP STRESS	INTEG STRESS	FLOW (m^3/s)
Maint AEC↓	B/C	C	40%	4	4	0.025

Flow will provide poor survival of *P. afer* and moderate survival of other species. The main impact will be poor recruitment and high mortalities due to the lack of FS habitat and poor quality of SD habitat available because of poor water quality and lack of suitable cover under high predation pressure.

WET SEASON REQUIREMENTS

BUILDING BLOCK	ECOSTATUS	FISH EC	STRESS DUR	SPP STRESS	INTEG STRESS	FLOW (m^3/s)
Maint REC	A/B	B	40%	2	2	2

Flows will provide some breeding habitat although sub-optimal and breeding success will be moderate. This flow will provide good survival of indicator species and allow good survival of other species and viable populations to exist. Most other preferred habitats will be available, although sub-optimal as there will be a lack of cover.

BUILDING BLOCK	ECOSTATUS	FISH EC	STRESS DUR	SPP STRESS	INTEG STRESS	FLOW (m^3/s)
Maint AEC↓	B/C	C	40%	2.8	3	0.032

Flows will provide an adequate amount of moderate breeding habitat, and ensure moderate breeding success and survival of young. This flow will provide moderate survival of indicator species and allow good survival of other species and viable but slightly less than optimum frequent occurrence of populations. Most other preferred habitats will be available, although sub-optimal as there will be a lack of cover.

E9 REFERENCES

Kleynhans CJ. 2007. Module D: Fish Response Assessment Index in River EcoClassification: Manual for EcoStatus Determination (version 2) Joint Water Research Commission and Department of Water Affairs and Forestry report. WRC Report No. TT 330/08.

King JM 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.

APPENDIX F: MACROINVERTEBRATE SPECIALIST REPORT

M UYS, Laughing Waters - Aquatic Systems: Research and Consulting
N MAJIZA, Walter Sisulu University: Trainee

F1 EWR 1: UPPER KNYSNA (KNYSNA RIVER) - ECOCLASSIFICATION

F1.1 DATA AVAILABILITY

The following data were available:

- Macroinvertebrate data and analysis from a single sampling trip to the site on 23 April 2007.
- Macroinvertebrate data for samples taken in the Groot River, a tributary of the Groot Brak River, upstream of the Wolwedans Dam, Site GB1 in March 2007 by Rembu Magoba (DWAF 2007). Macroinvertebrate data for samples taken in the Groot River, a tributary of the Groot Brak River, upstream of the Grootrivier Dam, over a six year period from October 2000 to October 2006. As supplied by Gerhard Diedericks (Diedericks, 2006).
- Preliminary maps and information on the catchment as supplied by Delana Louw, Water for Africa.

Specialist assessments for this study:

- Hydrological assessment by Prof Denis Hughes, September 2007
- IHI assessment by Delana Louw, September 2007
- Hydraulics Information supplied by Andrew Birkhead, 2007
- Level 1 EcoRegion system Classification: Kleynhans *et al.* (2005).
- Level 2 EcoRegion system Classification: Kleynhans *et al.* (2007).
- Geomorphic zone classification for the site.
- IHI segments and impacts for the site.

The confidence in the assessment was low (2.5), based on data collected during the single field visit and with reference to two different samplings on the Groot River, a tributary of the Groot Brak River. On balance, these were the two most similar sites for which suitable reference data could be accessed. The Groot River was in a neighbouring EcoRegion (Southern Folded Mountains, Level 1 Ecoregion 19).

F1.2 REFERENCE CONDITION

The reference condition for the Knysna is based on the following:

- SASS5 data collected at a National River Health Programme (NRHP) site (K2GROO-BROOK) over two samplings, October 2006 and September 2007, by Gerhard Diedericks (Diedericks, 2006). The site was situated on a third order stream on the Groot River (tributary of the Groot Brak), upstream of the Grootrivier Dam, at an estimated altitude of 524 m. The site was selected by Diedericks (2006) as a reference site. It occurs in a neighbouring EcoRegion to the Knysna River, and in a slightly different geomorphic zone (mountain stream), but was selected on the basis of available hydraulic habitat, canopy cover, and taxa collected, as the most appropriate reference site for the Knysna out of twenty two SASS5 sites in the Southern Cape for which data were made available (Table F1 and F2).
- SASS5 data collected in March 2007 by Magoba, Southern Waters (DWAF 2007), as part of an intermediate Reserve Determination study of Southern Cape Rivers. As with the former reference locality, this site (GB1) was on the Groot River, a tributary of the Groot

Brak, situated upstream of the Wolwedans Dam at an altitude of 150 m, a lower elevation than both the former reference site and the Knysna site (Table F1). Although the data providing details for this site were sparse, similar habitats were sampled, and the taxa collected are considered to be appropriate reference taxa for the Knysna River site (Table F2).

Table F1 Reference site details

RHP code[1]	Site code[2]	Locality[3]	Latitude	Longitude	Quat[4]	Maj Riv[5]	EcoRegion I[6]	Zone[7]	Alt[8]
K2Groo-Brook	K20A-01	Brookesbos	33 53.584S	22 10.311E	K20A	Groot Brak	Southern Folded Mts (19)	Mountain Stream	524 m (Google)
N/A	GB1	Kleinplaas Rd	33 58.621S	22 19.865E		Groot Brak	Southern Folded Mts (19)		150 m (Google)

1 River Health Programme code for site 2 Code used by sampler 3 Locality 4:Quaternary Catchment
5 Major River 6 EcoRegion Level 1 7 Geomorphic zone 8 Altitude

Table F2 Summary data for each of the reference sites and the test site

River	Site Code	Date	Flow	SASS5	No Taxa	ASPT
Groot	K20A-01	October 06	Moderate	154	18	8.6
Groot	K20A-01	September 07	Low	194	25	7.8
Groot	GB1	March 07		192	24	8
Knysna	EWR 1	April 07	Moderate	159	23	6.9

Data from reference sites (Table F2) were maintained separate in the Macro Invertebrate Assessment Index (MIRAI) to improve resolution and confidence in the RC. It must be noted that this, while increasing the accuracy of the final PES result, is a difficult task, and should only be entrusted to specialists. As a rule of thumb, if the taxon occurred in two or three of the reference samplings, it was read as reference. A great deal of thought and experience is however required to run the MIRAI in this manner. As the MIRAI calculations are dependent on the RC (and on deviation of the current state from reference state), the MIRAI is also considered low to moderate confidence (2.5).

The macroinvertebrates expected under reference conditions are recorded in Table F3, together with the taxa collected at EWR 1 at each of two fieldtrips.

Table F3 Total presence and abundance of taxa for the Knysna River, EWR 1, and for each of the two reference sites on the Groot River, GB1 and K2Groo-Brook

River:			Knysna R		Groot R		Groot River				
Site:			EWR1		GB1		K20GROO-BROOK				
		Score	Apr-07		Mar-07		Oct-06		Sep-07		Freq
PORIFERA	PORIFERA	5									
COELENTERATA	COELENTERATA	1									
TURBELLARIA	TURBELLARIA	3	3	A							
ANNELIDA	Oligochaeta	1			1	1	1	1	1	B	50
	HIRUDINEA	3									
CRUSTACEA	Amphipoda										
	Potamonautidae	3									
	Atyidae	8									
	Palaeomonidae	10									
HYDRACARINA	HYDRACARINA	12					8	1			50
PLECOPTERA	Notonemouridae	14	14	A	14	A	14	B			100
	Perlidae	12									
EPHEMEROPTERA	Baetidae 1sp	4	4	A							
	Baetidae 2 sp	6					6	A			50
	Baetidae >2sp	12			12	B					
	Caenidae	6									
	Ephemeridae	15									
	Heptageniidae	13	13	A	13	A					
	Leptophlebiidae	9	9	A	9	A	9	A	9	A	100
	Machadorythidae										
	Oligoneuridae	15									
	Polymytarcidae	10									
	Prosopistomatidae	15									
	Telagonodidae	12	12	B	12	A	12	A	12	A	100
	Tricorythidae	9									
ODONATA	Calopterygidae	10									
	Chlorocyphidae	10									
	Chlorolestidae	8					8	B	8	A	100
	Coenagriidae	4	4	A	4	A					
	Lestidae	8									
	Platycnemidae	10									
	Protoneuridae	8									
	Aeshnidae	8			8	A					
	Corduliidae	8									
	Gomphidae	6									
	Libellulidae	4	4	A	4	A					
LEPIDOPTERA	Crambidae (Pyralidae)	12									
HEMIPTERA	Belostomatidae	3									
	Corixidae	3									
	Gerridae	5									
	Hydrometridae	6									
	Naucoridae	7	7	A	7	A	7	B	7	A	100
	Nepidae										
	Notonectidae	3	3	A							
	Pleidae	4									
	Veliidae/ M...veliidae	5	5	A	5	A	5	A	5	A	100
MEGALOPTERA	Corydalidae	8	8	A	8	B	8	A	8	B	100
	Sialidae	6									
TRICHOPTERA	Dipseudopsidae	10			10	A					
	Ecnomidae	8									
	Hydropschychidae 1 sp	4	4	A					4	A	
	Hydropschychidae 2 sp	6					6	B			50
	Hydropsychidea >2sp	12									
	Philopotamidae	10	10	A	10	A	10	A	10	A	100
	Polycentropodidae	12									
	Psychomiidae	8									
	Xiphocentronidae										
	Barbarochthonidae	13	13	B	13	B	13	A	13	A	100
	Calamoceratidae	11									
	Glossosomatidae	11					11	A	11	B	100
	Hydroptilidae	6									
	Hydrosalpingidae	15									
	Lepidostomatidae	10			10	A					
	Leptoceridae	6	6	B			6	B	6	B	100
	Petrothrincidae	11							11	B	
	Pisullidae	10					10	B			100
	Sericostomatidae SWC	13					13	A			50
COLEOPTERA	Dytiscidae	5					5	A			50
	Elmidae	8	8	A	8	B	8	B	8	B	100
	Dryopidae	8									
	Gyrinidae	5	5	A	5	A	5	A			50
	Haliplidae	5									
	Helodidae	12			12	B	12	A	12	A	100
	Hydraenidae	8									
	Hydrophilidae	5									
	Limnichidae	10									
	Psepheniidae	10									
DIPTERA	Athericidae	10	10	A	10	B			10	A	50
	Blepharoceridae	15									
	Ceratopogonidae	5	5	A	5	A	5	A			50
	Chironomidae	2	2	A	2	A	2	A	2	A	100
	Culicidae	1									
	Dixidae	10									
	Empididae	6									
	Ephydridae	3									
	Muscidae	1									
	Psychodidae	1									
	Simuliidae	5	5	A	5	B	5	B	5	B	100
	Syrphidae	1									
	Tabanidae	5	5	A							
	Tipulidae	5			5	A	5	1	5		50
GASTROPODA	Ancylidae	6									
	Bulininae	3									
	Hydrobidae	3									
	Lymnaeidae	3									
	Physidae	3									
	Planorbinae	3									
	Thiaridae	3									
PELECYPODA	Corbiculiidae	5									
	Sphaeriidae	3									
	Unionidae	6									
	Viviparidae	5									
	SASS5 Score		159		192		194		154		
	No of taxa		23		24		25		18		
	ASPT		6.9		8.0		7.8		8.6		

F1.3 PES

The PES of the macroinvertebrates at the Knysna site was 86.92%, giving a MIRAI EC of B. At the single late summer sampling occasion in April 2007, hydraulic habitat was diverse and in all cases sufficient with adequate depth in the following classes: Fast Flow over Coarse Sediments including bedrock (FCS), Slow Flow over Coarse Sediments including bedrock (SCS), Fast flow over Fine Sediments (gravels; FFS), Slow flow over Fine Sediments (SFS), and Marginal Vegetation (MV). The latter comprised woody vegetation and sedges. All biotopes yielded Average Score Per Taxon (ASPT) values of over 7. According to Dallas (2007), this ASPT value equated to an A category for rivers in this Ecoregion.

The majority of expected or reference *sensitive* flow-dependent taxa were present in FCS (SIC) (Notonemouridae, Telogonodidae, Philopotamidae, Heptageniidae, and Corydalidae), and this biotope achieved the highest SASS scores, number of taxa, and second highest ASPT (116/15/7.7 respectively). The SCS (SOC) biotope yielded a similar fauna and scores to those of the reference state (70/10/7.0). Although the MIRAI model suggested that there were few taxa with a preference for SFS (GSM), this biotope in fact yielded the second highest SASS5 and number of taxa, and the highest ASPT (101/13/7.8). High-scoring taxa collected included notonemourids, heptageniids, barbarochthonids, athericids and telagonodids. These were sampled in flow areas.

The marginal vegetation yielded reasonably high scores (81/11/7.4), and all taxa were collected in flow areas. There was little difference between the taxa collected and the expected/reference taxa. Taxa collected included telagonodids, barbarochthonids, notonemourids, corydalids, leptocerids, and elmids.

Overall, expected taxa (i.e. those that occurred in at least two of the three reference samples) that were not collected, or were not identified, included glossosomatids, helodids, and tipulids. Taxa collected at only one of three reference samples, and absent from the EWR 1 samples included lepidostomatids and sericostomatids.

In general, the indication was that the macroinvertebrate community had sensitivity to high to moderate quality water, high to moderate flow velocities, and the FCS and FFS biotope. The presence of the more sensitive, flow-dependent taxa was considered natural in this system.

On average, a loss of approximately 10 cm depth would cause a loss of the useful MV biotope, 40 cm would cause a loss of hanging vegetation, 16 - 24 cm would cause substantial loss of FCS surface, 25 – 30 cm loss of the FCS, and at a loss of > 20 cm depth the FFS and SFS biotopes would be substantially reduced.

F2 EWR 1: UPPER KNYSNA (KNYSNA RIVER) – DETERMINATION OF STRESS INDICES AND EWR SCENARIOS

Section F2 provides supporting macroinvertebrate information for the determination of stress indices and EWR scenarios of EWR 1 (Chapter 5 and 6 of the Riverine RDM Report: Volume 1).

F2.1 MACROINVERTEBRATE INDICATOR TAXA

Only taxa that occurred commonly at the site were selected and included:

- **Flow dependent macroinvertebrate (FDI) indicator taxa**: Telogonodidae, Barbarochthonidae, Helodidae and Notonemouridae. Reference taxa which may have been present include Sericostomatidae, Glossosomatidae, and two or more species of Hydropsychidae.
- **Marginal vegetation macroinvertebrate (MVI) indicator taxa:** Barbarochthonidae and Notonemouridae.

F2.2 MACROINVERTEBRATE STRESS INDEX

The habitat flow index for flow dependent macroinvertebrate (FDI) and marginal vegetation macroinvertebrate (MVI) taxa is provided in Table F4 and provides the % occurrence of various velocity and substrate classes under different flow conditions.

Table F4 Habitat suitability for FDI and MVI taxa

Habitat Flow Response Index	Habitat Response	Habitat Abundance and Suitability (%)						Flow (m^3/s)
		FCS[1]	SCS[2]	FFS[3]	SFS[4]	FV[6]	FS[7]	
0	Plentiful FCS, with both shallow and deep sections and very fast to moderate flow sections. Vegetation is more plentiful (mostly leafy vegetation) due to greater depth of inundation.	46	26	5	3	13	7	0.58
2		38	37	4	4	8	8	0.36
3	Plentiful FCS and VFCS. MVI adequately inundated. Important to note is that recent high flows may have scoured out this biotope. If this flow was preceded by lower flow conditions, macroinvertebrates may be more diverse. Adequate depth over coarse substrate. Plentiful mobile cobbles. Upper surfaces only have isolated algae and no fines.	23	55	3	6	4	9	0.19
6	MVI only just present at approx 2%. Slow trickling flow over coarse sediments, with small areas of moderate flow. Water clear and no fines on rock surfaces. Algae isolated. Water temperature unlikely to rise due to shading.	7	81	1	9	0	2	0.062
8	Only VSCS still present, with a small percentage of SCS, and trickling flow through shallow areas. Few surfaces of rocks have any flow over them. MVI no longer inundated. Only hanging stems likely to remain as habitat and cover.	0	90	0	10	0	0	0.008
10	No surface water. No flow over coarse sediments. Majority of habitat SCS, with small amount SFS. No inundated MVI.	0	90	0	10	0	0	0

1 Fast over Coarse Sediment; 2 Slow over Coarse Sediment; 3 Fast over Fine Sediment
4 Slow over Fine Sediment; 5 Very Slow over Fine Sediment; 6 Fast to moderate flow through vegetation
7 Slow to no flow through vegetation

The stress index for FDI taxa is provided in Table F5 and in Table F6 for MVI taxa. These tables rate the response of the species according to various biotic response metrics.

Table F5 Macroinvertebrate (FDI) stress index

Habitat characteristics			Biotic Response	Flow	Species Stress
Max (Ave) depth	Av (98%) Velocity	Width			
0.5 (0.24)	0.47 (1.43)	5.2	FDI include Telogonodidae, Barbarochthonidae, Helodidae and Notonemouridae. Reference taxa which may now be present include Sericostomatidae, Glossosomatidae, and two or more species of Hydropsychidae.	0.58	0
0.46 (0.21)	0.35 (1.12)	4.9		0.36	
0.42 (0.2)	0.23 (0.77)	4.2	Indicator taxa: Barbarochthonidae (13), Philopotamidae (10), Heptageniidae (13), Notonemouridae (14). SIC SASS5 scores are 116/15/7.7.	0.19	2
0.34 (0.15)	0.12 (0.41)	3.6	FDI restricted to those with a preference for moderate to slow flows. The only sensitive taxon likely to still occur abundantly is Heptageniids. Other sensitive FDI taxa will be restricted in abundance. Indicator taxa for these flows include Elmidae, Corydalidae, Libellulidae, and Leptoceridae. All of these score 8 or less.	0.062	6
0.24 (0.1)	0.03 (0.12)	2.4		0.008	8
0.14	0.02	1	Loss of all flow dependent taxa within 1 - 2 weeks of loss of surface flow.	0	

Table F6 Macroinvertebrate (MVI) stress index

Habitat characteristics			Biotic Response	Flow	Species Stress
Max (Ave) depth	Av (98%) Velocity	Width			
0.5 (0.24)	0.47 (1.43)	5.2	MVI will include reference taxa present likely to include Barbarochthonidae and Notonemouridae.	0.58	0
0.46 (0.21)	0.35 (1.12)			0.36	2
0.42 (0.2)	0.23 (0.77)	4.9	Macroinvertebrates in this habitat score 81/11/7.4 in the SASS5. Indicator taxa include Barbarochthonidae, Notonemouridae.	0.19	3
0.34 (0.15)	0.12 (0.41)	4.2	Indicator taxa Barbarochthonidae, Notonemouridae present only in small numbers. Taxa with a preference for MVI and slower flows will become more abundant.	0.062	7
0.24 (0.1)	0.03 (0.12)		Few sensitive MVI still present. Leptophlebiidae are the most sensitive taxa likely to still be found, but for the remnant taxa with a requirement for higher velocity flows.	0.008	8
0.14	0.02		Those MVI that are capable of surviving will move into SCS biotope. This includes the more mobile Hemiptera and Coleopterans. Resilient macroinvertebrates with a preference for the water column will dominate. Indicators: Dytiscidae, Notonectidae, Veliidae.	0	10

F2.3 LOW FLOW REQUIREMENTS IN TERMS OF STRESS FOR MACROINVERTEBRATES

The FDI and MVI low flow requirements are summarised in Table B7 and B8 below.

Table F7 Low flow requirements: FDI taxa

GENERAL					
INDICATOR: Barbarochthonidae (13), Philopotamidae (10), Heptageniidae (13), Notonemouridae (14).					
BUILDING BLOCK[1]	**SEASON**	**STRESS DURATION**	**SPP STRESS**	**INTEG[2] STRESS**	**FLOW (m^3/s)**
Drought	Dry	5%	6	7	0.062
No sensitive rheophilic taxa present. Only VSCS (Very Slow flow over Coarse Sediment) still present, with a small percentage of SCS, and trickling flow through shallow areas. Few surfaces of rocks have any flow over them and marginal vegetation (MV) no longer inundated. Only hanging stems likely to remain as habitat and cover.					
BUILDING BLOCK	**SEASON**	**STRESS DURATION**	**SPP STRESS**	**INTEG STRESS**	**FLOW (m^3/s)**
Drought	Wet	5%	3	4	0.158
Sufficient flow through MV and over coarse sediments is available to enable survival of the less sensitive flow dependent macroinvertebrates.					

DRY SEASON REQUIREMENTS						
BUILDING BLOCK	ECOSTATUS	INVERT[4] EC	STRESS DUR	SPP STRESS	INTEG STRESS	FLOW (m^3/s)
Maint[3] REC	B	B	40%	1	2	0.4
Diverse flow habitat is present at adequate depth. Indicator taxa are present. High flows may reduce the occurrence of sensitive FDI.						
BUILDING BLOCK	ECOSTATUS	INVERT EC	STRESS DUR	SPP STRESS	INTEG STRESS	FLOW (m^3/s)
Maint AEC↓	C	C	40%	3	4	0.158
Adequate flow over coarse substrates and through marginal vegetation present. Depth and average velocity is reduced. Indicator taxa will be reduced in number, or may be absent from samples.						
WET SEASON REQUIREMENTS						
BUILDING BLOCK	ECOSTATUS	INVERT EC	STRESS DUR	SPP STRESS	INTEG STRESS	FLOW (m^3/s)
Maint REC	B	B	40%	1.8	2.8	0.37
Adequate flow over coarse substrates and through marginal vegetation is available to maintain the indicator taxa. Adequate depth to inundate MV and provide optimal habitat.						
BUILDING BLOCK	ECOSTATUS	INVERT EC	STRESS DUR	SPP STRESS	INTEG STRESS	FLOW (m^3/s)
Maint AEC↓	C	C	40%	2.5	3.5	0.17
Adequate flow and depth over coarse substrates and through marginal vegetation present. Depth and average velocity is reduced. Indicator taxa will be reduced in number, or may be absent from samples.						

1 Flow building block refers to drought and maintenance flows (King and Louw, 1998). Note that DROUGHTS ARE THE SAME FOR ALL CATEGORIES. This is applicable to all sites
2 Integrated 3 Maintenance

Table F8 Low flow requirements: MVI taxa

GENERAL					
INDICATOR: Barbarochthonidae (13), Notonemouridae (14).					
BUILDING BLOCK	SEASON	STRESS DURATION	SPP STRESS	INTEG STRESS	FLOW (m^3/s)
Drought	Dry	5%	6	6	0.094
A small proportion of FCS remains. There is only slow flow through vegetation. Indicators will be absent or rare, a range of resilient taxa scoring 1 - 8 likely to be present, including Simuliidae and Hydropsychidae (which have a preference for flow conditions).					
BUILDING BLOCK	SEASON	STRESS DURATION	SPP STRESS	INTEG STRESS	FLOW (m^3/s)
Drought	Wet	5%	4	4	0.158
This flow will maintain at least 75% of the macroinvertebrate community. Over time, rheophilic taxa will reduce in number and the indicators are likely to relocate and eventually disappear.					

DRY SEASON REQUIREMENTS						
BUILDING BLOCK*	ECOSTATUS	INVERT EC	STRESS DUR	SPP STRESS	INTEG STRESS	FLOW (m^3/s)
Maint[3]REC	B	B	40%	3	3	0.19
Heterogeneous hydraulic habitat, at adequate depth. MV sufficiently inundated. All indicators present. Flows higher than 0.3 m^3/s are likely to have a 'washout' effect. Indicator taxa present.						
BUILDING BLOCK	ECOSTATUS	INVERT EC	STRESS DUR	SPP STRESS	INTEG STRESS	FLOW (m^3/s)
Maint AEC↓	C	C	40%	4	4	0.158
Heterogeneous hydraulic habitat, at adequate depth. MV sufficiently inundated. Two indicators present. Flows higher than 0.3 m^3/s are likely to have a 'washout' effect. Indicator taxa present.						
WET SEASON REQUIREMENTS						
BUILDING BLOCK	ECOSTATUS	INVERT EC	STRESS DUR	SPP STRESS	INTEG STRESS	FLOW (m^3/s)
Maint REC	B	B	40%	1.5	2	0.4
Adequate flow over coarse substrates and through marginal vegetation to maintain a diverse community of MVI taxa, including indicator taxa. Adequate depth to inundate MV to provide optimal habitat.						
BUILDING BLOCK	ECOSTATUS	INVERT EC	STRESS DUR	SPP STRESS	INTEG STRESS	FLOW (m^3/s)
Maint AEC↓	C	C	40%	2.8	2.8	0.37
Adequate flow and depth through all habitats to support a diverse community of MVI taxa, including those with preferences for moderately fast flows over coarse substrates.						

F3 EWR2: GOUNA (GOUNA RIVER) - ECOCLASSIFICATION

F3.1 DATA AVAILABILITY

The following data were available:

- Macroinvertebrate data and analysis from a single sampling trip to the site on 23 April 2007.
- Macroinvertebrate data for samples taken in the Buffelsnek River, Gansvlei catchment, over a six year period from October 2002 to October 2006 (Diedericks, 2006).
- Preliminary maps and information on the catchment as supplied by Delana Louw, Water for Africa.

Specialist assessments for this study:

- System driver data analysis (water quality, hydrology) supplied by Patsy Scherman, and Prof Denis Hughes, September 2007.
- Hydrological assessment by Prof Denis Hughes, September 2007
- IHI assessment by Delana Louw, September 2007
- Hydraulics Information supplied by Andrew Birkhead, 2007
- Level 1 EcoRegion system Classification: Kleynhans *et al.* (2005).
- Level 2 EcoRegion system Classification: Kleynhans *et al.* (2007).
- Geomorphic zone classification for the site.
- IHI segments and impacts for the site.

F3.2 REFERENCE CONDITION

The reference condition for EWR 2 was based on data collected by Gerhard Diedericks at the Buffelsnek River, Gansvlei Catchment, in Quaternary Catchment K60F. The site is a River Health Programme site and six data sets were available (October 2002 - 2007). It was not located in the same EcoRegion as the Gouna, but in the adjacent Southern Folded Mountains Ecoregion. Of twenty two river sites in the Southern Cape region for which data were available, this site was considered the most suitable as a reference, based on the similarity of its characteristics to the Gouna (open canopy, with cobbles, boulders and sand/mud/silt dominating the substrate), on the SASS5 data, and on photographic evidence (Figure F1). Data from the Knysna River and its reference sites were also consulted in completing the MIRAI (Table F9).

Figure F1 The Buffelsnek River site used as a reference for the Gouna River Site

Table F9 Test and Reference site details

RHP code	Site code	Locality	Latitude	Longitude	Quat	Maj Riv	EcoRegion I	Zone	Alt
N/A	EWR 1	Usconfluence	33 59.27.3S	23 02.29.2E	K50A	Gouna	20.02	Upper Foothills	108 m (Google)
K6BUFF-PERDE	K60F-02	Perdeklopkloof	33 55.27.9S	23 13.10.2E	K60F	Buffelsnek	Southern Folded Mts (19)	Mountain Stream	312 m (Google)

Table F10 SASS5 Data from EWR 2 (Gouna River) and Reference Sites (Knysna River; Buffelsnek River)

River	Site Code	Date	Flow	SASS	No Taxa	ASPT
Test site: Gouna	EWR 2	April 07	Moderate	122	16	7.6
Reference Site: Knysna	EWR 1	April 07	Moderate	159	23	6.9

SITE		**K60F-02: Perdekopkloof**					
CO-ORDINATES (Decimal Degrees - WGS84)		**33.92441 S & 23.21945 E**					
DATE SAMPLED		**Oct-02**	**Oct-03**	**Nov-04**	**Oct-05**	**Oct-06**	**Sep-07**
Flow (L/s)		Moderate	Low	Low	Very Low	Moderate	Moderate
	SUMMARY RESULTS						
	SASS5 Score	188	191	219	226	167	180
	Number of Taxa	27	27	29	30	22	26
	ASPT	7.0	7.1	7.6	7.5	7.6	6.9
	% Air Breathers	22.2	22.2	24.1	30.0	22.7	23.1
	CLASS	**A**	**A**	**A**	**A**	**A**	**B**
	IHAS %	78	81	79	78	74	83

It is worth noting the range of scores from the Buffelsnek reference site over a period of six years (Table F10). The SASS5 scores for the reference site over the six samplings ranged between 167 to 226, with number of taxa varying from 22 to 30, and ASPT from 6.9 to 7.6. This appears to be a natural variability as there is not any trend in the data. According to Dallas (2007), sites in the Southern Folded Mountains EcoRegion are classified as 'A' if they have a total SASS5 > 160, with an ASPT of ≥ 7.0.

From the data available, the October 2005 and 2006 (lowest and highest of the six samples) were used as references in MIRAI, together with frequency of occurrence of taxa over the six samplings. If a taxon occurred in more than 80% of all the samples, it was taken to represent reference. The remainder of taxa in the two samples were considered individually in the MIRAI analysis. The taxa collected at the Gouna River on the single sampling occasion in April 2007, and those from the reference site, are presented in Table F11.

F3.3 PES

The PES of the macroinvertebrates at the EWR 2 site is 92.8%, which is a MIRAI EC of B (Table F8).

Taxa collected indicated a system with reasonable hydraulic habitat diversity and water quality. Six of the 16 families collected scored over 10, indicating sensitivity to water quality and/or flow conditions. These included Notonemouridae, Telogonodidae, philopotamids, barbarochthonids, and athericids. Of the families present, nine showed a preference (scoring 3 or 4 in MIRAI) for cobble-type habitat, which was plentiful and only three were collected in marginal vegetation. The latter included notonemourids and lower-scoring taxa with a preference for moderate to slow velocity flow. The marginal vegetation is a limiting habitat at this site (comprising chiefly Palmiet).

Only four taxa were collected in the GSM habitat, which was not well represented at this site. All but the Notonemourids were lower scoring taxa (less than 10, SASS5).

Table F11 Taxa collected at EWR 2 on two sampling occasions – August 2006 (Sample 1) and December 2006 (Sample 2), and at the reference condition (based on Kaap River)

GOUNA RIVER			SIC		MV		SOC		GSM		**TOTAL**		**REF 1 Ab**	**REF 2 A**	**% Frequency**
PORIFERA	PORIFERA	5													**0**
COELENTERATA	COELENTERATA	1													**0**
TURBELLARIA	TURBELLARIA	3													**0**
ANNELIDA	Oligochaeta	1													**33**
	HIRUDINEA	3													**0**
CRUSTACEA	Amphipoda														**0**
	Potamonautidae	3											**1**		**17**
	Atyidae	8													**0**
	Palaeomonidae	10													**0**
HYDRACARINA	HYDRACARINA	12													**67**
PLECOPTERA	Notonemouridae	14	14	B	14	A	14	A	14	A	**14**	**A**	**A**	**B**	**100**
	Perlidae	12													**0**
EPHEMEROPTERA	Baetidae 1sp	4			4	A					**4**	**A**			**0**
	Baetidae 2 sp	6													**0**
	Baetidae >2sp	12											**B**	**B**	**100**
	Caenidae	6					6	A			**6**	**A**	**B**	**1**	**100**
	Ephemeridae	15													**0**
	Heptageniidae	13													**0**
	Leptophlebiidae	9											**A**	**A**	**100**
	Machadorythidae														**0**
	Oligoneuridae	15													**0**
	Polymytarcidae	10													**0**
	Prosopistomatidae	15													**0**
	Telagonodidae	12	12	A							**12**	**A**	**B**	**A**	**0**
	Tricorythidae	9													**0**
ODONATA	Calopterygidae	10													**0**
	Chlorocyphidae	10													**0**
	Chlorolestidae	8											**A**		**50**
	Coenagriidae	4			4	A					**4**	**A**	**B**	**A**	**100**
	Lestidae	8													**33**
	Platycnemidae	10											**A**	**1**	**83**
	Protoneuridae	8											**A**		**0**
	Aeshnidae	8													**83**
	Corduliidae	8													**0**
	Gomphidae	6											**1**		**17**
	Libellulidae	4							4	A	**4**	**A**	**B**	**A**	**100**
LEPIDOPTERA	Crambidae (Pyralidae)	12													**0**
HEMIPTERA	Belostomatidae	3													**0**
	Corixidae	3											**1**		**50**
	Gerridae	5													**0**
	Hydrometridae	6													**0**
	Naucoridae	7											**B**	**A**	**67**
	Nepidae														**0**
	Notonectidae	3													**67**
	Pleidae	4											**A**		**33**
	Veliidae/ M…veliidae	5	5	B					5	A	**5**	**A**	**B**	**1**	**83**
MEGALOPTERA	Corydalidae	8	8	B			8	B			**8**	**A**	**A**		**67**
	Sialidae	6													**0**
TRICHOPTERA	Dipseudopsidae	10													**0**
	Ecnomidae	8					8	A			**8**	**A**	**A**		**50**
	Hydropschychidae 1 sp	4												**A**	**33**
	Hydropschychidae 2 sp	6													**50**
	Hydropsychidea >2sp	12											**B**		**17**
	Philopotamidae	10	10	A							**10**	**A**	**B**	**B**	**83**
	Polycentropodidae	12													**0**
	Psychomiidae	8													**0**
	Xiphocentronidae														**0**
	Barbarochthonidae	13	13	B							**13**	**B**	**A**		**17**
	Calamoceratidae	11													**0**
	Glossosomatidae	11													**0**
	Hydroptilidae	6													**17**
	Hydrosalpingidae	15													**0**
	Lepidostomatidae	10													**0**
	Leptoceridae	6	6	B							**6**	**B**	**B**	**A**	**100**
	Petrothrincidae	11													**17**
	Pisullidae	10												**1**	**0**
	Sericostomatidae SWC	13													**17**
COLEOPTERA	Dytiscidae	5											**B**	**A**	**83**
	Elmidae	8							8	A	**8**	**A**	**B**	**A**	**83**
	Dryopidae	8													**0**
	Gyrinidae	5											**A**	**A**	**100**
	Haliplidae	5													**17**
	Helodidae	12											**1**	**1**	**100**
	Hydraenidae	8													**0**
	Hydrophilidae	5													**0**
	Limnichidae	10													**0**
	Psepheniidae	10													**0**
DIPTERA	Athericidae	10	10	A							**10**	**A**	**1**	**1**	**100**
	Blepharoceridae	15													**0**
	Ceratopogonidae	5					5	A			**5**	**A**	**A**	**1**	**67**
	Chironomidae	2											**B**	**B**	**100**
	Culicidae	1													**0**
	Dixidae	10											**A**		**33**
	Empididae	6													**0**
	Ephydridae	3													**0**
	Muscidae	1													**0**
	Psychodidae	1													**0**
	Simuliidae	5											**B**	**B**	**100**
	Syrphidae	1													**0**
	Tabanidae	5	5	A							**5**	**A**			**0**
	Tipulidae	5													**33**
GASTROPODA	Ancylidae	6													**0**
	Bulininae	3													**0**
	Hydrobidae	3													**0**
	Lymnaeidae	3													**0**
	Physidae	3													**0**
	Planorbinae	3													**0**
	Thiaridae	3													**0**
PELECYPODA	Corbiculiidae	5													**0**
	Sphaeriidae	3													**0**
	Unionidae	6													**0**
	Viviparidae	5													**0**
	SASS5 Score		83		22		41		31		**122**			**167**	**0**
	No of taxa		9		3		5		4		**16**			**22**	**0**
	ASPT		9.2		7.3		8.2		7.8		**7.6**			**7.6**	**0**
	% of Reference SASS										**73.1**				
	% Reference No Bugs										**51.6**				
	% of Reference ASPT										**101.0**				

F4 EWR2: GOUNA (GOUNA RIVER) - DETERMINATION OF STRESS INDICES AND EWR SCENARIOS

Section F4 provides supporting macroinvertebrate information for the determination of stress indices and EWR scenarios of EWR 2 (Chapter 7 and 8 of the Riverine RDM Report: Volume 1).

F4.1 MACROINVERTEBRATE INDICATOR TAXA

Only taxa that occurred commonly at the site were selected and included:

- **Flow dependent macroinvertebrate (FDI) indicator taxa**: Notonemouridae, Baetidae (>2sp), Telogonodidae, Barbarochthonidae and Athericidae.
- **Marginal vegetation macroinvertebrate (MVI) indicator taxa:** Notonemouridae, Baetidae (>2sp), Platycnemidae. All but the last of these were collected in the sample. Platycnemidae were collected in the reference samples. Chlorolestidae, Coenagrionidae and Lestidae were collected in reference samples and could occur at the site under most flow conditions. The chief issue regarding indicator species at this site is the apparent inhospitability of the dominant Palmiet reed (hence the low SASS score, but high ASPT).

F4.2 MACROINVERTEBRATE STRESS INDEX

The habitat flow index for flow dependent macroinvertebrate (FDI) and marginal vegetation macroinvertebrate (MVI) taxa is provided in Table F12 and provides the % occurrence of various velocity and substrate classes under different flow conditions.

Table F12 Habitat suitability for FDI and MVI taxa

Habitat Flow Response Index	Habitat Response	Habitat Abundance and Suitability (%)								Flow (m^3/s)
		FCS[1]	SCS[2]	FFS[3]	SFS[4]	FBR[5]	SBR[6]	FV[7]	SV[8]	
0	Bedrock, boulders and cobbles dominate. All flow depth classes present. Marginal vegetation inundated, but dominated by Palmiet and not good habitat for a diverse MVI community.	26	16	7	5	4	3	24	15	0.462
2		24	28	7	8	3	4	12	14	0.234
4	Plentiful FCS, and SCS. Vegetation present and inundated beyond the root wads (Palmiet). Vegetation not very useful at this depth. Channels separated. Cobbles embedded.	18	45	5	13	3	5	3	8	0.111
5		12	58	3	17	2	6	7	0	0.11
6		10	59	3	17	2	7	9	0	0.049
8	SCS dominant habitat at these flows. Connectivity significantly reduced. Flow over bedrock maintains link between different pools.	4	66	1	19	2	9	9	0	0.015
10		0	70	0	20	1	9	10	0	0.002

1 Fast over Coarse Sediment 2 Slow over Coarse Sediment 3 Fast over Fine Sediment
4 Slow over Fine Sediment 5 Fast flow over Bedrock 6 Slow Flow over Bedrock
7 Fast to moderate flow through vegetation 8 Slow to no flow through vegetation

The stress index for FDI taxa is provided in Table F13 and in Table F14 for MVI taxa. These tables rate the response of the species according to various biotic response metrics.

Table F13 Macroinvertebrate (FDI) stress index

Habitat characteristics						Biotic Response	Flow	Species Stress
Max depth (m)	Ave depth (m)	Dis-charge (m^3/s)	Width (m)	Perim (m)	Ave vel (m/s)			
0.52	0.34	0.462	3.2	3.8	0.43	Indicator taxa include Notonemouridae, Baetidae (>2sp), Athericidae, Dixidae.	0.462	0
0.4	0.27	0.234	2.7	3.3	0.32		0.234	2
0.3	0.2	0.111	2.4	3	0.23	Philopotamidae, Barbarochthonidae, Athericidae at these flows. Low scoring for SCS habitat, but with high ASPT (7.3).	0.111	4
0.30	0.20	0.11	2.40	3.00	0.23		0.11	5
0.22	0.14	0.049	2.1	2.5	0.17		0.049	6
0.14	0.08	0.015	1.8	2	0.11	FDI are significantly reduced. The majority of taxa are resilient and do not have high habitat specificity. These will include Baetidae.	0.015	8
0.06	0.04	0.002	0.9	1	0.05		0.002	10

Table F14 Macroinvertebrate (MVI) stress index

Habitat characteristics						Biotic Response	Flow	Species Stress
Max depth (m)	Ave depth (m)	Dis-charge (m^3/s)	Width (m)	Perim (m)	Ave vel (m/s)			
0.52	0.34	0.462	3.2	3.8	0.43	Indicator taxa include Helodidae, Athericidae, Dixidae, and Notonemouridae.	0.462	0
0.4	0.27	0.234	2.7	3.3	0.32		0.234	2
0.3	0.2	0.111	2.4	3	0.23	Very low overall score for this biotope at this flow (22), despite high ASPT (9.2). This may be indicative of recent floods; however it is likely that Palmiet is a poor habitat for the greater diversity of MVI.	0.111	4
0.30	0.20	0.11	2.40	3.00	0.23		0.11	5
0.22	0.14	0.049	2.1	2.5	0.17		0.049	6
0.14	0.08	0.015	1.8	2	0.11	Loss of sensitive MVI. Less sensitive taxa which may persist include Baetidae and Coenagrionidae. Many of the more resilient MVI taxa are not present at higher flows, but may occur during lower flows - e.g. Gyrinidae, Naucoridae, and Notonectidae.	0.015	8
0.06	0.04	0.002	0.9	1	0.05		0.002	10

F4.3 LOW FLOW REQUIREMENTS IN TERMS OF STRESS FOR MACROINVERTEBRATES

The FDI and MVI low flow requirements are summarised in Table B15 and B16 below.

Table F15 Low flow requirements: FDI taxa

GENERAL					
INDICATOR: Indicator taxa include Notonemouridae, Baetidae (>2sp), Athericidae, and Dixidae.					
BUILDING BLOCK	**SEASON**	**STRESS DURATION**	**SPP STRESS**	**INTEG STRESS**	**FLOW (m^3/s)**
Drought	Dry	5%	7	7	0.032
No sensitive rheophilics are present. Small areas of FCS and no inundated vegetation present. Hanging stems of *Phragmites* may be present as vegetation habitat.					
BUILDING BLOCK	**SEASON**	**STRESS DURATION**	**SPP STRESS**	**INTEG STRESS**	**FLOW (m^3/s)**
Drought	Wet	5%	6	6	0.049
Sufficient flow through marginal vegetation and over coarse sediments is available to enable survival of the less sensitive FDI taxa.					

DRY SEASON REQUIREMENTS						
BUILDING BLOCK	**ECOSTATUS**	**INVERT EC**	**STRESS DUR**	**SPP STRESS**	**INTEG STRESS**	**FLOW (m^3/s)**
Maint REC	A/B	A	40%	2.8	4	0.17
Adequate flow and depth through all habitats to support a diverse community of taxa, including those with preferences for moderately fast flows over coarse substrates. Indicator taxa are present. Higher flows may reduce the occurrence of sensitive FDI.						
BUILDING BLOCK	**ECOSTATUS**	**INVERT EC**	**STRESS DUR**	**SPP STRESS**	**INTEG STRESS**	**FLOW (m^3/s)**
Maint AEC↓	B/C	A/B	40%	4.5	5	0.109
Adequate flow over coarse substrates and through marginal vegetation. Depth and average velocity is reduced. Indicator taxa will be reduced in number, or may be absent from samples.						
WET SEASON REQUIREMENTS						
BUILDING BLOCK	**ECOSTATUS**	**INVERT EC**	**STRESS DUR**	**SPP STRESS**	**INTEG STRESS**	**FLOW (m^3/s)**
Maint REC	A/B	A	40%	2	3.5	0.22
Heterogeneous hydraulic habitat. Adequate flow and depth over coarse substrates and through marginal vegetation to maintain the indicator taxa. Adequate depth to inundate MV and provide optimal habitat.						
BUILDING BLOCK	**ECOSTATUS**	**INVERT EC**	**STRESS DUR**	**SPP STRESS**	**INTEG STRESS**	**FLOW (m^3/s)**
Maint AEC↓	B/C	A/B	40%	2.8	4	0.17
Adequate flow and depth through all habitats to support a diverse community of taxa, including those with preferences for moderately fast flows over coarse substrates.						

Table F16 Low flow requirements: MVI taxa

GENERAL						
INDICATOR: Indicator taxa include Helodidae, Athericidae, Dixidae, and Notonemouridae.						
BUILDING BLOCK	**SEASON**	**STRESS DURATION**		**SPP STRESS**	**INTEG STRESS**	**FLOW (m^3/s)**
Drought	Dry	5%		7	7	0.032
Very little MV inundated. Over time, rheophilic taxa will reduce in number and the indicators are likely to relocate and eventually disappear.						
BUILDING BLOCK	**SEASON**	**STRESS DURATION**		**SPP STRESS**	**INTEG STRESS**	**FLOW (m^3/s)**
Drought	Wet	5%		6	6	0.049
A small proportion of FCS remains. There is no inundated vegetation. Indicators will be absent or rare; a range of more resilient taxa is likely to be present.						
DRY SEASON REQUIREMENTS						
BUILDING BLOCK	**ECOSTATUS**	**INVERT EC**	**STRESS DUR**	**SPP STRESS**	**INTEG STRESS**	**FLOW (m^3/s)**
Maint REC	A/B	A	40%	3	3	0.23
Plentiful and diverse habitat in all hydraulic habitat categories, at adequate depth. MV sufficiently inundated to provide good habitat and cover for juveniles. All indicators present.						
BUILDING BLOCK	**ECOSTATUS**	**INVERT EC**	**STRESS DUR**	**SPP STRESS**	**INTEG STRESS**	**FLOW (m^3/s)**
Maint AEC↓	B/C	A/B	40%	4	4	0.17
Heterogeneous hydraulic habitat, at adequate depth. MVI sufficiently inundated. All indicators present. Flows higher than 0.3 m^3/s are likely to have a 'washout' effect. Indicator taxa present.						
WET SEASON REQUIREMENTS						
BUILDING BLOCK	**ECOSTATUS**	**INVERT EC**	**STRESS DUR**	**SPP STRESS**	**INTEG STRESS**	**FLOW (m^3/s)**
Maint REC	A/B	A	40%	2	2	0.307
Adequate flow over coarse substrates and depth through marginal vegetation to maintain the community of MVI taxa, including indicator taxa. Adequate depth to inundate MV and provide optimal habitat.						
BUILDING BLOCK	**ECOSTATUS**	**INVERT EC**	**STRESS DUR**	**SPP STRESS**	**INTEG STRESS**	**FLOW (m^3/s)**
Maint AEC↓	B/C	A/B	40%	3	3	0.23
Adequate flow and depth through vegetation to support the MVI community, including those with preferences for moderately fast flows.						

F5 EWR 3: UPPER DIEP (DIEP RIVER) - ECOCLASSIFICATION

F5.1 DATA AVAILABILITY

The following data were available:

- Macroinvertebrate data and analysis from a single sampling trip to the site on 23 April 2007.
- Macroinvertebrate data for samples taken in the Diep River, at a site close to (or in the same locality as) EWR 3 over a six year period from October 2000 to October 2006, supplied by Gerhard Diedericks (Diedericks, 2006).
- Preliminary maps and information on the catchment as supplied by Delana Louw, Water for Africa.

Specialist assessments for this study:

- Hydrological assessment by Prof Denis Hughes, September 2007
- IHI assessment by Delana Louw, September 2007
- Hydraulics Information supplied by Andrew Birkhead, 2007
- Level 1 EcoRegion system Classification: Kleynhans *et al.* (2005).
- Level 2 EcoRegion system Classification: Kleynhans *et al.* (2007).
- Geomorphic zone classification for the site.
- IHI segments and impacts for the site.

Confidence was moderate (3) due to the lack of previous data for the site and river itself, the lack of geomorphological and water quality information, and the nature of the reference data available.

F5.2 REFERENCE CONDITION

The reference condition for EWR 3 was based on data from the Diep River, at the same locality as EWR 3, over a period of six years, during midsummer (October 02 to September 07). These data were collected for the River Health Programme (Table F18). The RHP Code for the site is K4DIEP-GATBO. Of the six years worth of data, only one – the October 2000 sample - was used to establish reference conditions, as this was the only sample which scored higher than our own sample. There was a clear downward trend from 2000 to 2007 in the SASS5 overall scores, however the ASPT remained at 6.2 or higher, and the overall category of the site remained a B throughout this period. The reference condition was considered to be moderate confidence. The MIRAI was moderate confidence. Reference taxa are recorded in Table F17.

Table F17 Reference site details

RHP code	Site code	Locality	Latitude	Longitude	Quat	Maj Riv	EcoRegion I	Zone	Alt
K4DIEP -GATBO	K40A-02	Gatbos	33 54.775S	22 42.460E	K40A	Swartvlei	Southern Folded Mts (19)	Transitional	206 m (Google)

Table F18 Summary data for the reference site

River	Site Code	Date	Flow	SASS	No Taxa	ASPT
Diep	K40A-02	Oct. 2000	Not given	229	37	6.2
		Oct 2001		162	25	6.5
		Oct 2002		191	28	6.8
		Oct 2003		150	22	6.8
		Oct 2006	Moderate	138	21	6.6

F5.3 PES

The PES of the macroinvertebrates at the EWR 3 site was 86.1%, a MIRAI EC of B. The SASS5 score was high, at 205, with 28 families collected, and an ASPT of 7.3 (greater than that of the reference site).

Of the twenty eight taxa, 8 scored in the range of 10 - 13, indicating a requirement for good water quality and unimpaired habitat. These included notonemourids, baetids (> 2sp), heptageniids, teloganodids, philopotamids, barbarochthonids and athericids. The greatest number of taxa were collected in the Stones in Current (Fast Flow over Coarse Sediments), and approximately 25% of these scored over 10. Only Marginal Vegetation Out of Current (MVOC) was sampled. This was considered poor habitat, comprising largely restios, as the Palmiet at the site was not inundated. However this habitat yielded a higher than expected score of 66, with 7 taxa and and ASPT of 9.4. This was due to the presence of mostly high-scoring taxa including > 2spp Baetidae, notonemourids, philopotamids, and barbarochthonids. As the majority of these taxa have a preference for moderate to high flows, it was assumed that they either drifted into the MVOC, or that flows had recently reduced, transforming an Marginal Vegetation in current (MVIC) habitat to MVOC.

GSM yielded a score of 72, with 11 taxa and an ASPT of 6.5. Stones out of current (Slow flow over Coarse Sediments) scored 85, with 10 taxa and a high ASPT of 8.5. Again this was indicative of antecedent higher flow conditions.

Interestingly, the major discrepancy between the sample and the reference data was in the lower number of resilient taxa collected in the April 2007 sample. This accounts for the slightly lower ASPT of the reference data.

Table F19 Taxa collected at Diep River, EWR 3 in April 2007, and at the Reference Site, same locality, RHP site K4DIEP-GATBO, in October 2000

			Diep EWR 4										K4DIEP-GATBO Oct '00	
			SIC		MVOC		GSM		SOC		TOTAL			
PORIFERA	PORIFERA	5												
COELENTERATA	COELENTERATA	1												
TURBELLARIA	TURBELLARIA	3											*3*	*A*
ANNELIDA	Oligochaeta	1	1	A							1	A	*1*	*A*
	HIRUDINEA	3												
CRUSTACEA	Amphipoda	13												
	Potamonautidae	3	3	A							3	A	*3*	*1*
	Atyidae	8												
	Palaeomonidae	10												
HYDRACARINA	HYDRACARINA	8			8	A					8	A	*8*	*B*
PLECOPTERA	Notonemouridae	14	14	B	14	A	14	A	14	A	14	A	*14*	*B*
	Perlidae	12												
EPHEMEROPTERA	Baetidae 1sp	4	4	A										
	Baetidae 2 sp	6					6	A						
	Baetidae >2sp	12			12	A					12	A	*12*	*C*
	Caenidae	6											*6*	*B*
	Ephemeridae	15												
	Heptageniidae	13	13	A					13	A	13	A		
	Leptophlebiidae	9	9	B					9	A	9	A		
	Machadorythidae													
	Oligoneuridae	15												
	Polymytarcidae	10												
	Prosopistomatidae	15												
	Telagonodidae	12	12	A							12	A	*12*	*B*
	Tricorythidae	9												
ODONATA	Calopterygidae	10												
	Chlorocyphidae	10							10	A	10	A		
	Chlorolestidae	8											*8*	*A*
	Coenagriidae	4			4	A	4	A			4	A	*4*	*B*
	Lestidae	8											*8*	*1*
	Platycnemidae	10												
	Protoneuridae	8												
	Aeshnidae	8					8	A			8	A	*8*	*1*
	Corduliidae	8											*8*	*1*
	Gomphidae	6					6	A	6	A	6	A	*6*	*A*
	Libellulidae	4	4	A			4	A	4	A	4	A	*4*	*A*
LEPIDOPTERA	Crambidae (Pyralidae)	12												
HEMIPTERA	Belostomatidae	3												
	Corixidae	3											*3*	*B*
	Gerridae	5											*5*	*A*
	Hydrometridae	6												
	Naucoridae	7					7	A			7	A	*7*	*1*
	Nepidae													
	Notonectidae	3											*3*	*B*
	Pleidae	4											*4*	*1*
	Veliidae/ M…veliidae	5					5	A			5	A	*5*	*1*
MEGALOPTERA	Corydalidae	8	8	A							8	A	*8*	*B*
	Sialidae	6												
TRICHOPTERA	Dipseudopsidae	10												
	Ecnomidae	8												
	Hydropschychidae 1 sp	4												
	Hydropschychidae 2 sp	6	6	A							6	A	*6*	*C*
	Hydropsychidea >2sp	12												
	Philopotamidae	10	10	A	10	A			10	A	10	A	*10*	*B*
	Polycentropodidae	12												
	Psychomiidae	8												
	Xiphocentronidae													
	Barbarochthonidae	13			13	A					13	A		
	Calamoceratidae	11												
	Glossosomatidae	11												
	Hydroptilidae	6											*6*	*1*
	Hydrosalpingidae	15												
	Lepidostomatidae	10												
	Leptoceridae	6					6	A			6	A	*6*	*B*
	Petrothrincidae	11												
	Pisullidae	10												
	Sericostomatidae SWC	13												
COLEOPTERA	Dytiscidae	5			5	A			5	A	5	A	*5*	*A*
	Elmidae	8	8	A							8	A	*8*	*A*
	Dryopidae	8											*5*	*A*
	Gyrinidae	5	5	A							5	A		
	Haliplidae	5												
	Helodidae	12												
	Hydraenidae	8												
	Hydrophilidae	5												
	Limnichidae	10												
	Psepheniidae	10												
DIPTERA	Athericidae	10					10	A	10	A	10	A	10	A
	Blepharoceridae	15												
	Ceratopogonidae	5											*5*	*1*
	Chironomidae	2	2	A			2	A	2	A	2	A	*2*	*C*
	Culicidae	1											*1*	*1*
	Dixidae	10											*10*	*1*
	Empididae	6												
	Ephydridae	3												
	Muscidae	1												
	Psychodidae	1												
	Simuliidae	5	5	C							5	C	*5*	*C*
	Syrphidae	1											*5*	*1*
	Tabanidae	5	5	A							5	A	*5*	*1*
	Tipulidae	5												
GASTROPODA	Ancylidae	6	6	A							6	A		
	Bulininae	3												
	Hydrobidae	3												
	Lymnaeidae	3												
	Physidae	3												
	Planorbinae	3												
	Thiaridae	3												
PELECYPODA	Corbiculiidae	5												
	Sphaeriidae	3												
	Unionidae	6												
	Viviparidae	5												
	SASS5 Score		115		66		72		83		205		229	
	No of taxa		17		7		11		10		28		37	
	ASPT		6.8		9.4		6.5		8.3		7.3		6.2	
	% of Reference SASS										89.5			
	% of Reference ASPT										118.3			

F6 EWR 3: UPPER DIEP (DIEP RIVER) – DETERMINATION OF STRESS INDICES AND EWR SCENARIOS

Section F6 provides supporting macroinvertebrate information for the determination of stress indices and EWR scenarios of EWR 2 (Chapter 9 and 10 of the Riverine RDM Report: Volume 1).

F6.1 MACROINVERTEBRATE INDICATOR TAXA

Only taxa that occurred commonly at the site were selected and included:

- **Flow dependent macroinvertebrate (FDI) indicator taxa**: Notonemouridae, Heptageniidae, Telogonodidae, Philopotamidae, Baetidae (>2sp), and Leptophlebiidae. All of these taxa have a preference for moderate to high flows and cobble habitat (FCS). Some, such as Notonemouridae and certain Baetidae, occur in other biotopes at most flow conditions.
- **Marginal vegetation macroinvertebrate (MVI) indicator taxa:** Baetidae (>2sp), Philopotamidae, and Barbarochthonidae. All of these taxa typically have a preference for moderate to high flows and cobbles, but all occur and were collected in the MVI biotope. Some (e.g. Baetidae) have a lower preference for other biotopes (e.g. GSM, and MVI) and will be found in these biotopes during higher and low flow conditions.

F6.2 MACROINVERTEBRATE STRESS INDEX

The habitat flow index for FDI and MVI taxa is provided in Table B20 and provides the % occurrence of various velocity and substrate classes under different flow conditions.

Table F20 Habitat suitability for FDI and MVI taxa

Habitat Flow Response Index	Habitat Response	Habitat Abundance and Suitability (%)						Flow (m^3/s)
		FCS[1]	SCS[2]	FFS[3]	SFS[4]	FBR[5]	SBR[6]	
0	Plentiful mobile SCS and FCS, no embeddedness, max depth ensures instream vegetation inundation, vegetation clear of algae, very high velocity flow.	12	46	2	8	7	25	0.223
2	Width slightly reduced from zero stress condition, all critical habitats (SCS, FCS, and MV) still plentiful; high velocity flows; majority of stream width comprises critical habitat for FDI and MVI taxa. Instream vegetation still inundated at these depths.	9	51	2	9	5	26	0.151
3	Discharge at which sampling was done. FCS restricted to small areas. Adequate depth and velocity across whole cross section. No flow through marginal vegetation. Only restios inundated, Palmiet exposed.	5	55	1	9	3	28	0.075
6	Very restricted areas of FCS (e.g. over chutes and through restricted upstream SIC areas). No vegetation inundated. Large areas of shallow slow flow over coarse substrates. Velocities just lower than the range of 'fast flows' (0.1 - 0.3 m/s).	1	59	0	10	1	30	0.031
8	No FCS, channel dominated by shallow slow flow over coarse substrates. Water quality likely to deteriorate and fines/algae may reduce habitat quality.	0	60	0	10	0	30	0.005
10	Only shallow slow flow or no flow over coarse substrates in narrow areas, and pools present. Habitat quality impaired by deteriorating water quality and associated algae and deposition of fines. No MV inundated.	0	60	0	10	0	30	0.001

1 Fast over Coarse Sediment 2 Slow over Coarse Sediment 3 Fast over Fine Sediment
4 Slow over Fine Sediment 5 Fast flow over Bedrock 6 Slow Flow over Bedrock

The stress index for FDI taxa is provided in Table F21 and in Table F22 for MVI. These tables rate the response of the species according to various biotic response metrics.

Table F21 Macroinvertebrate (FDI) stress index

Habitat characteristics						Biotic Response	Flow	Species Stress
Max depth (m)	Ave depth (m)	Dis-charge (m^3/s)	Width (m)	Perim (m)	Ave vel (m/s)			
0.42	0.18	0.223	6.6	8	0.19	All FDI indicators present in at least A abundance.	0.223	0
0.38	0.17	0.151	5.3	6.6	0.16	FDI indicators all present in at least A abundance.	0.151	2
0.32	0.14	0.075	4.5	5.7	0.12	All FDI indicators present in abundances reflected by SASS5.	0.075	3
0.26	0.12	0.031	3.2	4.2	0.08	Reduction in abundance and presence of FDI taxa. If these conditions persist, all FDIs will disappear or persist only in very low numbers in the remaining narrow flow areas.	0.031	6
0.18	0.08	0.005	2.2	2.9	0.03	Probable absence of all FDI taxa, although individuals may persist for a period in the narrow areas where flow velocities > 0.1 m/s.	0.005	8
0.14	0.06	0.001	1.8	2.2	0.01	No FDI taxa present.	0.001	10

Table F22 Macroinvertebrate (MVI) stress index

Habitat characteristics						Biotic Response	Flow	Species Stress
Max depth (m)	Ave depth (m)	Dis-charge (m^3/s)	Width (m)	Perim (m)	Ave vel (m/s)			
0.42	0.18	0.223	6.6	8	0.19	All MVI indicator taxa (and potentially additional high-scoring taxa) present, catered for by extent of inundation (max. depth 0.42 m) and the likely depth of vegetation into flow (not modelled). All taxa in at least A abundance.	0.223	0
0.38	0.17	0.151	5.3	6.6	0.16	All MVI indicator taxa present. Vegetation inundation (max. depth 0.38 m) and the likely depth of vegetation into flow (not modelled). All taxa in at least A abundance.	0.151	2
0.32	0.14	0.075	4.5	5.7	0.12	MVI indicator taxa are mostly flow-dependent taxa, and will be present in MVOC only if there has been recent flow through vegetation (as was likely during the fieldtrip). If not present in MV, these taxa should however still be present in FCS areas (i.e. total SASS sample should not change from survey sample).	0.075	3
0.26	0.12	0.031	3.2	4.2	0.08	Of the MVI taxa, only Baetidae (1 or more spp.) likely to be present. Barbarochtonids may be present in coarse substrates in flow areas.	0.031	6
0.18	0.08	0.005	2.2	2.9	0.03	One or more species of Baetidae likely to be present in marginal vegetation.	0.005	8
0.14	0.06	0.001	1.8	2.2	0.01	Only baetids (likely 1 spp.) may persist for a period in limited SCS areas.	0.001	10

F6.3 LOW FLOW REQUIREMENTS IN TERMS OF STRESS FOR MACROINVERTEBRATES

The FDI and MVI low flow requirements are summarised in Table F23 and F24 below.

Table F23 Low flow requirements: FDI taxa

GENERAL

INDICATOR: Indicator taxa include Notonemouridae, Baetidae (>2sp), Athericidae, Dixidae.

DROUGHT CONDITIONS:

Dry and wet season

The requirement during drought, for this perennial system is for 10 – 20 cm depth over coarse substrates to maintain the SCS (SOC), MVI and SFS (GSM) biotopes inundated, thus providing habitat for taxa with a preference for MV and coarse and fine substrates at lower flows. Connectivity should be maintained. This will require flow over bedrock. The requirement is to maintain the more resilient macroinvertebrate taxa (approx 60% of the community).

MAINTENANCE CONDITIONS:

Dry season

The dry season falls in June/July during winter. In general, macroinvertebrates are in a cycle of low growth and some may be in hibernation. Overall, conditions should favour adequate supply of food and oxygen, and maintenance of water quality conditions. Sufficient moderate to fast flows over coarse sediments are required to maintain indicator taxa through to winter. On the cross section, a depth of 15 – 30 cm is required.

Wet season

The dry season falls in October/November during early summer. In general, macroinvertebrates are in a cycle of breeding or development, with juveniles in a rapid growth phase. Requirements are for a plentiful supply of food and oxygen, maintenance of water quality conditions, and – for juveniles - access to cover (usually in the form of root wads or inundated vegetation). Plentiful moderate to fast flows over coarse sediments are required to maintain indicator taxa through summer. On the cross section, a depth of >15 to >30 cm is required, particularly for the inundation of MV.

BUILDING BLOCK	SEASON	STRESS DURATION	SPP STRESS	INTEG STRESS	FLOW (m^3/s)
Drought	Dry	5%	7.75	7.75	0.011

During the dry season drought, some flow is anticipated. Rheophilic taxa (including all indicators and Simuliidae and Hydropsychidae) will be eliminated within 1 - 2 weeks under these conditions. Conditions include a depth of 11 - 22cm, trickling flow, discharge of 0.011 m^3/s, velocities of 0.05 - 0.19 m/s and flow in habitat approximately 3% of the inundated width.

BUILDING BLOCK	SEASON	STRESS DURATION	SPP STRESS	INTEG STRESS	FLOW (m^3/s)
Drought	Wet	5%	5.25	6.25	0.028

Flows should be maintained to enable survival of juveniles (e.g. Ephemeroptera, Simuliidae and Hydropsychidae). This will also give protection against high temperatures and organic enrichment of pools. Conditions include a depth of 12 – 26 cm, discharge of 0.028 m^3/s, velocities of 0.08 - 0.28 m/s, and flow in habitat approx. 4% of the inundated width.

DRY SEASON REQUIREMENTS

BUILDING BLOCK	ECOSTATUS	INVERT EC	STRESS DUR	SPP STRESS	INTEG STRESS	FLOW (m^3/s)
Maint[3] REC	B	B	40%	2	3	0.075

Conditions include a depth of 14 - 32 cm, discharge of 0.075 m^3/s, velocities of 0.12 - 0.41 m/s, and flow habitat approx. 8% of the inundated width.

BUILDING BLOCK	ECOSTATUS	INVERT EC	STRESS DUR	SPP STRESS	INTEG STRESS	FLOW (m^3/s)
Maint AEC↓	C	C	40%	3	4	0.06

Conditions include a depth of 13 - 30 cm, discharge of 0.058 m^3/s, velocities of 0.11 - 0.37 m/s, and flow in habitat 7% of the inundated width.

WET SEASON REQUIREMENTS

BUILDING BLOCK	ECOSTATUS	INVERT EC	STRESS DUR	SPP STRESS	INTEG STRESS	FLOW (m^3/s)
Maint REC	B	B	40%	1.5	2.5	0.12

Conditions include a depth of 16 - 36 cm, discharge of 0.12 m^3/s, velocities of 0.15 - 0.52 m/s, and flow in habitat approx. 11% of the inundated width.

BUILDING BLOCK	ECOSTATUS	INVERT EC	STRESS DUR	SPP STRESS	INTEG STRESS	FLOW (m^3/s)
Maint AEC↓	C	C	40%	2.5	3.5	0.065

Conditions include a depth of 14 - 31 cm, discharge of 0.065 m^3/s, velocities 0.11 - 0.37m/s, and flow in habitat 8% of the inundated width.

Table F24 Low flow requirements: MVI

GENERAL

INDICATOR: Indicator taxa include Notonemouridae, Baetidae (>2sp), Athericidae, and Dixidae.

DROUGHT CONDITIONS:

The requirement during drought, for this perennial system is 10 – 20 cm depth over coarse substrates to maintain SOC and GSM. Greater depths are required to inundate MV, both in flow areas and in pools.

MAINTENANCE CONDITIONS:

Dry season

The dry season falls in June/July during winter. In general, macroinvertebrates are in a cycle of low growth and some may be in hibernation. Overall, conditions should favour adequate supply of food and oxygen, and maintenance of water quality conditions. Sufficient moderate flows through vegetation are required to maintain indicator taxa and a diverse community through to summer. On the cross section, a depth of >10 – 20 cm is required in order to provide adequate inundation.

Wet season

The wet season falls in October/November during early summer. In general, macroinvertebrates are in a cycle of breeding or development, with juveniles in a rapid growth phase, and requiring cover. Overall, a supply of food and oxygen, maintenance of water quality conditions are required (in this case, in the form of inundated *E. capensis*). On the cross section, a depth of >15 to >30 cm is required, particularly for the inundation of MV.

BUILDING BLOCK	SEASON	STRESS DURATION	SPP STRESS	INTEG STRESS	FLOW (m^3/s)
Drought	Dry	5%	7	7	0.015

During the dry season drought, some flow is anticipated. Rheophilic taxa (including all indicators, and Simuliidae, and Hydropsychidae) will be eliminated within 1 - 2 weeks under these conditions. Conditions include a depth of 11 – 22 cm, trickling flow, discharge of 0.015 m^3/s, velocities of 0.05 - 0.19 m/s, and flow in habitat approx 3% of the inundated width. It is unlikely that the MV will be sufficiently inundated at this depth to be a useful habitat. **Note:** Account has been taken of the fact that the hydraulics is overestimated for depth and underestimated for flow-habitat percentages and velocity. This was due to the position of the cross section upstream of the critical flow area.

BUILDING BLOCK	SEASON	STRESS DURATION	SPP STRESS	INTEG STRESS	FLOW (m^3/s)
Drought	Wet	5%	6	6	0.031

Flows should be maintained to enable survival of juveniles (e.g. Ephemeroptera, Simuliidae, and Hydropsychidae). These juveniles are likely to inhabit MV. Conditions include a depth of 12 – 26 cm, a discharge of 0.031 m^3/s, velocities of 0.08 - 0.28 m/s, and a flow in habitat approx. 4% of the inundated width.

DRY SEASON REQUIREMENTS

BUILDING BLOCK	ECOSTATUS	INVERT EC	STRESS DUR	SPP STRESS	INTEG STRESS	FLOW (m^3/s)
Maint REC	B	B	40%	3	3	0.075

Conditions include a depth of 10 - 26 cm, a discharge of 0.057 m^3/s, velocities of 0.19 - 0.62 m/s, and flow in habitat 13% of the inundated width.

BUILDING BLOCK	ECOSTATUS	INVERT EC	STRESS DUR	SPP STRESS	INTEG STRESS	FLOW (m^3/s)
Maint AEC↓	C	C	40%	4	4	0.06

Conditions include a depth of 9 - 22 cm, discharge of 0.032 m^3/s, velocities of 0.17 - 0.53 m/s, and flow in habitat 9% of the inundated width.

WET SEASON REQUIREMENTS

BUILDING BLOCK	ECOSTATUS	INVERT EC	STRESS DUR	SPP STRESS	INTEG STRESS	FLOW (m^3/s)
Maint REC	B	B	40%	2.25	2.25	0.13

Conditions include a depth of 17 - 38 cm, discharge of 0.15 m^3/s, velocities of 0.16 - 0.6 m/s, and flow in habitat approx. 12% of the inundated width.

BUILDING BLOCK	ECOSTATUS	INVERT EC	STRESS DUR	SPP STRESS	INTEG STRESS	FLOW (m^3/s)
Maint AEC↓	C	C	40%	3	3	0.075

Conditions include a depth of 14 - 31 cm, discharge of 0.075 m^3/s, velocities of 0.14 - 0.41 m/s, and flow in habitat approx. 8% of the inundated width.

F7 EWR4: KARATARA (KARATARA RIVER) - ECOCLASSIFICATION

F7.1 DATA AVAILABILITY

The following data were available:

- Macroinvertebrate data and analysis from a single sampling trip to the site on 23 April 2007.
- Macroinvertebrate data for samples taken in the Groot River, a tributary of the Groot Brak (National River Health Programme Site K3WITE-, quaternary catchment K30A, over a period of 2 years, October 2006 and September 2007, supplied by Gerhard Diedericks (2006).
- Preliminary maps and information on the catchment as supplied by Delana Louw, Water for Africa.

Specialist assessments for this study:

- Hydrological assessment by Prof Denis Hughes, September 2007
- IHI assessment by Delana Louw, September 2007
- Hydraulics Information supplied by Andrew Birkhead, 2007
- Level 1 EcoRegion system Classification: Kleynhans *et al.* (2005).
- Level 2 EcoRegion system Classification: Kleynhans *et al.* (2007).
- Geomorphic zone classification for the site.
- IHI segments and impacts for the site.

Confidence as a result of data availability and one site visit was low to moderate (2.5) due to the lack of previous data for the site and river itself, the lack of geomorphological and water quality information, and the nature of the reference data available.

F7.2 REFERENCE CONDITION

Data from a number of sites on the Groot River were examined to check their relevance as reference data for the Karatara River. Three data sets had equivalent merit – two supplied by Gerhard Diedericks for two different National River Health Programme sites on the Groot (tributary of the Groot Brak), and one supplied by Rembu Magoba (DWAF 2007) for an additional site on the Groot River.

The reference condition for EWR 4 was finally based on data collected at a National River Health Programme Site (K3WITE-) on the Groot River, a tributary of the Groot Brak. While this river is in a different Level 1 Ecoregion (Southern Folded Mountains) to the Karatara, it was considered to have similar characteristics to the EWR 4 site in terms of available habitat, general site description and condition, and on the basis of photographic records (Table F25). SASS5 results indicated a similarity of taxa between the sites. The lower of two reference condition SASS5's for the same site was used, with a total score of 146, number of taxa 20, and an ASPT of 7.3 (Table F26).

Table F25 Reference site details

RHP code	Site code	Locality	Latitude	Longitude	Quat	Maj Riv	EcoRegion I	Zone
K3WITE	K30A-01	Suigpunt 34	33 55.157S	22 16.139E	K30A	Groot Brak	Southern Folded Mts (19)	Mountain stream

Table F26 Summary data for the reference site and the test site

River	Site Code	Date	Flow	SASS	No Taxa	ASPT
Groot	K30A-01	Oct06	Moderate	146	20	7.3
Karatara	EWR4	April 07		121	15	8.1

F7.3 PES

The PES of the macroinvertebrates at the EWR 4 site is 92.3%, which is a MIRAI EC of A/B. The only two habitats sampled at the Karatara River were SIC (FFCS) and SOC (SCS). There was no inundated marginal vegetation, and gravel/sand/mud was absent.

The overall SASS score was 121, with 15 taxa and an ASPT of 8.1 (slightly higher than that of the reference site). The six taxa contributing to the high ASPT (and scoring 10 or greater) included Notonemouridae, Telogonodidae, Philopotamidae, Barbarochthonidae, Pisuliidae, and Athericidae. All these taxa have a preference for moderate to high flows, indicating the importance of this flow type and hydraulic habitat to the invertebrate community. According to the Groot River data supplied by Rembu Magoba (DWAF, 2007), the absence of inundated Marginal Vegetation and Gravel/Sand or Mud (GSM) at the Karatara may explain the absence of taxa such as Aeshnidae, Libellulidae, Naucoridae, Veliidae, Dipseudopsidae, Lepidostomatidae, Gyrinidae, and Tipulidae. This was one of the reasons for using reference data with the lower overall score. The inundation of the sparse existing marginal vegetation at the site would be expected to contribute to an increase in overall score and ASPT.

Table F27 Taxa collected at EWR 4 at the Karatara River, and the reference data from the Groot River Site

			Upper Karatara						Groot		
			SIC		SOC		TOTAL		Score	Ab	Freq.
PORIFERA	PORIFERA	5									
COELENTERATA	COELENTERATA	1									
TURBELLARIA	TURBELLARIA	3									
ANNELIDA	Oligochaeta	1							1	1	100
	HIRUDINEA	3									
CRUSTACEA	Amphipoda										
	Potamonautidae	3									
	Atyidae	8									
	Palaeomonidae	10									
HYDRACARINA	HYDRACARINA	8									
PLECOPTERA	Notonemouridae	14	14	B			14	B	14	A	100
	Perlidae	12									
EPHEMEROPTERA	Baetidae 1sp	4	4	A			4	A	4	1	100
	Baetidae 2 sp	6									
	Baetidae >2sp	12									
	Caenidae	6									
	Ephemeridae	15									
	Heptageniidae	13									
	Leptophlebiidae	9			9	A	9	A	9	A	100
	Machadorythidae										
	Oligoneuridae	15									
	Polymytarcidae	10									
	Prosopistomatidae	15									
	Telagonodidae	12			12	A	12	A	12	B	100
	Tricorythidae	9									
ODONATA	Calopterygidae	10									
	Chlorocyphidae	10									
	Chlorolestidae	8			8	A	8	A	8	A	100
	Coenagriidae	4							4	1	50
	Lestidae	8									
	Platycnemidae	10									
	Protoneuridae	8									
	Aeshnidae	8									
	Corduliidae	8									
	Gomphidae	6									
	Libellulidae	4			4	A	4	A			
LEPIDOPTERA	Crambidae (Pyralidae)	12									
HEMIPTERA	Belostomatidae	3									
	Corixidae	3							3	B	50
	Gerridae	5									50
	Hydrometridae	6									
	Naucoridae	7							7	A	100
	Nepidae										
	Notonectidae	3									
	Pleidae	4									50
	Veliidae/ M…veliidae	5							5	1	100
MEGALOPTERA	Corydalidae	8	8	A			8	A	8	B	100
	Sialidae	6									
TRICHOPTERA	Dipseudopsidae	10									
	Ecnomidae	8									
	Hydropschychidae 1 sp	4	4	A			4	A	4	A	100
	Hydropschychidae 2 sp	6									
	Hydropsychidea >2sp	12									
	Philopotamidae	10	10	A			10	A	10	A	100
	Polycentropodidae	12									
	Psychomiidae	8									
	Xiphocentronidae										
	Barbarochthonidae	13	13	A	13	A	13	A	13	B	100
	Calamoceratidae	11									
	Glossosomatidae	11									
	Hydroptilidae	6									
	Hydrosalpingidae	15									
	Lepidostomatidae	10									
	Leptoceridae	6							6	B	100
	Petrothrincidae	11									50
	Pisullidae	10			10	A	10	A	10	B	100
	Sericostomatidae SWC	13									50
COLEOPTERA	Dytiscidae	5							5	1	100
	Elmidae	8	8	B	8	A	8	A	8	B	100
	Dryopidae	8									
	Gyrinidae	5									50
	Haliplidae	5									
	Helodidae	12									
	Hydraenidae	8									
	Hydrophilidae	5									
	Limnichidae	10									
	Psepheniidae	10									
DIPTERA	Athericidae	10	10	A	10	A	10	A	10	1	100
	Blepharoceridae	15									
	Ceratopogonidae	5									
	Chironomidae	2	2	A	2	A	2	A			50
	Culicidae	1									
	Dixidae	10									
	Empididae	6									
	Ephydridae	3									
	Muscidae	1									
	Psychodidae	1									
	Simuliidae	5	5	B	5	B	5	B	5	A	100
	Syrphidae	1									
	Tabanidae	5									
	Tipulidae	5									
GASTROPODA	Ancylidae	6									
	Bulininae	3									
	Hydrobidae	3									
	Lymnaeidae	3									
	Physidae	3									
	Planorbinae	3									
	Thiaridae	3									
PELECYPODA	Corbiculiidae	5									
	Sphaeriidae	3									
	Unionidae	6									
	Viviparidae	5									
	SASS5 Score		78		81		121		146		
	No of taxa		10		10		15		20		
	ASPT		7.8		8.1		8.1		7.3		
	% of Reference SASS						82.9				
	% of Reference ASPT						110.5				

F8 EWR 4: KARATARA(KARATARA RIVER) – DETERMINATION OF STRESS INDICES AND EWR SCENARIOS

Section F8 provides supporting macroinvertebrate information for the determination of stress indices and EWR scenarios of EWR 2 (Chapter 11 and 12 of the Riverine RDM Report: Volume 1).

F8.1 MACROINVERTEBRATE INDICATOR TAXA

Only taxa that occurred commonly at the site were selected and included:

- **Flow dependent macroinvertebrate (FDI) indicator taxa**: Notonemouridae, Telogonodidae, Philopotamidae, Barbarochthonidae, Pisuliidae, Athericidae. All of these taxa have a preference for moderate to high flows and a cobble habitat. Some, such as Notonemouridae, have a lower preference for other biotopes (e.g. GSM, MV) and will be found in these biotopes during higher and low flow conditions.

F8.2 MACROINVERTEBRATE STRESS INDEX

The habitat flow index for FDI taxa is provided in Table F28 and provides the % occurrence of various velocity and substrate classes under different flow conditions.

Table F28 Habitat suitability for FDI taxa

Habitat Flow Response Index	Habitat Response	Habitat Abundance and Suitability (%)						Flow (m^3/s)
		FCS[1]	SCS[2]	FFS[3]	SFS[4]	FBR[5]	SBR[6]	
0		22	46	4	7	7	14	0.146
1		17	51	3	8	5	16	0.094
2		13	56	2	8	4	17	0.057
3	Bedrock and boulders dominate this system. Cobbles are interspersed, in the higher flow areas. Cobbles mobile but highly packed. No fines or algae at these flows.	9	60	1	9	3	18	0.032
4		9	61	1	9	3	17	0.023
5		7	63	1	9	2	18	0.016
6		5	65	1	9	1	19	0.011
7		3	67	0	10	1	19	0.007
8	Almost all flow through coarse substrates lost. SCS is the dominant biotope. Maximum velocities still indicate that there are small patches of flow, likely in the steeper areas at this site. MVI absent.	1	69	0	10	0	20	0.004
9		0	70	0	10	0	20	0.002
10		0	70	0	10	0	20	0.001

1 Fast over Coarse Sediment; 2 Slow over Coarse Sediment; 3 Fast over Fine Sediment
4 Slow over Fine Sediment; 5 Fast flow over Bedrock; 6 Slow Flow over Bedrock

The stress index for FDI taxa is provided in Table F28. The table rate the response of the species according to various biotic response metrics.

Table F29 FDI stress index

Habitat characteristics			Biotic Response	Flow	Species Stress
Max (Av) depth	Av (98%) Velocity	Width			
0.34	0.79	4.3		0.146	0
0.3	0.72	3.3		0.094	1
0.26	0.62	2.9		0.057	2
0.22	0.53	2.3	Sensitive taxa with preference for moderate to high flows include Telogonodidae, Philopotamidae, Barbarochthonidae, Pisuliidae, and Athericidae.	0.032	3
0.2	0.51	1.7		0.023	4
0.18	0.47	1.5		0.016	5
0.16	0.41	1.3		0.011	6
0.14	0.34	1.1		0.007	7
0.12	0.26	0.8	Loss of flow will correspond with a loss or reduction in numbers of indicator FDI (described at Stress level 3).	0.004	8
0.1	0.2	0.6		0.002	9
0.08	0.14	0.5		0.001	10

F8.3 LOW FLOW REQUIREMENTS IN TERMS OF STRESS FOR MACROINVERTEBRATES

The FDI low flow requirements are summarised in Table 30 below.

Table F30 Low flow requirements: FDI taxa

GENERAL					
INDICATOR: Notonemouridae, Telogonodidae, Philopotamidae, Barbarochthonidae, Pisuliidae and Athericidae. All of these taxa have a preference for moderate to high flows and a cobble habitat. Some, such as Notonemouridae, have a lower preference for other biotopes (e.g. GSM, MVI) and will be found in these biotopes during higher and low flow conditions. **DROUGHT CONDITIONS:** **Dry and wet season** The requirement during drought, for this perennial system is for 10 – 20 cm depth over coarse substrates to maintain the SCS (SOC) and SFS (GSM) biotopes inundated, thus providing habitat for at least the more resilient macroinvertebrate taxa, and for those taxa which will migrate to the water column or finer sediments as the flow diminishes. **MAINTENANCE CONDITIONS:** **Dry season** The dry season falls in June/July during winter. In general, macroinvertebrates are in a cycle of low growth and some may be in hibernation. Overall, conditions should favour adequate supply of food and oxygen, and maintenance of water quality conditions. Sufficient moderate to fast flows over coarse sediments are required to maintain indicator taxa through to summer. On the cross section, a depth of 10 – 20 cm is required. **Wet season** The dry season falls in October/November during early summer. In general, macroinvertebrates are in a cycle of breeding or development, with juveniles in a rapid growth phase. Requirements are for a plentiful supply of food and oxygen, maintenance of water quality conditions, and – for juveniles - access to cover (usually in the form of root wads or inundated vegetation). Plentiful moderate to fast flows over coarse sediments are required to maintain indicator taxa through summer. On the cross section, a depth of >10 to >30 cm is required, particularly for the inundation of MV.					
BUILDING BLOCK	**SEASON**	**STRESS DURATION**	**SPP STRESS**	**INTEG STRESS**	**FLOW (m^3/s)**
Drought	Dry	5%	6	6	0.011
Some flow is anticipated. Rheophilic taxa (including all indicators, Simuliidae, Hydropsychidae, and Leptophlebiidae) will be eliminated within 1 - 2 weeks under these conditions. Conditions equate to a depth of 7 – 16 cm, trickling flow, discharge of 0.011 m^3/s, velocities of 0.1 - 0.4m/s, and flow habitat 5% of the inundated width.					
BUILDING BLOCK	**SEASON**	**STRESS DURATION**	**SPP STRESS**	**INTEG STRESS**	**FLOW (m^3/s)**

Drought	Wet	5%	4.3	4.5	0.021	
Flows should be maintained to enable survival of juveniles (e.g. Ephemeroptera, Simuliidae, and Hydropsychidae). This will also guard against high temperatures and organic enrichment of pools. These conditions equate to a depth of 9 – 20 cm, discharge of 0.023m^3/s, velocities 0.15 - 0.51m/s, and flow habitat 9% of the inundated width.						
DRY SEASON REQUIREMENTS						
BUILDING BLOCK	**ECOSTATUS**	**INVERT EC**	**STRESS DUR**	**SPP STRESS**	**INTEG STRESS**	**FLOW (m^3/s)**
Maint REC	A/B	A	40%	2	2.3	0.06
These conditions equate to a depth of 10 - 26 cm, discharge of 0.057 m^3/s, velocities of 0.19 - 0.62 m/s, and flow habitat 13% of the inundated width.						
BUILDING BLOCK	**ECOSTATUS**	**INVERT EC**	**STRESS DUR**	**SPP STRESS**	**INTEG STRESS**	**FLOW (m^3/s)**
Maint AEC↓	B/C	B	40%	3	3	0.032
These conditions equate to a depth of 9 - 22 cm, discharge of 0.032m^3/s, velocities of 0.17 - 0.53m/s, and flow habitat 9% of the inundated width.						
WET SEASON REQUIREMENTS						
BUILDING BLOCK	**ECOSTATUS**	**INVERT EC**	**STRESS DUR**	**SPP STRESS**	**INTEG STRESS**	**FLOW (m^3/s)**
Maint REC	A/B	A	40%	1	1	0.104
These conditions equate to a depth of depth 13 - 30 cm, discharge of 0.094 m^3/s, velocities of 0.22 - 0.72m/s, and flow habitat 17% of the inundated width.						
BUILDING BLOCK	**ECOSTATUS**	**INVERT EC**	**STRESS DUR**	**SPP STRESS**	**INTEG STRESS**	**FLOW (m^3/s)**
Maint AEC↓	B/C	B	40%	2	2.3	0.06
These conditions equate to a depth 10 – 26 cm, a discharge of 0.057 m/s, velocities of 0.19 - 0.62m/s, and flow habitat 13% of the inundated width.						

F9 REFERENCES

Dallas, H. 2007. River Health Programme: SASS Data Interpretation Guidelines. Report Prepared for INR and DWAF.

Department of Water Affairs and Forestry (DWAF), 2007. Reserve Determination studies for selected surface water, groundwater, estuaries and wetlands in the Outeniqua (Groot Brak and other water resources, excluding wetlands) catchment: Ecological Water Requirements Study - Riverine RDM Report. Report No. RDM/10-K30, K40E/00/CON/0407. Pretoria.

Diedericks, G. 2006. Establishing stream conditions of the major rivers draining Mountain to Ocean Forests' Bergplaas, Buffelsnek, Jonkershoek and Longmore commercial tree plantations in the Eastern and Western Cape, South Africa. Internal Unpublished Report, MTO Forests.

King JM 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.

Kleynhans, CJ, Thirion, C and Moolman, J. (2005). A Level I River Ecoregion classification System for South Africa, Lesotho and Swaziland. Report No. N/0000/00/REQ0104. Resource Quality Services, Department of Water Affairs and Forestry, Pretoria, South Africa.

Kleynhans, CJ, Thirion, C, Moolman, J and Gaulana, L. (2007). A Level II River Ecoregion classification System for South Africa, Lesotho and Swaziland. Report No. N/000/00/REQ0XXX. Resource Quality Services, Department of Water Affairs and Forestry, Pretoria, South Africa.

APPENDIX G: RIPARIAN VEGETATION SPECIALIST REPORT
J MACKENZIE, Bio River Solutions

G1 EWR1: KNYSNA RIVER

G1.1 DATA AVAILABILITY

The following data were available:

- "The Reserve Determination Studies for selected Surface Water, Groundwater, Estuaries and Wetlands in the Outeniqua Catchment: Technical Component – Knysna and Swartvlei" Inception Report, draft.
- Satellite images (Google earth) of the respective reach.
- Hydraulic cross-section (profile) at the site together with surveyed key vegetation points for setting flows.
- Hydrology specialist report.
- EcoRegion class and associated information (Ecoregion 20.02: South eastern coastal belt -Fynbos, Renosterveld, Grassland, and Thicket vegetation types occur, but the dominant types are Afromontane Forest and Mesic Succulent Thicket).
- Geomorphic Zone classification (Upper Foothills).
- IHI: Instream IHI (91.7% A/B [3.6 conf]); Riparian IHI (86.2% B [3.8 conf]); Land Cover Classes (Indigenous forest, Exotic forest plantations, Shrubland and Low Fynbos).
- Biomes of South Africa: Forest/Fynbos (Rutherford and Westfall, 1986); Forest (van Wyk and van Wyk, 1997); Fynbos with Forests (Mucina and Rutherford, 2006).
- Bioregions of South Africa: Eastern Fynbos-Renosterveld Bioregion (F06) (Mucina and Rutherford, 2006).
- Vegetation Type: Afromontane and Inland Forest with grassland/fynbos (van Wyk and van Wyk, 1997).
- Vegetation Units: Southern Afrotemperate Forest (FOz 1: Zonal and Intrazonal forests) and South Outeniqua Sandstone Fynbos (FFs 19: Sandstone Fynbos), (Mucina and Rutherford, 2006).
- Veld Type: Mixed veld (Tainton, 1981; Acocks, 1988).
- Principle region of plant diversity and Endemism: Cape Floristic Region (van Wyk and van Wyk, 1997).
- Data collected from current field assessment (April, 2007).
- Previous reserve determination studies in vicinity (Groot, Klip, Sanddrift, Klipdrift and Tsitsikama Rivers), (MacKenzie, 2003).

Confidence as a result of data availability and one site visit is moderate to high (4).

G1.2 REFERENCE CONDITIONS

Area in general: The Knysna forest measures some 80, 000 ha in size. Outeniqua Yellowwoods are well known in this area. A particularly big, old specimen can be seen at Diepwalle forest station: the `King Edward VII´ tree, named in 1924, is an estimated 600 years old; its total height is 39 m, the bole's circumference is 6 m. Other common and well-known species in the Knysna forest include Stinkwood; Real Yellowwood; Blackwood; White Alder; Ironwood and Hard Pear. The Tree Fern, *Cyathea Capensis*, is protected species and grows in groups along banks of forest streams and under the canopy of moist forests. Fynbos is an evergreen heath-shrubland contributing a staggering 8000 species to the Fynbos floral kingdom. Three plant families characterize this area: Proteas, Ericas (heather) and Restios.

Reference conditions are similar for all the sites and would have consisted of predominantly forests (crown cover of 75% or more, dominated by trees) at the sites, but with Fynbos interdispersed. Southern Afrotemperate Forest (FOz 1: Zonal and Intrazonal forests) dominated by *Afrocarpus falcatus, Podocarpus latifolius, Ocotea bullata, Olea capensis subsp. macrocarpa, Pterocelastrus tricuspidatus,* and *Platylophus trifoliatus*. The shrub understorey and herbaceous layer is well developed, especially in wetter areas ((Mucina and Rutherford, 2006). For important and endemic taxa see Section G5.

Where forests do not occur, South Outeniqua Sandstone Fynbos (FFs 19: Sandstone Fynbos) dominates. Predominantly tall, open to medium dense shrubland with medium dense, medium tall shrub understorey, mainly proteoid, restiod and ericaceous fynbos. Scrub fynbos predominates riverine areas (Mucina and Rutherford, 2006). For important and endemic taxa see Section G5.

G1.2.1 Marginal Zone

The marginal zone was expected to be predominantly open with boulder/cobble/exposed bedrock. Riparian vegetation was predominantly non-woody (*Prionium serratum* and fynbos restios), with *Brachylaena neriifolia* as the only marginal zone tree comprising < 10% of vegetation (refers to rooted plants in marginal zone, although overhanging coverage is much higher). Limited sediment deposits as high-energy flow and short sunlight days (shading due to mountainous area and dense woody canopy) would keep *P. serratum* from dominating to a large extent/forming hydraulic controls.

G1.2.2 Lower Zone

The lower zone was expected to be a mix of open boulder/cobble/exposed bedrock and woody and non-woody riparian vegetation. Riparian vegetation was predominantly non-woody (*P. serratum*, fynbos restios and fern species), with *B. neriifolia* and *Ilex mitis* forming the woody component (10 - 30%). Woody vegetation performed an important shading effect for instream habitat. Limited sediment deposits would be present as high-energy flow and short sunlight days (shading due to mountainous area and dense woody canopy) would keep *P. serratum* from dominating to a large extent/forming hydraulic controls.

G1.2.3 Upper Zone

The upper zone was expected to be a mix of open boulder/cobble/exposed bedrock and woody and non-woody riparian vegetation on the macro channel floor, with frequent occurrence of typical forest species on the macro channel bank (see Section G5) and where enough sediment deposit was allowed within the macro channel. The vegetation component would be greater than the open rock in most settings. Riparian vegetation was predominantly woody, with forest woody species predominating on the macro channel banks. Non-woody species would not be typically riparian.

Confidence: 4

G1.3 PES

The PES of riparian vegetation at the Knysna site is 82.4%, which is a Vegetation Response Assessment Index (VEGRAI) EC of B (Table. G1). Riparian vegetation response was mainly due to non-flow-related impacts in the marginal, lower and upper zones (see main report – Volume 1).

Vegetation type, structure, cover, abundance and composition were close to what was expected for the marginal, lower and upper zones. Effects of large, recent floods had reduced recruitment throughout, but this was expected. Recovery of riparian vegetation, especially woody species, was occurring in marginal and lower zones. The presence of exotic trees (*Acacia melanoxylon* and *A. mearnsii*) in the marginal zone was a small problem, but had potential to increase. The presence of exotic trees (*A. melanoxylon* and *A. mearnsii*) in lower and upper zones were greater than marginal zone, and had the potential to increase due to the close proximity of forestry, from where these aliens could escape. Some bank erosion was noted, probably due to replacement of indigenous forest by exotic plantations, but this was only present at high flow zones.

Table G1 EWR 1: Contribution of riparian vegetation zones to the calculation of the Riparian Zone using VEGRAI level 4

RIPARIAN VEGETATION EC METRIC GROUP	CALCULATED RATING	WEIGHTED RATING	CONFIDENCE	RANK	WEIGHT	NOTES: (give reasons for each assessment)
MARGINAL	84.1	33.7	3.5	1.0	100.0	marginal zone most important for year-round refuge habitat
LOWER ZONE	82.7	29.8	3.6	2.0	90.0	lower zone has high seasonal importance for breeding habitat, also shading of aquatic habitats
UPPER ZONE	79.1	19.0	3.6	3.0	60.0	important shading role as flows traverse forest biome
	3.0				250.0	
LEVEL 4 VEGRAI (%)				82.4		
VEGRAI EC				**B**		
AVERAGE CONFIDENCE				3.5		

Upper and lower limits of important species or guilds were surveyed along a transect across the EWR 1 in April 2007 during the hydraulic survey. Figure G1 presents the hydraulic profile of the cross section and the blue and red lines indicate the different water levels at the time of hydraulic assessment. The green dots in the figure indicate the vegetation distribution along the profile. Species identified are indicated as follows:

- lo lim = lower limit
- up lim = upper limit
- Lz = Lower zone
- Uz = Upper zone
- El ca = *Elegia capensis*
- Pr se = *Prionium serratum*
- Br ne = *Brachylaena neriifolia*
- Il mi = *Ilex mitis*
- Nu fl = *Nuxia floribunda*

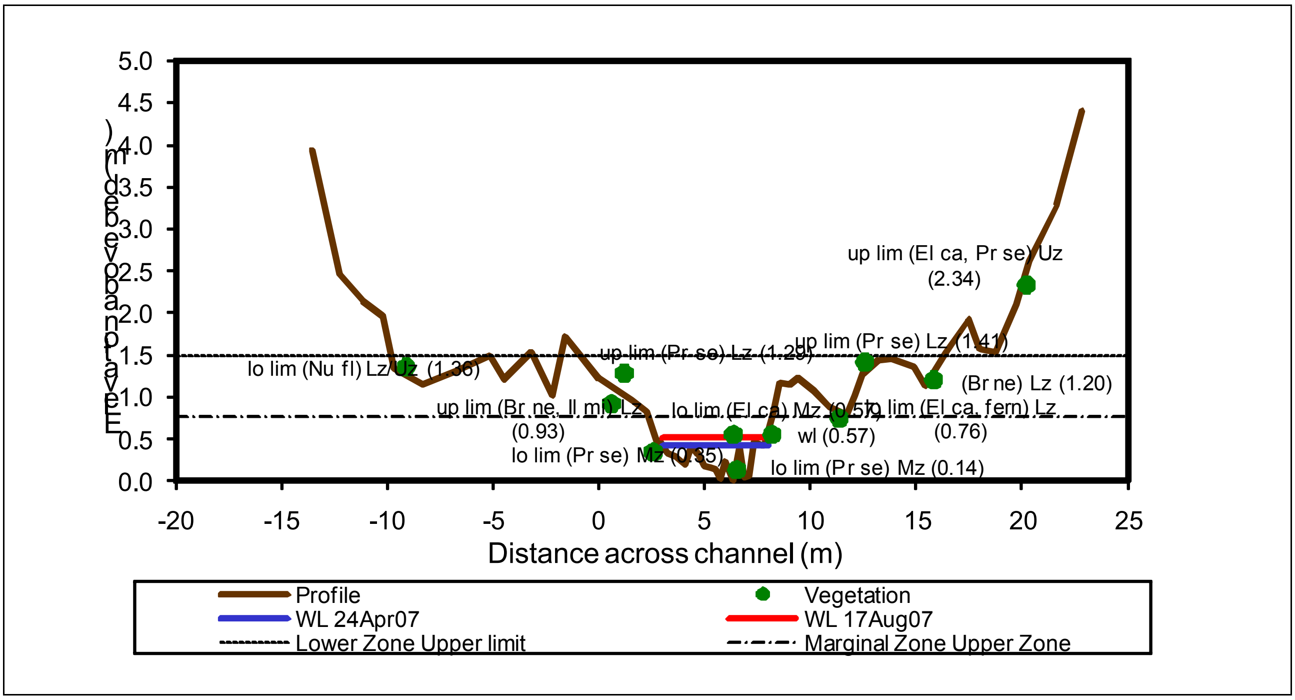

Figure G 1 Profile of Upper Knysna site showing water levels (WL) at 24 April and 17 Aug 2007, Riparian vegetation zones, and critical vegetation surveyed points

G2 EWR 2: GOUNA (GOUNA RIVER) - ECOCLASSIFICATION

G2.1 DATA AVAILIBILITY

The data availability is the same as for EWR 1

Confidence as a result of data availability and one site visit is moderate to high (4).

G2.2 REFERENCE CONDITIONS

Similar for all sites in study: See Knysna (EWR 1) site for description of reference vegetation types. Confidence: 4

G2.3 PES

The PES of riparian vegetation at the Gouna site is 86.5%, which is a VEGRAI EC of B (Table. G2). Riparian vegetation response was mainly due to non-flow-related impacts in the marginal, lower and upper zones (see main report). The effects of the flood (reduced cover, abundance and recruitment) were considered to be predominantly natural however, with the possibility of a small unnatural component due to changes in upstream land use (i.e. fynbos converted to exotic forest plantations, and indigenous forest shrinkage, which may have increased overland runoff, and hence velocity and flash floods).

Vegetation type, structure, cover, abundance and composition were close to what was expected for marginal, lower and upper zones. The effects of large, recent floods may have reduced recruitment throughout, but this was expected. Recovery of riparian vegetation, especially woody species, was occurring in the marginal and lower zones. The presence of exotic trees (*A. melanoxylon* and *A. mearnsii*) in lower and upper zones was a slight problem, and had the potential to increase due to close proximity to forestry, from where these aliens escaped. The exotic European Blackberry (*Rubus fruticosus)* in the lower zone was of greater concern as this invader is bird dispersed and can form dense stands. Sediment deposition increased markedly upstream of the low-level bridge.

Table G2 Contribution of riparian vegetation zones to the calculation of the Riparian Zone Ecological Category, using VEGRAI level 4

RIPARIAN VEGETATION EC METRIC GROUP	CALCULATED RATING	WEIGHTED RATING	CONFIDENCE	RANK	WEIGHT	NOTES: (give reasons for each assessment)
MARGINAL	88.1	35.2	3.5	1.0	100.0	marginal zone most important for year-round refuge habitat
LOWER ZONE	86.9	31.3	3.4	2.0	90.0	lower zone has high seasonal importance for breeding habitat, also shading of aquatic habitats
UPPER ZONE	87.2	20.9	3.4	3.0	60.0	not directly important for instream habitat, but bank stabilty indirectly important, possibly some shading
	3.0				250.0	
LEVEL 4 VEGRAI (%)				87.4		
VEGRAI EC				**A/B**		
AVERAGE CONFIDENCE				3.4		

Upper and lower limits of important species or guilds were surveyed along a transect across the EWR 2 in April 2007 during the hydraulic survey. Figure G2 presents the hydraulic profile of the cross section and the blue line indicates the water levels at the time of hydraulic assessment. The green dots in the figure indicate the vegetation distribution along the profile. Species identified are indicated as follows:

- lo lim = lower limit
- up lim = upper limit
- Lz = Lower zone
- Uz = Upper zone
- El ca = *Elegia capensis*
- Pr se = *Prionium serratum*
- Br ne = *Brachylaena neriifolia*
- Il mi = *Ilex mitis*
- Nu fl = *Nuxia floribunda*
- Cy ca = *Cyathea capensis*

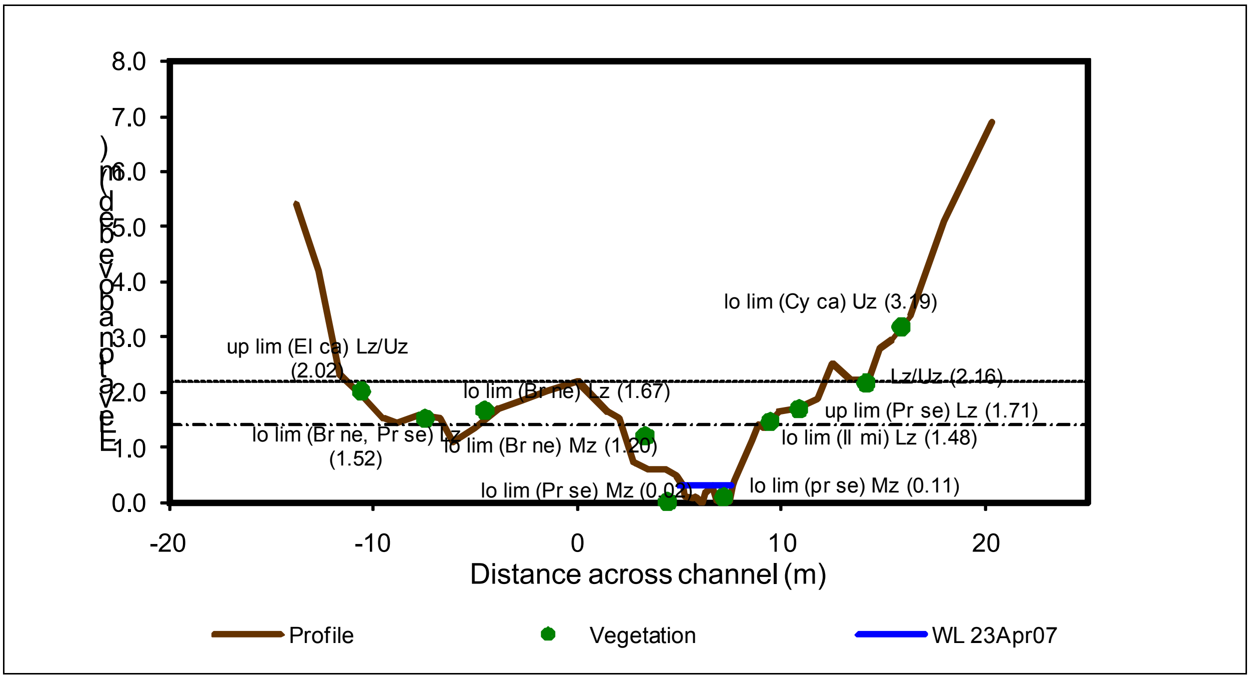

Figure G2 Profile of Gouna River site showing water level (WL) at 23 April 2007, riparian vegetation zones, and critical vegetation surveyed points

G3 EWR 3: UPPER DIEP (DIEP RIVER) - ECOCLASSIFICATION

G3.1 DATA AVAILIBILITY

The data availability is the same as for EWR 1

Confidence as a result of data availability and one site visit is moderate to high (4).

G3.2 REFERENCE CONDITION

Similar for all sites in study: See Knysna (EWR 1) site for description of reference vegetation types.

Confidence: 4

G3.3 PES

The PES of riparian vegetation at EWR 3 is 88.1%, which is a VEGRAI EC of A/B (Table. G3). Riparian vegetation response was mainly due to non-flow-related impacts in the marginal, lower and upper zones (see main report – Volume 1). The effects of the flood (reduced cover, abundance and recruitment) were considered to be predominantly natural however, with the possibility of a small unnatural component due to changes in upstream land use (i.e. fynbos converted to exotic forest plantations, and indigenous forest shrinkage, which may have increased overland runoff, and hence velocity and flash floods).

Vegetation type, structure, cover, abundance and composition were close to what was expected for marginal, lower and upper zones. The effects of large, recent floods reduced recruitment throughout, but this was expected. Recovery of riparian vegetation, especially woody species, was occurring in the marginal and lower zones. The presence of exotic trees (*A. melanoxylon* and *A. mearnsii*) in lower and upper zones was a slight problem, and had the potential to increase due to close proximity to forestry, from where these aliens escaped. The exotic European Blackberry (*Rubus fruticosus)* in the lower zone was of greater concern as this invader is bird dispersed and can form dense stands. The aquatic exotic *Myriophyllum aquaticum* occurred in the marginal zone, but was mainly associated with the weir. This exotic was probably not a threat to downstream habitat where flows had high energy as this species requires slower velocities and some sediment (finer) for rooting.

Table G3 Contribution of riparian vegetation zones to the calculation of the Riparian Zone Ecological Category, using VEGRAI level 4

RIPARIAN VEGETATION EC METRIC GROUP	CALCULATED RATING	WEIGHTED RATING	CONFIDENCE	RANK	WEIGHT	NOTES: (give reasons for each assessment)
MARGINAL	88.3	32.7	3.5	1.0	100.0	marginal zone most important for year-round refuge habitat
LOWER ZONE	87.6	29.2	2.8	2.0	90.0	lower zone has high seasonal importance for breeding habitat, also shading of aquatic habitats
UPPER ZONE	88.3	26.2	2.8	3.0	80.0	not directly important for instream habitat, but bank stabilty indirectly important, possibly some shading
	3.0				270.0	
LEVEL 4 VEGRAI (%)				88.1		
VEGRAI EC				**A/B**		
AVERAGE CONFIDENCE				3.1		

Upper and lower limits of important species or guilds were surveyed along a transect across the EWR 3 in April 2007 during the hydraulic surveys. Figure G3 presents the hydraulic profile of the cross section and the blue and red lines indicate the different water levels at the time of hydraulic assessment. The green dots in the figure indicate the vegetation distribution along the profile. Species identified are indicated as follows:

- lo lim = lower limit
- up lim = upper limit
- Lz = Lower zone
- Uz = Upper zone
- El ca = *Elegia capensis*
- Pr se = *Prionium serratum*
- Br ne = *Brachylaena neriifolia*
- Il mi = *Ilex mitis*
- Nu fl = *Nuxia floribunda*
- Pl tr = *Platylophus trifoliatus*
- Dros = *Drosera* spp.
- Sh = *Shizostylis* spp.

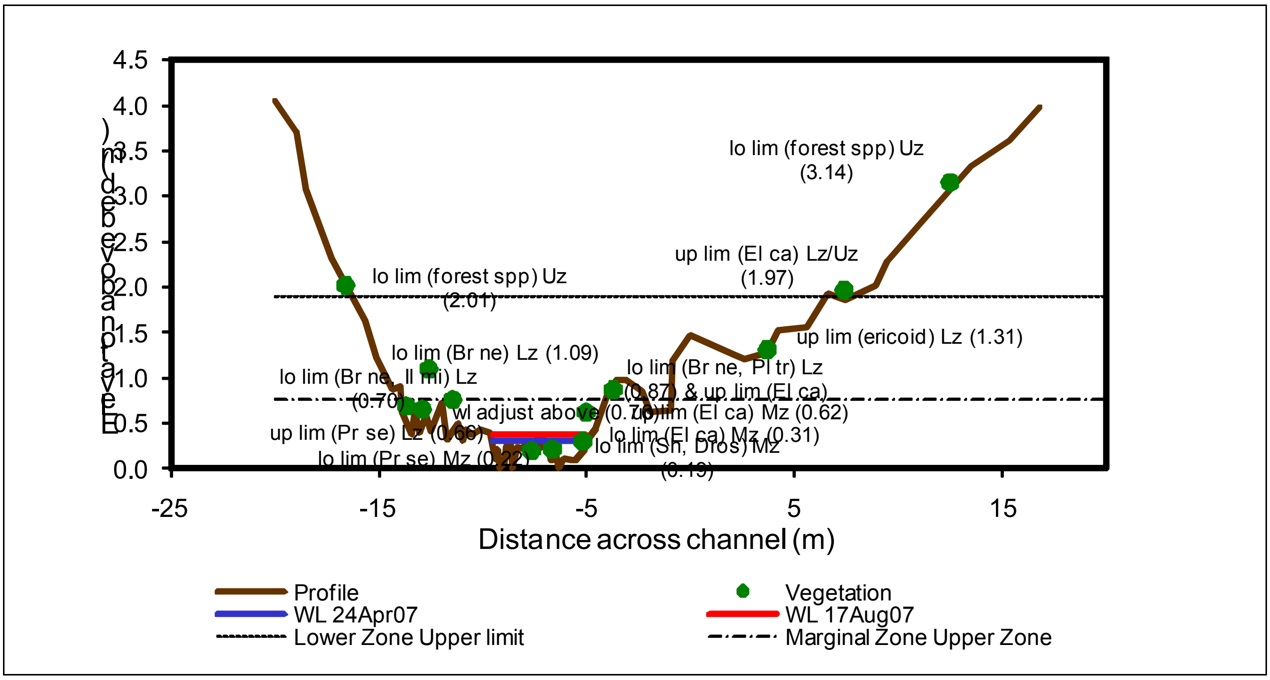

Figure G3 **Profile of Diep River site showing water levels (WL) at 24 Apr and 17 Aug 2007, riparian vegetation zones, and critical vegetation surveyed points**

G4 EWR 4: KARATARA (KARATARA RIVER) - ECOCLASSIFICATION

G4.1 DATA AVAILIBILITY

The data availability is the same as for EWR 1.

Confidence as a result of data availability and one site visit is moderate to high (4).

G4.2 REFERENCE CONDITION

Similar for all sites in study: See Knysna (EWR 1) site for description of reference vegetation types.

Confidence: 4

G4.3 PES

The PES of riparian vegetation at the Karatara site is 87.6%, which is a VEGRAI EC of A/B (Table. G4). Riparian vegetation response was mainly due to non-flow-related impacts in the marginal, lower and upper zones (see main report). The effects of the flood (reduced cover, abundance and recruitment) were considered to be predominantly natural however, with the possibility of a small unnatural component due to changes in upstream land use (i.e. fynbos converted to exotic forest plantations, and indigenous forest shrinkage, which may have increased overland runoff, and hence velocity and flash floods).

Vegetation type, structure, cover, abundance and composition close to what was expected for the marginal, lower and upper zones. The effects of large, recent floods have reduced recruitment throughout, but this was expected. Recovery of riparian vegetation, especially woody species, was occurring in the marginal and lower zones. The presence of exotic trees (*A. melanoxylon* and *A. mearnsii*) in lower and upper zones was a slight problem, and had the potential to increase due to close proximity to forestry, from where these aliens escaped. The exotic European Blackberry (*Rubus fruticosus)* in the lower zone was of greater concern as this invader is bird dispersed and can form dense stands. The marginal zone is currently free of exotics.

Table G4 Contribution of riparian vegetation zones to the calculation of the Riparian Zone Ecological Category, using VEGRAI level 4

RIPARIAN VEGETATION EC METRIC GROUP	CALCULATED RATING	WEIGHTED RATING	CONFIDENCE	RANK	WEIGHT	NOTES: (give reasons for each assessment)
MARGINAL	89.4	35.8	3.5	1.0	100.0	marginal zone most important for year-round refuge habitat
LOWER ZONE	88.9	32.0	2.8	2.0	90.0	lower zone has high seasonal importance for breeding habitat, also shading of aquatic habitats
UPPER ZONE	90.4	21.7	2.8	3.0	60.0	not directly important for instream habitat, but bank stabilty indirectly important, possibly some shading
	3.0				250.0	
LEVEL 4 VEGRAI (%)				89.5		
VEGRAI EC				**A/B**		
AVERAGE CONFIDENCE				3.1		

Upper and lower limits of important species or guilds were surveyed along a transect across the EWR 3 in April 2007 during the hydraulic surveys. Figure G3 presents the hydraulic profile of the cross section and the blue and red lines indicate the different water levels at the time of hydraulic assessment. The green dots in the figure indicate the vegetation distribution along the profile. Species identified are indicated as follows:

- lo lim = lower limit
- up lim = upper limit
- Lz = Lower zone
- Uz = Upper zone
- El ca = *Elegia capensis*
- Pr se = *Prionium serratum*
- Br ne = *Brachylaena neriifolia*
- Il mi = *Ilex mitis*
- Nu fl = *Nuxia floribunda*
- Podo = *Podocarpus* spp.
- Cy ca = *Cyathea capensis*

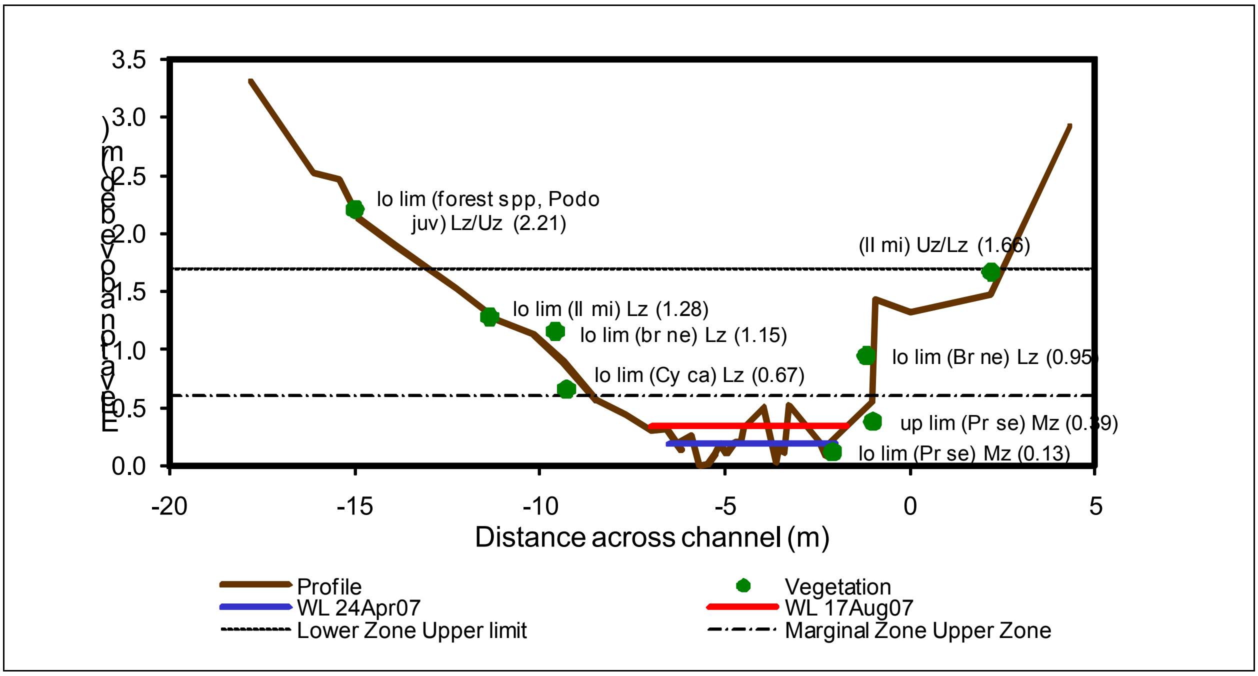

Figure G4 Profile of Karatara River site showing water levels (WL) at 24 April and 17 Aug 2007, riparian vegetation zones, and critical vegetation surveyed points.

G5 APPLICABLE SPECIES LISTS FOR REGION AND SITES

Species list for the EWR sites are provided below in Table G5. Abbreviations are listed at the end of the table.

Table G5 Species list of the riparian vegetation found at the EWR sites

SOUTHERN AFROTEMPERATE FOREST				
SPECIES	**IMP**	**END**	**BIT**	**Note**
Afrocarpus falcatus	√			tall tree
Allophylus decipiens			√	small tree
Amauropelta knysnaensis		√		geophytic herb
Apodytes geldenhuysii		√		small tree
Asparagus scandens		√	√	woody climber
Blechnum capense	√			geophytic herb
Blechnum tabulare	√			geophytic herb
Brabejum stellatifolium		√	√	tall tree
Brachylaena nerifolia		√	√	small tree
Burchelia bubalina	√			tall shrub
Canthium inerme	√			small tree
Cassine peragua	√			small tree
Cassine schinoides		√	√	small tree
Clivia mirabilis		√		geophytic herb
Cryptocarya angustifoloia		√		small tree
Cunonia capensis	√			tall tree
Curtisia dentate	√			tall tree
Cyathea capensis	√			tree fern
Dietes iridioides	√			geophytic herb
Diospyros whyteana	√			small tree
Freesia sparrmannii		√		geophytic herb
Gonioma kamassi			√	small tree
Heeria argenrea		√	√	small tree
Ilex mitis	√			tall tree
Lachnostylus hirta		√	√	small tree
Laurophyllus capensis		√	√	tall shrub
Metrosideros angustifolia		√	√	small tree
Nuxia floribunda	√			tall tree
Ochna arborea var, arborea			√	tall tree
Ocotea bullata	√			tall tree
Olea capensis subsp. *macrocarpa*	√			tall tree
Olinia ventosa	√			tall tree
Oplismenus hirtellis	√			graminoid
Oxalis incarnata	√			geophytic herb
Platylophus trifoliatus		√		tall tree
Podocarpus elongates	√			tall tree
Podocarpus latifolius	√			tall tree
Polystichum incongruum		√		geophytic herb
Pterocelastrus tricuspidatus	√			tall tree
Rapanea melonophloeos	√			tall tree
Rumohra adiantiformis	√			geophytic herb
Sparmannia africana	√			tall shrub
Strelitzia alba		√		megaherb
Todea barbara	√			geophytic herb
Trichocladys crinitus	√			tall shrub
Virgilia divaricata		√	√	small tree
Virgilia oroboides subsp. ferruginea		√		small tree
Virgilia oroboides subsp. oroboides		√		small tree

KNYSNA RIVER EWR1								
SPECIES	**MARGINAL ZONE**		**LOWER ZONE**		**UPPER ZONE**			
	W	**NW**	**W**	**NW**	**W**	**NW**	**EX**	**FOR**
Acacia mearnsii			√				√	
Acacia melanoxylon	√		√		√		√	
Brachylaena neriifolia	√		√					
Canthium inerme					√			
Cunonia capensis					√			√
Cyathea capensis					√			
Diospyros whyteana			√		√			√
Elegia capensis		√		√				
Ilex mitis			√					
Lobelia sp				√				
Nuxia floribunda					√			√
Olinia ventosa					√			√
Oxalis incarnata				√		√		
Platylophus trifoliatus					√			
Prionium serratum		√		√				
Pterocelastrus tricuspidatus					√			√
Tecomia capensis			√		√			

GOUNA RIVER EWR2								
SPECIES	**MARGINAL ZONE**		**LOWER ZONE**		**UPPER ZONE**			
	W	**NW**	**W**	**NW**	**W**	**NW**	**EX**	**FOR**
Acacia mearnsii			√				√	
Acacia melanoxylon			√		√		√	
Afrocarpus falcatus (Podocarpus)					√			√
Brachylaena neriifolia	√		√					
Buddleja			√		√			
Canthium inerme					√			
Centella		√		√			√	
Cunonia capensis					√			√
Cyathea capensis			√		√			
Dietes iridioides				√		√		
Diospyros whyteana			√					√
Elegia capensis				√				
Ilex mitis			√					
Nuxia floribunda			√		√			√
Olinia ventosa					√			√
Platylophus trifoliatus					√			
Polygala myrtifolia			√					
Prionium serratum		√		√				
Pteridium aquilinum		√		√				
Pterocelastrus tricuspidatus					√			√
Rubus fruticosus (European blackberry)			√				√	
Seteria megaphylla				√				
Tecomia capensis			√		√			
Zantedechia aethiopica				√				

DIEP RIVER EWR3								
SPECIES	**MARGINAL ZONE**		**LOWER ZONE**		**UPPER ZONE**			
	W	**NW**	**W**	**NW**	**W**	**NW**	**EX**	**FOR**
(ferns)				√		√		
Acacia mearnsii			√		√		√	
Acacia melanoxylon			√		√		√	
Afrocarpus falcatus (Podocarpus)					√			
Brachylaena neriifolia	√		√		√			

Canthium inerme					√			
Cunonia capensis					√			√
Dietes iridioides				√		√		
Diospyros whyteana					√			√
Elegia capensis				√		√		
Ilex mitis			√		√			
Juncus effesus		√		√				
Myriophyllum aquaticum		√					√	
Nuxia floribunda			√					
Olinia ventosa					√			√
Platylophus trifoliatus					√			
Podocarpus elongatus/latifolius					√			
Prionium serratum		√		√				
Pterocelastrus tricuspidatus					√			√
Rubus fruticosus (European blackberry)			√				√	
Seteria megaphylla						√		
Shizostylus		√		√				
Sparmania africana			√		√			
Trimeria grandifolia						√		√
Zantedechia aethiopica				√				
KARATARA RIVER EWR4								
SPECIES	**MARGINAL ZONE**		**LOWER ZONE**		**UPPER ZONE**			
	W	**NW**	**W**	**NW**	**W**	**NW**	**EX**	**FOR**
Acacia melanoxylon			√		√		√	
Adiantum aethiopicum (Maidenhair fern)						√		
Brachylaena neriifolia			√		√			
Burchellia bubalina					√			
Canthium inerme					√			
Centella sp						√	√	
Chionanthus foveolatus					√			
Cunonia capensis					√			√
Cyathea capensis		√		√		√		
Dietes iridioides				√		√		
Diospyros whyteana			√		√			√
Eligia capensis				√				
Hyperacanthus amoenus					√			
Ilex mitis			√		√			
Ocatea bullata					√			
Olinia ventosa					√			√
Oxlais incarnata						√		
Platylophus trifoliatus					√			
Plectranthus sp						√		
Podocarpus elongatus/latifolius					√			
Prionium serratum		√						
Pterocelastrus tricuspidatus					√			√
Rubus fruticosus (European blackberry)					√		√	
Shizostylis sp				√				
Sparmania africana			√		√			
Zantedechia aethiopica				√		√		

W = woody, NW = non-woody, EX = exotic species, FOR = forest species, IMP = important taxa* (high abundance, frequent occurrence or are prominent in vegetation unit), END = endemic taxa* (endemic to vegetation unit), BIT = biogeographically important taxa* (may be endemic or important, but more importantly are limited to a small group of vegetation units i.e. regionally endemic)*: See Mucina and Rutherford (2006).

G6 REFERENCES

Acocks JPH. (1988). Veld types of South Africa. Third Edition. Botanical Research. Institute.

Mucina L and Rutherford MC (eds). (2006). The Vegetation of South Africa, Lesotho and Swaziland. Strelitzia 19. National Biodiversity Institute, Pretoria.

Rutherford MC and Westfall RH (1986). Biomes of southern Africa – an objective categorization. Memoirs of the Botanical Survey of South Africa **54**: 1-98.

Tainton NM. (1981). Veld and pasture management. Shuter and. Shooter (Pty) Ltd, Durban, South Africa.

Van Wyk B and Van Wyk P (1997). *Field Guide to Trees of Southern Africa*, C. Struik Publishing, Cape Town, South Africa.

APPENDIX H: DIATOM ASSESSMENT

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H1 DIATOM ASSEMBLAGE AND EPILITHON ANALYSIS

H1.1 BACKGROUND

Koekemoer Aquatic Services was approached by Coastal and Environmental Services (CES) to analyse diatom samples taken at the 8 water quality (WQ) monitoring sites during the June 2007 site visit as part of the Reserve determination study for the Knysna and Swartvlei systems in the Outeniqua catchment. The diatom assessment was conducted following a baseline aquatic health assessment in the area, which focused on fish and invertebrates. The aim of the diatom study is to provide additional information concerning the aquatic health and functioning of the River systems, as an extra biomonitoring tool.

H1.1.1 Diatoms as water quality indicators

Diatoms are of great ecological importance because of their role as primary producers, and form the base of the aquatic food web. They usually account for the highest number of species among the primary producers in aquatic systems (Leira, 2005). Diatoms are photosynthetic unicellular organisms and are found in almost all aquatic and semi-aquatic habitats.

Diatoms are a siliceous class (*Bacilariophyceae* of the phylum *Bacilariophyt*a) of algae. A remarkable aspect of diatoms is their silicon dioxide cell walls. The cell walls are perforated and ornamented with many holes, which are arranged in defined and unique patterns. Identification is based on the nature of these perforations as well as their orientation and densities.

Recent studies, as well as studies in progress, have identified diatoms as useful organisms to include in the suite of biomonitoring tools currently used in South Africa (Bate *et al*., 2002, De la Rey *et al*., 2004, Taylor, 2004) both for assessments of current water quality and for establishing historical conditions in rivers in South Africa (Taylor *et al*., 2005a).

Diatoms have been shown to be reliable indicators of specific water quality problems such as organic pollution, eutrophication, acidification and metal pollution (Rott 1991, Tilman *et al*., 1982, Dixit *et al*., 1992, Cattaneo *et al.,* 2004), as well as for general water quality (AFNOR, 2000). The reasons why diatoms are useful tools for biomonitoring are listed by Round (1993):

- Diatoms have a universal occurrence throughout all rivers;
- Field sampling is rapid and easy;
- Cell cycle is rapid and they react quickly to perturbation;
- Diatoms are relatively insensitive to physical features in the environment;
- Cell counting by microscopic techniques is rapid and accurate;
- Cell numbers per unit area of substratum are enormous, making random counts excellent assessments of diatoms;
- The ecological requirements of diatoms are in many cases better known than those of any other group of riverine organisms;
- Permanent records can be made from every sample;
- Diatoms do not have specific food requirements, specialised habitat niches, and are not governed to a major extent by stream flow.

Although diatoms are widely distributed as a group, most species occur only in habitats with specific physical, chemical, and biological characteristics, consequently, they are frequently used as biological indicators of water quality (Leira and Sabater, 2005; Kelly *et al.*, 1998). Diatoms have tolerance limits and optima with respect to environmental conditions such as nutrients, organic pollution, pH, salinity and acidity (Van Dam *et al*, 1994; Bellingeri *et al*., 2006). As benthic diatom assemblages are sessile they are exposed to water quality at a site over a period antecedent to sampling. They therefore indicate recent as well as current water quality (Philibert *et al*., 2006).

The specific water quality tolerances of diatoms have been resolved into different diatom-based water quality indices, used around the world. In general, each diatom species used in the calculation of the index is assigned two values; the first value reflects the tolerance or affinity of the particular diatom species to a certain water quality (good or bad) while the second value indicates how strong (or weak) the relationship is. These values are then weighted by the abundance of the particular diatom species in the sample. The diatom index used in the present study is known as the Pollution Sensitivity Index (SPI) (Coste in CEMAGREF (1982)), one of the most extensively tested indices in Europe.

Diatom-based water quality indices have recently been evaluated and implemented in South Africa (Taylor 2004, River Health Programme, 2005). De la Rey *et al*. (2004) and Taylor (2004) showed that diatom-based pollution indices may be good bio-indicators of water quality in aquatic ecosystems in South Africa by demonstrating a measurable relationship between water quality variables such as pH, electrical conductivity, phosphorus and nitrogen, and the structure of diatom communities as reflected by diatom index scores.

The close association between diatom community composition and water quality allows for inferences to be drawn about water quality.

H1.2 SAMPLING METHODOLOGY AND ANALYSIS

H1.2.1 Epilithic diatom sampling and analysis

Epilithic[1] diatom samples were taken at all the WQ sites from submerged rocks on the riverbed. Epilithon was sampled as outlined Taylor *et al*. (2005b) and Taylor *et al*. (2005c). These methods were designed and refined as part of the Diatom Assessment Protocol (DAP), a Water Research Commission (WRC) initiative. Taylor *et al*. (2005c), have based the method manual on several key documents including Kelly *et al.* (1998), CEN (2003), DARES (2004) and Taylor *et al.* (2005b). Epilithon were taken at each site by scrubbing the substrate with a small brush and rinsing both the brush and the substrate with distilled water. Samples were taken from five or more cobbles (diameter > 64, ≤265 mm).

Preparation of diatom slides followed the Hot HCl and $KMnO_4$ method as outlined in Taylor *et al.* (2005b). Counts of diatom valves on slides were made using a Zeiss microscope with phase contrast optics (1000x). The aim of the analysis was to count diatom valves to produce semi-quantitative data from which ecological conclusions can be drawn (Taylor *et al*., 2005c). Schoeman, (1973) and Battarbee (1986) concluded that a count of 400 valves per slide is satisfactory for the calculation of relative abundance of diatom species and this range is supported

[1] Diatoms that grow on rock or stone surfaces and generally referred to in the report as Epilithon.

by Prygiel *et al.* (2002), according to Taylor *et al*. (2005c). Therefore a count of 400 valves per sample or more was counted and the nomenclature followed Krammer and Lange-Bertalot (1986-91).

Diatom index values were calculated in the database programme OMNIDIA (Lecointe *et al.*, 1993) for epilithon data in order to generate index scores to general water quality variables. OMNIDIA (Lecointe *et al*., 1993) has two main parts, a taxonomic database and a sample database. The taxonomic database contains additional species information and includes synonyms, taxonomic classification (family), the sensitivity and indicator values given by the different indices, the van Dam (1994) ecological values, the Denys (1991a,b) habitat- and life form classification and in many of the cases scaled light microscopical images. The sample database allows for the storage of sample information. Index scores can be generated and ecological characterisation of the samples on the basis of Lange-Bertalot (1979), Denys (1991a, b), and Van Dam *et al.* (1994) can be obtained (Ács *et al*., 2004).

H1.3 SITE DESCRIPTION

Details of the sampling sites are given in Table H1 below.

Table H1 Diatom sampling sites

Sample number	Site	River	South	East	WQS[1]
725	**DWQ1**	Knysna River	33°59'42.5"	23°00'13.9"	RU A
726	**DWQ2**	Knysna River	33°53'32.3"	23°01'50.1"	RU A
727	**DWQ3**	Gouna River	33°59'27.3"	23°02'25.5"	RU B
728	**DWQ4**	Karatara River	33°55'50.2"	22°50'15.1"	RU E
729	**DWQ5**	Hoëkraal River	33°55'33.4"	22°46'142.7"	RU D
730	**DWQ6**	Diep River	33°56'14.2"	22°42'28.4"	RU C
731	**DWQ7**	Hoëkraal River	33°58'48.2"	22°48'00"	RU D
732	**DWQ8**	Wolwe River	33°58'43.9"	22°43'08"	RU C

1 Water Quality Sub-unit

The main land use activities in the different Resource Units are given in Table H2 below.

Table H2 Main land use activities in the Resource Units

Resource Unit	Land use activities[1]
RU A	Primary land use is dairy farming (Charlesford Dairy farm). Charlesford Farm pumps water from the Knysna River upstream of Charlesford weir.
RU B	A large amount of scum was noted in the river downstream of the pump station. The new Simola Golf and Country Estate is being built on Kaapweg above the site.
RU C	There is a diary farm present in the area. Impact in this area may result from the Eco & Golf Estate (The Lake).
RU D	There is a citrus plantation below DWQ 7.
RU E	There is extensive farming in the area (e.g. dairy farming, timber processing at Geelhoutvlei, sawmills processing small wood items (e.g. floor boards), forestry activities e.g. nursery).

1 Information obtained from Appendix C.

H1.4 RESULTS

The diatom species assemblage of the different samples is provided in Table H3. The valve counts of the species per sample are also provided.

Table H3 Species list and diatom valve counts per sample

Taxon	Sample and site number							
	DWQ1	DWQ2	DWQ3	DWQ4	DWQ5	DWQ6	DWQ7	DWQ8
	725	726	727	728	729	730	731	732
Achnanthes sp.		3					1	
Achnanthes sperata Cholnoky			10	235	284		2	
Achnanthes standerii Cholnoky						59		
Achnanthes subaffinis Cholnoky						13		193
Achnanthes swazi Cholnoky						132		26
Achnanthidium macrocephalum (Hustedt) Round & Bukhtiyarova						2		4
Achnanthidium minutissima var. *affinis* (Grunow) Bukht.						1		
Achnanthidium minutissimum (Kützing) Czarnecki	1		1			13		15
Amphora sp.? (very small)	1			1	5			
Brachysira neoexilis Lange-Bertalot							1	1
Brachysira sp.?						15		7
Caloneis molaris (Grunow) Krammer							1	
Cocconeis placentula var.*euglypta* (Ehrenberg) Grunow							1	
Ctenophora pulchella (Ralfs) Williams & Round							3	
Cyclotella meneghiniana Kützing							1	
Diploneis oblongella (Naegeli) Cleve-Euler							2	
Encyonema gracile Rabenhorst								1
Encyonema sp.		1				1		
Eolimna minima (Grunow) Lange-Bertalot							1	
Eunotia exigua (Brébisson) Rabenhorst		1	4					
Eunotia flexuosa (Brébisson) Kützing	2		2					
Eunotia implicata Nörpel. Lange-Bertalot & Alles			10	3	2	2		1
Eunotia incisa Gregory (cf. *Eunotia hugenottorum* Cholnoky?)	298	300	27	2				
Eunotia minor (Kützing) Grunow in Van Heurck								1
Eunotia naegeli Migula	11		77			2		
Eunotia rhomboidea Hustedt	50	44	8					
Eunotia sp.			6	5				
Eunotia sudetica O.Müller	37	30	125	143	66			1
Fallacia monoculata (Hustedt) D.G. Mann							1	
Fragilaria biceps (Kützing) Lange-Bertalot								8
Fragilaria capucina var. *rumpens* (Kützing) Lange-Bertalot								5
Fragilaria tenera (W.Smith) Lange-Bertalot								1
Frustulia crassinervia (Brébisson) Lange-Bertalot et Krammer	1		2				1	
Frustulia erifuga Lange-Bertalot & Krammer		1						
Frustulia magaliesmontana Cholnoky	3		103		17			
Frustulia saxonica Rabenhorst		1	10	1	16	1		
Frustulia sp.			2		2			
Gomphonema lagenula Kützing		1						2
Gomphonema parvulum (Kützing) Kützing								3
Hippodonta avittata (Cholnoky) Lange-Bert, Metzeltin & Witkowski								1
Kobayasiella sp.		2						
Microcostatus sp.?							1	
Navicula agrestis Hustedt							4	
Navicula gregaria Donkin							1	
Navicula microcari Lange-Bertalot							1	
Navicula ranomafanensis (Manguin) Metzeltin & Lange-Bertalot								8
Navicula sp.?		2		7		18		

Taxon	Sample and site number							
	DWQ1	DWQ2	DWQ3	DWQ4	DWQ5	DWQ6	DWQ7	DWQ8
	725	726	727	728	729	730	731	732
Nitzschia acidoclinata Lange-Bertalot				1				
Nitzschia clausii Hantzsch							1	
Nitzschia filiformis (W.M.Smith) Van Heurck							15	2
Nitzschia frustulum (Kützing) Grunow								2
Nitzschia irremissa Cholnoky								1
Nitzschia obsidialis Hustedt ?							1	1
Nitzschia reversa W.Smith							1	
Nitzschia sp.			2				1	
Pinnularia sp. 1				5	2			
Pinnularia sp. 2				8	9			
Planothidium engelbrechtii (Cholnoky) Round & Bukhtiyarova						3		
Pleurosigma salinarum (Grunow) Cleve & Grunow							2	
Psammothidium oblongellum (Oestrup) Van de Vijver	1	19	2			170	365	94
Sellaphora seminulum (Grunow) D.G. Mann		2						
Stauroneis pachycephala Cleve							1	
Stenopterobia delicatissima (Lewis) Brébisson			3					1
Stenopterobia sp.?						2		
Tabellaria flocculosa (Roth) Kützing	4	1	4					25
TOTAL COUNT	**409**	**408**	**398**	**411**	**403**	**434**	**409**	**404**

The European numerical diatom index, the Specific Pollution sensitivity Index (SPI) was used to interpret results. De la Rey *et al.* (2004), concluded that the SPI reflects certain elements of water quality with a high degree of accuracy due to the broad species base of the SPI.

The SPI for the samples is given in Table H4 and the interpretation of the SPI scores is given in Table H5.

Table H4 SPI scores for the different samples

Index scores		
Site	**No. species**	**SPI**
DWQ1	11	19.1
DWQ2	19	18.9
DWQ3	27	19.8
DWQ4	10	19.9
DWQ5	13	19.8
DWQ6	13	17.6
DWQ7	25	16.2
DWQ8	24	18.3

Table H5 Interpretation of the SPI scores

Interpretation of index scores	
Index score	**Class**
>17	High quality
13 to 17	Good quality
9 to 13	Moderate quality
5 to 9	Poor quality
<5	Bad quality

The diatom based ecological classification based on van Dam *et al.* (1994) for water quality is given in Table H6.

Table H6 Diatom based ecological classification (based on van Dam *et al.*, 1994)

Site	pH	Salinity	Organic nitrogen	Oxygen levels	Pollution levels	Trophic status
DWQ1	Acidic	Fresh (<0.2% salinity)	Very low levels of organically bound nitrogen	Continuously high saturation (~100%)	Unpolluted to slightly polluted	Oligotrophic
DWQ2	Acidic	Fresh (<0.2% salinity)	Very low levels of organically bound nitrogen	Continuously high saturation (~100%)	Unpolluted to slightly polluted	Oligotrophic
DWQ3	Acidic	Fresh (<0.2% salinity)	Very low levels of organically bound nitrogen	Continuously high saturation (~100%)	Unpolluted to slightly polluted	Oligotrophic
DWQ4	Acidic	Fresh (<0.2% salinity)	Very low levels of organically bound nitrogen	Continuously high saturation (~100%)	Unpolluted to slightly polluted	Oligotrophic
DWQ5	Acidic	Fresh (<0.2% salinity)	Very low levels of organically bound nitrogen	Continuously high saturation (~100%)	Unpolluted to slightly polluted	Oligotrophic
DWQ6	Neutral	Fresh-brackish (<0.9% salinity)	Very low levels of organically bound nitrogen	Continuously high saturation (~100%)	Unpolluted to slightly polluted	Oligotrophic
DWQ7	Neutral	Fresh-brackish (<0.9% salinity)	Very low levels of organically bound nitrogen	Continuously high saturation (~100%)	Unpolluted to slightly polluted	Oligotrophic
DWQ8	Neutral	Fresh-brackish (<0.9% salinity)	Very low levels of organically bound nitrogen	Continuously high saturation (~100%)	Unpolluted to slightly polluted	Oligotrophic

H1.5 DISCUSSION

The dominant species of the different diatom samples for the site are given in Table H7 and the diatom assemblages are discussed. Note: Species contributing 5% or more to the total count were classified as dominant species.

Table H7 Dominant diatom species present at EWR sites

Site	Dominant Species	Species contribution to sample (%)
DWQ1	*Eunotia incisa*	73
	Eunotia rhomboidea	12
DWQ2	*Eunotia incisa*	74
	Eunotia rhomboidea	11
DWQ3	*Frustulia magaliesmontana*	26
	Eunotia sudetica	31
	Eunotia naegeli	19
DWQ4	*Achnanthes sperata*	57
	Eunotia sudetica	35
DWQ5	*Achnanthes sperata*	70
	Eunotia sudetica	16
DWQ6	*Achnanthes standerii*	14
	Achnanthes swazi	30
	Psammothidium oblongellum	39
DWQ7	*Psammothidium oblongellum*	89
	Nitzschia filiformis	4
DWQ8	*Achnanthes subaffinis*	48
	Achnanthes swazi	6
	Psammothidium oblongellum	23

The ecology of the dominant species is discussed below according to Taylor (2006).

The samples in general showed water of very high quality. The water at all the sites were well oxygenated with very low levels of organicaaly bound nitrogen, generally unpolluted and oligotrophic. All sites were Oligotrophic with DWQ1 – 5 having an acidic pH and DWQ6 – 8 a neutral pH. From Table H6 it seems that the water is close to Reference Conditions. The samples were generally dominated to a great extent by species endemic to South Africa. Endemic species were present in all samples except for DWQ2. The SPI scores indicate a high water quality (A/B category) for DWQ1 – 6, and DWQ8. DWQ7 had good water quality (B category).

DWQ1 and 2 were dominated by *Eunotia* spp. *E. rhomboidea* is usually found in oligotrophic, electrolyte-poor waters while *E. incisa* occurs in upland streams in acidic, oligotrophic, electrolyte-poor waters. DWQ3, 4, 5, 6 and 8 had a strong presence of endemic species which are found in clean, well oxygenated oligotrophic fresh waters (*A. standerii* and *A. swazi)*. The presence of *A. subaffinis* at DWQ8 also indicates oligotrophy. The presence of *Ctenophora pulchella* and *Nitzschia filiformis* at DWQ7 indicates slightly elevated salinity in comparison to the other sites.

H2 REFERENCES

Ács É, Szabó K, Tóth B and Kiss KT. (2004) Investigation of benthic algal communities, especially diatoms of some Hungarian streams in connection with reference conditions of the Water Framework Directives. *Acta Botanica Hungarica* **46**(3-4): 255-277.

AFNOR (2000). Norme Française NF T 90–354. Détermination de l'Indice Biologique Diatomées IBD. Association Française de Normalisation, 63 pp.

Battarbee RW (1986). Diatom Analysis. In Berglund BE (ed) Handbook of Holocene Paleoecology and Paleohydrology. John Wiley & Sons Ltd. Chichester. Great Briton. pp 527-570.

Bate GC, Adams JB & van Der Molen JS. (2002). Diatoms as indicators of water quality in South African river systems. WRC Report No 814/1/02. Water Research Commission. Pretoria.

Cattaneo A, Couillard Y, Wunsam S, and Courcelles M. (2004). Diatom taxonomic and morphological changes as indicators of metal pollution and recovery in Lac Dufault Québec, *Canada. Journal of Paleolimnology* **32**: 163-175.

Comité Européen de Normalisation (CEN). (2003). Water quality – Guidance standard for the routine sampling and pre-treatment of benthic diatoms from rivers. European Standard. EN 13946:2003.

CEMAGREF. (1982) Etude des méthodes biologiques quantitatives d'appréciation de la qualité des eaux. Rapport Division Qualité des Eaux Lyon - Agence Financiére de Bassin Rhône-Méditerranée- Corse. Pierre-Benite.

Diatoms for Assessing River Ecological Status (DARES). (2004). Sampling protocol. Version 1. http://craticula.ncl.ac.uk/dares/methods.htm

Deneys L. (1991a). A check-list of the diatoms in the Holocene deposits of the Western Belgian coastal plain with a survey of their apparent ecological requirements. I. Introduction, ecological code and complete list. *Professional paper. Ministere des Affaires Economiques – Service Géologique de Belgique*. **246**: 1–41.

Denys L. (1991b). A check-list of the diatoms in the Holocene deposits of the Western Belgian coastal plain with a survey of their apparent ecological requirements. II. Centrales. Professional paper Ministere des Affaires Economiques – *Service Géologique de Belgique*. **247**: 1–92.

De la Rey PA, Taylor JC, Laas A, Van Rensburg L & Vosloo A. (2004). Determining the possible application value of diatoms as indicators of general water quality: A comparison with SASS 5. *Water SA* **30**: 325-332.

Dixit SS, Smol JP, Kingston JC & Charles, DF. (1992). Diatoms: Powerful indicators of environmental change. *Environmental Science and Technology* **26**: 23–33.

Department of Water Affairs and Forestry (DWAF). (2007). Resource Directed Measures: Reserve Determination studies for selected surface water, groundwater, estuaries and wetlands in the

Outeniqua (Knysna and Swartvlei) catchment. Delineation Report. Prepared by Coastal and Environmental Services. Report no. RDM/ K40K50/00/ CON/0207.

Kelly MG, Cazaubon A, Coring E, Dell'uomo A, Ector L, Goldsmith B, Guasch H, Hürlimann J, Jarlman A, Kawecka B, Kwandrans J, Laugaste R, Lindstrøm EA, Leitao M, Marvan P, Padisak J, Pipp E, Prygiel J, Rott E, Sabater S, Van Dam H, and Vizinet J. (1998). Recommendations for the routine sampling of diatoms for water quality assessments in Europe. *Journal of Applied Phycology* **10**: 215-224.

Cholnoky BJ. (1968). Die Ökologie der Diatomeen in Binnengewässern. J Cramer, Lehre.
Krammer, K and Lange-Bertalot, H. (1986-1991). Bacillario-phyceae. Süßwasserflora von Mitteleuropa *2* (1-4). Spektrum Akademischer Verlag, Heidelberg. Berlin.

Lecointe C, Coste M and Prygiel J. (1993). "Omnidia": Software for taxonomy, calculation of diatom indices and inventories management. *Hydrobiologia* **269/270**: 509-513.

Leira, M and Sabater, S. (2005). Diatom assemblages distribution in Catalan rivers, NE Spain, in relation to chemical and physiographical factors. Water Research **39**: 73-82

Lenoir, A & Coste, M. (1996). Development of a practical diatom index of overall water quality applicable to the French National Water Board network. In: Whitton, B.A. & Rott, E. editors. *Use of Algae for Monitoring Rivers II*. Institut für Botanik. Universität Innsbruck: 29-43.

Prygiel J, Carpentier P, Almeida S, Coste M, Druart JC, Ector L, Guillard D, Honoré MA, Iserentant R, Ledeganck P, Lalanne-Cassou C, Lesnaik C, Mercier I, Moncout P, Nazart M, Nouchet N, Peres F, Peeters V, Rimet F, Rumeau A, Sabater S, Straub F, Torrisi M, Tudesque L, Van der Vijver B, Vidal H, Vizinet J and Zydek N. (2002). Determination of the biological diatom index (IBD NF T 90-354): results of an inter-comparison exercise. *Journal of Applied Phycology* **14**: 27-39.

River Health Programme (RHP). (2005). State-of-Rivers Report: Monitoring and Managing the Ecological State of Rivers in the Crocodile (West) Marico Water Management Area. Department of Environmental Affairs and Tourism, Pretoria.

Rott E. (1991). Methodological aspects and perspectives in the use of periphyton for monitoring and protecting rivers. In: Whitton, B.A., Rott, E. & Friedrich, G. editors. Use of Algae for Monitoring Rivers. E. Rott, Institüt für Botanik, Univ. Innsbruk. pp 9-16.

Round FE. (1993). A Review and Methods for the Use of Epilithic Diatoms for Detecting and Monitoring Changes in River Water Quality. Methods for the examination of water and associated materials. HMSO Publications, London.

Schoeman FR. (1973). A systematical and ecological study of the diatom flora of Lesotho with special reference to water quality. V&R Printers, Pretoria, South Africa.

Taylor .JC. (2004). The Application of Diatom-Based Pollution Indices in The Vaal Catchment. Unpublished M.Sc. thesis, North-West University, Potchefstroom Campus, Potchefstroom.

Taylor JC, Harding WR, Archibald CGM & van Rensburg L. (2005a). Diatoms as indicators of water quality in the Jukskei-Crocodile River system in 1956 and 1957, a re-analysis of diatom count data generated by BJ Cholnoky. *Water SA* **31 (2)**: 327-346.

Taylor JC, De la Rey PA and Van Rensburg, L. (2005b). Recommendations for the collection, preparation and enumeration of diatoms from riverine habitats for water quality monitoring in South Africa. *African Journal of Aquatic Science,* **30(1)**: 65–75.

Taylor JC, Harding WR and Archibald CGM. (2005c). A method manual for the collection, preparation and analysis of diatom samples. Part of a Water Research Commission (WRC) Project K5/1588 "Development of a Diatom Assessment Protocol (DAP) for River Health Assessment".

Taylor JC, Archibald, CGM and Harding WR. (2006). An illustrated guide to some common species from South Africa. Part of a Water Research Commission (WRC) Project K5/1588 "Development of a Diatom Assessment Protocol (DAP) for River Health Assessment".

Tilman D, Kilham, SS, & Kilham P. (1982). Phytoplankton community ecology: The role of limiting nutrients. *Annual Review of Ecology and Systematics* **13**: 349–372.

Van Dam H, Mertens A and Sinkeldam J. (1994) A coded checklist and ecological indicator values of freshwater diatoms from the Netherlands. *J. of Aquat. Ecol*. **28**:117-133.

APPENDIX I: WATER RESOURCES SCENARIO ANALYSIS
S MALLORY, Water for Africa

I1 INTRODUCTION

Ecological Reserve determination requires an understanding of the flow in the river system, both under natural and current conditions. Ecologists also need to know how the flow regime will respond to possible changes, such as the construction of dams or increased water abstractions. This understanding is usually provided by means of a water resources model, typically in the form of flow time series or flow duration curves. The purpose of this appendix is to document the changes in flow in the river systems due to changes in the operation and/or development options within the system. The assumptions made in setting up the model are also presented.

The systems modelled in this study are the Knysna and Swartvlei systems (see Figures I1 and I2) which both have large estuaries. The modelling therefore also addressed the needs of the estuary Reserve determination process.

The model used for this study was the Water Resource Modelling Platform (Mallory 2005; Mallory and Desai, 2008) which has been developed specifically for Reserve determination studies. The model was set up using the latest hydrological and water use information provided by the Outeniqua Coast Water Situation Study (DWAF, 2007) while the development scenarios were sourced mostly from the work carried out by Ninham Shand (Ninham Shand, 2007) for the Knysna Municipality in which they identified and analysed various development scenarios to meet possible future water requirements.

I1.1 LOCALITY OF DESCRIPTION OF THE CATCHMENT

The Knysna catchment consists of the K50A and K50B quaternary catchments (see Figure I1) while the Swartvlei catchment consist of the K40A, B, C and D catchments (see Figure I2). A large portion of the K50B catchment is occupied by the Knysna Estuary while the Swartvlei Lake lies in the K50D quaternary catchment. Both the Knysna and Swartvlei catchments rise in the Outeniqua mountains and flow to the coast over a relatively short distance. The rivers therefore have steep gradients over much of their lengths and experience above average rainfall compared with the rest of South Africa.

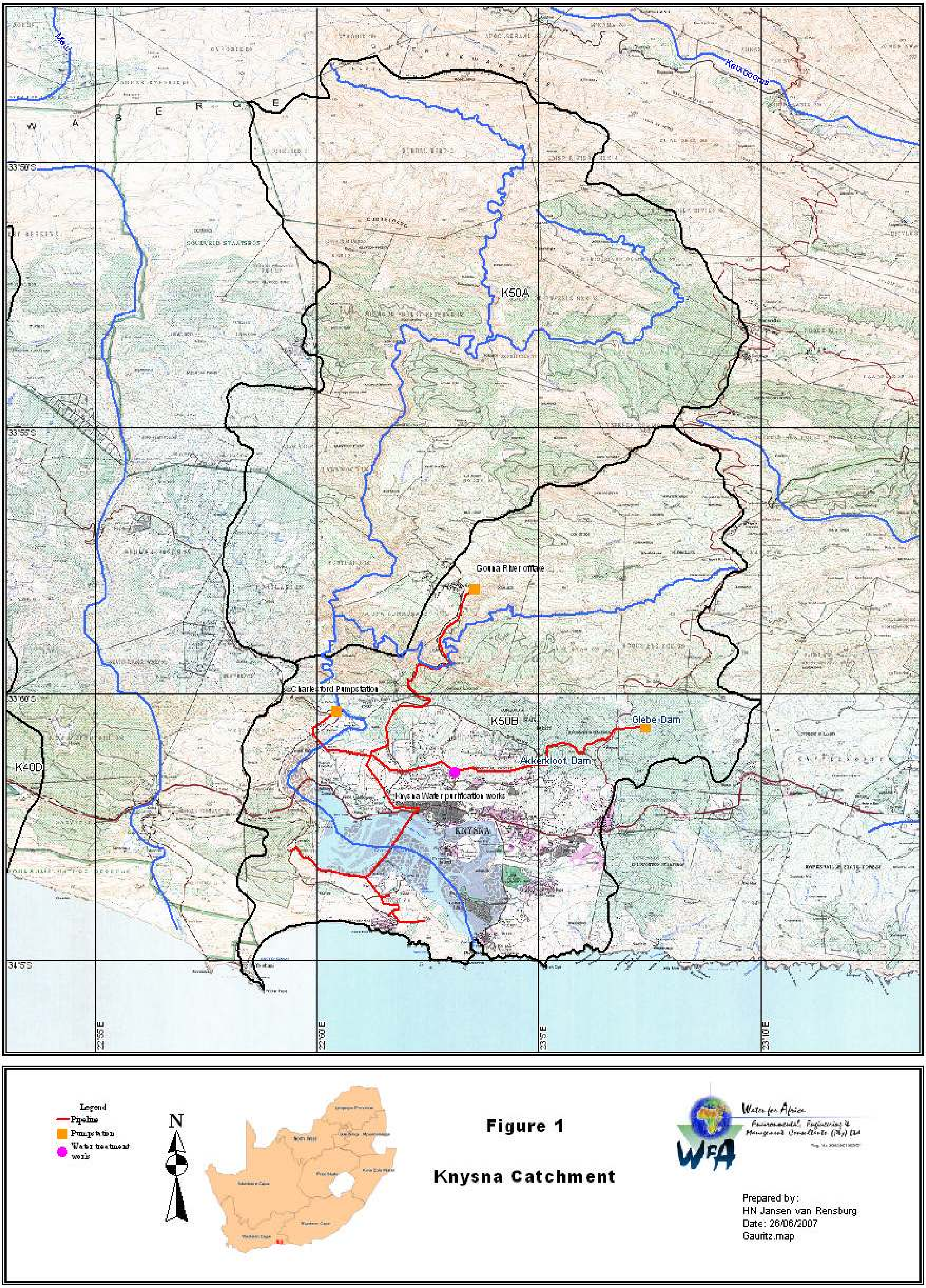

Figure I1 Knysna Catchment

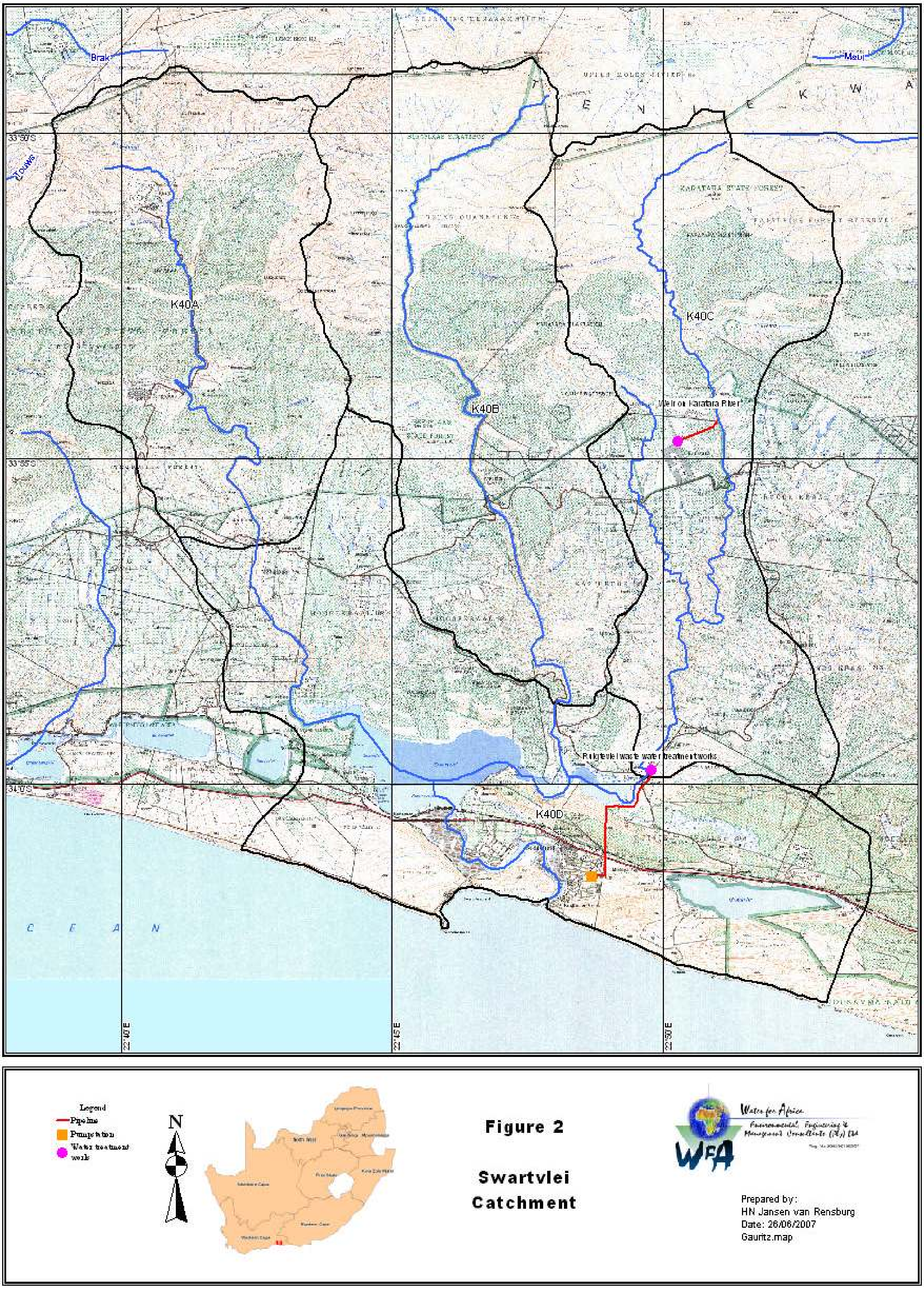

Figure I2 Swartvlei Catchment

I2 WATER REQUIREMENTS

Water requirements were sourced from the Outeniqua Water Situation Study (DWAF, 2007) and are described below for the various water use sectors. Figures from the final OCWSS are shown below. The time series used for the yield modelling are shown in Sections I5– 7

I2.1 URBAN WATER REQUIREMENTS

There are five distinct urban areas in the study area. The current supply to these towns is listed in Table I1.

Table I1 Urban water use (unit in million m^3/annum)

Town	Current water supply	Allocation
Knysna	3.416	4.827
Brenton-on-Sea		
Belvedere		
Sedgefield	0.706	1.460
Karatara	0.110	Unknown
Total	**4.232**	

Source: DWAF (2007a)

I2.2 IRRIGATION WATER REQUIREMENTS

There is a substantial amount of irrigation in the study area, with an estimated total area of 2 283 ha and an estimated total water demand of 7.4 million m^3/annum. The crops irrigated are mostly vegetables and grazing pastures. Table I2 summarises the irrigation requirements per quaternary catchment.

Table I2 Irrigation requirements

Quaternary catchment	Irrigated area (2005) (ha) (DWAF, 2007a;c)	Demand (million m^3/annum) (DWAF, 2007a;c)
K40A	34	0.1
K40B	745	2.0
K40C	772	3.5
K40D	38	0.1
K50A	627	1.5
K50B	67	0.2
Total	**2 283**	**7.4**

The irrigation time series used in the yield modelling are attached in Section I5.

I2.3 STREAMFLOW REDUCTION

I2.3.1 Afforestation and alien vegetation

There is a significant amount of afforestation in the study area with an estimated total area of 8 457 ha consisting mostly of Pine. The estimated areas under forestry and alien vegetation and the reductions in streamflow are summarised in Table I3 (DWAF, 2007a). There is a significant amount of alien vegetation in the study area, categorized as 'Tall Trees' which are mostly Wattle and Pine. The estimated reduction in streamflow due to riparian and upland alien vegetation is summarised in Table L4, as sourced mostly from the recent hydrology reports for the OCWSS. Note, however, that after consultation with the author of the report (Roux, DWAF, *pers. comm.*, 2007), the stream flow reduction by afforestation and alien trees in the K40 catchment was reduced from 4.9 million m^3/annum to 1.4 million m^3/annum.

More information can be found in the Delineation Report for the study, i.e. RDM/K40-K50/00/CON/207.

Table I3 Afforestation and alien vegetation: Areas and reduction in streamflow

Quaternary catchment.	Affores-tation area (2005) (ha)	Affores-tation run-off reduction (million m^3/a)	Upland alien vegetation area (2005) (ha)	Run-off reduction upland alien vegetation (million m^3/a)	Riparian alien vegetation area (2005) (ha)	Run-off reduction riparian alien vegetation (million m^3/a)	Total run-off reduction alien vegetation (million m^3/a)
K40A	4 625	7.4	635	2.7	242	2.2	4.9
K40B	2 992	3.6	595	1.1	283	0.6	1.7
K40C	3 255	4.4	641	1.4	246	0.7	2.1
K40D	3 300	4.4	191	0.3	187	0.4	0.7
K50A	6 096	8.1	274	0.5	274	0.7	1.2
K50B	4 015	5.6	379	0.8	198	0.5	1.3
Total	**24 283**	**33.5**	**2 715**	**6.8**	**1 430**	**5.1**	**11.9**

The afforestation time series used in the yield modelling are attached as Section I7, and the alien vegetation in Section I6.

I3 WATER RESOURCES RELATED INFRASTRUCTURE

I3.1 INTRODUCTION

The water resources of the Swartvlei and Knysna catchments are largely undeveloped. Although there are a large number of dams, both in-stream and off channel, they do not have a large influence on the natural hydrology of the catchment. The natural flow time series used for the yield modelling is shown in Section I7.

I3.2 DAMS

There are only two significant dams in the study area. These are the Glebe Dam located on the Grootkops River and the off-channel Akkerkloof Dam. Both of these dams are located near Knysna and form part of the Knysna Regional Water Supply Scheme (see Figure I1 and Table I4).

Table I4 Dams used for domestic water supply

Dam	FSA[1]	FSC[2]
Glebe Dam	4.5	150 000
Akkerkloof Dam	11	801 000

1 Full supply area (ha) 2 Full supply capacity (m^3)

There are several smaller dams in the study area which are used for irrigation, rural water supply and stock watering. Details of these were obtained from the Agricultural Developments report (DWAF, 2004c) which was compiled as part of the Outeniqua Coast Water Situation Study. These are listed in Table I5. Note that the updated list of farm dams from the final OCWSS reports are shown in the Delineation Report – a number of discrepancies were noted between the two sets of data, particularly for FSC in dams of K40B and K40D. Yield modelling was therefore based on the latest data available at the time of assessment. The impact of the discrepancies is insignificant as the modelling results are similar using either data set, due to the small size of the dams.

Table I5 Farm dams in the study area

Quaternary catchment	On-stream			Off-stream		
	Number of dams	FSA[1]	FSC[2]	Number of dams	FSA[1]	FSC[2]
K40A	0	0	0	0	0	0
K40B	2	2.78	30 369	38	9.88	90 086
K40C	2	0.72	6 083	140	33.09	310 229
K40D	0	0	0	4	0.42	3 342
K50A	10	24.31	522 048	43	23.98	781 065
K50B	3	7.56	133 527	7	3.13	29 862

1 FSA: Full Supply Area (ha)
2 FSC: Full Supply Capacity (m^3)

I3.3 WATER SUPPLY SCHEMES

There are two regional water supply schemes in the study area, the Knysna Regional Water Supply Scheme and the Sedgefield Water Supply Scheme. These are described briefly below.

I3.3.1 Knysna Regional Water Supply

The Knysna Regional Water Supply Scheme supplies water to the towns of Knysna, Brenton-on-Sea and Belveldere. Water for this scheme is sourced from the Knysna River, the Gouna River, the Glebe Dam on the Grootkops River, as well as from groundwater. The approximate supply from these four sources is indicated in Table I6.

Table I6 Source of water supply to Knysna

Source of supply to Knysna	Average supply (million m^3/annum)
Knysna River	2.36
Gouna River	0.84
Glebe Dam (Grootkops River)	0.10
Groundwater	0.12
Total	**3.42**

The Knysna River and Gouna River abstractions are both from run-of-river (see Figure I1). Water is pumped to balancing storage which then gravitates to the Knysna Water Treatment Plant. The supply from the Grootkops River is pumped from a small dam (the Glebe Dam) to an off-channel dam, the Akkerkloof Dam. From the Akkerkloof Dam water gravitates to the balancing storage near the water treatment plant.

Groundwater is sourced mostly from 5 boreholes located near Belvedere and supply only Belvedere. The water supply to Belvedere is however supplemented from the Knysna reticulation system when necessary. In addition, water can be sourced from springs located on the eastern side of Knysna. This water is not treated and is only used occasionally when the capacity of the water treatment plant is exceeded.

I3.3.2 Sedgefield Regional Water Supply Scheme

Water is supplied to Sedgefield from run-of-river abstraction out of the Karatara River located near the town (see Figure I2). The current estimated water use is 0.706 million m^3/annum.

I3.3.3 Karatara Regional Water Supply Scheme

The small town of Karatara located in the K40C catchment is supplied from run-of-river from the Karatara River. The current estimated water use in 0.011 million m^3/annum.

I3.4 RETURN FLOWS

Return flow from Knysna was recorded in 2003 as 1.78 million m^3/annum. This takes place in the form of treated effluent which is discharged into the estuary. Treated effluent from Sedgefield is disposed of by means of infiltration into the sand dunes.

I3.5 HYDROLOGY

The hydrology used for this study was that provided by the Outeniqua Coast Water Situation Study (DWAF, 2007b) and is summarised in Table I7. The natural flow time series are attached as Section I7.

Table I7 Summary of natural hydrology of the Knysna and Swartvlei catchment

Quaternary catchment	Mean Annual Runoff (million m^3/annum)	Catchment Area (ha)	Mean Annual Precipitation (mm)	Mean Annual Evaporation (mm)
K50A	57.8	235	850	1 536
K50B	53.4	203	882	1 536
K40A	18.4	87	706	1 536
K40B	25.0	112	846	1 536
K40C	27.9	100	930	1 536
K40D	29.0	130	757	1 536

Units: million m^3/annum

I3.6 WATER RESOURCES MODEL SETUP

The Water Resources Modelling Platform (Mallory, 2005; Mallory and Desai, 2008) was used to simulate flow in the two systems (Knysna and Swartvlei) based on various development scenarios. The two systems were subdivided into catchments based on the same catchment subdivision used in the WRSM2000 model for the hydrological analysis (DWAF, 2007b). Systems diagrams are provided in Figure I3 and I4.

The disaggregation of quaternary catchments into sub-catchments is summarised in Table I8 and I9.

Table I8 Disaggregation of the Knysna catchment

Node Name	Node Number	Flow file	Proportion	Catchment Area (km^2)
DummyDamK40A	1	K40A	0.20	17.50
NodeK40A	2	K40A	0.64	56.00
EWR3	3	K40A	0.00	0.00
NodeK40AEnd	4	K40A	0.16	14.00
EWR5	5	K40D	0.11	14.30
DummyDamK40B	6	K40B	0.20	22.30
NodeK40B-1	7	K40B	0.80	89.30
NodeK40B-2	8	K40B	0.00	0.00
NodeK40C-1	9	K40C	0.20	19.90
EWR4	10	K40C	0.33	32.90
DamK40C-2	11	K40C	0.20	19.90
EndK40C	12	K40C	0.27	27.00
NodeK40D-1	13	K40D	0.42	54.60
EstuaryIn	14	K40D	0.00	0.00
EstuaryOut	15	K40D	0.00	0.00

Table I9 Disaggregation of the Swartvlei catchment

Node Name	Node Number	Flow file	Proportion	Catchment Area (km^2)
DummyDamK50A	1	K50A	0.20	47.09
EWR1	2	K50A	0.55	129.49
NodeK50A-1	3	K50A	0.15	35.32
Node50A-2	4	K50A	0.10	23.54
GounaK50B	5	K50B	0.10	20.29
DummyDamK50B	6	K50B	0.13	26.38
NodeK50B-2	7	K50B	0.14	28.40
GlebeDam	8	K50B	0.05	10.14
EWR2	9	K50B	0.00	0.00
Node10	10	K50B	0.00	0.00
NodeK50B	11	K50B	0.03	6.09
DsNodK50B	12	K50B	0.00	0.00
Knynsna	13	K50B	0.00	0.00
IntoEstuary	14	K50B	0.03	6.09

I4 SCENARIOS AND FUTURE OPTIONS

I4.1 INTRODUCTION

The scenarios identified by the OCWSS and Ecological Reserve team relate mostly to the identified development options in the Knysna catchment and the possible withdrawal of afforestation from the Swartvlei catchment. The Knysna development options consist of possible small dams on the Gouna or Knysna rivers or an off-channel dam to be supplied from the Knysna River. At the commencement of this project no development scenarios could be identified in the Swartvlei catchment but subsequently a licence use application was submitted to DWAF for the development of off-channel storage at Hoëkraal in the lower K40C catchment. This was therefore modelled as a scenario for the Swartvlei Estuary due to the proximity of this site to the saline Swartvlei Lake. Finalization of the Hoëkraal license is dependent on DWAF's decision-making process regarding the Ecological Category for which Swartvlei Lake should be managed.

In the case of the estuary scenarios, a wide range of flows is required by the estuary team to assess the impact of changes in flow to the functioning of the estuary, and hence several hypothetical scenarios were generated in order to achieve a wide range of flows.

I4.2 SCENARIOS

I4.2.1 Knysna Estuary

Table I10 list the scenarios modelled to assess the flows into the Knysna Estuary. Assumptions and explanatory notes relating to these scenarios follow.

Natural (or reference) condition

Note that for this and all other scenarios, the indicator of the impact on the estuary has been assumed as the flow into the estuary from the Knysna River. A point approximately 2 km downstream of the Charlesford pump station was assumed as the transition between river and estuary. The natural flow at this point is less than the sum of the natural flows of the K50A and K50B quaternary catchments because only an estimated 48% of the K50B catchment flows into the estuary from the Knysna River. The remaining 52% enters from other minor streams downstream of the Knysna River.

1 Present Day conditions

- Afforestation: Approximately 130 km^2 upstream of the assumed discharge point, resulting in a streamflow reduction of 13.7 million m^3/annum.
- Irrigation: Demand of 1.65 million m^3/annum of which on average only 1.28 is supplied
- Urban Demand: Estimated to be 3.3 million m^3/annum from surface resources. A small amount is also supplied from groundwater.
- Alien vegetation: Streamflow reduction due to alien vegetation upstream of the discharge estimated at 1.9 million m^3/annum.
- Evaporation losses: Small evaporation losses from Glebe Dam and farm dams, estimated at 0.19 million m^3/annum.

Table I10 Knysna Estuary Scenarios

Scenario description	File name	Flow into Estuary (million m3/a)
0:Natural conditions		83.15
1:Present day	BaseScenario	68.02
2:No Alien vegetation	BaseScenario	69.89
3: Low growth supplied from Gouna	LowGrowth1	66.49
4: Small dam at Charlesford:High growth		
4.1 200 l/s from dam	EstuaryHGSmallDam1	61.46
4.2 500 l/s from dam		61.56
5: Large dam at Charlesford: High growth		
5.1 200 l/s release from dam	EstuaryHGLargeDam1	24.71
5.2 500 l/s release from dam		35.44
6 : Knysna dam in upper Knysna River: Release into river for abstraction at Charlesford		
6.1 200 l/s release	KnysnaDam-HG1	63.42
6.2 500 l/s release		63.45
7: Off-channel dam in the Knysna River catchment		
7.1 200 l/s release	OffChannelHGEstuary1	62.36
7.2 500 l/s release		63.45
8: High growth scenario with abstraction from Gouna	GounaHG1	62.26
9: High growth scenario with abstraction from Gouna	GounaHG2	62.52
10: Dam on the Gouna River: High growth scenario	GounaDamHG	61.90

2 Remove alien vegetation

Removing the alien vegetation increases the mean annual flow by 1.9 million m^3/annum and has a minimal impact on the estuary.

3 Low growth supplied from the Gouna River

One of the development options is to supply the increased demands of Knysna by increasing the pumping capacity of the pump station and Gouna River. This scenario results in only a very small decrease in flow to the estuary.

4 Build a dam at Charlesford

Assume a high priority release from the dam of 200 L/s and 500 L/s. From the Ninham Shand reports, the dam was taken to have a full supply capacity of 5 million m^3/annum. A high growth demand was placed in the dam.

4.1: 200 L/s release

Assume a high priority release from the dam of 200 L/s.

4.2: 500 L/s release

Assume a high priority release from the dam of 500 L/s.

5 Build a large hypothetical dam (65% of MAR) at Charlesford

The assumption was made that this hypothetical dam was fully utilised. The historic firm yield was estimated at 42 million m^3/annum after making releases of 200L/s to the estuary. A dam of this size will not spill very often and therefore the flow into the estuary would be substantially reduced.

5.1: 200 L/s release

The historic firm yield was estimated at 42 million m^3/annum after making releases of 200 L/s to the estuary. A dam of this size will not spill very often and therefore the flow into the estuary will be substantially reduced.

5.2: 500 L/s release

The historic firm yield was estimated at 42 million m^3/annum after making releases of 500L/s to the estuary. A dam of this size will not spill very often and therefore the flow into the estuary will be substantially reduced.

6 Knysna Dam in the upper reaches of the Knysna River

A possible dam site has been identified close to the location of the EWR1 site. For modelling purposes it was assumed that the dam is located just upstream of the EWR site so that the impact of such a dam on the hydrology at the EWR1 site can be ascertained. It was assumed that water will be supplied from the dam by releases into the river, to be abstracted at the Charlesford pumping station. The dam full supply capacity was assumed to be 7 million m^3 based on the Ninham Shand report (Ninham Shand, 2007).

6.1. 200 L/s release at Charlesford

As above with a minimum flow of 200L/s at Charlesford.

6.2: 500 L/s release at Charlesford

As above with a minimum flow of 500L/s at Charlesford.

7 Off-channel dam in the Knysna River catchment

Several possible off-channel dam sites have been identified by Ninham Shand (Ninham Shand, 2007). A dam with a full supply capacity of 7 million m^3 was assumed (Nimham Shand, 2007).

7.1: Off-channel dam in the Knysna River catchment

Off channel dam with a minimum flow of 200L/s at Charlesford.

7.2 Off-channel dam in the Knysna River catchment

Off channel dam with a minimum flow of 500L/s at Charlesford.

8 High growth scenario with run-of-river abstractions from the Gouna River

This scenario assumes that the increased demand of Knysna will be met from increased abstractions from Gouna. This is a highly unlikely scenario since the assurance of supply from this run-of-river scheme would be very low.

9 High growth scenario with a new dam on the Gouna River

This scenario assumes that the increased demand of Knysna will be met from increased abstractions from Gouna, but supported with dam with a full supply capacity of 6 million m^3.

A water resources model diagramme is provided for the Knysna Estuary in Figure I4.

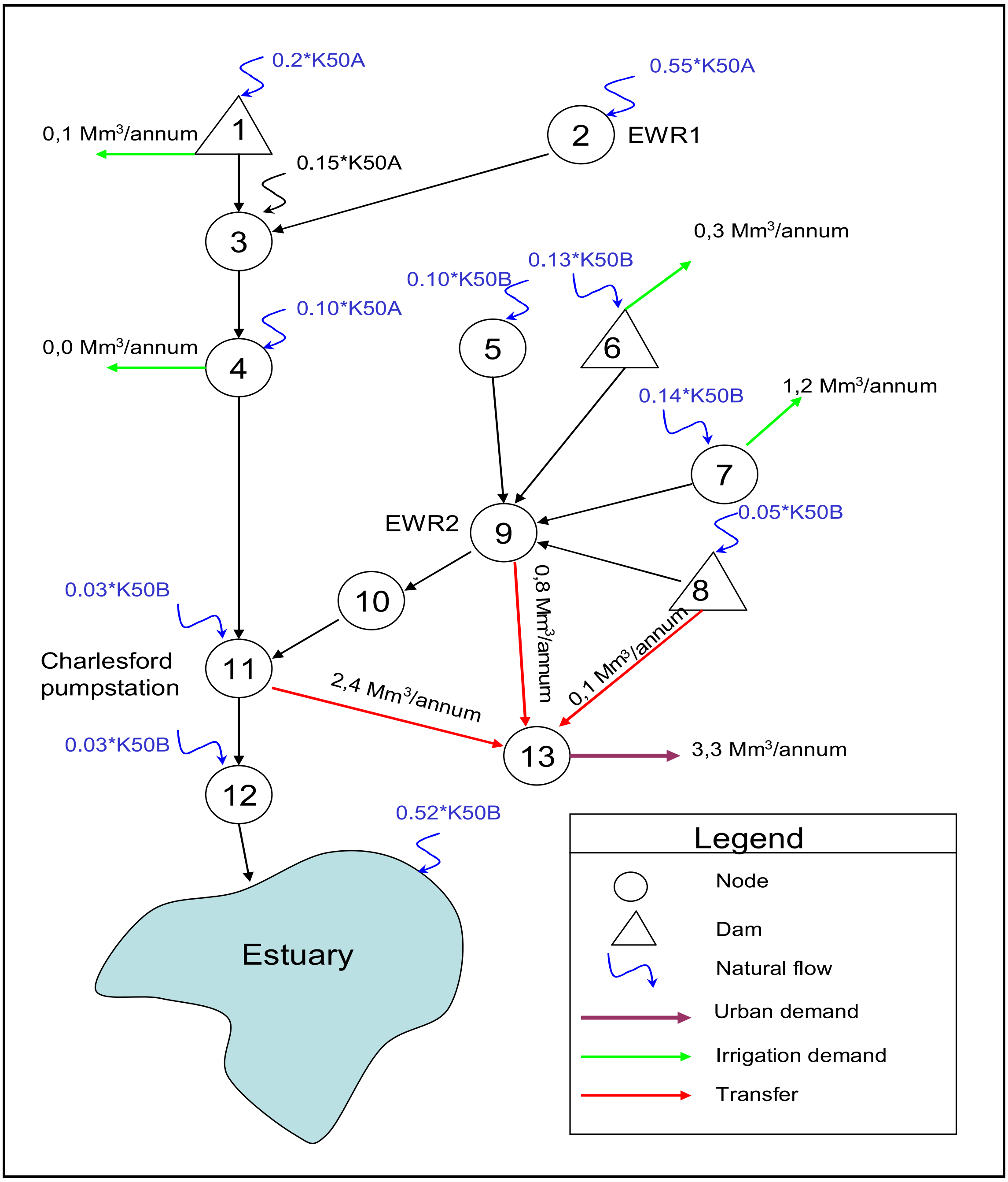

Figure I3 Knysna System

I4.2.2 EWR 1 Site (Upper Knysna)

Many of the scenarios listed in Table I10 do not influence the flow at EWR 1. The scenarios modelled for EWR 1 are listed below in Table I11.

Table I11 EWR 1 Scenarios

Scenario Description	File Name	Flow into Estuary (million m^3/a)
0: Natural conditions		31.64
1: Present day	BaseScenario	27.49
2: No Alien vegetation	BaseScenario	28.02
3: Knysna dam in upper Knysna River: Release into river for abstraction at Charlesford	KnysnaDam-HG1	27.22

I4.2.3 EWR 2 (Gouna River)

The scenarios modelled at EWR 2 are given in Table I12. Note that none of the scenarios modelled for possible developments on the Knysna River are relevant to EWR 2.

Table I12 EWR 2 Scenarios

Scenario Description	File Name	Flow into Estuary (million m^3/a)
0: Natural conditions		22.42
1: Present day	BaseScenario	17.15
2: No Alien vegetation	BaseScenario	17.76
3: Low growth supplied from Gouna	LowGrowth1	16.40
4: High growth scenario with abstraction from Gouna	GounaHG1	12.17
5: Dam on the Gouna River: High growth scenario	GounaDamHG	10.75

I4.2.4 Swartvlei Estuary

Table IL13 lists the scenarios modelled to assess the flows into the Swartvlei Estuary. Assumptions and explanatory notes relating to these scenarios follow.

Table I13 Swartvlei Estuary scenarios

Scenario Description	File Name	Flow into Estuary (million m^3/a)
0: Natural		83.40
1: Present day	BaseScenario	56.60
2: Exit strat 1	Exit1	70.16
3: Exit strat 2	Exit2	78.48
4: 1 MAR dam in each Quat	1MARDam	13.29
5: 0.5 MAR dam in each Quat	HalfMARdams	22.47
6: Hoekraal off-channel	Hoekraal	55.58
7: 50% Flow reduction	DamInK40C	40.80

Natural flow (Reference condition)

Note that for this and all other scenarios, the indicator of the impact on the estuary has been assumed as the flow into the estuary from the three cumulative upstream quaternary catchments (K40A, K40B, and K40C and 42 % of the K40D catchment).

Scenario 1 Present Day conditions

- Afforestation: Approximately 116 km^2 of mostly Pine upstream of the assumed discharge point, resulting in a streamflow reduction of 17 million m^3/annum.
- Irrigation: Demand of 5.8 million m^3/annum of which on average only 4.6 million m^3/annum is supplied.
- Urban demand: Estimated to be 0.7 million m^3/annum from surface resources. A small amount also supplied from groundwater.
- Alien vegetation: Streamflow reduction due to alien vegetation upstream of the discharge estimated at 6.2 million m^3/annum.
- Evaporation losses: Minor evaporation losses from small dam, estimated at 0.1 million m^3/annum.

Scenario 2 Forestry Exit strategy 1: Remove half the afforestation and all alien vegetation

Removing the alien vegetation increases the mean annual flow by 6.2 million m^3/annum while halving the afforestation increases the flow by a further 8.5 million m^3/annum. Total increase in MAR is 14.7 million m^3/annum.

Scenario 3 Forestry Exit strategy 2: Remove all afforestation and all alien vegetation

Flow into the estuary increases by 23 million m^3/annum.

Scenario 4: Assume 1 MAR dams in all the quaternary catchments with the historic firm yield assumed to be abstracted from each dam. Dams were also assumed in the two small parts of K40D which are assumed to be contributing to the flow into the estuary. Total yield (and hence abstraction) from the dams was calculated as 40.9 million m^3/annum. The low flows into the estuary are completely cut off by these dams and spills only occur occasionally.

Scenario 5: Assume 0.5 MAR dams in all the quaternary catchment with the historic firm yield assumed to be abstracted from each dam. Dams were also assumed in the two small part of K40D which are contributing to the flow into the estuary. Total yield (and hence abstraction) from the dams was calculated as 32.9 million m^3/annum. The low flows into the estuary are also completely cut off by these dams. Spill occurs slightly more often than under Scenario 5.

Scenario 6: The objective this scenario was to achieve an inflow into the estuary of approximately 50% of the natural MAR. This was achieved by assuming a dam with a full supply capacity of 30 million m^3 located at the outlet of the K40C catchment.

Scenario 7: The impact of the proposed off-channel dam at Hoëkraal was modelled. This dam was assumed to have a full supply capacity of 0.4 million m^3 and the target yield of the dam was 1.2 million m^3/annum.

A water resources model diagramme is provided for the Swartvlei Estuary in Figure I4.

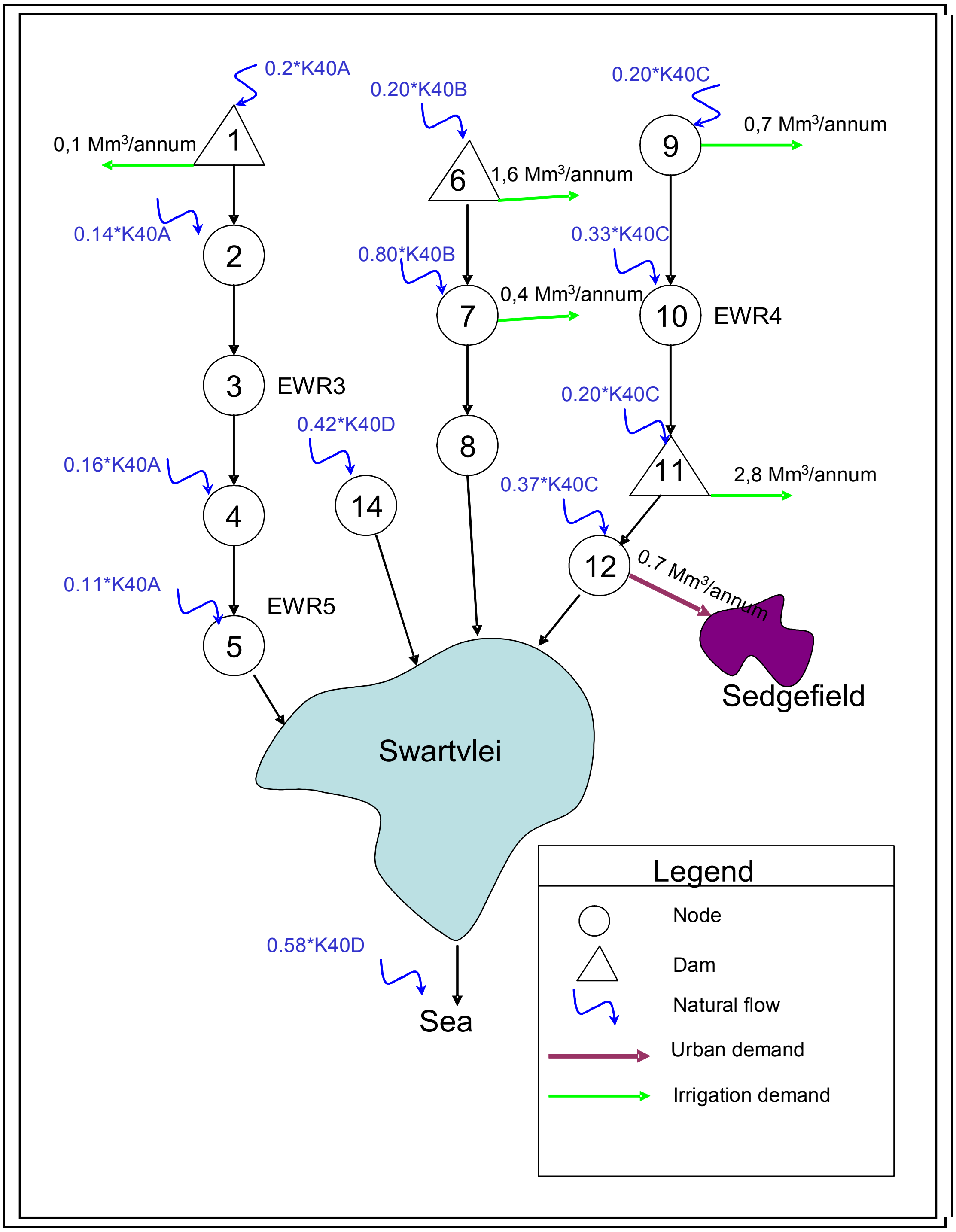

Figure I4 Swartvlei System

I4.2.5 EWR 3, 4 and 5

Table I14 lists the scenarios modelled to assess the flows at the EWR sites in the Swartvlei catchment. The flow at these sites is only influenced by the forestry exit scenarios.

Table I14 EWR 3, 4 and 5 Scenarios

Scenario Description	File Name	Flow at EWR3	Flow at EWR4	Flow at EWR5
0: Natural		14.00	9.21	19.86
1: Present day	BaseScenario	7.94	7.07	12.08
2: Exit strat 1	Exit1	11.53	8.49	16.69
3: Exit strat 2	Exit2	13.90	9.21	19.75

I4.3 RESULTS

Time series of all scenarios modelled have been provided electronically in the following files:

Knysna catchment
EWR1.xls
EWR2.xls
KnysnaJuly2008.xls (all Knysna Estuary scenarios)

Swartvlei catchment
EWR3.xls
EWR4.xls
EWR5.xls
SwartvleiJuly2008.xls (all Swartvlei Estuary scenarios)

I5 IRRIGATION WATER REQUIREMENTS

Irrigation requirements in the K50A catchment (from farm dams)

Units in million m^

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	TOTAL
1920	0.14	0.15	0.05	0.32	0	0	0	0.03	0	0	0.07	0	0.76
1921	0.2	0.11	0.08	0.24	0.15	0	0	0	0.05	0	0.07	0	0.9
1922	0	0	0.38	0.15	0.23	0.11	0	0	0	0.17	0.02	0.12	1.17
1923	0.06	0.03	0.31	0.32	0.18	0.15	0.01	0.04	0.02	0.21	0	0	1.34
1924	0.1	0.12	0.18	0.29	0.22	0.02	0	0.11	0	0.12	0	0	1.17
1925	0	0.1	0.12	0.29	0.14	0	0.01	0.06	0	0	0.01	0	0.73
1926	0.01	0	0.4	0.26	0.09	0.17	0.16	0	0.09	0.09	0	0.11	1.37
1927	0.17	0.25	0.37	0.28	0.07	0	0	0.17	0	0.15	0	0	1.46
1928	0.11	0	0.12	0.43	0.17	0.15	0.05	0	0.02	0	0	0	1.04
1929	0.08	0.25	0.18	0.28	0	0.04	0.07	0	0	0	0	0	0.9
1930	0.08	0.29	0.22	0.12	0.19	0.18	0	0.03	0.1	0	0.04	0	1.27
1931	0	0.27	0	0	0.06	0.04	0.16	0	0	0.04	0.1	0	0.67
1932	0	0.18	0.38	0.43	0.13	0	0	0	0.05	0.08	0	0.13	1.36
1933	0.33	0.07	0.41	0.36	0.14	0	0.16	0.08	0.11	0	0	0.04	1.7
1934	0	0.08	0.39	0.26	0.12	0.12	0	0	0	0.02	0	0	0.99
1935	0	0	0.15	0.19	0.05	0	0.1	0	0.12	0	0.17	0	0.78
1936	0.03	0	0.23	0.25	0	0	0.13	0.2	0	0	0.07	0	0.91
1937	0.06	0.08	0.21	0.18	0.37	0.05	0	0.14	0.04	0.1	0	0	1.22
1938	0	0	0.17	0.44	0	0	0.1	0.25	0.19	0	0	0	1.14
1939	0.11	0.13	0.27	0	0	0.01	0.01	0.04	0.12	0	0.21	0	0.9
1940	0.1	0.11	0.41	0.26	0.11	0.1	0	0.12	0	0.17	0.12	0	1.5
1941	0	0.09	0.06	0.03	0.21	0	0.06	0	0	0	0.01	0.06	0.52
1942	0.02	0.17	0.13	0.05	0.11	0	0.09	0.14	0.12	0.1	0	0	0.93
1943	0	0	0.09	0.45	0.09	0.05	0.01	0	0	0	0.02	0	0.71
1944	0.09	0.21	0.25	0.38	0.31	0.23	0.18	0	0	0	0.03	0.1	1.78
1945	0	0.26	0.16	0.25	0.15	0	0.08	0.17	0.06	0	0.09	0	1.21
1946	0.09	0.33	0.29	0.27	0.26	0	0	0	0	0	0.22	0	1.46
1947	0.09	0.17	0.34	0.1	0.15	0.15	0	0.19	0.08	0.04	0.13	0	1.44
1948	0	0.2	0.17	0.13	0.1	0.32	0	0	0.26	0.14	0.08	0	1.4
1949	0.13	0	0.36	0.35	0.22	0.13	0	0.09	0.26	0	0	0	1.53
1950	0	0	0.07	0	0.19	0.08	0.19	0	0	0	0	0	0.54
1951	0.27	0.42	0.38	0.04	0.1	0.17	0	0	0	0	0	0	1.4
1952	0	0.16	0.14	0.27	0	0.23	0	0.19	0	0	0	0	0.99
1953	0	0.06	0.2	0.4	0.27	0	0	0	0	0	0	0	0.93
1954	0.2	0	0.43	0.12	0	0.16	0.03	0.06	0	0.03	0.03	0	1.04
1955	0	0	0.44	0.25	0.09	0	0	0	0.16	0.19	0.05	0	1.18
1956	0	0.11	0.09	0.28	0.05	0.07	0.04	0	0	0.14	0	0	0.78
1957	0.05	0.38	0.29	0.26	0.21	0	0	0	0.06	0.26	0	0.13	1.64
1958	0.06	0.26	0.24	0	0.12	0.02	0	0	0.22	0	0	0	0.91
1959	0	0.31	0.21	0	0.29	0	0	0	0	0	0.16	0	0.98
1960	0.18	0.08	0.21	0.28	0.23	0	0	0	0.19	0	0	0.04	1.22
1961	0	0.2	0.3	0.07	0.14	0	0	0.14	0.12	0.07	0	0.13	1.18
1962	0	0.02	0.34	0.21	0.31	0	0.03	0.04	0.12	0	0.01	0.21	1.29
1963	0.13	0.25	0.08	0.16	0.22	0.03	0	0.17	0	0.14	0	0	1.17
1964	0.19	0.01	0.48	0.35	0.24	0	0	0	0	0.03	0.14	0.1	1.56
1965	0	0	0.19	0.22	0.04	0.22	0	0	0.19	0.08	0	0	0.95
1966	0.24	0.19	0.23	0.45	0.11	0	0	0	0	0	0	0	1.21
1967	0.18	0.13	0.31	0.3	0.14	0.01	0.04	0	0	0.24	0	0	1.36
1968	0.03	0.04	0.35	0.22	0.14	0.03	0.06	0.18	0	0.04	0.03	0.01	1.12
1969	0	0.27	0.46	0.24	0.08	0.21	0.13	0.13	0.04	0.02	0	0.08	1.68
1970	0.09	0.34	0	0.32	0	0	0	0	0	0	0	0.19	0.93
1971	0.16	0	0.39	0.24	0	0.07	0.06	0	0	0	0	0.15	1.07
1972	0.22	0.24	0.33	0.34	0.22	0.04	0	0.01	0.08	0.06	0.04	0	1.57
1973	0.17	0	0.31	0.11	0.04	0	0.11	0	0.12	0.18	0	0	1.05
1974	0.12	0.11	0.45	0.2	0.15	0.03	0.05	0.14	0.03	0	0	0	1.28
1975	0.26	0.08	0.21	0.28	0.12	0	0.16	0	0	0	0.06	0.1	1.28
1976	0	0.03	0.16	0.46	0	0.06	0.13	0	0	0.19	0	0	1.02

1977	0	0.06	0.33	0.34	0.3	0.13	0.04	0.04	0	0.17	0	0.07	1.49
1978	0	0.06	0.2	0.24	0.23	0.19	0.06	0	0.03	0	0	0	1.02
1979	0.24	0.27	0.34	0.21	0.28	0.22	0	0	0	0.14	0	0	1.71
1980	0	0	0.13	0	0.2	0	0	0	0	0.07	0	0.09	0.48
1981	0	0.21	0.23	0.33	0.2	0.02	0	0.21	0	0	0.09	0	1.29
1982	0.02	0.25	0.31	0.4	0.08	0.15	0.09	0	0	0	0.06	0	1.35
1983	0	0.24	0.15	0.37	0.2	0	0.17	0.09	0	0	0.14	0.15	1.5
1984	0	0.24	0.16	0.12	0	0.14	0	0.15	0	0	0.21	0.12	1.13
1985	0	0.08	0.05	0.18	0.27	0.12	0.14	0.16	0.12	0.05	0	0.1	1.26
1986	0	0.27	0.24	0.18	0.19	0.06	0	0.25	0	0.19	0	0	1.38
1987	0.23	0.3	0.31	0.32	0.3	0.19	0	0.01	0	0.11	0	0.01	1.77
1988	0.09	0.18	0.31	0.36	0.28	0.12	0	0.11	0.04	0	0.18	0	1.68
1989	0	0	0.39	0.28	0.02	0.18	0	0	0	0.22	0	0.04	1.13
1990	0	0.08	0.31	0.23	0.08	0.14	0.22	0	0.05	0	0.13	0.17	1.42
1991	0	0.33	0.18	0.28	0.04	0.13	0.03	0	0	0	0	0.1	1.08
1992	0	0.05	0.37	0.28	0.18	0.14	0	0	0	0.07	0	0	1.1
1993	0.23	0.25	0.12	0.28	0.09	0.16	0	0.06	0.08	0	0	0.05	1.33
1994	0	0.3	0	0.3	0.19	0	0	0	0.02	0.06	0.07	0.06	1
1995	0.18	0	0.21	0.21	0.3	0.17	0.14	0.17	0.14	0	0.01	0.06	1.6
1996	0	0	0.11	0.44	0.03	0	0	0	0	0.03	0	0.18	0.79
1997	0	0.23	0.43	0.25	0.35	0	0.19	0	0.13	0	0	0.06	1.63
1998	0.2	0.09	0.25	0.23	0.1	0	0	0.17	0.16	0	0.01	0.06	1.25
1999	0	0.4	0.43	0.06	0.05	0	0.16	0.21	0.24	0.15	0.22	0.05	1.97
2000	0.03	0	0.14	0.13	0.2	0.13	0	0.2	0.17	0	0	0.02	1.01
2001	0.15	0.01	0.31	0.19	0.26	0.34	0	0.02	0	0	0	0	1.27
2002	0.28	0.06	0.28	0.4	0.07	0	0.03	0	0	0.08	0	0.17	1.37
2003	0.09	0.29	0.35	0.28	0.06	0	0	0.09	0.02	0.06	0.04	0	1.28
Average	**0.07**	**0.14**	**0.25**	**0.24**	**0.14**	**0.07**	**0.04**	**0.06**	**0.05**	**0.05**	**0.04**	**0.04**	**1.20**

Irrigation requirements in the K50A catchment (from run-of-river)

Units in million m^3

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	TOTAL
1920	0.03	0.04	0.01	0.08	0	0	0	0.01	0	0	0.02	0	0.18
1921	0.05	0.03	0.02	0.06	0.04	0	0	0	0.01	0	0.02	0	0.22
1922	0	0	0.09	0.04	0.06	0.03	0	0	0	0.04	0	0.03	0.28
1923	0.02	0.01	0.08	0.08	0.04	0.04	0	0.01	0	0.05	0	0	0.32
1924	0.03	0.03	0.04	0.07	0.05	0.01	0	0.03	0	0.03	0	0	0.28
1925	0	0.02	0.03	0.07	0.03	0	0	0.01	0	0	0	0	0.17
1926	0	0	0.1	0.06	0.02	0.04	0.04	0	0.02	0.02	0	0.03	0.33
1927	0.04	0.06	0.09	0.07	0.02	0	0	0.04	0	0.04	0	0	0.35
1928	0.03	0	0.03	0.1	0.04	0.04	0.01	0	0	0	0	0	0.25
1929	0.02	0.06	0.04	0.07	0	0.01	0.02	0	0	0	0	0	0.22
1930	0.02	0.07	0.05	0.03	0.05	0.04	0	0.01	0.02	0	0.01	0	0.3
1931	0	0.07	0	0	0.01	0.01	0.04	0	0	0.01	0.02	0	0.16
1932	0	0.04	0.09	0.1	0.03	0	0	0	0.01	0.02	0	0.03	0.33
1933	0.08	0.02	0.1	0.09	0.03	0	0.04	0.02	0.03	0	0	0.01	0.41
1934	0	0.02	0.09	0.06	0.03	0.03	0	0	0	0.01	0	0	0.24
1935	0	0	0.03	0.05	0.01	0	0.02	0	0.03	0	0.04	0	0.19
1936	0.01	0	0.05	0.06	0	0	0.03	0.05	0	0	0.02	0	0.22
1937	0.01	0.02	0.05	0.04	0.09	0.01	0	0.03	0.01	0.02	0	0	0.29
1938	0	0	0.04	0.1	0	0	0.02	0.06	0.05	0	0	0	0.27
1939	0.03	0.03	0.06	0	0	0	0	0.01	0.03	0	0.05	0	0.22
1940	0.02	0.03	0.1	0.06	0.03	0.02	0	0.03	0	0.04	0.03	0	0.36
1941	0	0.02	0.01	0.01	0.05	0	0.01	0	0	0	0	0.02	0.13
1942	0	0.04	0.03	0.01	0.03	0	0.02	0.03	0.03	0.02	0	0	0.22
1943	0	0	0.02	0.11	0.02	0.01	0	0	0	0	0.01	0	0.17
1944	0.02	0.05	0.06	0.09	0.07	0.05	0.04	0	0	0	0.01	0.02	0.43
1945	0	0.06	0.04	0.06	0.04	0	0.02	0.04	0.02	0	0.02	0	0.29
1946	0.02	0.08	0.07	0.06	0.06	0	0	0	0	0	0.05	0	0.35
1947	0.02	0.04	0.08	0.02	0.04	0.04	0	0.05	0.02	0.01	0.03	0	0.35
1948	0	0.05	0.04	0.03	0.02	0.08	0	0	0.06	0.03	0.02	0	0.34
1949	0.03	0	0.09	0.08	0.05	0.03	0	0.02	0.06	0	0	0	0.37
1950	0	0	0.02	0	0.05	0.02	0.05	0	0	0	0	0	0.13
1951	0.07	0.1	0.09	0.01	0.03	0.04	0	0	0	0	0	0	0.34
1952	0	0.04	0.03	0.07	0	0.05	0	0.05	0	0	0	0	0.24
1953	0	0.01	0.05	0.1	0.06	0	0	0	0	0	0	0	0.22
1954	0.05	0	0.1	0.03	0	0.04	0.01	0.01	0	0.01	0.01	0	0.25
1955	0	0	0.11	0.06	0.02	0	0	0	0.04	0.05	0.01	0	0.28
1956	0	0.03	0.02	0.07	0.01	0.02	0.01	0	0	0.03	0	0	0.19
1957	0.01	0.09	0.07	0.06	0.05	0	0	0	0.01	0.06	0	0.03	0.39
1958	0.02	0.06	0.06	0	0.03	0	0	0	0.05	0	0	0	0.22
1959	0	0.07	0.05	0	0.07	0	0	0	0	0	0.04	0	0.23
1960	0.04	0.02	0.05	0.07	0.06	0	0	0	0.04	0	0	0.01	0.29
1961	0	0.05	0.07	0.02	0.03	0	0	0.03	0.03	0.02	0	0.03	0.28
1962	0	0.01	0.08	0.05	0.07	0	0.01	0.01	0.03	0	0	0.05	0.31
1963	0.03	0.06	0.02	0.04	0.05	0.01	0	0.04	0	0.03	0	0	0.28
1964	0.05	0	0.12	0.08	0.06	0	0	0	0	0.01	0.03	0.03	0.37
1965	0	0	0.05	0.05	0.01	0.05	0	0	0.05	0.02	0	0	0.23
1966	0.06	0.05	0.05	0.11	0.03	0	0	0	0	0	0	0	0.29
1967	0.04	0.03	0.07	0.07	0.03	0	0.01	0	0	0.06	0	0	0.33
1968	0.01	0.01	0.08	0.05	0.03	0.01	0.02	0.04	0	0.01	0.01	0	0.27
1969	0	0.07	0.11	0.06	0.02	0.05	0.03	0.03	0.01	0.01	0	0.02	0.4
1970	0.02	0.08	0	0.08	0	0	0	0	0	0	0	0.05	0.22
1971	0.04	0	0.09	0.06	0	0.02	0.01	0	0	0	0	0.04	0.26
1972	0.05	0.06	0.08	0.08	0.05	0.01	0	0	0.02	0.02	0.01	0	0.38
1973	0.04	0	0.07	0.03	0.01	0	0.03	0	0.03	0.04	0	0	0.25
1974	0.03	0.03	0.11	0.05	0.04	0.01	0.01	0.03	0.01	0	0	0	0.31
1975	0.06	0.02	0.05	0.07	0.03	0	0.04	0	0	0	0.02	0.02	0.31
1976	0	0.01	0.04	0.11	0	0.02	0.03	0	0	0.04	0	0	0.25

1979	0.06	0.06	0.08	0.05	0.07	0.05	0	0	0	0.03	0	0	0.41
1980	0	0	0.03	0	0.05	0	0	0	0	0.02	0	0.02	0.12
1981	0	0.05	0.05	0.08	0.05	0.01	0	0.05	0	0	0.02	0	0.31
1982	0	0.06	0.07	0.1	0.02	0.04	0.02	0	0	0	0.01	0	0.32
1983	0	0.06	0.04	0.09	0.05	0	0.04	0.02	0	0	0.03	0.03	0.36
1984	0	0.06	0.04	0.03	0	0.03	0	0.04	0	0	0.05	0.03	0.27
1985	0	0.02	0.01	0.04	0.07	0.03	0.03	0.04	0.03	0.01	0	0.02	0.3
1986	0	0.06	0.06	0.04	0.05	0.02	0	0.06	0	0.04	0	0	0.33
1987	0.05	0.07	0.07	0.08	0.07	0.05	0	0	0	0.03	0	0	0.43
1988	0.02	0.04	0.08	0.09	0.07	0.03	0	0.03	0.01	0	0.04	0	0.4
1989	0	0	0.09	0.07	0.01	0.04	0	0	0	0.05	0	0.01	0.27
1990	0	0.02	0.07	0.06	0.02	0.03	0.05	0	0.01	0	0.03	0.04	0.34
1991	0	0.08	0.04	0.07	0.01	0.03	0.01	0	0	0	0	0.02	0.26
1992	0	0.01	0.09	0.07	0.04	0.03	0	0	0	0.02	0	0	0.26
1993	0.06	0.06	0.03	0.07	0.02	0.04	0	0.02	0.02	0	0	0.01	0.32
1994	0	0.07	0	0.07	0.05	0	0	0	0	0.01	0.02	0.01	0.24
1995	0.04	0	0.05	0.05	0.07	0.04	0.03	0.04	0.03	0	0	0.01	0.38
1996	0	0	0.03	0.11	0.01	0	0	0	0	0.01	0	0.04	0.19
1997	0	0.05	0.1	0.06	0.08	0	0.05	0	0.03	0	0	0.01	0.39
1998	0.05	0.02	0.06	0.06	0.02	0	0	0.04	0.04	0	0	0.01	0.3
1999	0	0.1	0.1	0.01	0.01	0	0.04	0.05	0.06	0.04	0.05	0.01	0.47
2000	0.01	0	0.03	0.03	0.05	0.03	0	0.05	0.04	0	0	0	0.24
2001	0.04	0	0.07	0.05	0.06	0.08	0	0	0	0	0	0	0.3
2002	0.07	0.02	0.07	0.1	0.02	0	0.01	0	0	0.02	0	0.04	0.33
2003	0.02	0.07	0.08	0.07	0.01	0	0	0.02	0.01	0.01	0.01	0	0.31
Average	**0.02**	**0.03**	**0.06**	**0.06**	**0.03**	**0.02**	**0.01**	**0.01**	**0.01**	**0.01**	**0.01**	**0.01**	**0.29**

Irrigation requirements in the K50B catchment (from farm dams)
Units in million m^3

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	TOTAL
1920	0	0	0	0.01	0	0	0	0	0	0	0	0	0.02
1921	0.01	0	0	0.01	0	0	0	0	0	0	0	0	0.03
1922	0	0	0.01	0	0.01	0	0	0	0	0	0	0	0.03
1923	0	0	0.01	0.01	0	0	0	0	0	0.01	0	0	0.03
1924	0	0	0.01	0.01	0.01	0	0	0	0	0	0	0	0.03
1925	0	0	0	0.01	0	0	0	0	0	0	0	0	0.01
1926	0	0	0.01	0.01	0	0	0	0	0	0	0	0	0.03
1927	0	0.01	0.01	0.01	0	0	0	0	0	0	0	0	0.04
1928	0	0	0	0.01	0	0	0	0	0	0	0	0	0.02
1929	0	0.01	0	0.01	0	0	0	0	0	0	0	0	0.02
1930	0	0.01	0.01	0	0	0	0	0	0	0	0	0	0.03
1931	0	0.01	0	0	0	0	0	0	0	0	0	0	0.02
1932	0	0	0.01	0.01	0	0	0	0	0	0	0	0	0.03
1933	0.01	0	0.01	0.01	0	0	0	0	0	0	0	0	0.04
1934	0	0	0.01	0.01	0	0	0	0	0	0	0	0	0.03
1935	0	0	0	0	0	0	0	0	0	0	0	0	0.02
1936	0	0	0.01	0.01	0	0	0	0.01	0	0	0	0	0.02
1937	0	0	0	0	0.01	0	0	0	0	0	0	0	0.03
1938	0	0	0	0.01	0	0	0	0.01	0	0	0	0	0.03
1939	0	0	0.01	0	0	0	0	0	0	0	0.01	0	0.02
1940	0	0	0.01	0.01	0	0	0	0	0	0	0	0	0.04
1941	0	0	0	0	0.01	0	0	0	0	0	0	0	0.01
1942	0	0	0	0	0	0	0	0	0	0	0	0	0.03
1943	0	0	0	0.01	0	0	0	0	0	0	0	0	0.02
1944	0	0.01	0.01	0.01	0.01	0.01	0	0	0	0	0	0	0.04
1945	0	0.01	0	0.01	0	0	0	0	0	0	0	0	0.03
1946	0	0.01	0.01	0.01	0.01	0	0	0	0	0	0.01	0	0.04
1947	0	0	0.01	0	0	0	0	0.01	0	0	0	0	0.04
1948	0	0.01	0.01	0	0	0.01	0	0	0.01	0	0	0	0.03
1949	0	0	0.01	0.01	0.01	0	0	0	0.01	0	0	0	0.04
1950	0	0	0	0	0.01	0	0.01	0	0	0	0	0	0.01
1951	0.01	0.01	0.01	0	0.01	0	0	0	0	0	0	0	0.04
1952	0	0.01	0.01	0.01	0	0.01	0	0	0	0	0	0	0.03
1953	0	0	0.01	0.01	0.01	0	0	0	0	0	0	0	0.02
1954	0	0	0.01	0	0	0.01	0	0	0	0	0	0	0.02
1955	0	0	0.01	0.01	0	0	0	0	0	0.01	0	0	0.03
1956	0	0	0	0.01	0	0	0	0	0	0	0	0	0.02
1957	0	0.01	0.01	0.01	0.01	0	0	0	0	0.01	0	0	0.05
1958	0	0.01	0.01	0	0	0	0	0	0	0	0	0	0.02
1959	0	0.01	0.01	0	0.01	0	0	0	0	0	0	0	0.03
1960	0.01	0	0.01	0.01	0.01	0	0	0	0	0	0	0	0.03
1961	0	0.01	0.01	0	0	0	0	0	0	0	0	0	0.03
1962	0	0	0.01	0.01	0.01	0	0	0	0	0	0	0.01	0.04
1963	0	0.01	0	0	0.01	0	0	0	0	0	0	0	0.03
1964	0.01	0	0.01	0.01	0.01	0	0	0	0	0	0	0	0.04
1965	0	0	0.01	0.01	0	0	0	0	0.01	0	0	0	0.03
1966	0.01	0	0.01	0.01	0	0	0	0	0	0	0	0	0.03
1967	0	0	0.01	0.01	0	0	0	0	0	0.01	0	0	0.04
1968	0	0	0.01	0.01	0	0	0	0	0	0	0	0	0.03
1969	0	0.01	0.01	0.01	0	0.01	0	0	0	0	0	0	0.04
1970	0	0.01	0	0.01	0	0	0	0	0	0	0	0.01	0.03
1971	0	0	0.01	0.01	0	0	0	0	0	0	0	0	0.03
1972	0.01	0.01	0.01	0.01	0.01	0	0	0	0	0	0	0	0.04
1973	0	0	0.01	0	0	0	0	0	0	0	0	0	0.03
1974	0	0	0.01	0	0.01	0	0	0	0	0	0	0	0.04
1975	0.01	0	0.01	0.01	0	0	0	0	0	0	0	0	0.03
1976	0	0	0	0.01	0	0	0	0	0	0	0	0	0.03

1978	0	0	0.02	0.02	0.03	0.02	0	0	0	0	0	0	0.1
1979	0.03	0.03	0.03	0.02	0.03	0.02	0	0	0	0.01	0	0	0.18
1980	0	0	0.02	0	0.02	0	0	0	0	0.01	0	0.01	0.06
1981	0	0.02	0.02	0.04	0.02	0	0	0.02	0	0	0.01	0	0.14
1982	0	0.03	0.03	0.04	0	0.01	0.01	0	0	0	0.01	0	0.14
1983	0	0.01	0.01	0.04	0.02	0	0.01	0.01	0	0	0.01	0.02	0.14
1984	0	0.02	0.02	0.02	0	0.01	0	0.02	0	0	0.02	0.01	0.12
1985	0	0.01	0.01	0.01	0.03	0.01	0.01	0.02	0.01	0	0	0	0.12
1986	0	0.03	0.03	0.02	0.02	0.01	0	0.03	0	0.02	0	0	0.16
1987	0.03	0.04	0.04	0.04	0.03	0.03	0	0	0	0.01	0	0	0.21
1988	0.01	0.02	0.04	0.04	0.03	0.02	0	0.01	0	0	0.02	0	0.18
1989	0	0	0.04	0.03	0.01	0.02	0	0	0	0.02	0	0.01	0.13
1990	0	0.02	0.04	0.02	0.01	0.02	0.02	0	0	0	0.01	0.02	0.16
1991	0	0.04	0.01	0.03	0	0.02	0	0	0	0	0	0	0.11
1992	0	0	0.04	0.04	0.02	0.02	0	0	0	0	0	0	0.13
1993	0.03	0.02	0.01	0.03	0.01	0.01	0	0	0.01	0	0	0	0.13
1994	0	0.03	0	0.04	0.01	0	0	0	0	0	0	0	0.09
1995	0.02	0	0.02	0.02	0.04	0.02	0.02	0.02	0.02	0	0	0.01	0.18
1996	0	0	0.02	0.05	0.01	0	0	0	0	0	0	0.02	0.09
1997	0	0.02	0.04	0.02	0.04	0	0.02	0	0.01	0	0	0	0.16
1998	0.02	0.01	0.03	0.02	0.01	0	0	0.02	0.02	0	0	0.01	0.14
1999	0	0.05	0.05	0.01	0.01	0	0.02	0.02	0.03	0.02	0.02	0	0.22
2000	0	0	0.02	0.01	0.03	0.01	0	0.02	0.02	0	0	0	0.11
2001	0.02	0	0.03	0.02	0.03	0.03	0	0	0	0	0	0	0.14
2002	0.03	0	0.03	0.04	0.01	0	0	0	0	0.01	0	0.02	0.13
2003	0.01	0.03	0.03	0.04	0.01	0	0	0.01	0	0	0	0	0.13
Average	**0.01**	**0.02**	**0.03**	**0.03**	**0.02**	**0.01**	**0.00**	**0.01**	**0.00**	**0.00**	**0.00**	**0.00**	**0.13**

Irrigation requirements in the K50B catchment (from run-of-river)

Units in million m^3

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	TOTAL
1920	0.02	0.02	0.01	0.02	0	0	0	0.01	0.01	0	0.01	0	0.1
1921	0.02	0.01	0.01	0.02	0.02	0	0	0	0.01	0	0	0	0.08
1922	0	0	0.03	0.02	0.02	0.02	0	0	0	0.02	0.01	0.01	0.12
1923	0.01	0.01	0.03	0.03	0.02	0.02	0	0.01	0.01	0.01	0	0	0.14
1924	0.01	0.01	0.01	0.02	0.02	0	0	0	0	0.01	0	0	0.1
1925	0.01	0.01	0.02	0.03	0.02	0	0.01	0.01	0	0	0.01	0.01	0.12
1926	0	0	0.03	0.02	0	0.01	0.02	0	0.01	0.01	0	0.02	0.13
1927	0.01	0.01	0.03	0.02	0.01	0	0	0.01	0	0.01	0	0	0.12
1928	0.02	0	0.01	0.03	0.01	0.01	0.01	0	0.01	0	0	0	0.09
1929	0.01	0.02	0.02	0.02	0	0	0	0	0	0	0	0	0.08
1930	0.01	0.02	0.02	0.01	0.01	0.01	0	0.01	0.01	0	0.01	0	0.11
1931	0	0.02	0	0	0	0.01	0.01	0	0	0.01	0.01	0	0.06
1932	0.01	0.01	0.03	0.03	0.01	0	0	0	0.01	0.01	0	0.01	0.13
1933	0.02	0.01	0.03	0.02	0.01	0	0.01	0.01	0.01	0	0.01	0.01	0.13
1934	0	0	0.03	0.02	0.01	0.01	0	0	0	0	0	0	0.08
1935	0.01	0	0.01	0.02	0.01	0.01	0.01	0	0.01	0	0.02	0	0.1
1936	0.01	0	0.02	0.02	0.01	0	0.01	0.02	0	0	0.02	0	0.11
1937	0.01	0	0.01	0.02	0.03	0.01	0	0.01	0.01	0.01	0.01	0	0.12
1938	0.01	0	0.02	0.03	0	0	0.01	0.02	0.01	0	0	0	0.1
1939	0.01	0.01	0.02	0.01	0	0	0.01	0.01	0.01	0.01	0.02	0	0.1
1940	0.01	0.01	0.03	0.02	0.01	0.01	0	0.01	0	0.01	0.01	0.01	0.13
1941	0	0.01	0	0	0.02	0	0	0	0	0.01	0	0.01	0.06
1942	0	0.01	0.01	0.01	0.02	0	0.01	0.01	0.01	0.01	0	0	0.08
1943	0	0	0.01	0.03	0.01	0	0.01	0	0	0	0.01	0	0.08
1944	0.01	0.02	0.03	0.02	0.02	0.01	0.01	0	0	0.01	0	0.01	0.15
1945	0	0.02	0.03	0.02	0	0	0.01	0.01	0.01	0.01	0.01	0	0.12
1946	0.01	0.02	0.03	0.03	0.02	0	0.01	0	0	0	0.02	0	0.13
1947	0.01	0.01	0.03	0.01	0.01	0.01	0	0.01	0.01	0.01	0.01	0	0.12
1948	0	0.01	0.01	0.01	0.01	0.02	0	0	0.02	0.01	0.01	0	0.1
1949	0.01	0	0.03	0.03	0.01	0.01	0.01	0.01	0.02	0	0	0	0.13
1950	0	0	0.01	0	0.01	0.01	0.01	0	0	0	0	0	0.04
1951	0.02	0.03	0.03	0.01	0.01	0.02	0	0	0	0	0	0	0.13
1952	0	0.01	0.02	0.02	0	0.01	0	0.01	0	0	0	0	0.08
1953	0	0	0.02	0.03	0.02	0	0	0	0	0	0	0.01	0.09
1954	0.01	0	0.03	0.01	0	0.01	0.01	0.01	0	0	0.01	0	0.09
1955	0	0	0.03	0.02	0.01	0	0.01	0	0.01	0.01	0.01	0	0.1
1956	0	0.01	0.01	0.02	0	0	0.01	0	0	0.01	0	0	0.07
1957	0.01	0.03	0.02	0.02	0.02	0	0	0	0	0.02	0	0.01	0.14
1958	0.01	0.02	0.02	0	0.01	0	0	0	0.02	0	0	0.01	0.08
1959	0	0.02	0.02	0.01	0.02	0	0	0	0	0	0.01	0	0.09
1960	0.01	0.01	0.01	0.02	0.01	0	0	0	0.01	0.01	0	0.01	0.1
1961	0.01	0.01	0.02	0.01	0.01	0	0	0.01	0.01	0.01	0	0.02	0.12
1962	0	0	0.03	0.01	0.02	0	0	0	0.01	0	0.01	0.02	0.1
1963	0.01	0.02	0.01	0.01	0.01	0.01	0	0.01	0	0.01	0	0	0.1
1964	0.02	0.01	0.03	0.02	0.02	0	0.01	0	0.01	0	0.01	0.01	0.15
1965	0	0	0.01	0.02	0.01	0.02	0	0	0.01	0.01	0	0	0.08
1966	0.02	0.02	0.01	0.03	0	0	0	0	0	0	0	0	0.1
1967	0.01	0.01	0.03	0.03	0.02	0	0	0	0	0.02	0	0	0.13
1968	0.01	0	0.03	0.02	0.01	0	0.01	0.01	0	0.01	0.01	0.01	0.11
1969	0.01	0.03	0.04	0.02	0.01	0.02	0.01	0.01	0.01	0.01	0	0.01	0.16
1970	0.01	0.03	0	0.03	0.01	0	0	0	0	0	0	0.02	0.09
1971	0.01	0	0.03	0.02	0	0.01	0	0	0	0.01	0	0.01	0.1
1972	0.02	0.02	0.03	0.02	0.02	0.01	0	0.01	0.01	0.01	0.01	0.01	0.15
1973	0.02	0.01	0.02	0.01	0.01	0	0.01	0	0.01	0.01	0	0	0.11
1974	0.02	0.01	0.03	0.02	0.02	0.01	0.01	0.01	0	0	0	0	0.11
1975	0.02	0.01	0.02	0.02	0.01	0	0.01	0	0	0	0.01	0	0.12
1976	0	0	0.02	0.03	0	0	0.01	0	0.01	0.01	0	0	0.08

1979	0.01	0.01	0.01	0.01	0.01	0.01	0	0	0	0	0	0	0.04
1980	0	0	0	0	0.01	0	0	0	0	0	0	0	0.01
1981	0	0	0.01	0.01	0.01	0	0	0	0	0	0	0	0.03
1982	0	0.01	0.01	0.01	0	0	0	0	0	0	0	0	0.03
1983	0	0	0	0.01	0.01	0	0	0	0	0	0	0	0.03
1984	0	0.01	0	0	0	0	0	0	0	0	0.01	0	0.03
1985	0	0	0	0	0.01	0	0	0	0	0	0	0	0.03
1986	0	0.01	0.01	0.01	0	0	0	0.01	0	0	0	0	0.04
1987	0.01	0.01	0.01	0.01	0.01	0.01	0	0	0	0	0	0	0.05
1988	0	0	0.01	0.01	0.01	0	0	0	0	0	0.01	0	0.04
1989	0	0	0.01	0.01	0	0	0	0	0	0	0	0	0.03
1990	0	0	0.01	0.01	0	0	0.01	0	0	0	0	0	0.04
1991	0	0.01	0	0.01	0	0	0	0	0	0	0	0	0.03
1992	0	0	0.01	0.01	0.01	0.01	0	0	0	0	0	0	0.03
1993	0.01	0.01	0	0.01	0	0	0	0	0	0	0	0	0.03
1994	0	0.01	0	0.01	0	0	0	0	0	0	0	0	0.02
1995	0	0	0.01	0.01	0.01	0	0	0	0	0	0	0	0.04
1996	0	0	0	0.01	0	0	0	0	0	0	0	0	0.02
1997	0	0.01	0.01	0.01	0.01	0	0.01	0	0	0	0	0	0.04
1998	0	0	0.01	0	0	0	0	0.01	0	0	0	0	0.03
1999	0	0.01	0.01	0	0	0	0	0.01	0.01	0	0.01	0	0.05
2000	0	0	0	0	0.01	0	0	0.01	0	0	0	0	0.03
2001	0	0	0.01	0	0.01	0.01	0	0	0	0	0	0	0.03
2002	0.01	0	0.01	0.01	0	0	0	0	0	0	0	0	0.03
2003	0	0.01	0.01	0.01	0	0	0	0	0	0	0	0	0.03
Average	**0.00**	**0.00**	**0.01**	**0.01**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.03**

Irrigation requirements in the K40A catchment (from farm dams)

Units in million m^3

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	TOTAL
1920	0.02	0.02	0.01	0.02	0	0	0	0.01	0.01	0	0.01	0	0.1
1921	0.02	0.01	0.01	0.02	0.02	0	0	0	0.01	0	0	0	0.08
1922	0	0	0.03	0.02	0.02	0.02	0	0	0	0.02	0.01	0.01	0.12
1923	0.01	0.01	0.03	0.03	0.02	0.02	0	0.01	0.01	0.01	0	0	0.14
1924	0.01	0.01	0.01	0.02	0.02	0	0	0	0	0.01	0	0	0.1
1925	0.01	0.01	0.02	0.03	0.02	0	0.01	0.01	0	0	0.01	0.01	0.12
1926	0	0	0.03	0.02	0	0.01	0.02	0	0.01	0.01	0	0.02	0.13
1927	0.01	0.01	0.03	0.02	0.01	0	0	0.01	0	0.01	0	0	0.12
1928	0.02	0	0.01	0.03	0.01	0.01	0.01	0	0.01	0	0	0	0.09
1929	0.01	0.02	0.02	0.02	0	0	0	0	0	0	0	0	0.08
1930	0.01	0.02	0.02	0.01	0.01	0.01	0	0.01	0.01	0	0.01	0	0.11
1931	0	0.02	0	0	0	0.01	0.01	0	0	0.01	0.01	0	0.06
1932	0.01	0.01	0.03	0.03	0.01	0	0	0	0.01	0.01	0	0.01	0.13
1933	0.02	0.01	0.03	0.02	0.01	0	0.01	0.01	0.01	0	0.01	0.01	0.13
1934	0	0	0.03	0.02	0.01	0.01	0	0	0	0	0	0	0.08
1935	0.01	0	0.01	0.02	0.01	0.01	0.01	0	0.01	0	0.02	0	0.1
1936	0.01	0	0.02	0.02	0.01	0	0.01	0.02	0	0	0.02	0	0.11
1937	0.01	0	0.01	0.02	0.03	0.01	0	0.01	0.01	0.01	0.01	0	0.12
1938	0.01	0	0.02	0.03	0	0	0.01	0.02	0.01	0	0	0	0.1
1939	0.01	0.01	0.02	0.01	0	0	0.01	0.01	0.01	0.01	0.02	0	0.1
1940	0.01	0.01	0.03	0.02	0.01	0.01	0	0.01	0	0.01	0.01	0.01	0.13
1941	0	0.01	0	0	0.02	0	0	0	0	0.01	0	0.01	0.06
1942	0	0.01	0.01	0.01	0.02	0	0.01	0.01	0.01	0.01	0	0	0.08
1943	0	0	0.01	0.03	0.01	0	0.01	0	0	0	0.01	0	0.08
1944	0.01	0.02	0.03	0.02	0.02	0.01	0.01	0	0	0.01	0	0.01	0.15
1945	0	0.02	0.03	0.02	0	0	0.01	0.01	0.01	0.01	0.01	0	0.12
1946	0.01	0.02	0.03	0.03	0.02	0	0.01	0	0	0	0.02	0	0.13
1947	0.01	0.01	0.03	0.01	0.01	0.01	0	0.01	0.01	0.01	0.01	0	0.12
1948	0	0.01	0.01	0.01	0.01	0.02	0	0	0.02	0.01	0.01	0	0.1
1949	0.01	0	0.03	0.03	0.01	0.01	0.01	0.01	0.02	0	0	0	0.13
1950	0	0	0.01	0	0.01	0.01	0.01	0	0	0	0	0	0.04
1951	0.02	0.03	0.03	0.01	0.01	0.02	0	0	0	0	0	0	0.13
1952	0	0.01	0.02	0.02	0	0.01	0	0.01	0	0	0	0	0.08
1953	0	0	0.02	0.03	0.02	0	0	0	0	0	0	0.01	0.09
1954	0.01	0	0.03	0.01	0	0.01	0.01	0.01	0	0	0.01	0	0.09
1955	0	0	0.03	0.02	0.01	0	0.01	0	0.01	0.01	0.01	0	0.1
1956	0	0.01	0.01	0.02	0	0	0.01	0	0	0.01	0	0	0.07
1957	0.01	0.03	0.02	0.02	0.02	0	0	0	0	0.02	0	0.01	0.14
1958	0.01	0.02	0.02	0	0.01	0	0	0	0.02	0	0	0.01	0.08
1959	0	0.02	0.02	0.01	0.02	0	0	0	0	0	0.01	0	0.09
1960	0.01	0.01	0.01	0.02	0.01	0	0	0	0.01	0.01	0	0.01	0.1
1961	0.01	0.01	0.02	0.01	0.01	0	0	0.01	0.01	0.01	0	0.02	0.12
1962	0	0	0.03	0.01	0.02	0	0	0	0.01	0	0.01	0.02	0.1
1963	0.01	0.02	0.01	0.01	0.01	0.01	0	0.01	0	0.01	0	0	0.1
1964	0.02	0.01	0.03	0.02	0.02	0	0.01	0	0.01	0	0.01	0.01	0.15
1965	0	0	0.01	0.02	0.01	0.02	0	0	0.01	0.01	0	0	0.08
1966	0.02	0.02	0.01	0.03	0	0	0	0	0	0	0	0	0.1
1967	0.01	0.01	0.03	0.03	0.02	0	0	0	0	0.02	0	0	0.13
1968	0.01	0	0.03	0.02	0.01	0	0.01	0.01	0	0.01	0.01	0.01	0.11
1969	0.01	0.03	0.04	0.02	0.01	0.02	0.01	0.01	0.01	0.01	0	0.01	0.16
1970	0.01	0.03	0	0.03	0.01	0	0	0	0	0	0	0.02	0.09
1971	0.01	0	0.03	0.02	0	0.01	0	0	0	0.01	0	0.01	0.1
1972	0.02	0.02	0.03	0.02	0.02	0.01	0	0.01	0.01	0.01	0.01	0.01	0.15
1973	0.02	0.01	0.02	0.01	0.01	0	0.01	0	0.01	0.01	0	0	0.11
1974	0.02	0.01	0.03	0.02	0.02	0.01	0.01	0.01	0	0	0	0	0.11
1975	0.02	0.01	0.02	0.02	0.01	0	0.01	0	0	0	0.01	0	0.12
1976	0	0	0.02	0.03	0	0	0.01	0	0.01	0.01	0	0	0.08

1979	0.02	0.02	0.03	0.02	0.02	0.02	0	0.01	0	0.01	0.01	0	0.15
1980	0	0	0.01	0	0.01	0	0	0	0	0.01	0	0.01	0.04
1981	0	0.02	0.01	0.02	0.01	0	0	0.02	0	0	0.01	0	0.09
1982	0	0.02	0.02	0.03	0.02	0.01	0.01	0	0	0	0.01	0	0.12
1983	0	0.01	0.02	0.02	0.01	0	0.01	0.01	0.01	0	0.02	0.01	0.12
1984	0	0.02	0.02	0.01	0.01	0.01	0	0.01	0	0	0.02	0.01	0.1
1985	0	0.01	0.01	0.02	0.02	0.01	0.01	0.02	0.01	0.01	0	0.01	0.11
1986	0	0.01	0.02	0.02	0.02	0.01	0	0.02	0	0.01	0	0	0.11
1987	0.02	0.02	0.02	0.03	0.02	0.01	0	0	0	0.01	0	0	0.13
1988	0.01	0.02	0.02	0.02	0.02	0.01	0	0.01	0.01	0	0.01	0.01	0.15
1989	0	0	0.03	0.02	0	0.01	0	0	0	0.01	0.01	0.01	0.1
1990	0	0.01	0.03	0.02	0.01	0.01	0.01	0.01	0	0	0.01	0.01	0.12
1991	0	0.03	0.01	0.02	0.01	0.01	0.01	0	0	0	0	0.01	0.1
1992	0	0.01	0.03	0.01	0.02	0.01	0	0	0.01	0.01	0.01	0	0.1
1993	0.02	0.01	0.01	0.01	0.01	0	0	0.01	0.01	0	0	0.01	0.1
1994	0	0.02	0	0.01	0.01	0	0	0	0	0.01	0.01	0.01	0.08
1995	0.01	0	0.01	0.02	0.02	0.01	0.01	0.02	0.01	0	0.01	0.01	0.12
1996	0	0	0.01	0.03	0	0	0	0	0	0.01	0	0.01	0.06
1997	0	0.02	0.03	0.02	0.02	0	0.02	0.01	0.01	0.01	0	0.01	0.15
1998	0.02	0.01	0.02	0.02	0.01	0	0	0.01	0.02	0.01	0.01	0	0.13
1999	0	0.03	0.03	0	0.01	0	0.01	0.01	0.01	0.01	0.02	0.01	0.15
2000	0.01	0	0	0.02	0.01	0.01	0	0.01	0.01	0	0	0.01	0.09
2001	0.01	0	0.02	0.02	0.02	0.02	0.01	0.01	0	0	0	0	0.1
2002	0.02	0.02	0.02	0.03	0.01	0	0.01	0	0	0.01	0.01	0.02	0.14
2003	0	0.02	0.02	0.02	0.01	0	0	0.01	0.01	0.01	0	0	0.11
Average	**0.01**	**0.01**	**0.02**	**0.02**	**0.01**	**0.01**	**0.00**	**0.01**	**0.01**	**0.01**	**0.01**	**0.01**	**0.11**

Irrigation requirements in the K50B catchment (from farm dams)

Units in million m³/a

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	TOTAL
1920	0.25	0.29	0.04	0.4	0	0	0	0.05	0.16	0	0.19	0	1.38
1921	0.31	0.14	0.03	0.21	0.24	0	0	0	0.08	0	0	0	1.01
1922	0	0	0.45	0.26	0.23	0.27	0	0	0.02	0.27	0.05	0.24	1.78
1923	0.16	0.14	0.44	0.45	0.25	0.28	0.03	0.06	0.09	0.25	0	0	2.13
1924	0.17	0.2	0.14	0.35	0.38	0	0	0.04	0	0.22	0	0	1.48
1925	0.04	0.16	0.28	0.43	0.32	0	0.12	0.12	0	0	0.13	0.08	1.67
1926	0.01	0	0.46	0.36	0	0.19	0.27	0	0.22	0.21	0	0.26	1.98
1927	0.11	0.16	0.47	0.36	0.21	0	0	0.25	0.03	0.18	0	0	1.76
1928	0.23	0	0.14	0.48	0.13	0.04	0.07	0	0.08	0	0	0	1.17
1929	0.17	0.3	0.25	0.29	0	0	0	0	0	0	0	0	1.01
1930	0.04	0.35	0.27	0	0.2	0.12	0	0.23	0.15	0	0.06	0	1.43
1931	0	0.3	0	0	0	0.05	0.2	0	0	0.06	0.19	0	0.79
1932	0.03	0.16	0.45	0.6	0.11	0	0	0	0.14	0.15	0	0.22	1.86
1933	0.32	0.03	0.51	0.29	0.1	0	0.22	0.18	0.18	0	0.1	0.05	1.97
1934	0	0	0.52	0.35	0.04	0.2	0	0	0	0	0	0	1.1
1935	0.07	0	0.14	0.37	0.1	0.08	0.17	0	0.21	0	0.26	0	1.4
1936	0.11	0	0.29	0.36	0.09	0	0.24	0.27	0.04	0	0.26	0	1.65
1937	0.16	0.02	0.13	0.26	0.46	0.13	0	0.14	0.09	0.16	0.07	0	1.62
1938	0.13	0	0.28	0.54	0	0	0.11	0.31	0.26	0	0	0	1.62
1939	0.16	0.12	0.26	0.15	0	0	0.08	0.08	0.1	0.08	0.31	0	1.35
1940	0.19	0.15	0.58	0.24	0.15	0.15	0	0.15	0	0.18	0.14	0.05	1.98
1941	0	0.05	0	0	0.29	0	0	0	0.03	0.13	0.02	0.18	0.7
1942	0	0.1	0.11	0.06	0.24	0	0.06	0.19	0.1	0.18	0	0	1.04
1943	0.02	0	0.12	0.6	0.18	0	0.06	0	0	0	0.07	0	1.05
1944	0.17	0.31	0.41	0.39	0.34	0.23	0.2	0	0	0.11	0	0.14	2.31
1945	0	0.32	0.42	0.25	0.02	0	0.14	0.23	0.14	0.08	0.18	0.04	1.82
1946	0.17	0.28	0.47	0.43	0.22	0	0.08	0	0	0	0.32	0	1.97
1947	0.06	0.18	0.53	0	0.18	0.13	0	0.16	0.13	0.1	0.18	0	1.65
1948	0	0.15	0.19	0.11	0.05	0.27	0	0	0.33	0.23	0.11	0	1.45
1949	0.22	0	0.52	0.44	0.14	0.12	0.16	0.11	0.33	0	0	0	2.04
1950	0	0	0.07	0	0.17	0.04	0.23	0	0	0	0	0	0.51
1951	0.39	0.54	0.48	0.11	0.1	0.25	0	0	0.04	0	0	0	1.92
1952	0.02	0.13	0.22	0.35	0	0.21	0	0.24	0	0	0	0	1.16
1953	0	0	0.31	0.55	0.38	0	0	0	0	0	0	0.1	1.34
1954	0.21	0	0.54	0.15	0	0.07	0.06	0.05	0	0	0.08	0	1.15
1955	0	0	0.52	0.27	0.1	0	0.05	0	0.22	0.19	0.11	0	1.46
1956	0	0.07	0.04	0.37	0	0	0.15	0	0	0.18	0	0	0.81
1957	0.08	0.55	0.34	0.37	0.33	0	0	0	0.05	0.32	0	0.24	2.28
1958	0.07	0.33	0.29	0	0.12	0	0	0	0.29	0	0	0.09	1.19
1959	0	0.3	0.22	0.07	0.39	0	0	0	0	0.03	0.23	0	1.23
1960	0.2	0.11	0.16	0.36	0.18	0	0	0	0.19	0.05	0	0.06	1.32
1961	0.06	0.21	0.37	0.15	0.18	0	0	0.22	0.16	0.16	0	0.25	1.76
1962	0	0	0.47	0.1	0.28	0	0.04	0	0.13	0	0.13	0.25	1.41
1963	0.09	0.33	0.15	0.16	0.18	0.06	0	0.21	0	0.24	0	0	1.41
1964	0.26	0.13	0.59	0.39	0.33	0	0.09	0	0.05	0.04	0.21	0.16	2.25
1965	0	0	0.19	0.22	0.05	0.37	0	0	0.23	0.14	0	0	1.19
1966	0.3	0.36	0.2	0.57	0	0	0	0	0.01	0	0.04	0	1.47
1967	0.14	0.13	0.48	0.57	0.39	0	0.03	0	0	0.29	0	0	2.02
1968	0.03	0	0.5	0.31	0.21	0	0.07	0.25	0	0.11	0.06	0.07	1.63
1969	0.04	0.43	0.63	0.33	0.05	0.27	0.24	0.21	0.11	0.11	0	0.09	2.5
1970	0.03	0.43	0	0.46	0.05	0	0	0	0.04	0	0	0.28	1.3
1971	0.13	0	0.55	0.35	0	0.03	0.02	0	0	0.08	0	0.18	1.35
1972	0.29	0.32	0.45	0.37	0.31	0.13	0	0.08	0.05	0.1	0.07	0.06	2.24
1973	0.29	0.16	0.38	0.14	0.07	0	0.12	0	0.11	0.24	0	0.01	1.53
1974	0.26	0.09	0.59	0.22	0.26	0.03	0.07	0.14	0	0	0	0	1.66
1975	0.4	0.14	0.23	0.39	0.18	0	0.23	0	0.04	0	0.09	0.04	1.73
1976	0	0	0.27	0.54	0	0	0.16	0	0.09	0.24	0	0	1.29

1979	0.34	0.38	0.44	0.26	0.36	0.25	0	0.13	0	0.2	0.05	0	2.42
1980	0	0.01	0.14	0	0.19	0	0	0	0	0.08	0	0.05	0.46
1981	0	0.22	0.18	0.36	0.1	0.01	0	0.28	0	0	0.18	0	1.33
1982	0	0.32	0.37	0.5	0.23	0.19	0.07	0	0	0	0.2	0	1.88
1983	0	0.05	0.25	0.38	0.22	0	0.19	0.09	0.09	0	0.29	0.15	1.71
1984	0	0.29	0.22	0.18	0.04	0.15	0	0.15	0	0	0.27	0.14	1.43
1985	0	0.06	0.04	0.26	0.25	0.17	0.14	0.28	0.16	0.06	0	0.12	1.54
1986	0	0.17	0.31	0.28	0.23	0.08	0	0.31	0	0.2	0	0	1.59
1987	0.3	0.35	0.29	0.41	0.27	0.17	0	0	0	0.18	0	0.02	2
1988	0.11	0.32	0.3	0.37	0.3	0.15	0	0.23	0.11	0.05	0.24	0.14	2.32
1989	0	0	0.5	0.39	0	0.22	0	0	0	0.26	0.06	0.13	1.56
1990	0	0.17	0.43	0.3	0.13	0.17	0.08	0.13	0	0	0.15	0.22	1.78
1991	0	0.46	0.08	0.37	0.07	0.07	0.11	0	0.01	0	0	0.2	1.37
1992	0	0.07	0.47	0.1	0.22	0.1	0	0	0.13	0.18	0.09	0	1.35
1993	0.3	0.14	0.15	0.2	0.13	0	0	0.17	0.12	0	0	0.14	1.35
1994	0	0.36	0	0.2	0.08	0	0	0	0.03	0.19	0.12	0.19	1.16
1995	0.19	0	0.11	0.33	0.32	0.16	0.06	0.26	0.18	0	0.06	0.06	1.72
1996	0	0	0.14	0.46	0.01	0	0	0	0	0.15	0	0.16	0.92
1997	0	0.38	0.5	0.31	0.25	0	0.28	0.08	0.24	0.05	0.03	0.21	2.32
1998	0.33	0.21	0.33	0.28	0.13	0	0	0.23	0.27	0.07	0.12	0	1.96
1999	0	0.54	0.46	0	0.17	0	0.22	0.2	0.22	0.21	0.3	0.19	2.5
2000	0.19	0	0	0.35	0.13	0.04	0	0.22	0.22	0	0	0.05	1.2
2001	0.12	0	0.35	0.25	0.32	0.29	0.05	0.1	0	0	0	0	1.47
2002	0.39	0.31	0.24	0.47	0.21	0	0.08	0	0.04	0.1	0.1	0.25	2.2
2003	0.01	0.39	0.34	0.27	0.15	0	0	0.08	0.08	0.1	0.02	0	1.44
Average	**0.11**	**0.17**	**0.30**	**0.29**	**0.17**	**0.08**	**0.06**	**0.08**	**0.08**	**0.09**	**0.07**	**0.07**	**1.57**

Irrigation requirements in the K40B catchment (from run-of-river)

Units in million m^3

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	TOTAL
1920	0.06	0.07	0.01	0.1	0	0	0	0.01	0.04	0	0.05	0	0.35
1921	0.08	0.03	0.01	0.05	0.06	0	0	0	0.02	0	0	0	0.26
1922	0	0	0.11	0.06	0.06	0.07	0	0	0	0.07	0.01	0.06	0.45
1923	0.04	0.03	0.11	0.11	0.06	0.07	0.01	0.01	0.02	0.06	0	0	0.54
1924	0.04	0.05	0.03	0.09	0.09	0	0	0.01	0	0.06	0	0	0.37
1925	0.01	0.04	0.07	0.11	0.08	0	0.03	0.03	0	0	0.03	0.02	0.42
1926	0	0	0.12	0.09	0	0.05	0.07	0	0.06	0.05	0	0.06	0.5
1927	0.03	0.04	0.12	0.09	0.05	0	0	0.06	0.01	0.04	0	0	0.44
1928	0.06	0	0.03	0.12	0.03	0.01	0.02	0	0.02	0	0	0	0.3
1929	0.04	0.08	0.06	0.07	0	0	0	0	0	0	0	0	0.25
1930	0.01	0.09	0.07	0	0.05	0.03	0	0.06	0.04	0	0.02	0	0.36
1931	0	0.08	0	0	0	0.01	0.05	0	0	0.01	0.05	0	0.2
1932	0.01	0.04	0.11	0.15	0.03	0	0	0	0.04	0.04	0	0.06	0.47
1933	0.08	0.01	0.13	0.07	0.03	0	0.06	0.04	0.04	0	0.02	0.01	0.5
1934	0	0	0.13	0.09	0.01	0.05	0	0	0	0	0	0	0.28
1935	0.02	0	0.03	0.09	0.02	0.02	0.04	0	0.05	0	0.07	0	0.35
1936	0.03	0	0.07	0.09	0.02	0	0.06	0.07	0.01	0	0.06	0	0.41
1937	0.04	0	0.03	0.06	0.12	0.03	0	0.04	0.02	0.04	0.02	0	0.41
1938	0.03	0	0.07	0.13	0	0	0.03	0.08	0.06	0	0	0	0.41
1939	0.04	0.03	0.07	0.04	0	0	0.02	0.02	0.02	0.02	0.08	0	0.34
1940	0.05	0.04	0.15	0.06	0.04	0.04	0	0.04	0	0.04	0.03	0.01	0.5
1941	0	0.01	0	0	0.07	0	0	0	0.01	0.03	0.01	0.04	0.18
1942	0	0.02	0.03	0.01	0.06	0	0.02	0.05	0.03	0.04	0	0	0.26
1943	0.01	0	0.03	0.15	0.05	0	0.01	0	0	0	0.02	0	0.26
1944	0.04	0.08	0.1	0.1	0.09	0.06	0.05	0	0	0.03	0	0.04	0.58
1945	0	0.08	0.11	0.06	0	0	0.03	0.06	0.04	0.02	0.04	0.01	0.46
1946	0.04	0.07	0.12	0.11	0.06	0	0.02	0	0	0	0.08	0	0.5
1947	0.02	0.04	0.13	0	0.04	0.03	0	0.04	0.03	0.03	0.05	0	0.41
1948	0	0.04	0.05	0.03	0.01	0.07	0	0	0.08	0.06	0.03	0	0.36
1949	0.06	0	0.13	0.11	0.04	0.03	0.04	0.03	0.08	0	0	0	0.51
1950	0	0	0.02	0	0.04	0.01	0.06	0	0	0	0	0	0.13
1951	0.1	0.14	0.12	0.03	0.02	0.06	0	0	0.01	0	0	0	0.48
1952	0.01	0.03	0.05	0.09	0	0.05	0	0.06	0	0	0	0	0.29
1953	0	0	0.08	0.14	0.1	0	0	0	0	0	0	0.02	0.34
1954	0.05	0	0.13	0.04	0	0.02	0.01	0.01	0	0	0.02	0	0.29
1955	0	0	0.13	0.07	0.02	0	0.01	0	0.06	0.05	0.03	0	0.37
1956	0	0.02	0.01	0.09	0	0	0.04	0	0	0.04	0	0	0.2
1957	0.02	0.14	0.08	0.09	0.08	0	0	0	0.01	0.08	0	0.06	0.57
1958	0.02	0.08	0.07	0	0.03	0	0	0	0.07	0	0	0.02	0.3
1959	0	0.07	0.05	0.02	0.1	0	0	0	0	0.01	0.06	0	0.31
1960	0.05	0.03	0.04	0.09	0.05	0	0	0	0.05	0.01	0	0.01	0.33
1961	0.02	0.05	0.09	0.04	0.05	0	0	0.06	0.04	0.04	0	0.06	0.44
1962	0	0	0.12	0.03	0.07	0	0.01	0	0.03	0	0.03	0.06	0.36
1963	0.02	0.08	0.04	0.04	0.05	0.01	0	0.05	0	0.06	0	0	0.36
1964	0.07	0.03	0.15	0.1	0.08	0	0.02	0	0.01	0.01	0.05	0.04	0.57
1965	0	0	0.05	0.05	0.01	0.09	0	0	0.06	0.04	0	0	0.3
1966	0.08	0.09	0.05	0.14	0	0	0	0	0	0	0.01	0	0.37
1967	0.03	0.03	0.12	0.14	0.1	0	0.01	0	0	0.07	0	0	0.51
1968	0.01	0	0.13	0.08	0.05	0	0.02	0.06	0	0.03	0.01	0.02	0.41
1969	0.01	0.11	0.16	0.08	0.01	0.07	0.06	0.05	0.03	0.03	0	0.02	0.63
1970	0.01	0.11	0	0.12	0.01	0	0	0	0.01	0	0	0.07	0.33
1971	0.03	0	0.14	0.09	0	0.01	0.01	0	0	0.02	0	0.05	0.34
1972	0.07	0.08	0.11	0.09	0.08	0.03	0	0.02	0.01	0.03	0.02	0.01	0.56
1973	0.07	0.04	0.1	0.04	0.02	0	0.03	0	0.03	0.06	0	0	0.38
1974	0.07	0.02	0.15	0.06	0.06	0.01	0.02	0.04	0	0	0	0	0.42
1975	0.1	0.03	0.06	0.1	0.04	0	0.06	0	0.01	0	0.02	0.01	0.43
1976	0	0	0.07	0.14	0	0	0.04	0	0.02	0.06	0	0	0.33

1979	0.09	0.09	0.11	0.07	0.09	0.06	0	0.03	0	0.05	0.01	0	0.61
1980	0	0	0.04	0	0.05	0	0	0	0	0.02	0	0.01	0.12
1981	0	0.06	0.05	0.09	0.03	0	0	0.07	0	0	0.05	0	0.33
1982	0	0.08	0.09	0.13	0.06	0.05	0.02	0	0	0	0.05	0	0.47
1983	0	0.01	0.06	0.1	0.05	0	0.05	0.02	0.02	0	0.07	0.04	0.43
1984	0	0.07	0.05	0.05	0.01	0.04	0	0.04	0	0	0.07	0.03	0.36
1985	0	0.02	0.01	0.07	0.06	0.04	0.03	0.07	0.04	0.02	0	0.03	0.39
1986	0	0.04	0.08	0.07	0.06	0.02	0	0.08	0	0.05	0	0	0.4
1987	0.08	0.09	0.07	0.1	0.07	0.04	0	0	0	0.05	0	0.01	0.5
1988	0.03	0.08	0.08	0.09	0.08	0.04	0	0.06	0.03	0.01	0.06	0.04	0.58
1989	0	0	0.13	0.1	0	0.06	0	0	0	0.06	0.02	0.03	0.39
1990	0	0.04	0.11	0.08	0.03	0.04	0.02	0.03	0	0	0.04	0.06	0.45
1991	0	0.12	0.02	0.09	0.02	0.02	0.03	0	0	0	0	0.05	0.35
1992	0	0.02	0.12	0.03	0.06	0.02	0	0	0.03	0.05	0.02	0	0.34
1993	0.08	0.03	0.04	0.05	0.03	0	0	0.04	0.03	0	0	0.03	0.34
1994	0	0.09	0	0.05	0.02	0	0	0	0.01	0.05	0.03	0.05	0.29
1995	0.05	0	0.03	0.08	0.08	0.04	0.02	0.06	0.04	0	0.02	0.02	0.43
1996	0	0	0.04	0.11	0	0	0	0	0	0.04	0	0.04	0.23
1997	0	0.09	0.13	0.08	0.06	0	0.07	0.02	0.06	0.01	0.01	0.05	0.58
1998	0.08	0.05	0.08	0.07	0.03	0	0	0.06	0.07	0.02	0.03	0	0.49
1999	0	0.13	0.12	0	0.04	0	0.05	0.05	0.05	0.05	0.08	0.05	0.63
2000	0.05	0	0	0.09	0.03	0.01	0	0.05	0.06	0	0	0.01	0.3
2001	0.03	0	0.09	0.06	0.08	0.07	0.01	0.03	0	0	0	0	0.37
2002	0.1	0.08	0.06	0.12	0.05	0	0.02	0	0.01	0.02	0.03	0.06	0.55
2003	0	0.1	0.09	0.07	0.04	0	0	0.02	0.02	0.02	0.01	0	0.36
Average	**0.03**	**0.04**	**0.08**	**0.07**	**0.04**	**0.02**	**0.02**	**0.02**	**0.02**	**0.02**	**0.02**	**0.02**	**0.39**

Irrigation requirements in the K40C catchment (from farm dams)

Units in million m^3

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	TOTAL
1920	0.39	0.39	0.2	0.6	0	0	0	0.14	0.11	0.06	0.25	0.02	2.17
1921	0.38	0.28	0.21	0.35	0.34	0.13	0	0	0.16	0	0.13	0.05	2.03
1922	0.04	0	0.66	0.39	0.39	0.35	0	0	0.07	0.36	0.13	0.31	2.7
1923	0.25	0.23	0.58	0.53	0.36	0.38	0.12	0.13	0.13	0.34	0	0	3.04
1924	0.34	0.28	0.31	0.5	0.51	0	0.06	0.14	0	0.3	0	0	2.45
1925	0.18	0.35	0.43	0.59	0.42	0.04	0.21	0.18	0	0.07	0.18	0.15	2.8
1926	0.16	0	0.74	0.6	0.22	0.39	0.36	0	0.31	0.26	0.05	0.33	3.41
1927	0.3	0.42	0.66	0.54	0.29	0	0.01	0.34	0.11	0.3	0.07	0.06	3.12
1928	0.42	0	0.36	0.71	0.31	0.22	0.18	0.04	0.14	0	0	0.07	2.46
1929	0.28	0.52	0.49	0.49	0	0.15	0.17	0	0.04	0.06	0	0.08	2.27
1930	0.23	0.54	0.49	0.24	0.37	0.33	0	0.26	0.25	0	0.15	0	2.87
1931	0	0.52	0	0.06	0	0.21	0.34	0	0.04	0.16	0.26	0	1.6
1932	0.06	0.35	0.69	0.81	0.3	0.13	0.07	0.06	0.18	0.23	0	0.34	3.24
1933	0.47	0.19	0.75	0.53	0.28	0.08	0.35	0.25	0.24	0	0.16	0.14	3.43
1934	0	0.15	0.74	0.55	0.2	0.33	0	0	0	0.1	0.05	0	2.12
1935	0.16	0.06	0.35	0.53	0.22	0.21	0.29	0	0.28	0	0.38	0	2.47
1936	0.27	0	0.51	0.51	0.22	0	0.36	0.37	0.09	0	0.29	0	2.63
1937	0.27	0.24	0.4	0.44	0.64	0.22	0.05	0.25	0.16	0.23	0.15	0.03	3.09
1938	0.2	0.07	0.46	0.76	0	0.08	0.29	0.43	0.35	0	0	0	2.64
1939	0.29	0.34	0.52	0.24	0	0.12	0.21	0.18	0.2	0.15	0.42	0	2.68
1940	0.3	0.33	0.78	0.48	0.3	0.31	0	0.27	0	0.28	0.29	0.11	3.45
1941	0.02	0.26	0.09	0.12	0.41	0.01	0.16	0	0.1	0.17	0.11	0.28	1.72
1942	0.12	0.33	0.31	0.25	0.34	0	0.22	0.27	0.21	0.27	0	0	2.33
1943	0.18	0	0.34	0.79	0.3	0.12	0.16	0	0.01	0	0.15	0	2.04
1944	0.3	0.5	0.59	0.63	0.53	0.41	0.35	0	0	0.15	0.04	0.24	3.72
1945	0	0.5	0.54	0.44	0.25	0	0.25	0.33	0.2	0.12	0.25	0.11	2.99
1946	0.35	0.52	0.65	0.59	0.4	0	0.18	0.03	0.04	0	0.43	0	3.19
1947	0.24	0.36	0.73	0.12	0.33	0.29	0	0.29	0.22	0.17	0.3	0	3.04
1948	0	0.34	0.4	0.27	0.23	0.5	0.02	0	0.43	0.31	0.19	0.04	2.75
1949	0.35	0	0.74	0.65	0.34	0.27	0.19	0.2	0.44	0	0	0.04	3.23
1950	0.02	0	0.25	0	0.35	0.2	0.37	0.03	0	0	0	0	1.23
1951	0.55	0.75	0.71	0.28	0.27	0.39	0	0	0.09	0.05	0	0	3.09
1952	0.17	0.36	0.4	0.54	0.03	0.41	0.04	0.35	0	0	0	0.02	2.32
1953	0	0.12	0.47	0.74	0.55	0.14	0	0	0.06	0	0	0.15	2.23
1954	0.39	0	0.77	0.32	0	0.25	0.18	0.15	0.05	0.11	0.2	0.08	2.51
1955	0.1	0	0.76	0.46	0.24	0	0.13	0	0.33	0.31	0.23	0.11	2.66
1956	0	0.28	0.28	0.58	0.13	0.14	0.26	0.04	0	0.28	0	0	1.99
1957	0.25	0.74	0.55	0.53	0.45	0	0.07	0	0.14	0.44	0	0.36	3.53
1958	0.22	0.48	0.53	0	0.27	0	0	0	0.41	0	0	0.21	2.13
1959	0	0.51	0.45	0.22	0.54	0	0.04	0	0.02	0.1	0.33	0	2.22
1960	0.38	0.31	0.38	0.55	0.36	0	0	0	0.3	0.16	0.08	0.16	2.69
1961	0.19	0.39	0.56	0.28	0.34	0	0.13	0.34	0.27	0.24	0	0.38	3.11
1962	0	0.07	0.68	0.29	0.44	0	0.17	0.09	0.23	0	0.24	0.38	2.58
1963	0.23	0.51	0.36	0.36	0.33	0.21	0.06	0.29	0	0.34	0	0	2.7
1964	0.43	0.29	0.85	0.58	0.47	0	0.21	0	0.12	0.13	0.31	0.29	3.69
1965	0	0	0.37	0.4	0.16	0.53	0.05	0	0.32	0.26	0	0.11	2.21
1966	0.47	0.52	0.4	0.76	0.14	0	0	0	0.11	0	0.13	0.08	2.61
1967	0.31	0.29	0.68	0.72	0.52	0.1	0.17	0.04	0	0.41	0	0.03	3.26
1968	0.19	0.04	0.73	0.47	0.36	0.1	0.2	0.37	0	0.18	0.16	0.18	2.97
1969	0.15	0.62	0.87	0.55	0.15	0.42	0.4	0.29	0.2	0.18	0	0.24	4.07
1970	0.21	0.61	0	0.64	0.16	0.08	0	0	0.14	0	0	0.41	2.25
1971	0.31	0.13	0.78	0.53	0	0.18	0.2	0.04	0.07	0.16	0	0.31	2.72
1972	0.47	0.48	0.65	0.58	0.46	0.26	0.01	0.15	0.15	0.18	0.18	0.17	3.75
1973	0.44	0.29	0.62	0.27	0.19	0.02	0.3	0	0.23	0.35	0	0.14	2.86
1974	0.4	0.28	0.81	0.42	0.39	0.17	0.2	0.27	0.08	0.01	0	0	3.03
1975	0.57	0.3	0.47	0.6	0.32	0.14	0.38	0	0.11	0	0.22	0.19	3.3
1976	0	0	0.48	0.77	0	0.14	0.32	0	0.16	0.36	0.02	0	2.24

1977	0.33	0.24	0.65	0.55	0.61	0.35	0.15	0.25	0	0.36	0.06	0.24	3.8
1978	0.2	0.13	0.54	0.41	0.38	0.37	0.34	0	0.1	0	0	0	2.47
1979	0.51	0.57	0.69	0.46	0.55	0.42	0.05	0.19	0	0.3	0.15	0	3.88
1980	0	0.14	0.33	0	0.36	0	0	0	0	0.16	0	0.19	1.17
1981	0	0.43	0.39	0.55	0.31	0.16	0	0.38	0	0	0.29	0	2.52
1982	0.12	0.51	0.61	0.7	0.35	0.36	0.2	0.07	0	0	0.32	0	3.24
1983	0.01	0.27	0.48	0.6	0.4	0.06	0.34	0.18	0.16	0	0.42	0.29	3.21
1984	0.01	0.49	0.43	0.36	0.17	0.32	0	0.25	0.05	0	0.39	0.27	2.73
1985	0	0.23	0.23	0.46	0.43	0.33	0.28	0.39	0.26	0.14	0	0.23	2.99
1986	0	0.4	0.58	0.44	0.36	0.22	0	0.44	0	0.31	0	0	2.75
1987	0.47	0.58	0.53	0.59	0.47	0.34	0	0.05	0.06	0.27	0.01	0.15	3.53
1988	0.29	0.52	0.55	0.6	0.48	0.31	0	0.34	0.17	0.12	0.35	0.27	3.99
1989	0	0	0.74	0.59	0	0.4	0	0.03	0	0.37	0.17	0.25	2.56
1990	0.06	0.34	0.68	0.51	0.27	0.33	0.25	0.21	0.05	0.07	0.28	0.37	3.41
1991	0	0.66	0.26	0.59	0.21	0.22	0.23	0	0.06	0	0	0.35	2.58
1992	0	0.23	0.7	0.27	0.35	0.25	0	0	0.19	0.27	0.18	0	2.45
1993	0.46	0.31	0.37	0.39	0.3	0.16	0	0.26	0.21	0	0	0.24	2.71
1994	0	0.56	0	0.41	0.25	0	0	0	0.11	0.29	0.23	0.3	2.15
1995	0.37	0	0.33	0.53	0.49	0.32	0.22	0.37	0.27	0.06	0.16	0.19	3.32
1996	0	0	0.32	0.67	0.18	0	0	0	0	0.24	0	0.29	1.7
1997	0.04	0.57	0.76	0.5	0.4	0	0.44	0.16	0.32	0.1	0.1	0.33	3.73
1998	0.48	0.37	0.54	0.46	0.27	0.06	0	0.33	0.37	0.14	0.21	0.09	3.32
1999	0	0.73	0.7	0	0.31	0	0.35	0.32	0.32	0.31	0.43	0.31	3.78
2000	0.3	0	0	0.53	0.3	0.19	0	0.32	0.32	0.03	0	0.16	2.16
2001	0.26	0.03	0.57	0.47	0.48	0.48	0.15	0.21	0	0	0	0	2.64
2002	0.58	0.48	0.44	0.67	0.38	0	0.2	0	0.11	0.16	0.19	0.4	3.61
2003	0.15	0.57	0.57	0.47	0.27	0.08	0.09	0.16	0.14	0.17	0.13	0	2.82
Average	**0.21**	**0.31**	**0.51**	**0.47**	**0.30**	**0.18**	**0.14**	**0.14**	**0.14**	**0.15**	**0.13**	**0.13**	**2.80**

Irrigation requirements in the K40C catchment (from run-of-river)													
Units in million m^3													
	Oct	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**TOTAL**
1920	0.1	0.1	0.05	0.15	0	0	0	0.04	0.03	0.02	0.06	0.01	0.56
1921	0.1	0.07	0.05	0.09	0.09	0.03	0	0	0.04	0	0.03	0.01	0.52
1922	0.01	0	0.17	0.1	0.1	0.09	0	0	0.02	0.09	0.03	0.08	0.7
1923	0.07	0.06	0.15	0.14	0.09	0.1	0.03	0.03	0.03	0.09	0	0	0.78
1924	0.09	0.07	0.08	0.13	0.13	0	0.02	0.04	0	0.08	0	0	0.63
1925	0.05	0.09	0.11	0.15	0.11	0.01	0.06	0.05	0	0.02	0.05	0.04	0.72
1926	0.04	0	0.19	0.16	0.06	0.1	0.09	0	0.08	0.07	0.01	0.09	0.88
1927	0.08	0.11	0.17	0.14	0.08	0	0	0.09	0.03	0.08	0.02	0.02	0.81
1928	0.11	0	0.09	0.18	0.08	0.06	0.05	0.01	0.04	0	0	0.02	0.64
1929	0.07	0.13	0.13	0.13	0	0.04	0.04	0	0.01	0.01	0	0.02	0.59
1930	0.06	0.14	0.13	0.06	0.1	0.08	0	0.07	0.06	0	0.04	0	0.74
1931	0	0.13	0	0.02	0	0.06	0.09	0	0.01	0.04	0.07	0	0.41
1932	0.02	0.09	0.18	0.21	0.08	0.03	0.02	0.02	0.05	0.06	0	0.09	0.84
1933	0.12	0.05	0.19	0.14	0.07	0.02	0.09	0.06	0.06	0	0.04	0.04	0.88
1934	0	0.04	0.19	0.14	0.05	0.09	0	0	0	0.03	0.01	0	0.55
1935	0.04	0.02	0.09	0.14	0.06	0.05	0.08	0	0.07	0	0.1	0	0.64
1936	0.07	0	0.13	0.13	0.06	0	0.09	0.1	0.02	0	0.07	0	0.68
1937	0.07	0.06	0.1	0.11	0.17	0.06	0.01	0.06	0.04	0.06	0.04	0.01	0.8
1938	0.05	0.02	0.12	0.2	0	0.02	0.07	0.11	0.09	0	0	0	0.68
1939	0.08	0.09	0.14	0.06	0	0.03	0.06	0.05	0.05	0.04	0.11	0	0.69
1940	0.08	0.09	0.2	0.12	0.08	0.08	0	0.07	0	0.07	0.07	0.03	0.89
1941	0.01	0.07	0.02	0.03	0.11	0	0.04	0	0.02	0.04	0.03	0.07	0.44
1942	0.03	0.09	0.08	0.06	0.09	0	0.06	0.07	0.05	0.07	0	0	0.6
1943	0.05	0	0.09	0.2	0.08	0.03	0.04	0	0	0	0.04	0	0.53
1944	0.08	0.13	0.15	0.16	0.14	0.11	0.09	0	0	0.04	0.01	0.06	0.96
1945	0	0.13	0.14	0.11	0.06	0	0.06	0.09	0.05	0.03	0.06	0.03	0.77
1946	0.09	0.13	0.17	0.15	0.1	0	0.05	0.01	0.01	0	0.11	0	0.82
1947	0.06	0.09	0.19	0.03	0.08	0.07	0	0.08	0.06	0.04	0.08	0	0.79
1948	0	0.09	0.1	0.07	0.06	0.13	0	0	0.11	0.08	0.05	0.01	0.71
1949	0.09	0	0.19	0.17	0.09	0.07	0.05	0.05	0.11	0	0	0.01	0.83
1950	0.01	0	0.06	0	0.09	0.05	0.1	0.01	0	0	0	0	0.32
1951	0.14	0.19	0.18	0.07	0.07	0.1	0	0	0.02	0.01	0	0	0.8
1952	0.04	0.09	0.1	0.14	0.01	0.11	0.01	0.09	0	0	0	0	0.6
1953	0	0.03	0.12	0.19	0.14	0.04	0	0	0.02	0	0	0.04	0.57
1954	0.1	0	0.2	0.08	0	0.06	0.05	0.04	0.01	0.03	0.05	0.02	0.65
1955	0.03	0	0.2	0.12	0.06	0	0.03	0	0.08	0.08	0.06	0.03	0.69
1956	0	0.07	0.07	0.15	0.03	0.04	0.07	0.01	0	0.07	0	0	0.51
1957	0.06	0.19	0.14	0.14	0.12	0	0.02	0	0.04	0.11	0	0.09	0.91
1958	0.06	0.13	0.14	0	0.07	0	0	0	0.11	0	0	0.05	0.55
1959	0	0.13	0.12	0.06	0.14	0	0.01	0	0.01	0.03	0.09	0	0.57
1960	0.1	0.08	0.1	0.14	0.09	0	0	0	0.08	0.04	0.02	0.04	0.69
1961	0.05	0.1	0.14	0.07	0.09	0	0.03	0.09	0.07	0.06	0	0.1	0.8
1962	0	0.02	0.17	0.07	0.11	0	0.04	0.02	0.06	0	0.06	0.1	0.67
1963	0.06	0.13	0.09	0.09	0.09	0.05	0.01	0.08	0	0.09	0	0	0.7
1964	0.11	0.07	0.22	0.15	0.12	0	0.05	0	0.03	0.03	0.08	0.07	0.95
1965	0	0	0.1	0.1	0.04	0.14	0.01	0	0.08	0.07	0	0.03	0.57
1966	0.12	0.13	0.1	0.2	0.04	0	0	0	0.03	0	0.03	0.02	0.67
1967	0.08	0.08	0.18	0.18	0.13	0.03	0.04	0.01	0	0.11	0	0.01	0.84
1968	0.05	0.01	0.19	0.12	0.09	0.03	0.05	0.1	0	0.05	0.04	0.05	0.77
1969	0.04	0.16	0.22	0.14	0.04	0.11	0.1	0.07	0.05	0.05	0	0.06	1.05
1970	0.05	0.16	0	0.16	0.04	0.02	0	0	0.04	0	0	0.11	0.58
1971	0.08	0.03	0.2	0.14	0	0.05	0.05	0.01	0.02	0.04	0	0.08	0.7
1972	0.12	0.12	0.17	0.15	0.12	0.07	0	0.04	0.04	0.05	0.05	0.04	0.97
1973	0.11	0.07	0.16	0.07	0.05	0	0.08	0	0.06	0.09	0	0.04	0.74
1974	0.1	0.07	0.21	0.11	0.1	0.04	0.05	0.07	0.02	0	0	0	0.78
1975	0.15	0.08	0.12	0.15	0.08	0.04	0.1	0	0.03	0	0.06	0.05	0.85
1976	0	0	0.12	0.2	0	0.04	0.08	0	0.04	0.09	0	0	0.58

1977	0.09	0.06	0.17	0.14	0.16	0.09	0.04	0.07	0	0.09	0.02	0.06	0.98
1978	0.05	0.03	0.14	0.1	0.1	0.09	0.09	0	0.03	0	0	0	0.64
1979	0.13	0.15	0.18	0.12	0.14	0.11	0.01	0.05	0	0.08	0.04	0	1
1980	0	0.04	0.08	0	0.09	0	0	0	0	0.04	0	0.05	0.3
1981	0	0.11	0.1	0.14	0.08	0.04	0	0.1	0	0	0.07	0	0.65
1982	0.03	0.13	0.16	0.18	0.09	0.09	0.05	0.02	0	0	0.08	0	0.84
1983	0	0.07	0.12	0.15	0.1	0.02	0.09	0.05	0.04	0	0.11	0.07	0.83
1984	0	0.13	0.11	0.09	0.04	0.08	0	0.06	0.01	0	0.1	0.07	0.7
1985	0	0.06	0.06	0.12	0.11	0.09	0.07	0.1	0.07	0.04	0	0.06	0.77
1986	0	0.1	0.15	0.11	0.09	0.06	0	0.11	0	0.08	0	0	0.71
1987	0.12	0.15	0.14	0.15	0.12	0.09	0	0.01	0.02	0.07	0	0.04	0.91
1988	0.07	0.13	0.14	0.15	0.12	0.08	0	0.09	0.04	0.03	0.09	0.07	1.03
1989	0	0	0.19	0.15	0	0.1	0	0.01	0	0.1	0.04	0.06	0.66
1990	0.02	0.09	0.17	0.13	0.07	0.09	0.07	0.05	0.01	0.02	0.07	0.1	0.88
1991	0	0.17	0.07	0.15	0.06	0.06	0.06	0	0.02	0	0	0.09	0.66
1992	0	0.06	0.18	0.07	0.09	0.07	0	0	0.05	0.07	0.05	0	0.63
1993	0.12	0.08	0.1	0.1	0.08	0.04	0	0.07	0.05	0	0	0.06	0.7
1994	0	0.14	0	0.11	0.06	0	0	0	0.03	0.07	0.06	0.08	0.55
1995	0.09	0	0.09	0.14	0.13	0.08	0.06	0.1	0.07	0.01	0.04	0.05	0.86
1996	0	0	0.08	0.17	0.05	0	0	0	0	0.06	0	0.08	0.44
1997	0.01	0.15	0.2	0.13	0.1	0	0.11	0.04	0.08	0.03	0.03	0.09	0.96
1998	0.12	0.1	0.14	0.12	0.07	0.02	0	0.08	0.1	0.04	0.06	0.02	0.86
1999	0	0.19	0.18	0	0.08	0	0.09	0.08	0.08	0.08	0.11	0.08	0.97
2000	0.08	0	0	0.14	0.08	0.05	0	0.08	0.08	0.01	0	0.04	0.56
2001	0.07	0.01	0.15	0.12	0.12	0.12	0.04	0.05	0	0	0	0	0.68
2002	0.15	0.12	0.11	0.17	0.1	0	0.05	0	0.03	0.04	0.05	0.1	0.93
2003	0.04	0.15	0.15	0.12	0.07	0.02	0.02	0.04	0.04	0.04	0.03	0	0.73
Average	**0.05**	**0.08**	**0.13**	**0.12**	**0.08**	**0.05**	**0.04**	**0.04**	**0.03**	**0.04**	**0.03**	**0.04**	**0.72**

Irrigation requirements in the K40D catchment

Units in million m^3

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	TOTAL
1920	0.02	0.01	0.01	0.03	0	0	0	0	0	0	0.01	0	0.08
1921	0.01	0.01	0.01	0.01	0.01	0	0	0	0.01	0	0	0	0.07
1922	0	0	0.03	0.01	0.02	0.01	0	0	0	0.02	0	0.01	0.11
1923	0.01	0.01	0.02	0.02	0.01	0.02	0	0	0	0.02	0	0	0.11
1924	0.01	0.01	0.01	0.02	0.02	0	0	0	0	0.01	0	0	0.09
1925	0	0.01	0.02	0.03	0.02	0	0.01	0.01	0	0	0.01	0	0.1
1926	0	0	0.03	0.03	0.01	0.02	0.01	0	0.01	0.01	0	0.01	0.13
1927	0.01	0.02	0.03	0.02	0.01	0	0	0.02	0	0.01	0	0	0.12
1928	0.02	0	0.01	0.03	0.01	0.01	0	0	0.01	0	0	0	0.09
1929	0.01	0.02	0.02	0.02	0	0	0	0	0	0	0	0	0.08
1930	0.01	0.02	0.02	0.01	0.02	0.01	0	0.01	0.01	0	0.01	0	0.11
1931	0	0.02	0	0	0	0.01	0.01	0	0	0.01	0.01	0	0.06
1932	0	0.01	0.03	0.04	0.01	0	0	0	0.01	0.01	0	0.01	0.12
1933	0.02	0	0.03	0.02	0.01	0	0.01	0.01	0.01	0	0.01	0	0.13
1934	0	0	0.03	0.02	0.01	0.01	0	0	0	0	0	0	0.08
1935	0	0	0.01	0.02	0.01	0.01	0.01	0	0.01	0	0.02	0	0.09
1936	0.01	0	0.02	0.02	0.01	0	0.01	0.02	0	0	0.01	0	0.1
1937	0.01	0.01	0.01	0.02	0.03	0.01	0	0.01	0.01	0.01	0	0	0.11
1938	0	0	0.02	0.03	0	0	0.01	0.02	0.02	0	0	0	0.1
1939	0.01	0.01	0.02	0.01	0	0	0.01	0.01	0.01	0.01	0.02	0	0.1
1940	0.01	0.01	0.03	0.02	0.01	0.01	0	0.01	0	0.01	0.01	0	0.14
1941	0	0.01	0	0	0.02	0	0	0	0	0.01	0	0.01	0.05
1942	0	0.01	0.01	0.01	0.01	0	0.01	0.01	0.01	0.01	0	0	0.08
1943	0	0	0.01	0.04	0.01	0	0	0	0	0	0	0	0.07
1944	0.01	0.02	0.02	0.03	0.02	0.02	0.01	0	0	0.01	0	0.01	0.15
1945	0	0.02	0.02	0.02	0.01	0	0.01	0.01	0.01	0	0.01	0	0.11
1946	0.01	0.02	0.03	0.03	0.02	0	0	0	0	0	0.02	0	0.13
1947	0.01	0.01	0.03	0	0.01	0.01	0	0.01	0.01	0.01	0.01	0	0.12
1948	0	0.01	0.01	0.01	0.01	0.02	0	0	0.02	0.01	0.01	0	0.11
1949	0.01	0	0.03	0.03	0.01	0.01	0	0.01	0.02	0	0	0	0.13
1950	0	0	0.01	0	0.01	0.01	0.01	0	0	0	0	0	0.04
1951	0.02	0.03	0.03	0.01	0.01	0.02	0	0	0	0	0	0	0.13
1952	0	0.01	0.01	0.02	0	0.02	0	0.02	0	0	0	0	0.09
1953	0	0	0.02	0.03	0.02	0	0	0	0	0	0	0	0.08
1954	0.02	0	0.03	0.01	0	0.01	0	0.01	0	0	0.01	0	0.09
1955	0	0	0.03	0.02	0.01	0	0	0	0.02	0.01	0.01	0	0.1
1956	0	0.01	0.01	0.03	0	0	0.01	0	0	0.01	0	0	0.07
1957	0.01	0.03	0.02	0.02	0.02	0	0	0	0.01	0.02	0	0.01	0.14
1958	0.01	0.02	0.02	0	0.01	0	0	0	0.02	0	0	0.01	0.08
1959	0	0.02	0.02	0.01	0.02	0	0	0	0	0	0.01	0	0.09
1960	0.01	0.01	0.01	0.02	0.01	0	0	0	0.01	0.01	0	0	0.1
1961	0	0.01	0.02	0.01	0.01	0	0	0.01	0.01	0.01	0	0.02	0.12
1962	0	0	0.03	0.01	0.02	0	0	0	0.01	0	0.01	0.02	0.1
1963	0.01	0.02	0.01	0.01	0.01	0.01	0	0.01	0	0.02	0	0	0.1
1964	0.02	0.01	0.04	0.03	0.02	0	0.01	0	0	0	0.01	0.01	0.15
1965	0	0	0.01	0.02	0	0.02	0	0	0.01	0.01	0	0	0.08
1966	0.02	0.02	0.01	0.04	0	0	0	0	0	0	0	0	0.1
1967	0.01	0.01	0.03	0.03	0.02	0	0	0	0	0.02	0	0	0.13
1968	0	0	0.03	0.02	0.01	0	0.01	0.02	0	0.01	0.01	0	0.11
1969	0	0.03	0.04	0.02	0	0.02	0.02	0.01	0.01	0.01	0	0.01	0.16
1970	0.01	0.03	0	0.03	0	0	0	0	0.01	0	0	0.02	0.09
1971	0.01	0	0.03	0.02	0	0	0.01	0	0	0.01	0	0.01	0.1
1972	0.02	0.02	0.03	0.03	0.02	0.01	0	0.01	0.01	0.01	0.01	0	0.15
1973	0.02	0.01	0.03	0.01	0.01	0	0.01	0	0.01	0.02	0	0	0.11
1974	0.02	0.01	0.04	0.02	0.02	0	0.01	0.01	0	0	0	0	0.12
1975	0.02	0.01	0.02	0.03	0.01	0	0.01	0	0	0	0.01	0.01	0.13
1976	0	0	0.02	0.04	0	0	0.01	0	0.01	0.02	0	0	0.09

1977	0.01	0.01	0.03	0.02	0.03	0.01	0	0.01	0	0.02	0	0.01	0.15
1978	0.01	0	0.02	0.02	0.02	0.01	0.01	0	0	0	0	0	0.09
1979	0.02	0.02	0.03	0.02	0.02	0.02	0	0.01	0	0.01	0.01	0	0.16
1980	0	0	0.01	0	0.01	0	0	0	0	0.01	0	0.01	0.04
1981	0	0.02	0.01	0.02	0.01	0	0	0.02	0	0	0.01	0	0.1
1982	0	0.02	0.03	0.03	0.01	0.01	0.01	0	0	0	0.01	0	0.13
1983	0	0.01	0.02	0.03	0.02	0	0.01	0.01	0.01	0	0.02	0.01	0.12
1984	0	0.02	0.02	0.01	0	0.01	0	0.01	0	0	0.02	0.01	0.1
1985	0	0.01	0.01	0.02	0.02	0.01	0.01	0.02	0.01	0.01	0	0.01	0.11
1986	0	0.02	0.02	0.02	0.01	0.01	0	0.02	0	0.01	0	0	0.11
1987	0.02	0.03	0.02	0.03	0.02	0.01	0	0	0	0.01	0	0	0.14
1988	0.01	0.02	0.02	0.03	0.02	0.01	0	0.01	0.01	0	0.02	0.01	0.16
1989	0	0	0.03	0.03	0	0.02	0	0	0	0.02	0.01	0.01	0.11
1990	0	0.01	0.03	0.02	0.01	0.01	0.01	0.01	0	0	0.01	0.01	0.13
1991	0	0.03	0.01	0.03	0.01	0.01	0.01	0	0	0	0	0.01	0.1
1992	0	0.01	0.03	0.01	0.01	0.01	0	0	0.01	0.01	0.01	0	0.1
1993	0.02	0.01	0.01	0.01	0.01	0	0	0.01	0.01	0	0	0.01	0.1
1994	0	0.02	0	0.02	0.01	0	0	0	0	0.01	0.01	0.01	0.09
1995	0.01	0	0.01	0.02	0.02	0.01	0.01	0.02	0.01	0	0.01	0.01	0.13
1996	0	0	0.01	0.03	0	0	0	0	0	0.01	0	0.01	0.07
1997	0	0.02	0.03	0.02	0.02	0	0.02	0.01	0.01	0	0	0.01	0.15
1998	0.02	0.01	0.02	0.02	0.01	0	0	0.01	0.02	0	0.01	0	0.13
1999	0	0.03	0.03	0	0.01	0	0.01	0.01	0.01	0.01	0.02	0.01	0.16
2000	0.01	0	0	0.02	0.01	0.01	0	0.01	0.01	0	0	0	0.08
2001	0.01	0	0.02	0.02	0.02	0.02	0	0.01	0	0	0	0	0.1
2002	0.03	0.02	0.02	0.03	0.02	0	0.01	0	0	0.01	0.01	0.02	0.14
2003	0	0.02	0.02	0.02	0.01	0	0	0.01	0.01	0.01	0	0	0.1
Average	**0.01**	**0.01**	**0.02**	**0.02**	**0.01**	**0.01**	**0.00**	**0.01**	**0.01**	**0.01**	**0.01**	**0.00**	**0.11**

I6 STREAMFLOW REDUCTION TIME SERIES (AFFORESTATION)

Streamflow Reduction due to afforetation in the K50A catchment

Units in million m^3

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	TOTAL
1920	0.07	0.13	0.8	0.3	1.03	1.37	1.19	0.55	0.35	0.46	0.36	0.73	7.34
1921	0.36	0.3	0.8	0.46	0.26	0.72	1.85	1.31	0.51	1.19	0.74	0.68	9.18
1922	0.94	1.35	0.22	0.37	0.18	0.16	0.89	1.07	0.88	0.37	0.25	0.2	6.88
1923	0.38	0.77	0.31	0.11	0.19	0.2	0.29	0.34	0.39	0.23	0.76	1.35	5.32
1924	0.9	0.53	0.48	0.26	0.14	0.42	0.59	0.37	0.64	0.49	0.86	3.05	8.73
1925	2.03	0.64	0.54	0.18	0.18	0.83	0.55	0.27	0.52	0.88	0.8	0.78	8.2
1926	0.81	1.53	0.36	0.09	0.39	0.24	0.08	0.92	0.63	0.28	0.95	0.68	6.96
1927	0.3	0.12	0.06	0.18	0.52	1.66	1.06	0.31	0.31	0.24	0.43	0.93	6.12
1928	0.7	1.67	1.09	0.14	0.11	0.17	0.21	0.44	0.49	1.25	1.21	0.99	8.47
1929	0.67	0.2	0.35	0.27	1.48	0.91	0.29	0.73	0.65	0.56	1.18	1.1	8.39
1930	0.62	0.08	0.16	0.69	0.37	0.13	0.65	0.56	0.29	0.98	0.89	1.47	6.89
1931	1.8	0.48	1.73	1.83	0.77	0.35	0.04	0.21	0.52	0.47	0.28	2.17	10.65
1932	1.92	0.5	0	0	0.2	0.66	0.6	0.59	0.45	0.31	1.75	0.98	7.96
1933	0.12	0.38	0.14	0.06	0.26	0.66	0.34	0.17	0.16	0.87	1.11	0.78	5.05
1934	2.11	1.21	0.15	0.15	0.32	0.29	0.79	3.49	1.9	0.58	0.58	1.02	12.59
1935	1.19	1.02	0.53	0.31	0.48	0.57	0.22	0.72	0.42	0.8	0.48	1	7.74
1936	0.9	1.53	0.58	0.16	0.7	1.18	0.41	0	0.21	0.93	0.76	1.31	8.67
1937	0.94	0.59	0.36	0.43	0.09	0.26	0.39	0.24	0.22	0.24	0.45	1.03	5.24
1938	1.42	1.48	0.76	0.08	0.99	0.99	0.36	0.02	0	1.36	2.96	2.04	12.46
1939	0.69	0.23	0.08	1.02	1.76	0.89	0.32	0.2	0.08	0.25	0.16	0.7	6.38
1940	0.63	0.51	0.11	0.17	0.39	0.37	1.52	0.78	1.11	0.6	0.16	0.64	6.99
1941	1.8	0.98	0.89	1.11	0.33	0.43	0.3	0.99	0.84	0.58	0.51	0.36	9.12
1942	0.56	0.36	0.6	1.04	0.58	0.89	0.41	0.07	0.02	0.08	0.64	2.46	7.71
1943	1.47	1.78	1.11	0.06	0.21	0.4	0.36	2.19	1.64	1.41	0.67	1.3	12.6
1944	0.65	0	0.02	0	0	0.03	0.05	1.69	2.09	1.08	0.58	0.31	6.5
1945	0.69	0.29	0.45	0.36	0.29	1.33	0.65	0.11	0.09	0.41	0.45	0.59	5.71
1946	0.58	0.19	0.14	0.24	0.16	0.75	0.77	0.85	0.75	1.83	0.73	0.58	7.57
1947	0.52	0.27	0.08	0.72	0.46	0.22	0.91	0.47	0.13	0.22	0.24	0.72	4.96
1948	1.54	0.69	0.48	0.74	0.53	0.11	0.26	0.92	0.45	0.07	0.14	0.64	6.57
1949	0.59	1.49	0.52	0.07	0.12	0.22	0.34	0.29	0.12	1.04	1.27	1.02	7.09
1950	1.17	2.14	1.36	1.64	0.49	0.13	0.01	0.19	0.78	2.63	1.88	1.36	13.78
1951	0.28	0	0	0.87	0.65	0.25	0.64	0.78	0.84	0.91	2.03	2.85	10.1
1952	1.18	0.1	0.3	0.16	1.32	0.45	0.19	0.09	1.2	1.63	2.56	1.05	10.23
1953	1.72	0.84	0.15	0	0	0.52	0.58	1.28	0.95	1.39	4.07	1.56	13.06
1954	0	1.23	0.25	0.47	1.86	0.67	0.14	0.14	0.35	0.41	0.43	0.7	6.65
1955	1.21	1.78	0.38	0.1	0.4	1.13	0.79	1.96	0.84	0	0.02	0.7	9.31
1956	1.83	0.9	0.73	0.29	0.45	0.42	0.28	0.64	1.1	0.59	0.95	1.49	9.67
1957	0.93	0.06	0	0.18	0.17	1.17	1.13	1.44	0.77	0.11	0.73	0.48	7.17
1958	0.41	0.17	0.22	1.45	0.77	0.51	1.69	1.12	0.24	0.6	1.96	0.95	10.09
1959	1.53	0.34	0.06	1.07	0.33	1.38	0.87	0.48	0.57	0.67	0.33	1.09	8.72
1960	0.55	0.41	0.34	0.2	0.12	0.99	0.78	1.06	0.49	0.26	0.71	0.63	6.54
1961	1.06	0.47	0.11	0.8	0.5	1.03	0.76	0.26	0.06	0.12	2.14	1.03	8.34
1962	1.28	1.09	0.2	0.23	0.09	1.72	0.93	0.32	0.15	0.83	0.87	0.32	8.03
1963	0.18	0.12	0.77	0.77	0.29	0.4	0.76	0.39	1.08	0.67	0.76	2.59	8.78
1964	0.89	0.6	0.07	0	0.07	1.04	1	1.01	0.72	0.45	0.23	0.16	6.24
1965	1.72	1.73	0.68	0.32	0.56	0.21	0.26	1.01	0.51	0.13	1.22	1.1	9.45
1966	0.36	0.14	0.27	0.08	0.3	0.92	2.39	2.42	0.87	1.04	0.86	0.52	10.17
1967	0.12	0.12	0.05	0.1	0.26	0.53	0.4	0.6	2.25	0.83	0.41	0.78	6.45
1968	0.78	0.74	0.17	0.23	0.31	0.48	0.32	0.13	0.75	0.72	0.55	0.55	5.73
1969	1.03	0.41	0	0.21	0.49	0.26	0.11	0.11	0.2	0.36	1.73	1.16	6.07
1970	0.62	0.17	1.54	0.64	0.9	0.94	1.25	1.62	0.9	2.51	2.74	0.38	14.21
1971	0	0.45	0.06	0.11	1.45	0.79	0.24	0.62	0.73	0.95	1.33	0.59	7.32
1972	0.05	0	0.05	0.09	0.14	0.4	0.7	0.61	0.39	0.3	0.39	0.77	3.89
1973	0.53	0.96	0.41	0.73	0.81	0.9	0.37	1.04	0.58	0.09	1.47	1.25	9.14
1974	0.56	0.39	0.03	0.28	0.32	0.47	0.36	0.18	0.2	0.66	1.11	1.9	6.46
1975	0.77	0.46	0.39	0.23	0.3	0.95	0.42	0.4	0.47	0.96	0.77	0.37	6.49
1976	1.85	1.35	0.62	0.05	1.29	0.77	0.17	1.88	1.36	0.34	0.33	0.63	10.64
1977	0.8	0.7	0.16	0.04	0.02	0.15	0.25	0.31	0.68	0.47	0.92	0.76	5.26

1977	0.8	0.7	0.16	0.04	0.02	0.15	0.25	0.31	0.68	0.47	0.92	0.76	5.26
1978	0.85	0.85	0.51	0.33	0.15	0.1	0.16	0.55	0.56	1.56	2.17	1.29	9.08
1979	0.31	0	0.01	0.31	0.16	0.08	0.52	0.6	0.71	0.46	0.45	0.76	4.37
1980	1.21	1.4	0.92	1.45	0.49	1.53	2.19	3.24	1.01	0	1.76	0.52	15.72
1981	0.76	0.12	0	0	0.07	0.39	2.4	1.04	0.24	0.52	0.45	1.11	7.1
1982	1	0.27	0.04	0.01	0.37	0.3	0.19	0.5	2.02	3.86	1.39	0.92	10.87
1983	1.52	0.35	0.28	0.06	0.06	0.5	0.25	0.11	0.26	0.75	0.58	0.26	4.98
1984	0.74	0.41	0.52	0.83	1.06	0.46	0.79	0.42	0.35	0.75	0.43	0.15	6.91
1985	1.77	1.15	0.99	0.63	0.13	0.12	0.09	0.05	0.07	0.19	1.73	1.12	8.04
1986	1.78	0.67	0.2	0.46	0.29	0.33	1.43	0.6	0.35	0.22	0.5	2.36	9.19
1987	0.88	0	0.03	0.12	0.07	0.1	1.02	0.82	0.73	0.5	0.52	0.61	5.4
1988	0.58	0.37	0.17	0.09	0.07	0.2	1.14	0.69	0.33	0.57	0.4	0.47	5.08
1989	2.1	2.05	0.43	0.08	0.62	0.33	0.68	0.71	1.9	0.86	0.29	0.33	10.38
1990	1.02	0.78	0.19	0.22	0.46	0.29	0.07	0.35	0.4	0.45	0.36	0.19	4.78
1991	1.01	0.43	0.43	0.32	0.62	0.42	0.3	0.69	0.69	1.84	2.87	0.91	10.53
1992	1.75	1	0	0	0.13	0.16	0.78	1.05	0.78	0.43	0.44	2.69	9.21
1993	0.96	0	0.5	0.3	0.39	0.26	0.82	0.57	0.25	0.5	1.86	0.98	7.39
1994	1.05	0.3	1.14	0.47	0.13	1.06	1.49	1.39	0.7	0.26	0.16	0.19	8.34
1995	0.14	1.61	0.81	0.35	0.08	0.06	0.08	0.06	0.06	0.41	0.66	0.59	4.91
1996	2.27	2.92	1.38	0.11	0.43	1.04	1.29	1.78	1.07	0.41	1.07	0.4	14.17
1997	0.78	0.25	0	0.14	0.07	0.91	0.43	0.55	0.4	0.4	0.72	0.62	5.27
1998	0.32	0.49	0.37	0.35	0.46	0.68	0.79	0.36	0.07	0.2	0.46	0.49	5.04
1999	1.22	0.42	0	0.84	0.85	1.48	0.57	0.03	0	0	0.02	0.19	5.62
2000	0.61	1.34	1.02	0.86	0.35	0.2	1.24	0.57	0.05	0.23	1.02	0.92	8.41
2001	0.47	0.82	0.34	0.39	0.18	0.02	0.29	0.41	0.79	1.65	1.6	2.09	9.05
2002	0.55	0.31	0.17	0	0.41	2.25	1.12	1.58	1.06	0.36	0.32	0.13	8.26
2003	0.19	0.06	0.03	0.18	0.54	0.93	0.94	0.49	0.3	0.29	0.35	0.97	5.27
Average	**0.92**	**0.69**	**0.40**	**0.38**	**0.44**	**0.61**	**0.66**	**0.74**	**0.62**	**0.69**	**0.93**	**0.96**	**8.04**

Streamflow Reduction due to afforestation in the K50B catchment

Units in million m^3

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	TOTAL
1920	0.13	0.16	0.49	0.18	0.72	0.77	0.78	0.39	0.34	0.42	0.33	0.6	5.31
1921	0.23	0.12	0.43	0.17	0.14	0.57	1.18	0.87	0.36	0.89	0.38	0.42	5.76
1922	0.55	0.83	0.12	0.28	0.12	0.13	0.65	0.65	0.63	0.31	0.19	0.15	4.61
1923	0.28	0.52	0.21	0.05	0.12	0.17	0.19	0.2	0.25	0.16	0.49	0.85	3.49
1924	0.61	0.32	0.26	0.13	0.1	0.29	0.43	0.24	0.46	0.37	0.56	2.09	5.86
1925	1.49	0.48	0.43	0.16	0.16	0.62	0.38	0.16	0.28	0.6	0.57	0.54	5.87
1926	0.59	1.05	0.23	0.12	0.31	0.22	0.07	0.72	0.49	0.22	0.76	0.49	5.27
1927	0.16	0.04	0.02	0.11	0.32	1.13	0.7	0.19	0.24	0.19	0.36	0.7	4.16
1928	0.52	1.12	0.76	0.1	0.07	0.09	0.11	0.3	0.37	0.97	0.89	0.7	6
1929	0.45	0.1	0.22	0.14	0.91	0.52	0.17	0.59	0.5	0.41	0.79	0.78	5.58
1930	0.37	0.02	0.05	0.37	0.22	0.09	0.45	0.41	0.23	0.84	0.71	1.12	4.88
1931	1.22	0.25	1.09	1.13	0.47	0.23	0.02	0.13	0.38	0.37	0.25	1.66	7.2
1932	1.46	0.32	0	0	0.11	0.44	0.47	0.5	0.38	0.26	1.24	0.55	5.73
1933	0	0.19	0.07	0.03	0.13	0.49	0.25	0.11	0.11	0.71	0.95	0.66	3.7
1934	1.42	0.67	0.02	0.1	0.14	0.16	0.47	2.29	1.28	0.42	0.33	0.63	7.93
1935	0.71	0.59	0.33	0.24	0.38	0.39	0.13	0.53	0.31	0.59	0.32	0.64	5.16
1936	0.67	1.01	0.39	0.05	0.45	0.83	0.28	0	0.24	0.82	0.68	1.08	6.5
1937	0.66	0.28	0.27	0.28	0.04	0.18	0.25	0.15	0.16	0.18	0.34	0.75	3.54
1938	1.02	0.83	0.48	0.06	0.6	0.53	0.2	0.02	0	0.9	2.09	1.37	8.1
1939	0.39	0.08	0.06	0.7	1.11	0.54	0.21	0.19	0.1	0.18	0.12	0.55	4.23
1940	0.48	0.31	0.06	0.1	0.24	0.25	1	0.54	0.88	0.46	0.11	0.52	4.95
1941	1.17	0.54	0.62	0.71	0.17	0.24	0.15	0.75	0.62	0.47	0.39	0.23	6.06
1942	0.28	0.17	0.31	0.57	0.38	0.43	0.2	0.05	0.03	0.08	0.67	1.97	5.14
1943	1.13	1.11	0.65	0.01	0.12	0.19	0.16	1.45	1.24	1.1	0.49	0.87	8.52
1944	0.42	0	0	0	0.01	0.04	0.05	1.06	1.64	0.84	0.46	0.2	4.72
1945	0.4	0.13	0.29	0.18	0.14	0.85	0.4	0.07	0.07	0.37	0.39	0.4	3.69
1946	0.33	0.08	0.09	0.21	0.14	0.43	0.55	0.61	0.53	1.45	0.53	0.3	5.25
1947	0.29	0.15	0.05	0.37	0.24	0.12	0.63	0.33	0.11	0.17	0.19	0.51	3.16
1948	0.99	0.38	0.17	0.52	0.38	0.08	0.21	0.72	0.34	0.08	0.19	0.48	4.54
1949	0.34	0.87	0.31	0.02	0.04	0.1	0.29	0.22	0.07	0.51	0.73	0.69	4.19
1950	0.78	1.26	0.77	1.05	0.31	0.1	0.02	0.22	0.64	1.86	1.19	0.77	8.97
1951	0.14	0	0	0.44	0.25	0.09	0.67	0.58	0.64	0.84	1.52	1.65	6.82
1952	0.4	0	0.05	0.07	0.46	0.18	0.13	0.1	1.2	1.7	1.79	0.57	6.65
1953	1.04	0.49	0.01	0	0	0.35	0.38	0.98	0.77	1.07	2.41	0.82	8.32
1954	0	0.78	0.13	0.46	1.27	0.39	0.02	0.08	0.23	0.29	0.32	0.53	4.5
1955	0.93	1.13	0.2	0.01	0.18	0.65	0.46	1.33	0.62	0.02	0.07	0.59	6.19
1956	1.2	0.55	0.37	0.12	0.2	0.17	0.2	0.57	0.83	0.46	0.73	1.16	6.56
1957	0.49	0	0	0.04	0.07	0.7	0.89	1.28	0.55	0.02	0.4	0.27	4.71
1958	0.27	0.1	0.12	0.94	0.46	0.24	1.05	0.78	0.2	0.35	1.25	0.64	6.4
1959	1.08	0.21	0	0.68	0.21	0.85	0.61	0.34	0.33	0.6	0.31	0.68	5.9
1960	0.31	0.26	0.19	0.21	0.08	0.52	0.56	0.97	0.42	0.22	0.54	0.43	4.71
1961	0.67	0.27	0.01	0.51	0.29	0.7	0.52	0.2	0.07	0.1	1.43	0.67	5.44
1962	0.8	0.65	0.09	0.08	0.03	1.11	0.64	0.25	0.11	0.66	0.7	0.24	5.36
1963	0.06	0.05	0.57	0.6	0.16	0.22	0.43	0.23	0.81	0.51	0.59	1.94	6.17
1964	0.59	0.37	0.05	0	0.04	0.78	1.01	1.08	0.57	0.26	0.11	0.07	4.93
1965	0.85	0.94	0.3	0.17	0.25	0.12	0.24	0.85	0.4	0.12	0.94	0.82	6
1966	0.2	0.06	0.08	0.02	0.15	0.63	1.58	1.76	0.64	0.85	0.52	0.24	6.73
1967	0	0	0	0.04	0.23	0.36	0.25	0.52	1.8	0.61	0.31	0.5	4.62
1968	0.39	0.3	0.07	0.18	0.22	0.28	0.19	0.1	0.92	0.7	0.36	0.3	4.01
1969	0.54	0.25	0	0.2	0.25	0.12	0.08	0.07	0.15	0.27	1.2	0.72	3.85
1970	0.38	0.09	0.96	0.4	0.54	0.62	0.9	1.2	0.61	1.75	1.78	0.11	9.34
1971	0	0.33	0.05	0.1	0.95	0.48	0.13	0.54	0.55	0.82	1	0.25	5.2
1972	0	0	0.01	0.07	0.08	0.26	0.38	0.37	0.32	0.28	0.3	0.56	2.63
1973	0.36	0.5	0.24	0.48	0.43	0.57	0.25	0.69	0.39	0.07	0.98	0.97	5.93
1974	0.43	0.2	0	0.23	0.17	0.21	0.18	0.11	0.14	0.74	0.98	1.41	4.8
1975	0.41	0.26	0.24	0.1	0.13	0.62	0.28	0.2	0.28	0.77	0.63	0.31	4.23
1976	1.22	0.88	0.35	0	0.81	0.49	0.12	1.26	0.98	0.28	0.31	0.43	7.13

1977	0.47	0.38	0.08	0.01	0.02	0.09	0.17	0.23	0.51	0.35	0.61	0.51	3.43
1978	0.6	0.6	0.34	0.23	0.11	0.05	0.17	0.38	0.37	0.99	1.38	0.72	5.94
1979	0.13	0	0.03	0.19	0.1	0.05	0.43	0.47	0.73	0.45	0.36	0.5	3.44
1980	0.82	0.86	0.42	0.91	0.31	0.98	1.5	2.03	0.53	0	1.25	0.3	9.91
1981	0.48	0.1	0.04	0	0.04	0.27	1.59	0.7	0.19	0.45	0.29	0.74	4.89
1982	0.68	0.15	0.05	0.01	0.34	0.26	0.12	0.42	1.55	2.3	0.73	0.58	7.19
1983	0.99	0.35	0.22	0	0	0.27	0.16	0.09	0.25	0.56	0.46	0.21	3.56
1984	0.57	0.31	0.34	0.42	0.58	0.29	0.66	0.31	0.21	0.52	0.3	0.13	4.64
1985	1.2	0.76	0.62	0.52	0.09	0.07	0.07	0.04	0.08	0.17	1.26	0.86	5.74
1986	1.11	0.36	0.08	0.17	0.17	0.2	0.93	0.41	0.23	0.15	0.38	1.74	5.93
1987	0.59	0	0	0.04	0.03	0.04	0.64	0.5	0.57	0.41	0.52	0.62	3.96
1988	0.48	0.28	0.09	0.03	0.03	0.08	0.61	0.43	0.3	0.53	0.33	0.33	3.52
1989	1.52	1.36	0.24	0.04	0.21	0.12	0.44	0.44	1.32	0.51	0.26	0.2	6.66
1990	0.55	0.29	0.03	0.21	0.38	0.22	0.05	0.29	0.32	0.28	0.22	0.12	2.96
1991	0.72	0.3	0.38	0.21	0.37	0.23	0.2	0.67	0.69	1.34	2.24	0.73	8.08
1992	1.1	0.63	0	0	0.01	0.04	0.31	0.51	0.58	0.47	0.49	2.15	6.29
1993	0.69	0	0.39	0.19	0.19	0.16	0.56	0.42	0.2	0.35	1.43	0.77	5.35
1994	0.68	0.15	0.7	0.25	0.14	0.64	1.06	1	0.57	0.3	0.23	0.2	5.92
1995	0.07	0.93	0.45	0.16	0.03	0.02	0.04	0.05	0.04	0.29	0.44	0.37	2.89
1996	1.41	1.78	0.75	0.04	0.19	0.59	0.72	1.08	0.68	0.4	0.71	0.26	8.61
1997	0.55	0.19	0	0.15	0.07	0.6	0.27	0.56	0.37	0.42	0.79	0.58	4.55
1998	0.21	0.28	0.14	0.25	0.28	0.39	0.46	0.2	0.03	0.17	0.4	0.39	3.2
1999	0.91	0.3	0	0.47	0.48	0.97	0.39	0.03	0	0	0.02	0.16	3.73
2000	0.53	1.08	0.59	0.62	0.21	0.11	0.98	0.43	0.03	0.17	1.06	0.88	6.69
2001	0.31	0.59	0.21	0.26	0.11	0	0.19	0.4	0.55	1.2	1.25	1.24	6.31
2002	0.21	0.39	0.17	0	0.13	1.33	0.79	1.23	0.52	0.09	0.24	0.11	5.21
2003	0.09	0.04	0.07	0.06	0.21	0.64	0.62	0.28	0.21	0.28	0.33	0.7	3.53
Average	**0.59**	**0.42**	**0.24**	**0.23**	**0.26**	**0.38**	**0.44**	**0.53**	**0.47**	**0.53**	**0.68**	**0.67**	**5.44**

Streamflow Reduction dure to afforestationin the K40A catchment

Units in million m^3

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	TOTAL
1920	0	0	0.62	0.23	0.68	1.12	0.89	0.36	0.08	0.12	0.1	0.26	4.46
1921	0.15	0.21	0.77	0.53	0.17	0.5	1.52	0.87	0.3	0.78	0.65	0.45	6.9
1922	0.74	1.24	0.3	0.14	0.11	0.03	0.32	0.71	0.47	0.15	0.12	0.08	4.41
1923	0.13	0.27	0.11	0.04	0.08	0.07	0.12	0.16	0.16	0.11	0.46	0.73	2.44
1924	0.46	0.26	0.55	0.27	0.05	0.9	0.59	0.28	0.33	0.2	0.66	2.38	6.93
1925	1.13	0.31	0.18	0.05	0.01	0.38	0.22	0.09	0.31	0.4	0.29	0.22	3.59
1926	0.46	1.33	0.42	0.07	0.51	0.26	0.05	0.37	0.23	0.07	0.2	0.15	4.12
1927	0.2	0.29	0.11	0.1	0.14	1.12	0.9	0.29	0.12	0.1	0.29	0.47	4.13
1928	0.29	1.3	0.91	0.18	0.17	0.3	0.19	0.21	0.19	0.58	0.82	0.66	5.8
1929	0.34	0.11	0.2	0.22	1.29	0.76	0.33	0.44	0.43	0.39	0.74	0.62	5.87
1930	0.47	0.13	0.13	0.86	0.38	0.15	0.47	0.23	0.06	0.45	0.42	0.44	4.19
1931	1.01	0.39	1.77	1.6	1.23	0.48	0.06	0.21	0.27	0.22	0.11	1.63	8.98
1932	0.98	0.32	0.04	0	0.2	0.41	0.38	0.34	0.2	0.11	1.19	0.59	4.76
1933	0.09	0.47	0.16	0.15	0.3	0.58	0.23	0.05	0.03	0.57	0.46	0.32	3.41
1934	1.46	1.3	0.27	0.06	0.4	0.22	0.47	2.38	1.24	0.46	0.4	0.98	9.64
1935	0.61	0.77	0.64	0.15	0.21	0.22	0.08	0.54	0.28	0.49	0.29	0.57	4.85
1936	0.43	1.32	0.53	0.1	0.27	1.16	0.41	0	0.04	0.43	0.29	0.35	5.33
1937	0.3	0.6	0.68	0.37	0.06	0.09	0.3	0.2	0.12	0.1	0.15	0.35	3.32
1938	0.35	0.92	0.46	0.06	1.02	0.98	0.33	0.05	0	0.88	1.78	1.06	7.89
1939	0.4	0.3	0.24	0.51	1.52	0.9	0.24	0.08	0.07	0.08	0.04	0.23	4.61
1940	0.22	0.26	0.07	0.24	0.26	0.17	1.38	0.63	0.37	0.24	0.13	0.17	4.14
1941	0.8	0.73	1.05	1.26	0.35	0.54	0.34	0.54	0.38	0.17	0.19	0.13	6.48
1942	0.44	0.46	0.65	0.84	0.29	0.84	0.4	0.07	0.04	0.04	0.34	1.12	5.53
1943	0.82	1.46	0.92	0.13	0.07	0.43	0.27	1.56	0.85	0.89	0.51	1.25	9.16
1944	0.57	0.05	0	0.03	0.02	0.04	0.04	1.5	1.47	0.58	0.42	0.27	4.99
1945	1.03	0.39	0.03	0.2	0.52	1.53	0.56	0.04	0.01	0.07	0.08	0.17	4.63
1946	0.21	0.14	0.05	0.04	0.11	0.92	0.46	0.25	0.29	0.95	0.46	1.01	4.89
1947	0.69	0.3	0.05	0.79	0.41	0.17	0.71	0.36	0.1	0.09	0.09	0.38	4.14
1948	1.49	0.73	0.41	0.66	0.53	0.15	0.27	0.5	0.21	0.01	0.03	0.32	5.31
1949	0.25	1.5	0.5	0.03	0.18	0.21	0.11	0.08	0.03	1.26	1.04	0.73	5.92
1950	1.07	2.02	1.19	1.68	0.6	0.21	0.04	0.11	0.33	1.7	1.11	1.07	11.13
1951	0.29	0	0	0.52	0.44	0.14	0.27	0.52	0.36	0.29	1.06	2.3	6.19
1952	1.05	0.35	0.28	0.13	0.67	0.28	0.29	0.14	1.09	1.41	1.99	1.08	8.76
1953	1.77	1.19	0.21	0	0	0.23	0.59	1.39	0.76	0.77	2.96	1.08	10.95
1954	0.04	1.09	0.28	0.37	1.61	0.68	0.13	0.09	0.16	0.22	0.21	0.31	5.19
1955	0.69	1.3	0.34	0.13	0.28	0.71	0.35	0.95	0.44	0.06	0.05	0.21	5.51
1956	1.35	0.84	0.8	0.27	0.49	0.6	0.21	0.16	0.54	0.33	0.52	1.36	7.47
1957	0.7	0.06	0.03	0.07	0.04	0.62	0.45	0.89	0.53	0.14	0.7	0.36	4.59
1958	0.27	0.13	0.15	1.15	0.61	0.79	1.33	0.79	0.2	0.57	1.72	0.69	8.4
1959	1.29	0.42	0.18	0.66	0.18	1.1	0.71	0.49	0.4	0.28	0.11	0.69	6.51
1960	0.36	0.29	0.45	0.19	0.14	1	0.88	0.56	0.23	0.11	0.24	0.26	4.71
1961	0.34	0.23	0.1	0.49	0.29	0.84	0.48	0.13	0.04	0.03	1.83	0.84	5.64
1962	1.15	1.23	0.28	0.53	0.22	1.66	0.73	0.22	0.12	0.36	0.29	0.09	6.88
1963	0.18	0.1	0.43	0.57	0.28	0.25	0.33	0.17	0.98	0.49	0.75	2.25	6.78
1964	0.79	0.21	0.02	0.01	0.03	0.59	0.32	0.38	0.31	0.25	0.16	0.1	3.17
1965	1.54	1.86	0.79	0.37	0.43	0.12	0.22	0.46	0.23	0.08	0.77	0.68	7.55
1966	0.24	0.05	0.29	0.1	0.58	0.9	1.99	2.3	0.8	0.41	0.33	0.32	8.31
1967	0.22	0.24	0.04	0	0	0.34	0.28	0.28	1.65	0.7	0.48	0.55	4.78
1968	0.52	0.9	0.25	0.09	0.11	0.43	0.26	0.07	0.61	0.42	0.25	0.24	4.15
1969	0.4	0.15	0	0.09	0.42	0.2	0.05	0.03	0.06	0.11	1.05	0.67	3.23
1970	0.51	0.19	1.35	0.49	0.37	0.73	0.96	1.05	0.52	1.82	2.25	0.57	10.81
1971	0.03	0.56	0.13	0.03	0.96	0.58	0.21	0.23	0.24	0.2	0.55	0.33	4.05
1972	0.09	0.04	0.02	0.08	0.06	0.13	0.36	0.27	0.2	0.18	0.21	0.25	1.89
1973	0.16	0.23	0.14	0.52	0.52	0.71	0.32	0.69	0.41	0.12	0.62	0.53	4.97
1974	0.22	0.35	0.1	0.26	0.16	0.28	0.21	0.12	0.2	0.41	0.64	1.18	4.13
1975	0.44	0.23	0.3	0.13	0.15	0.35	0.16	0.28	0.28	0.56	0.45	0.33	3.66
1976	1.65	1.56	0.5	0.02	1.15	0.79	0.2	1.5	0.71	0.1	0.26	0.58	9.02

1977	0.34	0.45	0.15	0.11	0.03	0.05	0.13	0.11	0.3	0.21	0.28	0.25	2.41
1978	0.4	0.73	0.33	0.35	0.21	0.1	0.05	0.37	0.35	1.12	1.1	1.1	6.21
1979	0.4	0.02	0	0.19	0.09	0.04	0.22	0.18	0.31	0.23	0.2	0.52	2.4
1980	1.1	0.94	0.69	1.55	0.59	1.39	1.68	2.74	1.05	0.14	1.64	0.64	14.15
1981	0.75	0.21	0.21	0.07	0.18	0.32	1.67	0.61	0.32	0.51	0.27	0.81	5.93
1982	0.81	0.2	0.01	0	0.06	0.09	0.1	0.19	1.22	2.52	0.89	0.41	6.5
1983	0.79	0.65	0.32	0.08	0.08	0.48	0.21	0.08	0.09	0.61	0.35	0.12	3.86
1984	0.66	0.32	0.29	0.46	0.53	0.26	0.35	0.2	0.19	0.53	0.32	0.13	4.24
1985	1.39	0.91	0.85	0.41	0.12	0.08	0.06	0.03	0.02	0.08	1.23	0.69	5.87
1986	1.19	0.59	0.18	0.2	0.14	0.19	1.33	0.53	0.2	0.14	0.41	1.78	6.88
1987	0.67	0.03	0.11	0.09	0.07	0.09	0.6	0.51	0.36	0.21	0.38	0.4	3.52
1988	0.34	0.14	0.15	0.11	0.07	0.12	0.94	0.44	0.11	0.14	0.13	0.1	2.79
1989	1.45	1.7	0.42	0.04	0.92	0.39	0.66	0.5	0.77	0.38	0.16	0.12	7.51
1990	0.61	0.39	0.09	0.13	0.25	0.16	0.12	0.1	0.22	0.31	0.25	0.13	2.76
1991	1.04	0.39	0.6	0.28	0.35	0.32	0.16	0.33	0.33	1.21	0.98	0.38	6.37
1992	1.59	0.92	0.12	0.52	0.26	0.16	1.05	0.81	0.31	0.09	0.09	1.79	7.71
1993	0.74	0.23	0.46	0.44	0.28	0.39	0.63	0.29	0.07	0.27	1.34	0.62	5.76
1994	0.68	0.23	1.14	0.69	0.37	0.71	0.98	0.66	0.32	0.11	0.05	0.03	5.97
1995	0.08	1.31	0.97	0.27	0.04	0.07	0.11	0.06	0.03	0.15	0.24	0.27	3.6
1996	1.67	2.34	1.1	0.16	0.43	1.03	0.76	0.97	0.7	0.28	0.3	0.18	9.92
1997	0.51	0.17	0	0.09	0.1	1.16	0.44	0.07	0.04	0.08	0.21	0.17	3.04
1998	0.08	0.15	0.16	0.22	0.28	0.55	0.59	0.25	0.05	0.06	0.12	0.37	2.88
1999	1	0.35	0.03	1.15	0.55	1.26	0.47	0.04	0.01	0.01	0.01	0.02	4.9
2000	0.1	1.02	1.57	0.52	0.23	0.3	0.58	0.28	0.06	0.14	0.52	0.45	5.77
2001	0.32	0.95	0.38	0.22	0.1	0.03	0.09	0.12	0.26	1	0.9	1.23	5.6
2002	0.44	0.04	0.2	0.09	0.1	1.77	0.77	0.72	0.46	0.2	0.16	0.08	5.03
2003	0.33	0.15	0.09	0.21	0.25	0.44	0.35	0.21	0.15	0.15	0.24	0.52	3.09
Average	**0.64**	**0.59**	**0.38**	**0.33**	**0.35**	**0.51**	**0.48**	**0.47**	**0.35**	**0.40**	**0.56**	**0.60**	**5.64**

Streamflow Reduction due to afforestation in the K40B catchment
Units in million m^3

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	TOTAL
1920	0	0	0.42	0.16	0.45	0.74	0.62	0.27	0.05	0.06	0.05	0.16	2.98
1921	0.08	0.12	0.49	0.33	0.1	0.32	0.96	0.54	0.18	0.58	0.38	0.23	4.31
1922	0.45	0.74	0.14	0.05	0.05	0.01	0.2	0.49	0.34	0.11	0.06	0.04	2.68
1923	0.07	0.16	0.07	0.02	0.04	0.03	0.08	0.11	0.11	0.07	0.31	0.54	1.61
1924	0.34	0.17	0.34	0.16	0.03	0.57	0.39	0.2	0.22	0.14	0.44	1.81	4.81
1925	0.77	0.14	0.07	0	0	0.24	0.15	0.06	0.2	0.28	0.22	0.15	2.28
1926	0.31	0.83	0.25	0.03	0.33	0.16	0.02	0.23	0.15	0.04	0.12	0.1	2.57
1927	0.13	0.18	0.06	0.06	0.09	0.7	0.61	0.21	0.07	0.06	0.18	0.32	2.67
1928	0.2	0.77	0.55	0.09	0.09	0.18	0.12	0.14	0.13	0.4	0.69	0.45	3.81
1929	0.2	0.05	0.11	0.13	0.76	0.49	0.22	0.29	0.31	0.28	0.59	0.38	3.81
1930	0.26	0.04	0.05	0.52	0.23	0.08	0.3	0.15	0.03	0.29	0.3	0.31	2.56
1931	0.69	0.26	1	0.95	0.75	0.27	0	0.1	0.15	0.13	0.05	1.03	5.38
1932	0.57	0.15	0	0	0.12	0.27	0.26	0.25	0.15	0.06	0.78	0.35	2.96
1933	0.03	0.29	0.09	0.08	0.19	0.39	0.16	0.03	0.01	0.38	0.33	0.22	2.2
1934	0.93	0.84	0.17	0.02	0.25	0.14	0.31	1.79	0.86	0.28	0.24	0.76	6.59
1935	0.34	0.4	0.35	0.05	0.11	0.12	0.04	0.35	0.19	0.32	0.19	0.37	2.83
1936	0.29	0.8	0.3	0.04	0.16	0.72	0.26	0	0.01	0.27	0.19	0.23	3.27
1937	0.2	0.39	0.43	0.22	0.03	0.05	0.2	0.14	0.08	0.06	0.09	0.23	2.12
1938	0.24	0.61	0.29	0.03	0.62	0.64	0.22	0.02	0	0.56	1.41	0.74	5.38
1939	0.22	0.15	0.12	0.3	0.89	0.56	0.14	0.03	0.02	0.04	0.01	0.14	2.62
1940	0.14	0.16	0.04	0.14	0.16	0.11	0.86	0.42	0.25	0.17	0.08	0.1	2.63
1941	0.53	0.48	0.65	0.76	0.19	0.32	0.21	0.36	0.26	0.1	0.1	0.07	4.03
1942	0.27	0.29	0.4	0.53	0.17	0.52	0.25	0.04	0.01	0.01	0.21	0.86	3.56
1943	0.53	0.84	0.54	0.05	0.02	0.27	0.18	1.01	0.51	0.72	0.32	0.85	5.84
1944	0.29	0	0	0	0.01	0.02	0.02	0.9	1.25	0.45	0.25	0.16	3.35
1945	0.65	0.23	0	0.11	0.33	0.94	0.35	0.02	0	0.03	0.05	0.11	2.82
1946	0.14	0.08	0.03	0.03	0.07	0.6	0.31	0.17	0.2	0.82	0.34	0.62	3.41
1947	0.45	0.18	0.01	0.49	0.25	0.1	0.47	0.25	0.06	0.05	0.05	0.25	2.61
1948	0.96	0.43	0.23	0.4	0.33	0.09	0.16	0.34	0.15	0	0.01	0.21	3.31
1949	0.16	0.88	0.29	0.01	0.1	0.13	0.07	0.05	0.02	0.79	0.81	0.51	3.82
1950	0.72	1.22	0.72	0.93	0.3	0.09	0	0.04	0.21	1.33	0.81	0.74	7.11
1951	0.11	0	0	0.33	0.29	0.09	0.17	0.36	0.27	0.21	0.86	1.58	4.27
1952	0.62	0.15	0.12	0.04	0.41	0.16	0.18	0.09	0.69	1.18	1.48	0.65	5.77
1953	1.04	0.57	0	0	0	0.14	0.39	1.1	0.48	0.59	2.05	0.62	6.98
1954	0	0.57	0.11	0.21	0.94	0.41	0.07	0.04	0.09	0.15	0.14	0.2	2.93
1955	0.46	0.82	0.19	0.06	0.18	0.46	0.24	0.61	0.25	0	0.01	0.12	3.4
1956	0.84	0.54	0.5	0.15	0.3	0.38	0.13	0.1	0.35	0.23	0.34	1.12	4.98
1957	0.47	0	0	0.03	0.02	0.4	0.31	0.62	0.34	0.07	0.44	0.24	2.94
1958	0.16	0.06	0.08	0.7	0.37	0.51	0.88	0.48	0.09	0.34	1.33	0.43	5.43
1959	0.7	0.18	0.05	0.38	0.09	0.65	0.46	0.34	0.27	0.18	0.06	0.43	3.79
1960	0.23	0.17	0.27	0.1	0.07	0.63	0.59	0.4	0.15	0.05	0.14	0.16	2.96
1961	0.21	0.13	0.05	0.3	0.18	0.54	0.32	0.08	0.01	0.01	1.22	0.51	3.56
1962	0.69	0.77	0.16	0.32	0.13	0.97	0.46	0.15	0.07	0.23	0.19	0.05	4.19
1963	0.1	0.05	0.27	0.36	0.18	0.16	0.23	0.11	0.64	0.34	0.51	1.72	4.67
1964	0.52	0.06	0	0	0.01	0.38	0.22	0.26	0.23	0.17	0.11	0.06	2.02
1965	0.92	1.14	0.48	0.21	0.26	0.06	0.13	0.3	0.16	0.04	0.51	0.48	4.69
1966	0.17	0.01	0.17	0.06	0.37	0.6	1.38	1.58	0.46	0.2	0.16	0.16	5.32
1967	0.09	0.1	0	0	0	0.22	0.19	0.2	1.25	0.48	0.29	0.37	3.19
1968	0.34	0.58	0.13	0.03	0.06	0.28	0.17	0.04	0.41	0.29	0.18	0.15	2.66
1969	0.26	0.09	0	0.06	0.28	0.13	0.03	0.01	0.03	0.06	0.69	0.42	2.06
1970	0.33	0.11	0.78	0.28	0.23	0.48	0.66	0.85	0.33	1.27	1.58	0.28	7.18
1971	0	0.28	0.04	0	0.59	0.37	0.14	0.15	0.16	0.14	0.38	0.23	2.48
1972	0.05	0.01	0.01	0.04	0.04	0.08	0.24	0.19	0.14	0.12	0.14	0.18	1.24
1973	0.11	0.14	0.08	0.33	0.34	0.47	0.21	0.46	0.28	0.07	0.4	0.36	3.25
1974	0.14	0.2	0.04	0.15	0.1	0.18	0.14	0.08	0.13	0.29	0.48	1.04	2.97
1975	0.33	0.11	0.17	0.08	0.09	0.23	0.1	0.18	0.19	0.4	0.33	0.23	2.44
1976	1.01	0.93	0.27	0	0.66	0.49	0.12	0.87	0.39	0.02	0.14	0.38	5.28

1977	0.21	0.27	0.07	0.05	0.01	0.02	0.09	0.07	0.2	0.15	0.19	0.18	1.51
1978	0.27	0.49	0.22	0.21	0.12	0.06	0.03	0.24	0.25	0.94	0.9	0.82	4.55
1979	0.2	0	0	0.11	0.05	0.02	0.13	0.12	0.21	0.17	0.14	0.36	1.51
1980	0.77	0.64	0.44	0.89	0.33	0.8	1.11	1.88	0.6	0	1.12	0.32	8.9
1981	0.37	0.04	0.06	0.01	0.09	0.2	1.06	0.34	0.16	0.33	0.18	0.51	3.35
1982	0.54	0.11	0	0	0.02	0.05	0.07	0.13	0.87	1.76	0.57	0.22	4.34
1983	0.5	0.41	0.17	0.02	0.03	0.31	0.14	0.04	0.05	0.41	0.26	0.07	2.41
1984	0.43	0.21	0.17	0.29	0.34	0.16	0.22	0.13	0.11	0.37	0.23	0.07	2.73
1985	0.83	0.58	0.53	0.23	0.05	0.03	0.03	0	0.01	0.04	0.83	0.43	3.59
1986	0.75	0.38	0.1	0.1	0.07	0.11	0.84	0.35	0.12	0.08	0.27	1.35	4.52
1987	0.45	0	0.05	0.04	0.04	0.06	0.4	0.37	0.27	0.15	0.25	0.27	2.35
1988	0.23	0.08	0.07	0.07	0.04	0.07	0.62	0.3	0.08	0.09	0.07	0.06	1.78
1989	0.88	1.07	0.26	0.02	0.57	0.25	0.43	0.34	0.58	0.23	0.06	0.05	4.74
1990	0.38	0.24	0.04	0.07	0.15	0.1	0.08	0.06	0.14	0.22	0.18	0.08	1.74
1991	0.66	0.26	0.38	0.17	0.22	0.2	0.11	0.22	0.23	0.99	0.69	0.18	4.31
1992	0.9	0.54	0.04	0.31	0.15	0.08	0.67	0.56	0.22	0.05	0.03	1.2	4.75
1993	0.44	0.1	0.27	0.26	0.17	0.24	0.42	0.19	0.04	0.17	1.08	0.42	3.8
1994	0.4	0.12	0.65	0.4	0.22	0.46	0.65	0.46	0.21	0.05	0	0	3.62
1995	0.02	0.76	0.59	0.16	0.01	0.03	0.07	0.04	0.01	0.09	0.17	0.19	2.14
1996	1.03	1.39	0.66	0.07	0.25	0.65	0.51	0.75	0.43	0.11	0.14	0.07	6.06
1997	0.29	0.07	0	0.05	0.06	0.72	0.28	0.04	0.02	0.05	0.14	0.12	1.84
1998	0.05	0.09	0.1	0.14	0.18	0.37	0.42	0.18	0.03	0.03	0.06	0.24	1.89
1999	0.69	0.23	0.01	0.68	0.34	0.78	0.3	0.02	0	0	0	0.01	3.06
2000	0.07	0.64	0.96	0.31	0.13	0.19	0.39	0.19	0.03	0.07	0.35	0.32	3.65
2001	0.23	0.61	0.23	0.13	0.05	0.01	0.05	0.07	0.17	0.86	0.63	0.93	3.97
2002	0.27	0	0.1	0.04	0.06	1.06	0.51	0.5	0.32	0.13	0.09	0.03	3.11
2003	0.19	0.08	0.05	0.13	0.15	0.28	0.24	0.15	0.1	0.09	0.15	0.36	1.97
Average	**0.39**	**0.35**	**0.22**	**0.19**	**0.21**	**0.32**	**0.31**	**0.31**	**0.23**	**0.28**	**0.39**	**0.41**	**3.60**

Streamflow Reduction due to afforestation in the K40C catchment													
Units in million m^3													
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	TOTAL
1920	0.01	0.07	0.56	0.2	0.59	0.86	0.67	0.26	0.12	0.17	0.12	0.35	3.98
1921	0.18	0.29	0.64	0.57	0.24	0.36	0.93	0.61	0.22	0.56	0.4	0.38	5.38
1922	0.66	0.83	0.18	0.29	0.15	0.06	0.48	0.69	0.38	0.09	0.1	0.07	3.98
1923	0.18	0.45	0.2	0.13	0.15	0.08	0.15	0.17	0.15	0.07	0.47	0.85	3.05
1924	0.41	0.36	0.56	0.3	0.05	0.55	0.43	0.2	0.29	0.16	0.5	1.37	5.18
1925	0.79	0.28	0.3	0.11	0.05	0.49	0.23	0.09	0.31	0.34	0.24	0.23	3.46
1926	0.44	0.79	0.2	0.03	0.34	0.16	0.02	0.34	0.18	0.05	0.24	0.16	2.95
1927	0.17	0.16	0.07	0.11	0.24	0.81	0.62	0.17	0.09	0.06	0.2	0.4	3.1
1928	0.2	0.71	0.64	0.13	0.15	0.25	0.17	0.23	0.18	0.55	0.68	0.54	4.43
1929	0.32	0.08	0.17	0.21	0.8	0.56	0.22	0.43	0.36	0.3	0.57	0.49	4.51
1930	0.35	0.07	0.15	0.57	0.26	0.09	0.42	0.19	0.03	0.46	0.38	0.56	3.53
1931	0.87	0.27	0.88	0.94	0.82	0.37	0.04	0.22	0.25	0.17	0.09	1	5.92
1932	0.95	0.36	0.01	0	0.15	0.4	0.34	0.26	0.15	0.08	0.88	0.41	3.99
1933	0.05	0.43	0.13	0.1	0.26	0.54	0.19	0.03	0.03	0.57	0.43	0.3	3.06
1934	0.93	0.82	0.15	0.08	0.39	0.2	0.48	1.46	0.87	0.34	0.33	0.73	6.78
1935	0.59	0.67	0.55	0.18	0.31	0.28	0.07	0.47	0.21	0.44	0.21	0.5	4.48
1936	0.35	0.77	0.36	0.15	0.34	0.81	0.24	0	0.05	0.41	0.26	0.57	4.31
1937	0.4	0.44	0.46	0.34	0.05	0.15	0.3	0.14	0.08	0.08	0.14	0.41	2.99
1938	0.47	0.73	0.43	0.06	0.61	0.66	0.19	0	0	0.69	1.29	0.93	6.06
1939	0.39	0.23	0.17	0.55	0.93	0.62	0.18	0.06	0.04	0.07	0.03	0.37	3.64
1940	0.29	0.26	0.05	0.16	0.25	0.16	0.84	0.36	0.33	0.19	0.06	0.21	3.16
1941	0.68	0.57	0.76	0.83	0.26	0.53	0.29	0.55	0.34	0.15	0.2	0.12	5.28
1942	0.45	0.34	0.53	0.66	0.28	0.58	0.24	0.02	0.01	0.02	0.43	1.07	4.63
1943	0.73	0.9	0.66	0.09	0.13	0.42	0.24	0.95	0.63	0.77	0.4	0.84	6.76
1944	0.41	0.03	0.02	0.01	0	0.01	0.01	0.87	1	0.43	0.37	0.23	3.39
1945	0.66	0.24	0.11	0.28	0.35	0.86	0.33	0.01	0.01	0.1	0.12	0.24	3.31
1946	0.19	0.07	0.04	0.08	0.1	0.67	0.35	0.26	0.29	0.94	0.37	0.64	4
1947	0.46	0.25	0.03	0.61	0.36	0.16	0.65	0.26	0.04	0.07	0.06	0.42	3.37
1948	0.95	0.48	0.4	0.6	0.46	0.09	0.26	0.52	0.18	0	0.04	0.32	4.3
1949	0.24	0.84	0.26	0.01	0.14	0.17	0.13	0.1	0.03	0.74	0.71	0.59	3.96
1950	0.79	1.14	0.84	0.96	0.35	0.2	0.04	0.12	0.41	1.24	0.89	0.79	7.77
1951	0.19	0	0	0.47	0.4	0.11	0.33	0.41	0.29	0.28	0.79	1.28	4.55
1952	0.7	0.24	0.34	0.17	0.58	0.2	0.22	0.09	0.78	1.05	1.33	0.75	6.45
1953	1.04	0.79	0.29	0	0	0.29	0.47	0.89	0.48	0.55	1.8	0.76	7.36
1954	0.07	0.66	0.14	0.37	0.96	0.42	0.1	0.07	0.15	0.18	0.15	0.28	3.55
1955	0.59	0.86	0.19	0.17	0.34	0.7	0.35	0.83	0.31	0	0.01	0.19	4.54
1956	0.85	0.59	0.59	0.2	0.47	0.48	0.14	0.16	0.48	0.24	0.47	0.95	5.62
1957	0.52	0.03	0.05	0.13	0.07	0.61	0.44	0.62	0.34	0.06	0.49	0.24	3.6
1958	0.23	0.11	0.14	0.76	0.48	0.69	0.97	0.55	0.1	0.46	1.16	0.47	6.12
1959	0.8	0.24	0.2	0.59	0.15	0.73	0.51	0.38	0.31	0.24	0.09	0.58	4.82
1960	0.27	0.25	0.44	0.19	0.12	0.7	0.6	0.5	0.18	0.06	0.2	0.23	3.74
1961	0.37	0.22	0.11	0.52	0.28	0.65	0.36	0.07	0	0.01	1.04	0.5	4.13
1962	0.77	0.84	0.19	0.46	0.19	0.94	0.46	0.18	0.08	0.34	0.24	0.06	4.75
1963	0.2	0.09	0.42	0.53	0.27	0.25	0.3	0.12	0.69	0.32	0.51	1.29	4.99
1964	0.44	0.26	0.03	0.03	0.04	0.58	0.29	0.37	0.27	0.19	0.1	0.06	2.66
1965	0.9	1.07	0.65	0.43	0.53	0.12	0.19	0.48	0.19	0.02	0.62	0.51	5.71
1966	0.14	0.02	0.35	0.1	0.45	0.72	1.17	1.3	0.48	0.36	0.29	0.32	5.7
1967	0.2	0.27	0.06	0	0	0.4	0.26	0.25	1.03	0.43	0.39	0.53	3.82
1968	0.48	0.72	0.17	0.16	0.16	0.44	0.23	0.03	0.43	0.29	0.19	0.2	3.5
1969	0.45	0.13	0	0.09	0.48	0.2	0.02	0.01	0.04	0.09	0.78	0.46	2.75
1970	0.37	0.12	0.79	0.3	0.45	0.61	0.76	0.83	0.37	1.11	1.42	0.35	7.48
1971	0.04	0.48	0.1	0.06	0.67	0.47	0.16	0.19	0.22	0.17	0.53	0.27	3.36
1972	0.04	0.03	0.03	0.07	0.06	0.15	0.39	0.25	0.15	0.13	0.15	0.21	1.66
1973	0.12	0.31	0.15	0.53	0.57	0.68	0.23	0.58	0.28	0.03	0.63	0.46	4.57
1974	0.16	0.32	0.07	0.26	0.17	0.3	0.18	0.06	0.13	0.31	0.56	0.97	3.49
1975	0.33	0.25	0.28	0.11	0.17	0.38	0.13	0.26	0.24	0.56	0.37	0.2	3.28
1976	0.95	0.99	0.41	0.02	0.71	0.58	0.13	0.9	0.45	0.06	0.23	0.58	6.01

1977	0.31	0.42	0.13	0.08	0	0.04	0.14	0.09	0.3	0.17	0.23	0.21	2.12
1978	0.35	0.65	0.31	0.35	0.2	0.08	0.02	0.41	0.31	0.92	0.95	0.86	5.41
1979	0.25	0	0	0.2	0.07	0.02	0.25	0.18	0.3	0.19	0.15	0.5	2.11
1980	0.89	0.8	0.63	0.92	0.35	0.81	1.08	1.63	0.75	0.17	1.04	0.44	9.51
1981	0.64	0.19	0.27	0.12	0.14	0.29	1.03	0.35	0.33	0.48	0.22	0.7	4.76
1982	0.67	0.14	0	0	0.1	0.08	0.09	0.18	0.94	1.67	0.56	0.43	4.86
1983	0.74	0.51	0.25	0.07	0.05	0.47	0.17	0.04	0.07	0.6	0.28	0.06	3.31
1984	0.6	0.26	0.31	0.49	0.55	0.22	0.35	0.17	0.16	0.56	0.26	0.07	4
1985	0.83	0.69	0.68	0.38	0.1	0.06	0.05	0	0	0.06	0.9	0.52	4.27
1986	0.84	0.4	0.11	0.26	0.19	0.22	0.88	0.31	0.2	0.11	0.43	1.2	5.15
1987	0.42	0	0.1	0.1	0.05	0.08	0.57	0.43	0.28	0.14	0.32	0.32	2.81
1988	0.26	0.09	0.11	0.09	0.04	0.11	0.72	0.29	0.07	0.14	0.1	0.08	2.1
1989	0.89	1.04	0.24	0.05	0.65	0.26	0.6	0.45	0.77	0.32	0.1	0.1	5.47
1990	0.55	0.38	0.08	0.12	0.28	0.16	0.07	0.06	0.17	0.26	0.18	0.07	2.38
1991	0.72	0.25	0.53	0.24	0.37	0.32	0.14	0.33	0.31	0.98	0.86	0.26	5.31
1992	0.9	0.7	0.11	0.46	0.26	0.16	0.76	0.65	0.23	0.05	0.06	1.07	5.41
1993	0.45	0.24	0.44	0.45	0.28	0.33	0.55	0.21	0.03	0.27	1.01	0.44	4.7
1994	0.64	0.18	0.66	0.5	0.35	0.65	0.85	0.66	0.27	0.05	0.01	0.02	4.84
1995	0.04	0.77	0.69	0.24	0.03	0.07	0.08	0.02	0	0.14	0.22	0.22	2.52
1996	1.02	1.32	0.81	0.15	0.38	0.8	0.72	0.84	0.63	0.22	0.32	0.15	7.36
1997	0.52	0.14	0	0.11	0.11	0.75	0.25	0.05	0.02	0.09	0.24	0.16	2.44
1998	0.05	0.15	0.19	0.27	0.33	0.57	0.58	0.19	0	0.05	0.11	0.28	2.77
1999	0.77	0.23	0	0.69	0.42	0.82	0.29	0.01	0	0	0	0.02	3.25
2000	0.15	0.74	0.96	0.37	0.23	0.29	0.52	0.2	0.01	0.15	0.54	0.41	4.57
2001	0.31	0.71	0.28	0.21	0.08	0	0.1	0.1	0.26	0.9	0.75	0.98	4.68
2002	0.29	0.02	0.26	0.09	0.09	1.03	0.49	0.68	0.39	0.16	0.13	0.04	3.67
2003	0.34	0.12	0.08	0.21	0.31	0.54	0.36	0.17	0.11	0.12	0.19	0.53	3.08
Average	**0.48**	**0.42**	**0.30**	**0.28**	**0.29**	**0.40**	**0.37**	**0.35**	**0.27**	**0.32**	**0.43**	**0.46**	**4.35**

Streamflow Reduction due to afforestation in the K40D catchment

Units in million m^3

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	TOTAL
1920	0.01	0.07	0.56	0.2	0.59	0.86	0.67	0.26	0.12	0.17	0.12	0.35	3.98
1921	0.18	0.29	0.64	0.57	0.24	0.36	0.93	0.61	0.22	0.56	0.4	0.38	5.38
1922	0.66	0.83	0.18	0.29	0.15	0.06	0.48	0.69	0.38	0.09	0.1	0.07	3.98
1923	0.18	0.45	0.2	0.13	0.15	0.08	0.15	0.17	0.15	0.07	0.47	0.85	3.05
1924	0.41	0.36	0.56	0.3	0.05	0.55	0.43	0.2	0.29	0.16	0.5	1.37	5.18
1925	0.79	0.28	0.3	0.11	0.05	0.49	0.23	0.09	0.31	0.34	0.24	0.23	3.46
1926	0.44	0.79	0.2	0.03	0.34	0.16	0.02	0.34	0.18	0.05	0.24	0.16	2.95
1927	0.17	0.16	0.07	0.11	0.24	0.81	0.62	0.17	0.09	0.06	0.2	0.4	3.1
1928	0.2	0.71	0.64	0.13	0.15	0.25	0.17	0.23	0.18	0.55	0.68	0.54	4.43
1929	0.32	0.08	0.17	0.21	0.8	0.56	0.22	0.43	0.36	0.3	0.57	0.49	4.51
1930	0.35	0.07	0.15	0.57	0.26	0.09	0.42	0.19	0.03	0.46	0.38	0.56	3.53
1931	0.87	0.27	0.88	0.94	0.82	0.37	0.04	0.22	0.25	0.17	0.09	1	5.92
1932	0.95	0.36	0.01	0	0.15	0.4	0.34	0.26	0.15	0.08	0.88	0.41	3.99
1933	0.05	0.43	0.13	0.1	0.26	0.54	0.19	0.03	0.03	0.57	0.43	0.3	3.06
1934	0.93	0.82	0.15	0.08	0.39	0.2	0.48	1.46	0.87	0.34	0.33	0.73	6.78
1935	0.59	0.67	0.55	0.18	0.31	0.28	0.07	0.47	0.21	0.44	0.21	0.5	4.48
1936	0.35	0.77	0.36	0.15	0.34	0.81	0.24	0	0.05	0.41	0.26	0.57	4.31
1937	0.4	0.44	0.46	0.34	0.05	0.15	0.3	0.14	0.08	0.08	0.14	0.41	2.99
1938	0.47	0.73	0.43	0.06	0.61	0.66	0.19	0	0	0.69	1.29	0.93	6.06
1939	0.39	0.23	0.17	0.55	0.93	0.62	0.18	0.06	0.04	0.07	0.03	0.37	3.64
1940	0.29	0.26	0.05	0.16	0.25	0.16	0.84	0.36	0.33	0.19	0.06	0.21	3.16
1941	0.68	0.57	0.76	0.83	0.26	0.53	0.29	0.55	0.34	0.15	0.2	0.12	5.28
1942	0.45	0.34	0.53	0.66	0.28	0.58	0.24	0.02	0.01	0.02	0.43	1.07	4.63
1943	0.73	0.9	0.66	0.09	0.13	0.42	0.24	0.95	0.63	0.77	0.4	0.84	6.76
1944	0.41	0.03	0.02	0.01	0	0.01	0.01	0.87	1	0.43	0.37	0.23	3.39
1945	0.66	0.24	0.11	0.28	0.35	0.86	0.33	0.01	0.01	0.1	0.12	0.24	3.31
1946	0.19	0.07	0.04	0.08	0.1	0.67	0.35	0.26	0.29	0.94	0.37	0.64	4
1947	0.46	0.25	0.03	0.61	0.36	0.16	0.65	0.26	0.04	0.07	0.06	0.42	3.37
1948	0.95	0.48	0.4	0.6	0.46	0.09	0.26	0.52	0.18	0	0.04	0.32	4.3
1949	0.24	0.84	0.26	0.01	0.14	0.17	0.13	0.1	0.03	0.74	0.71	0.59	3.96
1950	0.79	1.14	0.84	0.96	0.35	0.2	0.04	0.12	0.41	1.24	0.89	0.79	7.77
1951	0.19	0	0	0.47	0.4	0.11	0.33	0.41	0.29	0.28	0.79	1.28	4.55
1952	0.7	0.24	0.34	0.17	0.58	0.2	0.22	0.09	0.78	1.05	1.33	0.75	6.45
1953	1.04	0.79	0.29	0	0	0.29	0.47	0.89	0.48	0.55	1.8	0.76	7.36
1954	0.07	0.66	0.14	0.37	0.96	0.42	0.1	0.07	0.15	0.18	0.15	0.28	3.55
1955	0.59	0.86	0.19	0.17	0.34	0.7	0.35	0.83	0.31	0	0.01	0.19	4.54
1956	0.85	0.59	0.59	0.2	0.47	0.48	0.14	0.16	0.48	0.24	0.47	0.95	5.62
1957	0.52	0.03	0.05	0.13	0.07	0.61	0.44	0.62	0.34	0.06	0.49	0.24	3.6
1958	0.23	0.11	0.14	0.76	0.48	0.69	0.97	0.55	0.1	0.46	1.16	0.47	6.12
1959	0.8	0.24	0.2	0.59	0.15	0.73	0.51	0.38	0.31	0.24	0.09	0.58	4.82
1960	0.27	0.25	0.44	0.19	0.12	0.7	0.6	0.5	0.18	0.06	0.2	0.23	3.74
1961	0.37	0.22	0.11	0.52	0.28	0.65	0.36	0.07	0	0.01	1.04	0.5	4.13
1962	0.77	0.84	0.19	0.46	0.19	0.94	0.46	0.18	0.08	0.34	0.24	0.06	4.75
1963	0.2	0.09	0.42	0.53	0.27	0.25	0.3	0.12	0.69	0.32	0.51	1.29	4.99
1964	0.44	0.26	0.03	0.03	0.04	0.58	0.29	0.37	0.27	0.19	0.1	0.06	2.66
1965	0.9	1.07	0.65	0.43	0.53	0.12	0.19	0.48	0.19	0.02	0.62	0.51	5.71
1966	0.14	0.02	0.35	0.1	0.45	0.72	1.17	1.3	0.48	0.36	0.29	0.32	5.7
1967	0.2	0.27	0.06	0	0	0.4	0.26	0.25	1.03	0.43	0.39	0.53	3.82
1968	0.48	0.72	0.17	0.16	0.16	0.44	0.23	0.03	0.43	0.29	0.19	0.2	3.5
1969	0.45	0.13	0	0.09	0.48	0.2	0.02	0.01	0.04	0.09	0.78	0.46	2.75
1970	0.37	0.12	0.79	0.3	0.45	0.61	0.76	0.83	0.37	1.11	1.42	0.35	7.48
1971	0.04	0.48	0.1	0.06	0.67	0.47	0.16	0.19	0.22	0.17	0.53	0.27	3.36
1972	0.04	0.03	0.03	0.07	0.06	0.15	0.39	0.25	0.15	0.13	0.15	0.21	1.66
1973	0.12	0.31	0.15	0.53	0.57	0.68	0.23	0.58	0.28	0.03	0.63	0.46	4.57
1974	0.16	0.32	0.07	0.26	0.17	0.3	0.18	0.06	0.13	0.31	0.56	0.97	3.49
1975	0.33	0.25	0.28	0.11	0.17	0.38	0.13	0.26	0.24	0.56	0.37	0.2	3.28
1976	0.95	0.99	0.41	0.02	0.71	0.58	0.13	0.9	0.45	0.06	0.23	0.58	6.01

1977	0.31	0.42	0.13	0.08	0	0.04	0.14	0.09	0.3	0.17	0.23	0.21	2.12
1978	0.35	0.65	0.31	0.35	0.2	0.08	0.02	0.41	0.31	0.92	0.95	0.86	5.41
1979	0.25	0	0	0.2	0.07	0.02	0.25	0.18	0.3	0.19	0.15	0.5	2.11
1980	0.89	0.8	0.63	0.92	0.35	0.81	1.08	1.63	0.75	0.17	1.04	0.44	9.51
1981	0.64	0.19	0.27	0.12	0.14	0.29	1.03	0.35	0.33	0.48	0.22	0.7	4.76
1982	0.67	0.14	0	0	0.1	0.08	0.09	0.18	0.94	1.67	0.56	0.43	4.86
1983	0.74	0.51	0.25	0.07	0.05	0.47	0.17	0.04	0.07	0.6	0.28	0.06	3.31
1984	0.6	0.26	0.31	0.49	0.55	0.22	0.35	0.17	0.16	0.56	0.26	0.07	4
1985	0.83	0.69	0.68	0.38	0.1	0.06	0.05	0	0	0.06	0.9	0.52	4.27
1986	0.84	0.4	0.11	0.26	0.19	0.22	0.88	0.31	0.2	0.11	0.43	1.2	5.15
1987	0.42	0	0.1	0.1	0.05	0.08	0.57	0.43	0.28	0.14	0.32	0.32	2.81
1988	0.26	0.09	0.11	0.09	0.04	0.11	0.72	0.29	0.07	0.14	0.1	0.08	2.1
1989	0.89	1.04	0.24	0.05	0.65	0.26	0.6	0.45	0.77	0.32	0.1	0.1	5.47
1990	0.55	0.38	0.08	0.12	0.28	0.16	0.07	0.06	0.17	0.26	0.18	0.07	2.38
1991	0.72	0.25	0.53	0.24	0.37	0.32	0.14	0.33	0.31	0.98	0.86	0.26	5.31
1992	0.9	0.7	0.11	0.46	0.26	0.16	0.76	0.65	0.23	0.05	0.06	1.07	5.41
1993	0.45	0.24	0.44	0.45	0.28	0.33	0.55	0.21	0.03	0.27	1.01	0.44	4.7
1994	0.64	0.18	0.66	0.5	0.35	0.65	0.85	0.66	0.27	0.05	0.01	0.02	4.84
1995	0.04	0.77	0.69	0.24	0.03	0.07	0.08	0.02	0	0.14	0.22	0.22	2.52
1996	1.02	1.32	0.81	0.15	0.38	0.8	0.72	0.84	0.63	0.22	0.32	0.15	7.36
1997	0.52	0.14	0	0.11	0.11	0.75	0.25	0.05	0.02	0.09	0.24	0.16	2.44
1998	0.05	0.15	0.19	0.27	0.33	0.57	0.58	0.19	0	0.05	0.11	0.28	2.77
1999	0.77	0.23	0	0.69	0.42	0.82	0.29	0.01	0	0	0	0.02	3.25
2000	0.15	0.74	0.96	0.37	0.23	0.29	0.52	0.2	0.01	0.15	0.54	0.41	4.57
2001	0.31	0.71	0.28	0.21	0.08	0	0.1	0.1	0.26	0.9	0.75	0.98	4.68
2002	0.29	0.02	0.26	0.09	0.09	1.03	0.49	0.68	0.39	0.16	0.13	0.04	3.67
2003	0.34	0.12	0.08	0.21	0.31	0.54	0.36	0.17	0.11	0.12	0.19	0.53	3.08
Average	**0.48**	**0.42**	**0.30**	**0.28**	**0.29**	**0.40**	**0.37**	**0.35**	**0.27**	**0.32**	**0.43**	**0.46**	**4.35**

I7 STREAMFLOW REDUCTION TIME SERIES (ALIEN VEGETATION)

Streamflow Reduction due to alien vegetation in the K50A catchment

Units in million m^3

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	TOTAL
1920	0.04	0.04	0.12	0.05	0.15	0.19	0.14	0.08	0.05	0.06	0.05	0.11	1.08
1921	0.05	0.05	0.11	0.08	0.04	0.1	0.27	0.17	0.07	0.16	0.1	0.1	1.3
1922	0.14	0.23	0.08	0.07	0.03	0.02	0.11	0.13	0.1	0.07	0.04	0.03	1.05
1923	0.05	0.1	0.06	0.02	0.02	0.02	0.03	0.04	0.04	0.04	0.09	0.16	0.67
1924	0.11	0.07	0.06	0.04	0.02	0.04	0.06	0.05	0.06	0.06	0.1	0.57	1.24
1925	0.33	0.1	0.1	0.03	0.04	0.12	0.07	0.04	0.07	0.09	0.1	0.11	1.2
1926	0.11	0.26	0.09	0.02	0.06	0.03	0.02	0.12	0.07	0.03	0.11	0.08	1
1927	0.05	0.02	0.02	0.02	0.06	0.25	0.15	0.04	0.04	0.03	0.05	0.11	0.84
1928	0.09	0.3	0.18	0.03	0.03	0.02	0.04	0.04	0.04	0.14	0.14	0.11	1.16
1929	0.08	0.05	0.05	0.04	0.25	0.13	0.04	0.09	0.09	0.07	0.15	0.13	1.17
1930	0.1	0.03	0.03	0.1	0.06	0.02	0.08	0.06	0.04	0.12	0.11	0.17	0.92
1931	0.23	0.08	0.55	0.4	0.12	0.06	0.01	0.03	0.07	0.05	0.03	0.5	2.13
1932	0.33	0.09	0.02	0.01	0.02	0.08	0.08	0.06	0.05	0.05	0.25	0.13	1.17
1933	0.04	0.06	0.02	0	0.04	0.08	0.05	0.02	0.02	0.09	0.12	0.08	0.62
1934	0.37	0.19	0.03	0.03	0.04	0.03	0.09	0.77	0.37	0.08	0.09	0.14	2.23
1935	0.17	0.17	0.1	0.07	0.07	0.07	0.05	0.11	0.05	0.11	0.07	0.15	1.19
1936	0.13	0.27	0.12	0.03	0.1	0.15	0.07	0.02	0.04	0.1	0.09	0.15	1.27
1937	0.13	0.09	0.05	0.07	0.03	0.04	0.04	0.04	0.02	0.02	0.05	0.12	0.7
1938	0.17	0.19	0.11	0.03	0.14	0.13	0.05	0.01	0	0.19	0.38	0.27	1.67
1939	0.1	0.06	0.03	0.17	0.3	0.14	0.04	0.03	0.02	0.04	0.02	0.09	1.04
1940	0.07	0.07	0.02	0.02	0.04	0.04	0.21	0.1	0.14	0.09	0.03	0.08	0.91
1941	0.26	0.15	0.14	0.17	0.07	0.07	0.05	0.11	0.11	0.09	0.07	0.05	1.34
1942	0.07	0.05	0.08	0.15	0.08	0.12	0.07	0.02	0	0.02	0.07	0.4	1.13
1943	0.22	0.34	0.2	0.02	0.03	0.06	0.05	0.42	0.25	0.17	0.09	0.19	2.04
1944	0.12	0.03	0.03	0.02	0	0	0.02	0.27	0.27	0.13	0.07	0.05	1.01
1945	0.09	0.04	0.06	0.05	0.04	0.18	0.1	0.01	0.02	0.05	0.05	0.07	0.76
1946	0.06	0.04	0.02	0.02	0.02	0.08	0.08	0.09	0.08	0.21	0.09	0.09	0.88
1947	0.07	0.05	0.02	0.11	0.06	0.04	0.1	0.07	0.02	0.04	0.03	0.09	0.7
1948	0.19	0.09	0.07	0.11	0.06	0.02	0.03	0.1	0.06	0.02	0.02	0.08	0.85
1949	0.06	0.21	0.09	0.02	0.02	0.04	0.04	0.02	0.02	0.13	0.13	0.11	0.89
1950	0.15	0.44	0.24	0.34	0.11	0.02	0.02	0.02	0.09	0.34	0.24	0.18	2.19
1951	0.08	0.01	0	0.12	0.08	0.04	0.07	0.08	0.09	0.09	0.25	0.48	1.39
1952	0.22	0.06	0.06	0.05	0.24	0.09	0.03	0.03	0.15	0.19	0.34	0.16	1.62
1953	0.37	0.19	0.06	0.01	0	0.07	0.06	0.16	0.11	0.17	0.77	0.32	2.29
1954	0.05	0.31	0.11	0.09	0.42	0.15	0.03	0.03	0.05	0.05	0.06	0.09	1.44
1955	0.15	0.28	0.08	0.03	0.05	0.15	0.11	0.29	0.12	0.03	0.02	0.09	1.4
1956	0.26	0.14	0.11	0.05	0.07	0.06	0.04	0.09	0.13	0.07	0.11	0.19	1.32
1957	0.13	0.03	0.02	0.03	0.02	0.16	0.13	0.17	0.09	0.03	0.11	0.07	0.99
1958	0.07	0.04	0.04	0.25	0.13	0.06	0.25	0.15	0.04	0.09	0.25	0.14	1.51
1959	0.25	0.1	0.03	0.17	0.07	0.24	0.12	0.05	0.07	0.08	0.06	0.16	1.4
1960	0.08	0.07	0.05	0.03	0.03	0.13	0.1	0.13	0.07	0.04	0.09	0.08	0.9
1961	0.15	0.07	0.02	0.11	0.07	0.13	0.1	0.05	0.02	0.03	0.43	0.19	1.37
1962	0.18	0.16	0.04	0.03	0.02	0.38	0.17	0.03	0.01	0.09	0.11	0.05	1.27
1963	0.02	0.02	0.1	0.09	0.04	0.06	0.08	0.05	0.13	0.09	0.09	0.44	1.21
1964	0.17	0.11	0.03	0.02	0.01	0.12	0.12	0.11	0.09	0.05	0.03	0.04	0.9
1965	0.3	0.26	0.11	0.05	0.08	0.04	0.03	0.13	0.06	0.02	0.16	0.13	1.37
1966	0.06	0.03	0.05	0.02	0.04	0.1	0.43	0.33	0.11	0.14	0.12	0.08	1.51
1967	0.04	0.04	0.03	0.03	0.04	0.06	0.06	0.08	0.33	0.13	0.07	0.09	1
1968	0.11	0.11	0.05	0.04	0.04	0.06	0.04	0.03	0.08	0.08	0.07	0.07	0.78
1969	0.12	0.07	0.02	0.04	0.06	0.04	0.02	0.02	0.02	0.03	0.21	0.14	0.79
1970	0.08	0.03	0.33	0.13	0.11	0.12	0.15	0.2	0.12	0.42	0.43	0.12	2.24
1971	0.02	0.11	0.03	0.03	0.25	0.13	0.03	0.09	0.09	0.11	0.17	0.09	1.15
1972	0.03	0.02	0.02	0.02	0.02	0.04	0.08	0.06	0.05	0.04	0.04	0.08	0.5
1973	0.06	0.12	0.06	0.09	0.11	0.11	0.05	0.14	0.07	0.03	0.22	0.16	1.22
1974	0.09	0.07	0.01	0.04	0.04	0.04	0.04	0.03	0.02	0.08	0.12	0.23	0.81
1975	0.1	0.06	0.06	0.04	0.03	0.12	0.06	0.06	0.05	0.11	0.1	0.05	0.84
1976	0.35	0.22	0.09	0.03	0.21	0.11	0.02	0.35	0.21	0.04	0.06	0.08	1.77

1977	0.1	0.1	0.04	0.02	0	0.02	0.02	0.02	0.06	0.04	0.1	0.08	0.6
1978	0.1	0.11	0.07	0.04	0.02	0.02	0.02	0.06	0.06	0.18	0.25	0.17	1.1
1979	0.07	0.02	0.02	0.05	0.02	0	0.06	0.06	0.08	0.06	0.05	0.08	0.57
1980	0.13	0.19	0.13	0.25	0.09	0.28	0.35	0.59	0.21	0.03	0.41	0.16	2.82
1981	0.16	0.06	0.03	0.03	0.02	0.05	0.56	0.22	0.03	0.07	0.07	0.15	1.45
1982	0.13	0.06	0.01	0.01	0.04	0.04	0.02	0.06	0.27	0.53	0.2	0.14	1.51
1983	0.23	0.08	0.07	0.03	0.02	0.06	0.04	0.02	0.04	0.08	0.06	0.04	0.77
1984	0.1	0.06	0.07	0.11	0.13	0.06	0.09	0.06	0.04	0.09	0.06	0.04	0.91
1985	0.33	0.2	0.15	0.09	0.03	0.03	0.02	0.02	0.01	0.02	0.22	0.13	1.25
1986	0.26	0.11	0.03	0.07	0.04	0.04	0.19	0.08	0.05	0.04	0.06	0.41	1.38
1987	0.17	0.03	0.02	0.02	0.02	0.02	0.12	0.09	0.07	0.06	0.06	0.06	0.74
1988	0.07	0.06	0.02	0.02	0	0.02	0.12	0.07	0.03	0.06	0.04	0.06	0.57
1989	0.38	0.33	0.08	0.03	0.08	0.04	0.08	0.08	0.25	0.13	0.05	0.05	1.58
1990	0.15	0.12	0.05	0.04	0.06	0.04	0.01	0.04	0.04	0.05	0.05	0.02	0.67
1991	0.12	0.05	0.06	0.03	0.08	0.06	0.04	0.08	0.08	0.23	0.38	0.16	1.37
1992	0.42	0.21	0.02	0.02	0.03	0.02	0.1	0.12	0.1	0.05	0.06	0.59	1.74
1993	0.23	0.02	0.07	0.04	0.06	0.04	0.09	0.06	0.03	0.06	0.24	0.13	1.07
1994	0.15	0.06	0.21	0.09	0.03	0.15	0.19	0.16	0.08	0.06	0.03	0.04	1.25
1995	0.03	0.35	0.15	0.05	0.02	0	0	0	0	0.04	0.06	0.06	0.76
1996	0.45	0.68	0.27	0.02	0.05	0.13	0.15	0.22	0.15	0.06	0.16	0.08	2.42
1997	0.14	0.07	0.01	0.04	0.02	0.11	0.05	0.07	0.06	0.04	0.08	0.07	0.76
1998	0.04	0.06	0.05	0.04	0.06	0.08	0.1	0.05	0.02	0.02	0.05	0.05	0.62
1999	0.15	0.06	0.02	0.12	0.1	0.19	0.09	0.01	0	0	0	0.02	0.76
2000	0.07	0.17	0.13	0.1	0.05	0.03	0.15	0.07	0.01	0.02	0.11	0.11	1.02
2001	0.05	0.11	0.04	0.06	0.02	0.02	0.04	0.04	0.08	0.19	0.19	0.27	1.11
2002	0.11	0.07	0.04	0.01	0.06	0.55	0.23	0.2	0.14	0.06	0.05	0.04	1.56
2003	0.05	0.02	0.02	0.04	0.06	0.11	0.11	0.06	0.03	0.05	0.04	0.12	0.71
Average	0.12	0.08	0.06	0.07	0.09	0.09	0.1	0.08	0.09	0.13	0.14	1.2	**1.20**

Streamflow Reduction due to alien vegetation in the K50B catchment

Units in million m^3

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	TOTAL
1920	0.05	0.06	0.13	0.05	0.17	0.16	0.17	0.09	0.07	0.09	0.07	0.14	1.25
1921	0.07	0.05	0.11	0.05	0.05	0.13	0.27	0.18	0.07	0.2	0.12	0.12	1.42
1922	0.13	0.23	0.07	0.07	0.03	0.03	0.13	0.13	0.13	0.07	0.05	0.03	1.1
1923	0.07	0.13	0.07	0.01	0.02	0.03	0.03	0.05	0.04	0.03	0.09	0.15	0.72
1924	0.11	0.08	0.06	0.03	0.01	0.06	0.08	0.05	0.08	0.07	0.11	0.64	1.38
1925	0.41	0.13	0.12	0.05	0.05	0.14	0.08	0.04	0.07	0.13	0.11	0.11	1.44
1926	0.13	0.31	0.11	0.04	0.06	0.05	0.02	0.16	0.09	0.05	0.15	0.1	1.27
1927	0.04	0.03	0.01	0.03	0.06	0.28	0.16	0.03	0.05	0.05	0.07	0.14	0.95
1928	0.11	0.36	0.21	0.04	0.02	0.01	0.02	0.06	0.07	0.18	0.16	0.15	1.39
1929	0.1	0.05	0.07	0.03	0.25	0.11	0.03	0.11	0.1	0.09	0.16	0.16	1.26
1930	0.1	0.02	0.02	0.08	0.05	0.02	0.08	0.07	0.05	0.16	0.14	0.24	1.03
1931	0.28	0.08	0.6	0.42	0.11	0.06	0.01	0.04	0.07	0.07	0.05	0.61	2.4
1932	0.42	0.1	0.02	0.01	0.03	0.08	0.09	0.1	0.06	0.05	0.32	0.15	1.43
1933	0.02	0.05	0.02	0	0.02	0.09	0.04	0.01	0.03	0.14	0.16	0.12	0.7
1934	0.42	0.18	0.02	0.03	0.03	0.04	0.08	0.79	0.36	0.08	0.08	0.14	2.25
1935	0.17	0.16	0.11	0.09	0.1	0.1	0.03	0.11	0.08	0.13	0.08	0.14	1.3
1936	0.16	0.29	0.12	0.02	0.1	0.18	0.07	0	0.05	0.15	0.13	0.24	1.51
1937	0.17	0.09	0.09	0.07	0.03	0.05	0.05	0.03	0.03	0.03	0.06	0.14	0.84
1938	0.2	0.19	0.11	0.02	0.16	0.11	0.05	0.02	0	0.2	0.47	0.3	1.83
1939	0.09	0.04	0.04	0.19	0.29	0.14	0.04	0.04	0.02	0.04	0.03	0.13	1.09
1940	0.1	0.08	0.02	0.03	0.04	0.05	0.22	0.12	0.18	0.1	0.04	0.11	1.09
1941	0.27	0.14	0.17	0.18	0.05	0.05	0.03	0.16	0.13	0.1	0.09	0.05	1.42
1942	0.07	0.05	0.08	0.13	0.08	0.09	0.05	0.03	0.01	0.02	0.13	0.52	1.26
1943	0.28	0.35	0.18	0.03	0.04	0.03	0.05	0.5	0.29	0.21	0.11	0.24	2.31
1944	0.14	0.03	0.04	0.02	0.02	0	0.02	0.26	0.32	0.16	0.1	0.05	1.16
1945	0.1	0.04	0.08	0.05	0.03	0.19	0.08	0.02	0.02	0.06	0.08	0.08	0.83
1946	0.06	0.02	0.03	0.05	0.03	0.08	0.11	0.11	0.1	0.3	0.14	0.08	1.11
1947	0.07	0.06	0.02	0.08	0.06	0.03	0.12	0.08	0.03	0.04	0.03	0.1	0.72
1948	0.19	0.08	0.03	0.12	0.08	0.02	0.05	0.14	0.08	0.01	0.04	0.09	0.93
1949	0.07	0.22	0.08	0.02	0.02	0.03	0.06	0.05	0.01	0.1	0.12	0.12	0.9
1950	0.16	0.37	0.2	0.37	0.11	0.03	0.01	0.05	0.13	0.39	0.25	0.19	2.26
1951	0.06	0.02	0.02	0.11	0.05	0.01	0.12	0.11	0.11	0.16	0.3	0.42	1.49
1952	0.16	0.01	0.05	0.03	0.11	0.04	0.03	0.03	0.33	0.35	0.39	0.16	1.69
1953	0.39	0.19	0.05	0.01	0.02	0.08	0.07	0.2	0.14	0.22	0.77	0.3	2.44
1954	0.04	0.33	0.1	0.12	0.47	0.15	0.01	0.03	0.05	0.07	0.06	0.1	1.53
1955	0.19	0.28	0.08	0.01	0.03	0.13	0.1	0.34	0.15	0.02	0.02	0.13	1.48
1956	0.28	0.13	0.1	0.05	0.05	0.05	0.03	0.1	0.16	0.08	0.14	0.26	1.43
1957	0.13	0.04	0.02	0.02	0.01	0.16	0.18	0.27	0.13	0.04	0.1	0.07	1.17
1958	0.07	0.04	0.03	0.27	0.12	0.05	0.24	0.17	0.04	0.07	0.27	0.15	1.52
1959	0.33	0.12	0.02	0.19	0.07	0.24	0.13	0.07	0.07	0.12	0.07	0.16	1.59
1960	0.08	0.07	0.05	0.05	0.02	0.11	0.11	0.19	0.08	0.07	0.11	0.09	1.03
1961	0.15	0.07	0.02	0.13	0.06	0.16	0.1	0.04	0.02	0.03	0.46	0.2	1.44
1962	0.18	0.15	0.04	0.02	0	0.4	0.18	0.04	0.02	0.13	0.13	0.07	1.36
1963	0.02	0.02	0.13	0.13	0.03	0.05	0.08	0.05	0.17	0.1	0.11	0.58	1.47
1964	0.19	0.1	0.04	0.01	0.01	0.17	0.2	0.21	0.12	0.07	0.03	0.03	1.18
1965	0.21	0.23	0.07	0.04	0.07	0.04	0.05	0.17	0.08	0.03	0.21	0.16	1.36
1966	0.05	0.04	0.03	0.01	0.03	0.13	0.45	0.39	0.14	0.19	0.14	0.1	1.7
1967	0.05	0.02	0.02	0.02	0.04	0.08	0.04	0.09	0.46	0.17	0.09	0.12	1.2
1968	0.09	0.08	0.03	0.05	0.05	0.06	0.05	0.03	0.2	0.14	0.08	0.07	0.93
1969	0.11	0.07	0	0.05	0.05	0.03	0.02	0	0.02	0.03	0.25	0.14	0.77
1970	0.08	0.02	0.34	0.14	0.11	0.11	0.19	0.26	0.14	0.46	0.45	0.11	2.41
1971	0.02	0.12	0.05	0.03	0.26	0.12	0.04	0.11	0.11	0.16	0.21	0.09	1.32
1972	0.02	0.02	0	0.02	0.01	0.05	0.06	0.06	0.06	0.05	0.06	0.11	0.52
1973	0.08	0.11	0.06	0.11	0.1	0.11	0.05	0.14	0.08	0.03	0.25	0.21	1.33
1974	0.09	0.07	0.02	0.06	0.05	0.03	0.03	0.03	0.03	0.14	0.17	0.28	1
1975	0.1	0.07	0.07	0.03	0.03	0.12	0.07	0.03	0.05	0.16	0.13	0.07	0.93
1976	0.37	0.23	0.1	0.02	0.24	0.12	0.03	0.39	0.22	0.06	0.07	0.1	1.95

1977	0.1	0.1	0.03	0.02	0	0.03	0.03	0.04	0.09	0.07	0.12	0.1	0.73
1978	0.12	0.12	0.08	0.05	0.03	0.01	0.03	0.06	0.06	0.19	0.25	0.16	1.16
1979	0.07	0.02	0.02	0.03	0.03	0.02	0.08	0.08	0.12	0.08	0.08	0.09	0.72
1980	0.18	0.19	0.11	0.27	0.1	0.3	0.42	0.56	0.17	0.02	0.48	0.16	2.96
1981	0.16	0.07	0.04	0.02	0.02	0.05	0.58	0.23	0.04	0.09	0.07	0.18	1.55
1982	0.16	0.06	0.02	0.01	0.06	0.05	0.03	0.08	0.36	0.56	0.21	0.16	1.76
1983	0.26	0.11	0.08	0.04	0.02	0.05	0.05	0.03	0.05	0.11	0.08	0.05	0.93
1984	0.12	0.07	0.06	0.09	0.11	0.06	0.14	0.07	0.05	0.1	0.07	0.05	0.99
1985	0.39	0.2	0.15	0.12	0.04	0.02	0.01	0.01	0.02	0.03	0.28	0.17	1.44
1986	0.25	0.1	0.02	0.03	0.03	0.05	0.21	0.1	0.05	0.03	0.06	0.51	1.44
1987	0.19	0.02	0	0	0	0.02	0.12	0.09	0.1	0.08	0.09	0.13	0.84
1988	0.1	0.07	0.04	0.02	0.02	0.01	0.12	0.08	0.05	0.09	0.06	0.06	0.72
1989	0.52	0.37	0.07	0.02	0.05	0.02	0.08	0.08	0.31	0.14	0.07	0.05	1.78
1990	0.13	0.08	0.02	0.04	0.08	0.05	0.01	0.05	0.05	0.06	0.03	0.03	0.63
1991	0.15	0.06	0.09	0.05	0.08	0.04	0.05	0.12	0.12	0.26	0.6	0.23	1.85
1992	0.45	0.24	0.02	0.01	0.02	0.02	0.05	0.09	0.09	0.1	0.1	0.74	1.93
1993	0.26	0.01	0.11	0.05	0.03	0.03	0.11	0.08	0.05	0.08	0.32	0.18	1.31
1994	0.16	0.05	0.21	0.08	0.04	0.14	0.23	0.2	0.12	0.08	0.06	0.07	1.44
1995	0.03	0.31	0.14	0.04	0.02	0	0.01	0.02	0	0.05	0.08	0.07	0.77
1996	0.43	0.61	0.22	0.02	0.03	0.11	0.14	0.22	0.14	0.1	0.15	0.09	2.26
1997	0.15	0.07	0	0.05	0.01	0.13	0.06	0.11	0.06	0.08	0.14	0.12	0.98
1998	0.05	0.08	0.04	0.05	0.05	0.08	0.1	0.05	0.02	0.03	0.08	0.08	0.71
1999	0.19	0.08	0	0.09	0.1	0.22	0.09	0.02	0.01	0	0.02	0.03	0.85
2000	0.09	0.25	0.13	0.13	0.05	0.02	0.22	0.1	0.02	0.04	0.22	0.18	1.45
2001	0.07	0.15	0.07	0.06	0.03	0	0.03	0.08	0.09	0.22	0.24	0.29	1.33
2002	0.09	0.13	0.07	0.02	0.03	0.52	0.23	0.29	0.14	0.03	0.06	0.04	1.65
2003	0.04	0.02	0.03	0.01	0.04	0.12	0.12	0.05	0.03	0.05	0.07	0.13	0.71
Average	0.12	0.08	0.07	0.06	0.09	0.1	0.12	0.1	0.11	0.15	0.17	1.33	**1.33**

Streamflow Reduction due to alien vegetation in the K40A catchment

Units in million m^3

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	TOTAL
1920	0.01	0	0.17	0.07	0.18	0.28	0.2	0.09	0.02	0.03	0.03	0.06	1.14
1921	0.05	0.06	0.2	0.13	0.04	0.11	0.41	0.2	0.05	0.16	0.14	0.1	1.65
1922	0.16	0.33	0.09	0.05	0.04	0.01	0.09	0.16	0.1	0.03	0.03	0.03	1.12
1923	0.03	0.06	0.03	0.02	0.02	0.02	0.02	0.02	0.03	0.03	0.1	0.15	0.53
1924	0.08	0.04	0.13	0.07	0.01	0.22	0.13	0.06	0.06	0.04	0.14	0.81	1.79
1925	0.32	0.05	0.05	0.03	0	0.08	0.04	0.01	0.07	0.09	0.06	0.04	0.84
1926	0.11	0.35	0.12	0.02	0.11	0.06	0.01	0.08	0.06	0.01	0.06	0.03	1.02
1927	0.04	0.07	0.03	0.03	0.03	0.29	0.21	0.06	0.01	0.02	0.06	0.1	0.95
1928	0.06	0.38	0.23	0.05	0.03	0.07	0.04	0.04	0.04	0.12	0.16	0.14	1.36
1929	0.07	0.02	0.06	0.06	0.38	0.18	0.08	0.09	0.07	0.07	0.14	0.13	1.35
1930	0.09	0.05	0.03	0.22	0.1	0.03	0.11	0.06	0.02	0.1	0.08	0.09	0.98
1931	0.22	0.09	0.91	0.55	0.3	0.1	0.03	0.05	0.06	0.06	0.03	0.59	2.99
1932	0.29	0.07	0.02	0	0.06	0.1	0.08	0.07	0.04	0.03	0.29	0.14	1.19
1933	0.01	0.11	0.04	0.04	0.06	0.13	0.05	0.01	0	0.13	0.08	0.07	0.73
1934	0.41	0.32	0.06	0.01	0.08	0.06	0.1	0.95	0.38	0.07	0.07	0.2	2.71
1935	0.13	0.18	0.16	0.05	0.06	0.06	0.03	0.12	0.06	0.12	0.07	0.13	1.17
1936	0.1	0.39	0.14	0.03	0.06	0.31	0.12	0.01	0.02	0.1	0.07	0.07	1.42
1937	0.06	0.14	0.16	0.08	0.02	0.01	0.07	0.04	0.02	0.03	0.03	0.09	0.75
1938	0.07	0.22	0.1	0.01	0.28	0.24	0.07	0.02	0	0.21	0.41	0.22	1.85
1939	0.08	0.08	0.06	0.13	0.5	0.25	0.05	0.02	0.02	0.01	0.01	0.06	1.27
1940	0.04	0.06	0.03	0.06	0.05	0.03	0.39	0.16	0.07	0.05	0.03	0.03	1
1941	0.18	0.17	0.27	0.34	0.1	0.13	0.07	0.11	0.09	0.05	0.05	0.03	1.59
1942	0.1	0.1	0.16	0.2	0.07	0.21	0.1	0.01	0.01	0.02	0.09	0.26	1.33
1943	0.19	0.43	0.25	0.05	0.01	0.1	0.07	0.48	0.22	0.18	0.09	0.31	2.38
1944	0.13	0.03	0	0.02	0.01	0.02	0.02	0.5	0.35	0.11	0.08	0.05	1.32
1945	0.25	0.09	0.02	0.06	0.11	0.47	0.15	0	0	0.02	0.02	0.03	1.22
1946	0.06	0.03	0.02	0.01	0.03	0.22	0.1	0.04	0.06	0.21	0.1	0.23	1.11
1947	0.15	0.06	0.01	0.21	0.1	0.04	0.17	0.09	0.03	0.03	0.02	0.08	0.99
1948	0.39	0.18	0.09	0.16	0.11	0.04	0.07	0.1	0.04	0	0.01	0.07	1.26
1949	0.06	0.53	0.18	0.02	0.04	0.05	0.03	0.01	0	0.34	0.24	0.14	1.64
1950	0.23	0.79	0.35	0.65	0.21	0.04	0.01	0.03	0.07	0.42	0.25	0.23	3.28
1951	0.07	0.01	0.01	0.14	0.11	0.04	0.06	0.12	0.07	0.07	0.24	0.63	1.57
1952	0.25	0.07	0.06	0.05	0.17	0.07	0.07	0.04	0.28	0.31	0.45	0.24	2.06
1953	0.59	0.32	0.05	0.01	0	0.05	0.13	0.34	0.18	0.16	1.01	0.35	3.19
1954	0.02	0.34	0.11	0.1	0.62	0.23	0.04	0.02	0.05	0.05	0.05	0.07	1.7
1955	0.16	0.34	0.1	0.03	0.07	0.17	0.08	0.21	0.1	0.02	0.02	0.04	1.34
1956	0.37	0.2	0.19	0.06	0.11	0.14	0.06	0.03	0.13	0.08	0.12	0.33	1.82
1957	0.15	0.02	0.02	0.03	0.01	0.15	0.1	0.2	0.1	0.04	0.17	0.07	1.06
1958	0.06	0.03	0.04	0.32	0.16	0.19	0.33	0.17	0.04	0.12	0.41	0.15	2.02
1959	0.35	0.12	0.05	0.17	0.06	0.31	0.17	0.11	0.09	0.07	0.03	0.17	1.7
1960	0.07	0.07	0.12	0.06	0.04	0.27	0.2	0.12	0.05	0.02	0.05	0.06	1.13
1961	0.08	0.05	0.03	0.13	0.07	0.21	0.11	0.03	0.02	0	0.73	0.28	1.74
1962	0.28	0.29	0.06	0.13	0.05	0.71	0.26	0.04	0.02	0.07	0.06	0.02	1.99
1963	0.04	0.03	0.1	0.14	0.06	0.05	0.07	0.04	0.24	0.1	0.15	0.7	1.72
1964	0.24	0.04	0.02	0.01	0.01	0.14	0.07	0.09	0.07	0.06	0.04	0.03	0.82
1965	0.53	0.56	0.2	0.08	0.1	0.03	0.06	0.1	0.06	0.03	0.17	0.16	2.08
1966	0.05	0.02	0.07	0.03	0.14	0.21	0.7	0.62	0.15	0.05	0.05	0.06	2.15
1967	0.04	0.06	0.03	0	0	0.09	0.07	0.05	0.48	0.19	0.09	0.1	1.2
1968	0.1	0.2	0.08	0.02	0.02	0.1	0.06	0.02	0.14	0.08	0.04	0.04	0.9
1969	0.09	0.03	0.02	0.01	0.1	0.04	0.02	0.02	0.02	0.03	0.23	0.15	0.76
1970	0.1	0.05	0.47	0.16	0.08	0.17	0.21	0.22	0.11	0.5	0.54	0.11	2.72
1971	0.02	0.15	0.05	0.02	0.25	0.16	0.04	0.06	0.05	0.04	0.11	0.07	1.02
1972	0.03	0.02	0.02	0.02	0.01	0.02	0.07	0.05	0.04	0.03	0.04	0.04	0.39
1973	0.03	0.06	0.03	0.11	0.11	0.15	0.07	0.14	0.07	0.03	0.14	0.12	1.06
1974	0.05	0.09	0.03	0.07	0.04	0.06	0.04	0.02	0.04	0.08	0.12	0.26	0.9
1975	0.1	0.06	0.07	0.03	0.03	0.07	0.04	0.05	0.05	0.13	0.1	0.07	0.8
1976	0.53	0.42	0.11	0.01	0.35	0.2	0.05	0.49	0.2	0.02	0.06	0.12	2.56

1977	0.08	0.1	0.05	0.03	0.01	0.02	0.02	0.02	0.05	0.06	0.06	0.04	0.54
1978	0.09	0.17	0.07	0.09	0.04	0.03	0.01	0.07	0.07	0.25	0.23	0.23	1.35
1979	0.09	0.01	0.01	0.04	0.03	0.01	0.06	0.04	0.07	0.04	0.05	0.11	0.56
1980	0.24	0.21	0.16	0.55	0.2	0.43	0.44	0.87	0.28	0.02	0.55	0.18	4.13
1981	0.17	0.06	0.08	0.04	0.06	0.08	0.6	0.22	0.06	0.11	0.05	0.19	1.72
1982	0.18	0.05	0	0.01	0.03	0.03	0.01	0.04	0.3	0.62	0.2	0.08	1.55
1983	0.18	0.13	0.08	0.03	0.03	0.11	0.04	0.03	0.03	0.14	0.07	0.03	0.9
1984	0.15	0.09	0.06	0.11	0.11	0.05	0.09	0.04	0.04	0.11	0.06	0.04	0.95
1985	0.42	0.23	0.2	0.09	0.03	0.02	0.01	0.02	0.02	0.03	0.31	0.15	1.53
1986	0.28	0.13	0.03	0.06	0.03	0.04	0.35	0.14	0.05	0.04	0.09	0.51	1.75
1987	0.18	0.01	0.03	0.03	0.03	0.01	0.12	0.1	0.07	0.05	0.09	0.09	0.81
1988	0.08	0.03	0.04	0.03	0.01	0.03	0.22	0.1	0.03	0.03	0.03	0.01	0.64
1989	0.44	0.47	0.11	0.01	0.22	0.1	0.16	0.1	0.16	0.07	0.03	0.02	1.89
1990	0.14	0.08	0.03	0.03	0.05	0.03	0.03	0.01	0.04	0.05	0.04	0.03	0.56
1991	0.25	0.1	0.14	0.05	0.07	0.07	0.03	0.07	0.07	0.28	0.2	0.07	1.4
1992	0.56	0.26	0.02	0.12	0.06	0.04	0.25	0.17	0.06	0.03	0.03	0.7	2.3
1993	0.25	0.05	0.1	0.1	0.07	0.1	0.15	0.07	0.01	0.07	0.32	0.15	1.44
1994	0.16	0.06	0.35	0.19	0.09	0.17	0.23	0.13	0.08	0.04	0.02	0.01	1.53
1995	0.03	0.42	0.26	0.06	0.02	0.01	0.03	0.01	0.01	0.04	0.05	0.06	1
1996	0.56	0.93	0.34	0.03	0.1	0.24	0.17	0.21	0.14	0.06	0.05	0.05	2.88
1997	0.12	0.05	0	0.02	0.02	0.32	0.11	0.02	0.01	0.02	0.04	0.04	0.77
1998	0.02	0.04	0.03	0.04	0.05	0.12	0.12	0.06	0.02	0.02	0.01	0.09	0.62
1999	0.22	0.08	0.01	0.33	0.14	0.34	0.11	0.01	0	0.02	0	0	1.26
2000	0.01	0.25	0.45	0.15	0.06	0.05	0.11	0.06	0.02	0.03	0.11	0.1	1.4
2001	0.06	0.22	0.09	0.04	0.03	0.02	0.01	0.03	0.06	0.22	0.2	0.25	1.23
2002	0.1	0.02	0.04	0.03	0.01	0.77	0.28	0.13	0.08	0.03	0.04	0.02	1.55
2003	0.07	0.05	0.03	0.06	0.06	0.1	0.07	0.04	0.03	0.03	0.06	0.1	0.7
Average	**0.16**	**0.16**	**0.11**	**0.09**	**0.09**	**0.13**	**0.12**	**0.12**	**0.08**	**0.09**	**0.13**	**0.15**	**1.44**

Streamflow Reduction due to alien vegetation in the K40C catchment

Units in million m^3

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	TOTAL
1920	0.03	0.05	0.33	0.12	0.33	0.47	0.29	0.1	0.05	0.06	0.05	0.13	2.01
1921	0.07	0.13	0.34	0.27	0.1	0.16	0.58	0.28	0.07	0.21	0.14	0.12	2.47
1922	0.28	0.47	0.12	0.14	0.07	0.03	0.2	0.27	0.15	0.05	0.05	0.05	1.88
1923	0.08	0.2	0.1	0.06	0.07	0.04	0.05	0.05	0.06	0.03	0.18	0.34	1.26
1924	0.15	0.15	0.25	0.14	0.03	0.26	0.17	0.08	0.1	0.06	0.19	0.91	2.49
1925	0.41	0.11	0.14	0.06	0.03	0.21	0.1	0.05	0.11	0.12	0.09	0.07	1.5
1926	0.17	0.43	0.13	0.03	0.14	0.07	0.01	0.13	0.07	0.02	0.09	0.05	1.34
1927	0.06	0.07	0.03	0.04	0.08	0.45	0.27	0.05	0.03	0.03	0.08	0.13	1.32
1928	0.07	0.43	0.31	0.06	0.06	0.1	0.07	0.07	0.05	0.2	0.23	0.19	1.84
1929	0.12	0.05	0.07	0.09	0.57	0.29	0.08	0.16	0.12	0.09	0.19	0.16	1.99
1930	0.14	0.05	0.08	0.29	0.13	0.04	0.17	0.07	0.02	0.18	0.14	0.2	1.51
1931	0.39	0.14	0.95	0.72	0.46	0.16	0.02	0.08	0.09	0.06	0.04	0.78	3.89
1932	0.51	0.15	0.02	0	0.07	0.16	0.12	0.1	0.06	0.04	0.5	0.21	1.94
1933	0.03	0.2	0.07	0.04	0.1	0.22	0.09	0.03	0.01	0.23	0.14	0.1	1.26
1934	0.57	0.42	0.07	0.04	0.17	0.07	0.19	1.09	0.49	0.09	0.1	0.28	3.58
1935	0.22	0.33	0.27	0.09	0.15	0.11	0.05	0.2	0.09	0.17	0.09	0.21	1.98
1936	0.13	0.53	0.22	0.07	0.14	0.46	0.14	0.01	0.03	0.14	0.1	0.23	2.2
1937	0.15	0.17	0.2	0.14	0.03	0.07	0.12	0.06	0.03	0.04	0.04	0.16	1.21
1938	0.17	0.36	0.2	0.05	0.34	0.29	0.08	0	0	0.34	0.6	0.36	2.79
1939	0.13	0.09	0.07	0.28	0.66	0.32	0.07	0.02	0.03	0.03	0.02	0.14	1.86
1940	0.11	0.12	0.03	0.07	0.1	0.06	0.52	0.19	0.12	0.06	0.02	0.07	1.47
1941	0.28	0.25	0.45	0.49	0.14	0.24	0.12	0.21	0.12	0.06	0.08	0.04	2.48
1942	0.19	0.15	0.26	0.33	0.13	0.27	0.11	0.01	0.02	0.03	0.17	0.54	2.21
1943	0.32	0.61	0.36	0.07	0.06	0.17	0.09	0.62	0.3	0.27	0.13	0.41	3.41
1944	0.17	0.03	0.03	0.01	0.01	0.01	0.01	0.6	0.45	0.14	0.12	0.08	1.66
1945	0.29	0.11	0.05	0.12	0.14	0.55	0.21	0	0.01	0.05	0.05	0.09	1.67
1946	0.07	0.03	0.03	0.03	0.04	0.32	0.16	0.09	0.1	0.39	0.15	0.29	1.7
1947	0.17	0.11	0.03	0.37	0.19	0.06	0.3	0.12	0.02	0.03	0.03	0.17	1.6
1948	0.49	0.22	0.17	0.28	0.2	0.05	0.1	0.18	0.07	0.02	0.03	0.11	1.92
1949	0.08	0.65	0.21	0	0.06	0.06	0.04	0.04	0.02	0.38	0.27	0.19	2
1950	0.31	0.92	0.53	0.8	0.26	0.06	0.02	0.04	0.14	0.59	0.35	0.29	4.31
1951	0.08	0.01	0.01	0.22	0.17	0.04	0.13	0.14	0.1	0.09	0.33	0.74	2.06
1952	0.33	0.1	0.16	0.09	0.3	0.12	0.09	0.05	0.46	0.43	0.62	0.3	3.05
1953	0.72	0.44	0.14	0.01	0	0.13	0.19	0.4	0.2	0.19	1.14	0.45	4.01
1954	0.03	0.53	0.16	0.19	0.8	0.3	0.03	0.03	0.06	0.06	0.06	0.1	2.35
1955	0.25	0.52	0.15	0.07	0.14	0.34	0.14	0.42	0.15	0	0.02	0.07	2.27
1956	0.49	0.28	0.29	0.11	0.22	0.2	0.06	0.06	0.17	0.09	0.17	0.42	2.56
1957	0.21	0.04	0.03	0.06	0.03	0.3	0.19	0.23	0.12	0.04	0.2	0.11	1.56
1958	0.09	0.04	0.06	0.56	0.26	0.31	0.5	0.21	0.02	0.18	0.56	0.2	2.99
1959	0.49	0.15	0.09	0.32	0.1	0.52	0.26	0.13	0.09	0.08	0.04	0.26	2.53
1960	0.11	0.12	0.2	0.09	0.06	0.38	0.26	0.18	0.08	0.03	0.07	0.07	1.65
1961	0.13	0.09	0.06	0.26	0.13	0.33	0.16	0.03	0	0.01	0.82	0.33	2.35
1962	0.41	0.42	0.1	0.23	0.09	0.87	0.32	0.06	0.02	0.12	0.09	0.04	2.77
1963	0.08	0.04	0.18	0.24	0.12	0.1	0.1	0.04	0.31	0.13	0.2	0.81	2.35
1964	0.26	0.11	0.03	0.03	0.03	0.28	0.13	0.13	0.09	0.07	0.03	0.03	1.22
1965	0.69	0.73	0.34	0.18	0.23	0.06	0.07	0.17	0.06	0.01	0.27	0.19	3
1966	0.06	0.02	0.16	0.06	0.2	0.32	0.82	0.73	0.18	0.1	0.07	0.09	2.81
1967	0.06	0.11	0.05	0.02	0.01	0.16	0.1	0.09	0.6	0.22	0.15	0.18	1.75
1968	0.16	0.36	0.11	0.07	0.06	0.18	0.09	0.01	0.17	0.1	0.06	0.07	1.44
1969	0.17	0.06	0	0.04	0.2	0.09	0.01	0	0.01	0.03	0.34	0.17	1.12
1970	0.11	0.04	0.66	0.23	0.18	0.24	0.32	0.32	0.12	0.66	0.7	0.16	3.74
1971	0.02	0.24	0.08	0.04	0.39	0.23	0.06	0.07	0.07	0.06	0.2	0.1	1.56
1972	0.03	0.03	0.01	0.03	0.03	0.05	0.14	0.08	0.06	0.06	0.04	0.07	0.63
1973	0.04	0.12	0.07	0.26	0.24	0.3	0.1	0.24	0.1	0.02	0.29	0.18	1.96
1974	0.06	0.13	0.05	0.11	0.07	0.11	0.07	0.03	0.05	0.1	0.2	0.39	1.37
1975	0.13	0.1	0.12	0.06	0.07	0.15	0.06	0.1	0.09	0.2	0.13	0.07	1.28
1976	0.68	0.6	0.2	0.02	0.52	0.31	0.05	0.67	0.25	0.02	0.08	0.2	3.6

1977	0.11	0.18	0.08	0.04	0.01	0.01	0.05	0.03	0.11	0.07	0.08	0.08	0.85
1978	0.13	0.29	0.14	0.16	0.09	0.03	0.01	0.16	0.11	0.4	0.36	0.32	2.2
1979	0.1	0.01	0	0.09	0.03	0.02	0.09	0.06	0.1	0.07	0.04	0.19	0.8
1980	0.39	0.37	0.29	0.72	0.25	0.59	0.66	1.11	0.37	0.03	0.7	0.24	5.72
1981	0.31	0.1	0.13	0.08	0.08	0.13	0.81	0.26	0.12	0.16	0.08	0.33	2.59
1982	0.28	0.07	0.02	0.02	0.06	0.03	0.04	0.07	0.5	0.83	0.26	0.15	2.33
1983	0.31	0.21	0.11	0.04	0.03	0.2	0.09	0.03	0.03	0.23	0.1	0.03	1.41
1984	0.29	0.12	0.13	0.21	0.23	0.09	0.13	0.07	0.06	0.2	0.09	0.03	1.65
1985	0.59	0.37	0.33	0.17	0.05	0.03	0.03	0.02	0.01	0.02	0.48	0.23	2.33
1986	0.43	0.19	0.04	0.1	0.07	0.07	0.53	0.18	0.08	0.03	0.16	0.74	2.62
1987	0.25	0.01	0.04	0.04	0.03	0.03	0.24	0.16	0.09	0.04	0.12	0.1	1.15
1988	0.08	0.04	0.06	0.05	0.01	0.04	0.34	0.13	0.03	0.05	0.05	0.03	0.91
1989	0.63	0.64	0.13	0.02	0.34	0.13	0.27	0.16	0.28	0.12	0.04	0.05	2.81
1990	0.23	0.16	0.05	0.06	0.11	0.06	0.03	0.03	0.07	0.08	0.07	0.03	0.98
1991	0.38	0.14	0.27	0.12	0.14	0.12	0.04	0.11	0.1	0.43	0.33	0.09	2.27
1992	0.71	0.4	0.06	0.23	0.12	0.06	0.4	0.26	0.08	0.04	0.03	0.86	3.25
1993	0.3	0.09	0.2	0.2	0.13	0.13	0.23	0.09	0.03	0.1	0.47	0.19	2.16
1994	0.31	0.09	0.5	0.29	0.15	0.3	0.39	0.25	0.08	0.02	0.02	0.02	2.42
1995	0.03	0.6	0.4	0.12	0.02	0.03	0.04	0.01	0.02	0.04	0.07	0.07	1.45
1996	0.76	1.15	0.5	0.07	0.16	0.42	0.31	0.34	0.21	0.06	0.12	0.06	4.16
1997	0.24	0.08	0	0.06	0.04	0.47	0.16	0.03	0	0.03	0.07	0.06	1.24
1998	0.02	0.05	0.07	0.11	0.13	0.24	0.21	0.08	0.02	0.03	0.04	0.09	1.09
1999	0.34	0.1	0.01	0.46	0.22	0.5	0.17	0	0	0.02	0.02	0.01	1.85
2000	0.04	0.4	0.63	0.21	0.09	0.1	0.2	0.08	0.02	0.06	0.2	0.13	2.16
2001	0.12	0.37	0.14	0.1	0.04	0	0.03	0.04	0.09	0.35	0.27	0.42	1.97
2002	0.14	0.02	0.11	0.06	0.04	1	0.37	0.27	0.14	0.05	0.05	0.02	2.27
2003	0.13	0.06	0.05	0.09	0.13	0.23	0.14	0.06	0.04	0.05	0.07	0.18	1.23
Average	**0.24**	**0.23**	**0.17**	**0.15**	**0.15**	**0.21**	**0.18**	**0.16**	**0.11**	**0.13**	**0.19**	**0.21**	**2.13**

Streamflow Reduction due to alein vegetaiton in the K40D catchment

Units in million m^3

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	TOTAL
1920	0.02	0.03	0.15	0.06	0.15	0.21	0.14	0.06	0.02	0.03	0.03	0.07	0.97
1921	0.03	0.06	0.15	0.12	0.05	0.07	0.28	0.13	0.04	0.1	0.07	0.06	1.16
1922	0.13	0.22	0.06	0.06	0.03	0.01	0.09	0.12	0.08	0.02	0.03	0.03	0.88
1923	0.04	0.09	0.04	0.03	0.03	0.01	0.02	0.02	0.03	0.02	0.08	0.16	0.57
1924	0.08	0.07	0.11	0.06	0.02	0.11	0.08	0.05	0.05	0.03	0.09	0.48	1.23
1925	0.22	0.05	0.07	0.03	0.02	0.1	0.04	0.03	0.05	0.06	0.04	0.03	0.74
1926	0.08	0.2	0.06	0.01	0.06	0.04	0	0.06	0.03	0.02	0.05	0.02	0.63
1927	0.03	0.03	0.01	0.01	0.03	0.21	0.13	0.03	0.01	0.01	0.04	0.06	0.6
1928	0.03	0.2	0.14	0.03	0.03	0.04	0.03	0.03	0.03	0.09	0.11	0.09	0.85
1929	0.06	0.03	0.03	0.04	0.28	0.14	0.04	0.08	0.06	0.04	0.09	0.08	0.97
1930	0.07	0.03	0.04	0.13	0.06	0.01	0.07	0.03	0.01	0.07	0.07	0.09	0.68
1931	0.19	0.07	0.58	0.37	0.22	0.08	0.01	0.04	0.05	0.03	0.03	0.42	2.09
1932	0.26	0.08	0.02	0	0.03	0.08	0.05	0.05	0.03	0.02	0.24	0.1	0.96
1933	0.02	0.09	0.03	0.02	0.04	0.09	0.04	0.02	0.01	0.1	0.06	0.05	0.57
1934	0.27	0.19	0.03	0.01	0.07	0.03	0.09	0.62	0.28	0.06	0.05	0.13	1.83
1935	0.11	0.16	0.12	0.04	0.07	0.05	0.03	0.09	0.05	0.08	0.04	0.09	0.93
1936	0.06	0.26	0.11	0.03	0.06	0.21	0.06	0.01	0.01	0.06	0.05	0.1	1.02
1937	0.08	0.08	0.09	0.06	0.02	0.03	0.06	0.03	0.02	0.01	0.02	0.07	0.57
1938	0.08	0.16	0.09	0.02	0.16	0.12	0.04	0	0	0.16	0.28	0.17	1.28
1939	0.07	0.05	0.03	0.12	0.32	0.15	0.04	0.01	0.01	0.01	0.02	0.06	0.89
1940	0.05	0.05	0.01	0.03	0.05	0.03	0.24	0.1	0.05	0.03	0.01	0.03	0.68
1941	0.13	0.11	0.21	0.22	0.07	0.1	0.06	0.09	0.06	0.03	0.04	0.02	1.14
1942	0.09	0.07	0.12	0.15	0.06	0.12	0.04	0	0.02	0.01	0.07	0.25	1
1943	0.15	0.3	0.18	0.03	0.03	0.08	0.04	0.31	0.15	0.13	0.07	0.2	1.67
1944	0.09	0.02	0.02	0	0	0	0.01	0.29	0.21	0.07	0.06	0.05	0.82
1945	0.13	0.06	0.02	0.06	0.06	0.26	0.1	0	0.01	0.02	0.03	0.04	0.79
1946	0.03	0.01	0.02	0.02	0.02	0.15	0.07	0.05	0.05	0.18	0.07	0.14	0.81
1947	0.08	0.05	0.01	0.16	0.08	0.03	0.13	0.06	0.01	0.02	0.02	0.07	0.72
1948	0.23	0.11	0.08	0.12	0.09	0.03	0.05	0.08	0.03	0.01	0.01	0.04	0.88
1949	0.03	0.33	0.1	0	0.03	0.03	0.02	0.02	0.01	0.17	0.13	0.09	0.96
1950	0.14	0.52	0.28	0.44	0.15	0.03	0.02	0.02	0.07	0.28	0.17	0.15	2.27
1951	0.05	0.01	0.01	0.09	0.08	0.01	0.06	0.07	0.04	0.05	0.15	0.37	0.99
1952	0.16	0.05	0.07	0.04	0.13	0.06	0.05	0.03	0.21	0.2	0.3	0.15	1.45
1953	0.39	0.23	0.07	0.01	0	0.05	0.09	0.19	0.09	0.09	0.63	0.27	2.11
1954	0.02	0.26	0.08	0.09	0.43	0.17	0.01	0.01	0.03	0.03	0.03	0.05	1.21
1955	0.11	0.24	0.07	0.03	0.06	0.15	0.06	0.19	0.08	0	0.01	0.03	1.03
1956	0.23	0.14	0.13	0.05	0.11	0.09	0.03	0.03	0.08	0.05	0.07	0.2	1.21
1957	0.1	0.02	0.02	0.03	0.02	0.13	0.09	0.11	0.06	0.03	0.09	0.06	0.76
1958	0.04	0.02	0.03	0.27	0.12	0.14	0.23	0.11	0.01	0.09	0.28	0.1	1.44
1959	0.24	0.09	0.04	0.14	0.04	0.24	0.12	0.06	0.05	0.04	0.03	0.12	1.21
1960	0.06	0.05	0.09	0.04	0.03	0.17	0.13	0.09	0.04	0.02	0.03	0.03	0.78
1961	0.07	0.04	0.03	0.11	0.06	0.15	0.08	0.02	0	0	0.45	0.18	1.19
1962	0.19	0.19	0.06	0.1	0.04	0.5	0.18	0.04	0.01	0.06	0.04	0.02	1.43
1963	0.05	0.02	0.08	0.11	0.06	0.05	0.05	0.02	0.15	0.07	0.1	0.42	1.18
1964	0.14	0.05	0.02	0.02	0.02	0.12	0.06	0.06	0.04	0.03	0.02	0.02	0.6
1965	0.36	0.36	0.16	0.08	0.1	0.03	0.03	0.08	0.04	0.01	0.12	0.1	1.47
1966	0.03	0.01	0.08	0.03	0.1	0.13	0.44	0.36	0.1	0.06	0.04	0.05	1.43
1967	0.04	0.05	0.02	0.01	0	0.07	0.05	0.04	0.29	0.11	0.07	0.08	0.83
1968	0.08	0.16	0.06	0.03	0.03	0.08	0.04	0.01	0.08	0.05	0.03	0.03	0.68
1969	0.08	0.03	0	0.01	0.09	0.04	0	0.01	0	0.01	0.16	0.08	0.51
1970	0.06	0.02	0.35	0.12	0.08	0.1	0.15	0.14	0.06	0.34	0.34	0.09	1.85
1971	0.02	0.12	0.04	0.02	0.18	0.1	0.03	0.03	0.03	0.04	0.09	0.05	0.75
1972	0.02	0.01	0	0.02	0.01	0.02	0.06	0.03	0.03	0.03	0.02	0.04	0.29
1973	0.01	0.05	0.03	0.12	0.11	0.14	0.05	0.11	0.05	0.01	0.14	0.09	0.91
1974	0.03	0.06	0.03	0.05	0.03	0.04	0.03	0.02	0.03	0.05	0.09	0.17	0.63
1975	0.06	0.05	0.05	0.03	0.03	0.07	0.03	0.05	0.05	0.09	0.07	0.03	0.61
1976	0.34	0.29	0.09	0.01	0.25	0.14	0.02	0.35	0.13	0.01	0.04	0.09	1.76

1977	0.06	0.09	0.04	0.02	0.01	0	0.02	0.02	0.05	0.03	0.04	0.05	0.43
1978	0.06	0.12	0.06	0.07	0.04	0.02	0.01	0.08	0.05	0.18	0.17	0.15	1.01
1979	0.06	0.01	0	0.05	0.01	0.02	0.04	0.03	0.04	0.03	0.02	0.09	0.4
1980	0.17	0.17	0.14	0.37	0.13	0.3	0.32	0.61	0.24	0.03	0.4	0.15	3.03
1981	0.16	0.06	0.07	0.05	0.04	0.06	0.43	0.15	0.06	0.07	0.05	0.15	1.35
1982	0.13	0.04	0.02	0.01	0.02	0.02	0.02	0.04	0.23	0.39	0.13	0.07	1.12
1983	0.15	0.1	0.06	0.02	0.02	0.1	0.04	0.02	0.02	0.1	0.05	0.02	0.7
1984	0.13	0.05	0.06	0.09	0.1	0.05	0.06	0.03	0.03	0.1	0.05	0.01	0.76
1985	0.29	0.18	0.15	0.07	0.03	0.01	0.02	0.02	0	0.01	0.22	0.11	1.11
1986	0.21	0.09	0.01	0.05	0.03	0.03	0.25	0.09	0.04	0.01	0.07	0.38	1.26
1987	0.13	0.01	0.02	0.02	0.01	0.01	0.11	0.07	0.05	0.02	0.06	0.05	0.56
1988	0.03	0.02	0.03	0.02	0	0.02	0.15	0.06	0.02	0.02	0.03	0.02	0.42
1989	0.32	0.31	0.06	0.01	0.15	0.06	0.13	0.08	0.13	0.06	0.02	0.03	1.36
1990	0.11	0.07	0.03	0.03	0.04	0.03	0.02	0.01	0.03	0.03	0.03	0.01	0.44
1991	0.17	0.06	0.12	0.06	0.07	0.06	0.02	0.05	0.04	0.2	0.16	0.05	1.06
1992	0.39	0.2	0.04	0.1	0.05	0.03	0.19	0.13	0.04	0.03	0.02	0.48	1.7
1993	0.17	0.04	0.08	0.09	0.06	0.06	0.1	0.05	0.02	0.05	0.22	0.09	1.03
1994	0.14	0.05	0.25	0.13	0.07	0.14	0.18	0.12	0.05	0.01	0.02	0.01	1.17
1995	0.01	0.3	0.19	0.06	0.02	0.01	0.01	0.01	0.01	0.02	0.03	0.03	0.7
1996	0.4	0.66	0.27	0.03	0.07	0.19	0.14	0.16	0.11	0.04	0.06	0.04	2.17
1997	0.11	0.04	0	0.03	0.02	0.22	0.08	0.02	0	0.01	0.03	0.03	0.59
1998	0.02	0.02	0.03	0.04	0.06	0.11	0.1	0.04	0.01	0.02	0.02	0.04	0.51
1999	0.15	0.05	0.01	0.21	0.11	0.23	0.09	0	0	0.01	0.01	0.01	0.88
2000	0.02	0.19	0.29	0.11	0.04	0.05	0.09	0.04	0.01	0.03	0.09	0.07	1.03
2001	0.06	0.16	0.06	0.05	0.01	0	0.01	0.02	0.04	0.15	0.12	0.2	0.88
2002	0.07	0.01	0.04	0.02	0.01	0.59	0.21	0.12	0.07	0.03	0.02	0.01	1.2
2003	0.06	0.03	0.03	0.05	0.06	0.1	0.06	0.03	0.02	0.03	0.04	0.08	0.59
Average	**0.12**	**0.11**	**0.08**	**0.07**	**0.07**	**0.10**	**0.09**	**0.08**	**0.06**	**0.06**	**0.09**	**0.10**	**1.03**

I8 NATURAL FLOW TIME SERIES

Natrural flow in the K50A catchment

Units in million m^3

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	TOTAL
1920	2.05	1.45	4.22	1.85	5.61	8.03	5.56	2.79	1.95	2.18	1.96	2.95	40.6
1921	2.02	1.87	3.88	2.29	1.12	4.06	7.99	5.91	3.09	5.35	4.12	3.58	45.28
1922	4.39	7.96	2.87	1.72	1.08	0.81	2.99	4.11	3.51	1.9	1.68	1.47	34.49
1923	2.08	3.8	1.82	0.77	0.84	0.8	1.08	1.44	1.73	1.16	3.88	5.98	25.38
1924	4.38	3.08	3.13	1.72	0.9	2.31	2.93	1.99	3.25	2.61	4.54	25.55	56.39
1925	16.5	6.01	4.3	2.08	1.26	5.08	3.66	2.1	3.28	4.94	4.85	4.99	59.05
1926	6.14	12.03	4.1	1.34	2.5	1.56	0.71	6.04	4.01	1.97	5.27	3.96	49.63
1927	2.13	1.19	0.74	1.19	3.2	10.79	6.25	2.09	1.91	1.54	2.68	5.19	38.9
1928	4.24	13.44	7.28	1.41	0.9	1	1.09	2.02	2.16	6.35	5.78	5.45	51.12
1929	4.07	1.84	2.52	1.95	10.31	5.69	1.98	3.83	3.56	3.36	6.85	6.69	52.65
1930	4.81	1.88	2.09	4.14	2.2	0.94	3.67	3.3	2	4.88	4.59	7.86	42.36
1931	10.53	4.08	28.62	19.97	5.86	2.75	1.36	1.66	3.07	3.15	2.47	23.99	107.51
1932	15.78	4.71	1.19	0.42	1.12	2.97	2.86	2.98	2.43	1.99	11.54	6.6	54.59
1933	1.66	2.58	1.22	0.51	1.27	2.67	1.47	0.92	0.87	4.04	4.29	3.21	24.71
1934	16.05	8.78	1.75	1.26	1.78	1.44	3.95	42.43	18.53	4.67	5.18	7.39	113.21
1935	8.95	8.86	5.38	3.19	3.2	3.38	1.85	4.25	2.81	4.43	3.19	6.21	55.7
1936	5.74	11.14	5.24	1.98	3.79	5.8	2.67	0.77	1.68	5.14	4.29	7.25	55.49
1937	5.72	4.04	2.94	2.74	0.95	1.15	1.75	1.24	1.2	1.3	2.34	5.23	30.6
1938	6.93	7.87	4.78	1.26	5.96	5.68	2.45	0.76	0.27	7.91	17.16	12.15	73.18
1939	5.48	2.94	1.69	6.95	12.11	5.99	2.59	2	1.4	1.91	1.47	3.47	48
1940	3.41	3.17	1.22	1.16	2.28	2.07	7.94	4.29	5.88	3.57	1.51	4.49	40.99
1941	11.71	6.99	5.69	7.58	2.88	3.24	2.39	5.72	5.52	4.57	4.14	3.35	63.78
1942	4.22	3.03	3.67	5.7	3.61	4.55	2.51	1.01	0.71	0.96	3.48	16.98	50.43
1943	9.51	15.99	9.52	1.92	1.89	2.44	2.1	21.04	11.63	8.24	5.46	10.31	100.05
1944	7.2	2.89	1.74	0.84	0.41	0.39	0.35	12.84	12.46	5.75	3.47	2.39	50.73
1945	4.66	2.54	3.32	2.58	1.72	8.34	4.12	1.13	0.93	2.27	2.63	3.48	37.72
1946	3.71	1.62	0.9	1.25	0.83	4.23	3.99	4.25	4.05	10.59	5	4.15	44.57
1947	3.99	2.7	1.4	4.01	2.53	1.29	4.62	2.58	1.16	1.47	1.51	3.78	31.04
1948	9.72	4.88	3.64	4.54	3.19	1.05	1.55	4.58	2.51	0.81	0.96	3.1	40.53
1949	3.1	11.79	4.73	0.9	0.87	0.99	1.51	1.42	0.68	6.88	7.28	5.42	45.57
1950	6.84	24.04	13.61	17.42	6.45	2.02	1.06	1.91	4.81	18.55	13.07	9.71	119.49
1951	4.27	0.86	0.45	6.34	4.07	1.52	3.49	4.27	4.88	5.05	13.06	27.45	75.71
1952	12.47	3.92	4.07	2.6	10.99	4.43	1.75	1.11	8.7	10.3	17.1	9.02	86.46
1953	19.45	10.48	3.96	1.24	0.56	2.94	3.25	7	5.32	7.98	40.45	16.7	119.33
1954	3.03	14.33	5.26	3.89	19.47	7.72	1.97	1.75	2.49	2.74	3.07	4.65	70.37
1955	7.53	15.11	4.99	1.4	2.23	5.42	4.03	14.18	6.78	1.47	1.34	5.06	69.54
1956	13.37	7.48	6.62	3.31	3.83	3.21	2.13	3.27	5.89	4	6.47	8.79	68.37
1957	6.97	2.36	1.15	1.41	1.11	6.87	6.57	8.01	4.97	1.76	6.28	4.25	51.71
1958	3.65	1.92	1.92	10.46	5.16	3.28	11.45	7.2	2.37	4.09	13.27	7.5	72.27
1959	12.41	5.17	2.31	7.7	2.99	9.8	5.84	3.51	3.95	4.78	3.34	6.98	68.78
1960	4.5	3.14	2.79	1.81	1.21	7.09	4.45	5.24	3.02	1.98	4.56	4.23	44.02
1961	6.97	4.1	1.61	5.38	3.18	6.09	4.67	2.16	1.05	1.17	22.98	10.14	69.5
1962	9.76	8.36	2.58	1.76	0.89	20.86	9.35	2.64	1.71	4.97	5.25	2.66	70.79
1963	1.99	1.48	5.14	4.4	2.12	2.56	5.47	2.95	6.3	4.17	5.29	22.86	64.73
1964	9.2	5.67	2.09	0.58	0.62	6.25	6.28	5.44	4.16	2.98	1.89	1.49	46.65
1965	14.35	13.7	6.13	3.22	4.51	1.94	1.64	4.76	2.85	1.34	6.36	5.79	66.59
1966	2.68	1.77	2.06	0.79	1.83	4.92	22.39	17.56	6.52	7.39	6.64	5.68	80.23
1967	3.48	2.53	1.53	1.24	1.78	3	2.35	3.58	16.44	6.8	3.96	5.7	52.39
1968	5.5	5.31	2.28	1.76	1.81	2.64	1.92	1	3.62	3.76	3.5	3.59	36.69
1969	6.34	3.05	0.65	1.06	2.65	1.51	0.77	0.74	1.18	1.96	10.01	6.28	36.2
1970	3.57	1.49	15.5	6.01	5.86	6.56	7.78	9.62	5.76	20.41	21.38	6.96	110.9
1971	1.94	5.81	2.46	1.35	12.64	6.5	2.31	4.08	4.55	5.91	9.03	4.51	61.09
1972	1.62	1.13	0.91	0.82	0.89	1.91	3.39	3.03	1.98	1.48	1.92	3.84	22.92
1973	2.93	5.44	2.68	4.92	5.89	5.49	2.51	5.55	3.55	1.31	10.95	8.01	59.23
1974	4.33	3.75	1.36	2.03	1.89	2.66	1.96	1.08	1.19	3.25	5.08	9.46	38.04
1975	4.56	3.03	2.82	1.87	2.1	6.04	2.87	2.4	2.68	4.75	3.97	2.46	39.55
1976	15.65	11.52	5.94	1.65	10.02	5.36	1.47	15.43	8.67	2.61	2.56	4.24	85.12

1977	5.55	5.19	2.3	1.17	0.59	0.94	1.57	1.58	2.91	2.15	5.61	4.4	33.96
1978	4.77	4.51	3.07	1.97	1.16	0.82	0.7	2.36	2.48	7.42	11.54	8.14	48.94
1979	3.47	1.38	0.69	2.08	1.21	0.64	2.55	2.62	3.08	2.21	2.59	3.66	26.18
1980	6.3	8.4	6.39	11.69	4.84	13.23	16.07	30.45	12.92	3.64	18.75	8.6	141.28
1981	8.36	4.63	2.3	1.05	0.97	2.08	28.53	11.42	2.12	3.08	2.99	6.29	73.82
1982	6.8	3.23	1.31	0.62	2.43	2.12	1.38	2.38	12.05	25.43	10.26	7.64	75.65
1983	11.59	5.07	3.15	1.63	0.99	2.76	1.53	0.87	1.36	3.41	2.87	1.71	36.94
1984	3.6	2.22	3.1	5.42	7.6	3.46	3.8	2.39	2.47	4.22	2.81	1.71	42.8
1985	14.64	8.43	7.64	3.88	1.16	1.04	0.65	0.36	0.42	1.02	9.92	6.07	55.23
1986	10.84	4.87	1.91	3.14	1.77	1.67	8.41	3.9	2.79	2.06	2.62	18.43	62.41
1987	7.92	1.39	1.14	1.12	0.72	0.88	6.02	4.74	4.41	3.25	3.12	3.37	38.08
1988	3.38	2.43	1.56	0.7	0.32	1.01	5.51	3.23	1.51	2.72	2.31	1.96	26.64
1989	16.39	14.94	3.96	1.6	5.15	2.76	3.33	3.7	9.05	4.89	2.69	3.14	71.6
1990	7.55	6.71	2.98	2.51	2.18	1.42	0.61	1.28	1.79	2.56	2.45	1.71	33.75
1991	7.38	3.25	2.74	1.96	2.42	2.29	1.93	3.6	3.33	8.8	14.2	6.09	57.99
1992	21.62	11.48	2.15	1.86	1.6	1.26	5.04	6.39	5.08	2.9	2.39	24.2	85.97
1993	9.9	2.42	3.93	2.89	3.31	2.05	5.31	3.52	1.7	2.62	10.47	6.24	54.36
1994	5.89	2.62	10.1	4.54	1.38	5.34	7.47	8.18	4.82	2.48	2.02	1.79	56.63
1995	1.67	13.64	8.93	2.86	0.79	0.84	0.79	0.51	0.46	2.02	3.6	3.62	39.73
1996	22.15	33.59	12.99	1.92	2.59	4.48	9	11.72	6.71	3.51	6.06	4.2	118.92
1997	5.23	3.01	1.28	2.54	1.2	7.63	3.49	2.93	2.17	1.84	5.16	4.07	40.55
1998	2.25	3.88	3.36	2.19	2.91	2.8	3.64	2.12	0.91	1.59	2.36	2.76	30.77
1999	7.93	3.31	0.62	4.25	3.42	7.69	3.82	0.99	0.32	0.29	0.43	1.27	34.34
2000	3.07	6.58	9.06	4.54	1.99	2.2	4.55	2.48	0.82	1.73	4.47	4.32	45.81
2001	3.08	5.36	2.32	2.14	1.29	0.43	1.3	1.69	3.6	8.16	8.15	11.03	48.55
2002	4.58	3.15	2.89	1.23	1.35	24.37	10.34	7.54	5.41	2.93	2.66	1.87	68.32
2003	2.51	1.78	1.04	1.9	2.63	5.28	3.5	1.74	1.61	1.99	2.33	5.88	32.19
Average	0.12	0.08	0.06	0.07	0.09	0.09	0.1	0.08	0.09	0.13	0.14	1.2	**57.53**

Natrural flow in the K50B catchment

Units in million m^3

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	TOTAL
1920	2.67	2.59	4.84	2.21	6.67	6.51	6.32	3.77	3.45	4.01	3.52	5.57	52.13
1921	3.25	2.2	4.17	1.98	1.36	4.31	9.62	6.96	3.58	7.9	4.59	4.84	54.76
1922	5.94	9.54	3.3	3.19	1.57	1.32	4.83	4.7	4.68	2.89	2.21	1.9	46.07
1923	2.65	4.47	2.19	0.85	1.02	1.18	1.29	1.35	1.67	1.14	3.26	5.62	26.69
1924	4.37	2.73	2.36	1.31	0.94	2.03	2.88	1.79	3.23	2.67	4	27.23	55.54
1925	17.11	6.27	5.6	2.76	2.05	5.25	3.46	1.85	2.52	4.59	4.59	4.73	60.78
1926	5.42	12.51	4.46	1.84	2.75	1.9	0.85	5.56	3.81	1.97	5.81	4.15	51.03
1927	2	1.04	0.57	0.92	2.18	10.36	5.79	1.78	2.07	1.75	2.79	5.04	36.29
1928	4.16	13.98	8.68	1.9	1.09	0.97	0.94	2	2.45	6.63	6.18	5.38	54.36
1929	4.19	1.87	2.34	1.47	8.9	4.74	1.64	4.49	3.86	3.33	6.13	6.42	49.38
1930	4.05	1.61	1.18	3.1	1.87	0.86	3.17	2.86	1.79	6.12	5.16	8.99	40.76
1931	10.72	3.94	29.05	18.44	5.83	3.03	1.36	1.73	3.21	3.21	2.5	27.69	110.71
1932	18.53	5.27	1.11	0.33	1.04	3.15	3.22	3.43	2.86	2.19	11.32	5.66	58.11
1933	1.19	2.22	1.03	0.5	0.91	3.35	1.76	0.87	0.79	4.78	6.15	4.56	28.11
1934	16.37	7.97	1.39	1.3	1.28	1.23	3.24	39.05	17.48	4.57	4.1	6.37	104.35
1935	7.45	7.14	4.81	3.31	3.85	3.59	1.77	4.47	2.91	4.82	3.23	5.66	53.01
1936	5.96	11.21	5.37	1.58	4.08	6.98	3	0.72	2.16	5.89	5.18	8.98	61.11
1937	6.35	3.72	3.32	2.99	0.96	1.57	1.86	1.19	1.25	1.36	2.27	5.05	31.89
1938	7.42	6.88	4.65	1.32	5.29	4.26	1.86	0.67	0.25	7.5	17.17	11.66	68.93
1939	4.87	2.5	1.61	6.99	11.32	5.56	2.5	2.23	1.6	1.98	1.52	4.42	47.1
1940	3.96	2.92	1.09	1.02	1.73	1.74	8.02	4.29	6.82	4.06	1.73	4.41	41.79
1941	10.39	5.7	6.63	7.1	2.53	2.44	1.66	5.98	4.92	3.96	3.59	2.75	57.65
1942	3.04	2.17	2.99	4.87	3.27	3.43	1.94	0.85	0.61	0.82	4.61	19.75	48.35
1943	11.17	14.62	8.72	1.82	1.65	1.79	1.4	19.98	12.19	8.55	5.4	9.33	96.62
1944	6.06	2.3	1.42	0.69	0.37	0.4	0.35	9.48	12.06	6.27	4.05	2.59	46.04
1945	3.96	2.02	2.86	1.72	1.21	7.21	3.5	0.88	0.82	2.58	2.72	2.9	32.38
1946	2.61	1.07	0.86	1.47	0.95	2.92	3.54	3.97	3.65	11.26	5.12	3.35	40.77
1947	3.2	2.14	1.11	3.1	1.98	1.05	4.59	2.52	1.05	1.34	1.45	3.55	27.08
1948	7.37	3.4	1.81	4.28	3.09	0.93	1.59	4.89	2.62	1	1.54	3.38	35.9
1949	2.63	7.96	3.29	0.58	0.44	0.7	1.8	1.41	0.55	3.36	4.56	4.47	31.75
1950	5.63	13.75	8.27	14.6	5.43	1.61	0.85	1.9	4.56	14.73	10.18	7.59	89.1
1951	3.59	0.83	0.3	3.57	2	0.83	4.86	4.02	4.43	5.86	11.39	16.29	57.97
1952	7.17	1.68	1.9	1.31	3.82	1.72	1.18	0.87	12.41	12.93	14.71	6.99	66.69
1953	16.28	8.88	2.74	0.85	0.47	2.74	2.74	7.28	5.77	8.13	34.03	14.24	104.15
1954	2.92	14.19	5.13	5.14	19.19	6.98	1.16	1.22	2.04	2.37	2.65	4.09	67.08
1955	7.58	11.27	3.56	0.83	1.56	4.88	3.45	12.89	6.29	1.37	1.45	4.81	59.94
1956	10.64	5.87	4.21	1.94	1.97	1.57	1.63	4.04	5.72	3.7	5.93	9.48	56.7
1957	5.56	1.53	0.63	0.63	0.61	5.35	6.26	9.7	4.99	1.44	3.86	2.94	43.5
1958	2.84	1.53	1.42	10.33	4.75	2.03	9.18	6.42	2.39	3.31	10.22	6.48	60.9
1959	13.26	5.17	1.2	6.99	2.64	8.5	5.4	2.91	2.92	4.71	3.09	6.06	62.85
1960	3.53	2.96	2.14	1.96	0.9	3.93	3.99	7.03	3.64	2.2	4.31	3.8	40.39
1961	5.82	3.18	0.97	4.46	2.49	5.65	4.12	1.9	1.06	1.11	18.04	8.1	56.9
1962	7.51	6.4	2.03	1.27	0.59	15.75	7.26	2.08	1.24	4.93	5.09	2.39	56.54
1963	1.22	0.88	4.83	4.77	1.55	1.73	2.94	1.72	6.06	3.98	4.47	22.77	56.92
1964	8.93	4.78	1.74	0.29	0.49	6.26	7.39	7.66	4.65	2.81	1.88	1.5	48.38
1965	8.01	8.74	3.59	2.08	2.26	1.25	1.9	6.08	3.27	1.41	7.51	6.49	52.59
1966	2.57	1.34	1.09	0.43	1.09	4.4	17.37	15.1	6.06	8.05	6.23	4.41	68.14
1967	2.53	1.78	0.98	0.76	1.79	2.55	1.81	3.56	17.25	6.9	3.36	4.63	47.9
1968	4.23	3.61	1.65	1.8	1.84	1.97	1.48	0.9	6.21	4.82	3.09	2.73	34.33
1969	4.51	2.5	0.59	1.26	1.81	1	0.67	0.59	1.02	1.74	9.09	5.27	30.05
1970	3.04	1.25	13.15	5.14	4.37	5.07	7.18	9.41	5.62	17.96	18.51	5.85	96.55
1971	1.5	5.11	2.13	1.42	10.54	5.29	1.68	4.12	4.21	6.03	7.87	3.65	53.55
1972	1.37	0.75	0.62	0.73	0.63	1.61	2.34	2.28	2	1.79	2.02	3.8	19.94
1973	2.88	3.96	2.18	4.06	3.79	4.4	2.22	5.12	3.26	1.23	9.62	7.97	50.69
1974	4.36	2.91	0.95	2.12	1.4	1.62	1.32	0.85	1.02	4.73	6.21	10.02	37.51
1975	4.15	3	2.57	1.41	1.26	5.05	2.44	1.7	2.15	5.2	4.37	2.66	35.96
1976	13.97	9.44	4.16	1.09	7.89	4.39	1.35	15.19	9.06	2.97	3.16	3.95	76.62

1977	4.72	4.18	1.95	0.8	0.46	0.81	1.43	1.56	3.22	2.31	4.18	3.54	29.16
1978	4.68	4.58	3.02	2.09	1.21	0.71	1.11	2.48	2.53	6.71	9.87	6.42	45.41
1979	2.69	1.05	0.78	1.86	0.99	0.47	2.77	2.82	4.72	3.16	2.86	3.65	27.82
1980	6.1	7.69	4.65	11.03	4.55	11.7	16.38	24.24	9.78	2.99	19.65	8.49	127.25
1981	8.03	4.46	2.31	1.08	0.85	1.98	25.58	10.38	2.15	3.64	2.87	6.23	69.56
1982	6.36	2.7	1.37	0.62	2.8	2.17	1.15	2.81	12.7	21.67	8.74	7.24	70.33
1983	10.89	5.58	3.65	1.51	0.86	2.25	1.37	0.87	1.72	3.55	3.19	1.91	37.35
1984	3.99	2.52	2.98	3.76	4.92	2.62	4.9	2.7	2.05	3.78	2.58	1.77	38.57
1985	14.81	8.21	6.12	4.42	1.34	0.97	0.77	0.5	0.63	1.11	10.28	6.46	55.62
1986	9.84	4.25	1.58	2.04	1.59	1.62	7.57	3.55	2.2	1.63	2.95	19.58	58.4
1987	7.86	0.93	0.61	0.64	0.42	0.38	4.78	3.49	3.92	3.05	3.72	4.33	34.13
1988	3.87	2.71	1.31	0.53	0.3	0.62	3.91	2.67	1.89	3.37	2.45	2.45	26.08
1989	20.57	14.8	3.42	1.22	2.07	1.29	3.18	3.05	10.67	4.96	2.96	2.61	70.8
1990	5.49	3.67	1.32	2.42	2.47	1.51	0.62	1.82	2.17	2.16	1.94	1.33	26.92
1991	6.5	2.92	3.08	1.89	2.6	1.73	1.49	4.68	4.6	9.49	20.87	8.94	68.79
1992	19.04	10.95	2.22	0.64	0.66	0.53	2.55	3.73	4.23	3.31	3.38	31.33	82.57
1993	11.9	1.54	3.71	2.01	1.98	1.47	4.31	3.12	1.63	2.62	11.27	6.77	52.33
1994	5.63	2.46	8.33	3.39	1.35	4.84	8.07	7.91	5.03	3.36	3.01	2.68	56.06
1995	1.85	12.37	6.44	2.26	0.79	0.54	0.48	0.39	0.37	1.88	2.85	2.57	32.79
1996	17.61	27.33	10.56	1.48	1.97	4.08	6.36	9.05	5.39	3.56	6.49	3.86	97.74
1997	6.15	3.27	0.89	1.81	0.9	5.04	2.39	3.97	2.73	2.86	5.61	4.49	40.11
1998	2.36	3.14	1.89	1.9	2.09	2.41	2.95	1.6	0.62	1.42	2.65	2.86	25.89
1999	7.51	3.05	0.38	3.16	2.84	7.37	3.42	0.77	0.26	0.24	0.29	1.21	30.5
2000	3.45	8.28	5.21	4.76	1.96	1.17	7.37	3.58	0.8	1.52	6.91	6.18	51.19
2001	3.1	5.49	2.32	2.12	1.1	0.3	1.23	2.31	3.25	8.02	8.48	10.3	48.02
2002	4.12	5.06	2.83	0.8	1.14	21.75	9.86	11.11	6.44	2.84	3.24	2.34	71.53
2003	2.04	1.28	0.99	0.87	1.62	4.35	3.86	1.95	1.63	1.98	2.48	5.1	28.15
Average	0.12	0.08	0.07	0.06	0.09	0.1	0.12	0.1	0.11	0.15	0.17	1.33	**53.39**

Natrual low in the K40A catchment													
Units in million m^3													
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	TOTAL
1920	0.01	0	0.17	0.07	0.18	0.28	0.2	0.09	0.02	0.03	0.03	0.06	1.14
1921	0.39	0.28	1.81	0.77	1.79	2.92	2.24	1.01	0.42	0.46	0.41	0.74	13.24
1922	0.48	0.6	1.98	1.34	0.47	1.2	4.37	2.34	0.83	1.94	1.62	1.21	18.38
1923	1.96	3.62	1.19	0.53	0.39	0.18	0.77	1.6	1.09	0.45	0.37	0.29	12.44
1924	0.36	0.65	0.31	0.13	0.19	0.15	0.26	0.34	0.34	0.23	0.96	1.54	5.46
1925	0.98	0.59	1.28	0.65	0.16	2.28	1.38	0.63	0.74	0.5	1.52	9.79	20.5
1926	4.17	0.94	0.62	0.27	0.13	0.91	0.54	0.26	0.69	0.87	0.67	0.54	10.61
1927	1.06	3.78	1.32	0.25	1.22	0.63	0.16	0.84	0.54	0.2	0.46	0.36	10.82
1928	0.47	0.64	0.27	0.23	0.31	2.92	2.11	0.67	0.33	0.28	0.65	1.03	9.91
1929	0.67	4.01	2.52	0.52	0.45	0.69	0.46	0.5	0.46	1.28	1.79	1.48	14.83
1930	0.86	0.38	0.55	0.55	3.95	2.1	0.81	1.03	1.03	0.96	1.75	1.51	15.48
1931	1.24	0.52	0.46	2.3	1.05	0.42	1.1	0.59	0.22	1.05	0.97	1.02	10.94
1932	2.47	1.06	14.49	7.77	3.49	1.44	0.38	0.66	0.76	0.65	0.44	6.94	40.55
1933	3.45	0.98	0.32	0.06	0.5	0.94	0.86	0.78	0.5	0.31	3.11	1.53	13.34
1934	0.33	1.17	0.47	0.38	0.69	1.31	0.56	0.16	0.12	1.26	1	0.7	8.15
1935	4.31	3.48	0.82	0.25	0.96	0.53	1.08	13.16	5.46	1.21	1.1	2.53	34.89
1936	1.69	2.18	1.85	0.63	0.65	0.63	0.31	1.31	0.75	1.17	0.75	1.39	13.31
1937	1.09	4.13	1.72	0.37	0.69	3.15	1.21	0.14	0.19	0.97	0.69	0.83	15.18
1938	0.72	1.46	1.67	0.93	0.23	0.24	0.67	0.47	0.3	0.26	0.35	0.75	8.05
1939	0.76	2.26	1.15	0.21	2.81	2.43	0.81	0.2	0.06	2.15	4.2	2.49	19.53
1940	1.05	0.87	0.7	1.31	5.52	2.84	0.71	0.36	0.31	0.33	0.22	0.6	14.82
1941	0.56	0.65	0.24	0.56	0.58	0.39	4.09	1.76	0.85	0.6	0.37	0.45	11.1
1942	1.92	1.75	2.81	3.54	1.11	1.36	0.89	1.3	0.97	0.54	0.56	0.44	17.19
1943	1.11	1.17	1.64	2.16	0.82	2.18	1.07	0.29	0.21	0.2	0.79	2.63	14.27
1944	1.94	4.61	2.74	0.51	0.28	1.04	0.66	5.21	2.55	2.11	1.35	3.44	26.44
1945	1.73	0.44	0.19	0.19	0.13	0.14	0.12	5.26	3.91	1.34	1.01	0.72	15.18
1946	2.71	1.14	0.22	0.53	1.22	4.89	1.84	0.23	0.14	0.23	0.26	0.43	13.84
1947	0.5	0.35	0.16	0.12	0.24	2.23	1.07	0.55	0.62	2.14	1.09	2.54	11.61
1948	1.69	0.8	0.24	2.09	1.06	0.43	1.67	0.88	0.31	0.28	0.27	0.88	10.6
1949	4.17	1.99	1.05	1.66	1.32	0.45	0.67	1.15	0.57	0.15	0.17	0.75	14.1
1950	0.6	6.12	2.14	0.14	0.42	0.46	0.26	0.2	0.11	3.51	2.48	1.58	18.02
1951	2.55	10.59	4.98	8.75	3.19	0.72	0.33	0.41	0.86	4.46	2.86	2.74	42.44
1952	1.09	0.15	0.06	1.32	1.07	0.38	0.64	1.15	0.84	0.69	2.49	6.88	16.76
1953	3.15	1.09	0.9	0.48	1.76	0.8	0.74	0.43	2.91	3.32	4.99	2.89	23.46
1954	7.51	4.44	1.08	0.18	0.06	0.64	1.39	3.53	1.93	1.9	14.33	5.39	42.38
1955	0.63	3.94	1.39	1.13	7.46	2.97	0.52	0.41	0.52	0.65	0.63	0.82	21.07
1956	1.71	3.68	1.19	0.44	0.72	1.71	0.89	2.33	1.15	0.3	0.26	0.56	14.94
1957	3.84	2.29	2.13	0.82	1.25	1.47	0.61	0.47	1.26	0.84	1.26	3.42	19.66
1958	1.86	0.4	0.24	0.25	0.15	1.47	1.03	2.02	1.23	0.41	1.7	0.94	11.7
1959	0.71	0.39	0.4	3.41	1.67	1.91	3.39	1.97	0.64	1.47	4.37	1.97	22.3
1960	4.12	1.65	0.74	1.82	0.65	3.34	1.96	1.23	1.04	0.81	0.48	1.78	19.62
1961	1.05	0.86	1.2	0.57	0.39	2.61	2.14	1.34	0.65	0.4	0.65	0.7	12.56
1962	0.87	0.64	0.34	1.19	0.72	2.05	1.16	0.37	0.18	0.16	9.37	3.72	20.77
1963	3.1	3.3	0.93	1.43	0.64	9.4	3.63	0.63	0.43	0.92	0.78	0.37	25.56
1964	0.53	0.34	1.06	1.37	0.69	0.6	0.76	0.43	2.4	1.22	1.79	8.05	19.24
1965	3	0.75	0.26	0.15	0.13	1.39	0.75	0.85	0.71	0.58	0.41	0.29	9.27
1966	5.86	6.3	2.36	1	1.11	0.4	0.57	1.04	0.59	0.27	1.83	1.58	22.91
1967	0.66	0.23	0.73	0.29	1.37	2.1	8.28	7.22	2.28	1.21	1.05	1.02	26.44
1968	0.81	0.82	0.32	0.06	0.04	0.78	0.62	0.61	5.04	2.08	1.16	1.31	13.65
1969	1.27	2.35	0.81	0.32	0.33	1.01	0.62	0.23	1.43	0.97	0.61	0.58	10.53
1970	0.93	0.41	0.07	0.23	0.93	0.44	0.12	0.08	0.13	0.22	2.44	1.47	7.47
1971	1.09	0.45	5.15	1.84	0.87	1.69	2.22	2.42	1.28	5.66	6.17	1.88	30.72
1972	0.52	1.7	0.62	0.24	2.65	1.52	0.59	0.61	0.63	0.55	1.3	0.86	11.79
1973	0.35	0.2	0.13	0.2	0.16	0.28	0.76	0.58	0.43	0.39	0.45	0.54	4.47
1974	0.37	0.51	0.33	1.21	1.17	1.61	0.74	1.59	0.96	0.34	1.46	1.23	11.52
1975	0.58	0.88	0.32	0.62	0.39	0.62	0.47	0.28	0.45	0.87	1.36	2.67	9.51
1976	1.1	0.62	0.76	0.37	0.37	0.8	0.39	0.63	0.62	1.21	0.99	0.75	8.61

1977	6	4.75	1.44	0.23	3.6	2.19	0.57	5.31	2.36	0.43	0.75	1.44	29.07
1978	0.93	1.23	0.53	0.35	0.15	0.15	0.31	0.26	0.64	0.47	0.6	0.56	6.18
1979	0.87	1.7	0.81	0.82	0.5	0.26	0.15	0.81	0.76	2.56	2.46	2.53	14.23
1980	1.08	0.24	0.12	0.47	0.24	0.12	0.46	0.39	0.65	0.49	0.44	1.1	5.8
1981	2.56	2.24	1.69	6.36	2.38	4.94	5.05	13.65	5.21	0.91	6.88	3.03	54.9
1982	2.62	1.24	1.01	0.52	0.64	0.89	6.81	2.59	0.95	1.33	0.86	2.15	21.61
1983	2.15	0.79	0.27	0.12	0.21	0.24	0.26	0.42	2.97	6.5	2.41	1.11	17.45
1984	2	1.73	0.95	0.37	0.29	1.16	0.56	0.25	0.27	1.37	0.84	0.34	10.13
1985	1.58	0.81	0.72	1.1	1.25	0.63	0.8	0.51	0.46	1.19	0.77	0.37	10.19
1986	4.43	2.58	2.2	1.11	0.38	0.27	0.21	0.12	0.09	0.21	3.08	1.65	16.33
1987	3.06	1.54	0.52	0.52	0.36	0.45	3.74	1.51	0.51	0.39	0.95	5.43	18.98
1988	2.14	0.27	0.37	0.26	0.19	0.23	1.35	1.11	0.78	0.49	0.85	0.9	8.94
1989	0.79	0.39	0.38	0.29	0.18	0.26	2.24	1.04	0.28	0.34	0.3	0.25	6.74
1990	4.71	5.03	1.3	0.19	2.4	1.02	1.55	1.15	1.76	0.96	0.48	0.41	20.96
1991	1.49	1	0.32	0.37	0.58	0.39	0.29	0.25	0.49	0.67	0.55	0.32	6.72
1992	2.67	1.05	1.48	0.69	0.8	0.71	0.38	0.73	0.72	2.85	2.23	0.95	15.26
1993	6.45	3.2	0.5	1.41	0.72	0.44	2.69	1.96	0.82	0.37	0.34	8.58	27.48
1994	3.36	0.73	1.23	1.13	0.74	0.96	1.49	0.75	0.3	0.68	3.28	1.62	16.27
1995	1.76	0.76	3.78	2.07	0.98	1.79	2.42	1.65	0.92	0.48	0.34	0.28	17.23
1996	0.33	4.48	2.87	0.78	0.22	0.23	0.29	0.18	0.11	0.34	0.52	0.58	10.93
1997	6.29	12.74	4.86	0.56	1.12	2.63	1.9	2.34	1.75	0.87	0.92	0.67	36.65
1998	1.4	0.63	0.12	0.3	0.28	3.27	1.26	0.22	0.15	0.23	0.48	0.4	8.74
1999	0.21	0.34	0.36	0.48	0.61	1.22	1.29	0.58	0.16	0.17	0.28	0.8	6.5
2000	2.32	0.87	0.12	3.46	1.54	3.59	1.39	0.18	0.1	0.09	0.07	0.09	13.82
2001	0.24	2.64	4.7	1.56	0.56	0.7	1.31	0.67	0.2	0.35	1.15	1.01	15.09
2002	0.77	2.45	1.04	0.59	0.29	0.12	0.22	0.27	0.54	2.23	1.96	2.82	13.3
2003	1.14	0.25	0.55	0.27	0.26	10.54	3.96	1.69	1.1	0.57	0.47	0.3	21.1
	0.84	0.43	0.27	0.49	0.55	0.97	0.77	0.48	0.37	0.36	0.53	1.13	
Average	**1.88**	**1.87**	**1.31**	**1.04**	**1.01**	**1.47**	**1.33**	**1.40**	**0.96**	**1.04**	**1.56**	**1.73**	**16.59**

Natural flow in the K40B catchment													
Units in million m^3													
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	TOTAL
1920	0.52	0.38	2.58	1.1	2.55	4.28	3.4	1.64	0.7	0.69	0.62	1.07	19.53
1921	0.72	0.84	2.83	1.91	0.67	1.7	6.47	3.42	1.27	3.19	2.36	1.78	27.16
1922	2.97	5.43	1.82	0.73	0.53	0.26	1.06	2.37	1.74	0.76	0.55	0.43	18.65
1923	0.5	0.9	0.44	0.17	0.24	0.19	0.35	0.48	0.49	0.33	1.35	2.33	7.77
1924	1.57	0.9	1.81	0.91	0.23	3.27	2.04	0.99	1.13	0.79	2.24	15.8	31.68
1925	6.57	1.38	0.88	0.37	0.18	1.26	0.79	0.39	0.97	1.32	1.07	0.84	16.02
1926	1.55	5.59	1.98	0.34	1.71	0.91	0.24	1.16	0.79	0.31	0.63	0.53	15.74
1927	0.66	0.89	0.38	0.3	0.41	4.23	3.15	1.08	0.51	0.42	0.92	1.54	14.49
1928	1.05	5.88	3.68	0.76	0.61	0.95	0.67	0.74	0.7	1.9	3.15	2.25	22.34
1929	1.27	0.58	0.75	0.74	5.74	3.11	1.23	1.56	1.64	1.56	3.04	2.26	23.48
1930	1.83	0.8	0.64	3.29	1.52	0.6	1.57	0.9	0.34	1.49	1.5	1.58	16.06
1931	3.75	1.67	21.77	11.64	5.18	2.16	0.59	0.94	1.14	1.01	0.69	10.55	61.09
1932	5.06	1.4	0.47	0.09	0.66	1.31	1.26	1.2	0.8	0.47	4.62	2.17	19.51
1933	0.45	1.64	0.67	0.5	0.94	1.87	0.85	0.25	0.17	1.78	1.54	1.09	11.75
1934	6.43	5.24	1.28	0.34	1.33	0.76	1.54	20.85	8.54	1.9	1.76	4.37	54.34
1935	2.56	3.14	2.69	0.91	0.9	0.88	0.46	1.88	1.15	1.72	1.17	2.05	19.51
1936	1.68	6.12	2.55	0.52	0.95	4.59	1.83	0.23	0.25	1.37	1.05	1.22	22.36
1937	1.09	2.13	2.4	1.32	0.33	0.32	0.93	0.7	0.45	0.37	0.49	1.07	11.6
1938	1.14	3.32	1.68	0.31	4.04	3.54	1.25	0.32	0.09	3.09	7.05	3.91	29.74
1939	1.6	1.28	0.99	1.84	8.1	4.23	1.12	0.56	0.46	0.49	0.33	0.83	21.83
1940	0.82	0.93	0.34	0.74	0.79	0.55	6.01	2.7	1.3	0.95	0.58	0.66	16.37
1941	2.82	2.6	4.12	5.17	1.64	1.93	1.32	1.95	1.54	0.88	0.85	0.68	25.5
1942	1.61	1.71	2.36	3.12	1.2	3.15	1.61	0.47	0.31	0.28	1.1	4.31	21.23
1943	2.87	6.76	4.03	0.76	0.37	1.45	0.97	7.92	3.73	3.68	2.13	5.5	40.17
1944	2.57	0.59	0.26	0.24	0.17	0.18	0.15	7.7	6.76	2.25	1.45	1.11	23.43
1945	4.02	1.74	0.32	0.7	1.71	7.2	2.82	0.39	0.21	0.31	0.37	0.61	20.4
1946	0.72	0.5	0.22	0.16	0.31	3.21	1.6	0.83	0.94	3.82	1.76	3.66	17.73
1947	2.56	1.23	0.37	2.99	1.51	0.61	2.42	1.36	0.49	0.41	0.39	1.25	15.59
1948	6.22	2.89	1.47	2.36	1.89	0.67	0.94	1.7	0.91	0.25	0.24	1.06	20.6
1949	0.89	9.03	3.19	0.2	0.55	0.63	0.38	0.29	0.16	5.1	4.04	2.39	26.85
1950	3.83	15.96	7.53	13.01	4.77	1.05	0.5	0.57	1.26	7.46	4.66	4.4	65
1951	1.66	0.2	0.07	1.84	1.5	0.55	0.89	1.69	1.33	1.09	4.26	10.71	25.79
1952	4.72	1.59	1.28	0.66	2.51	1.17	1.06	0.65	4.27	5.81	8.15	4.39	36.26
1953	11.52	6.55	1.53	0.26	0.08	0.86	2	5.9	2.9	3.18	22.17	8.22	65.17
1954	0.93	5.77	2.06	1.58	11.01	4.46	0.81	0.62	0.77	0.99	0.98	1.24	31.22
1955	2.56	5.5	1.81	0.6	0.99	2.46	1.35	3.4	1.63	0.41	0.36	0.79	21.86
1956	5.68	3.46	3.13	1.2	1.77	2.12	0.93	0.7	1.86	1.33	1.9	5.99	30.07
1957	3	0.59	0.32	0.32	0.2	2.07	1.51	3.01	1.78	0.59	2.44	1.44	17.27
1958	1.04	0.57	0.54	4.94	2.42	2.78	5.08	2.88	0.97	2.15	7.38	3.17	33.92
1959	6.08	2.52	1.05	2.59	0.94	4.85	2.92	1.92	1.67	1.32	0.79	2.61	29.26
1960	1.63	1.27	1.7	0.8	0.52	3.78	3.2	2.12	1.08	0.63	0.97	1.07	18.77
1961	1.3	0.95	0.48	1.66	1.01	2.96	1.74	0.59	0.27	0.23	14.36	5.51	31.06
1962	4.45	4.89	1.42	2.03	0.92	13.97	5.53	1.02	0.68	1.36	1.22	0.6	38.09
1963	0.75	0.48	1.48	1.92	0.98	0.85	1.11	0.66	3.52	1.9	2.69	13.19	29.53
1964	4.81	1.04	0.37	0.19	0.17	1.95	1.11	1.24	1.1	0.9	0.64	0.43	13.95
1965	8.64	9.41	3.53	1.43	1.57	0.59	0.78	1.51	0.93	0.41	2.67	2.45	33.92
1966	1.1	0.36	0.99	0.4	1.92	3.04	12.9	11.28	3.44	1.81	1.67	1.62	40.53
1967	1.28	1.21	0.46	0.09	0.05	1.05	0.88	0.91	8.23	3.27	1.63	2	21.06
1968	1.98	3.52	1.22	0.43	0.44	1.41	0.91	0.35	2.05	1.49	0.96	0.89	15.65
1969	1.37	0.63	0.11	0.3	1.28	0.63	0.17	0.1	0.16	0.29	3.5	2.05	10.59
1970	1.56	0.67	7.52	2.7	1.21	2.43	3.33	4.16	1.97	9.01	9.84	2.89	47.29
1971	0.7	2.43	0.91	0.32	3.82	2.21	0.9	0.91	0.97	0.86	1.96	1.37	17.36
1972	0.56	0.28	0.17	0.25	0.21	0.37	1.06	0.87	0.65	0.59	0.66	0.81	6.48
1973	0.56	0.7	0.45	1.69	1.65	2.34	1.12	2.35	1.51	0.56	2.12	1.9	16.95
1974	0.94	1.25	0.46	0.83	0.53	0.85	0.68	0.42	0.64	1.29	2.12	4.9	14.91
1975	1.88	0.83	1.04	0.52	0.5	1.12	0.57	0.89	0.93	1.82	1.59	1.19	12.88
1976	8.98	6.98	2.1	0.34	5.2	3.2	0.88	7.79	3.4	0.61	1.06	2.17	42.71

1977	1.47	1.81	0.77	0.47	0.21	0.19	0.42	0.37	0.9	0.7	0.86	0.85	9.02
1978	1.27	2.48	1.19	1.13	0.69	0.36	0.21	1.13	1.14	4.47	4.24	4.14	22.45
1979	1.57	0.3	0.15	0.62	0.32	0.16	0.61	0.56	0.93	0.75	0.65	1.61	8.23
1980	3.88	3.4	2.49	9.36	3.53	7.28	7.86	21.28	8.01	1.42	11.09	4.74	84.34
1981	3.88	1.9	1.44	0.73	0.87	1.26	10.27	3.82	1.31	2.01	1.41	3.23	32.13
1982	3.33	1.28	0.4	0.16	0.26	0.31	0.36	0.59	4.6	9.99	3.61	1.57	26.46
1983	2.99	2.62	1.39	0.52	0.39	1.63	0.84	0.37	0.38	1.98	1.31	0.53	14.95
1984	2.28	1.2	1.01	1.53	1.77	0.92	1.15	0.78	0.68	1.78	1.23	0.57	14.9
1985	6.51	3.85	3.23	1.6	0.53	0.37	0.3	0.16	0.12	0.27	4.59	2.35	23.88
1986	4.46	2.32	0.76	0.7	0.49	0.62	5.5	2.31	0.76	0.58	1.38	8.94	28.82
1987	3.43	0.37	0.49	0.34	0.25	0.31	1.92	1.69	1.24	0.79	1.25	1.38	13.46
1988	1.22	0.6	0.51	0.39	0.24	0.34	3.24	1.58	0.44	0.5	0.43	0.36	9.85
1989	6.91	7.5	1.99	0.27	3.45	1.5	2.24	1.76	2.83	1.42	0.65	0.59	31.11
1990	2.15	1.48	0.47	0.5	0.79	0.55	0.42	0.36	0.69	1	0.86	0.49	9.76
1991	3.89	1.58	2.1	0.98	1.11	1	0.57	1.05	1.1	4.91	3.51	1.32	23.12
1992	9.51	4.81	0.79	2	1.02	0.61	3.94	3.03	1.37	0.61	0.5	13.27	41.46
1993	5.04	0.97	1.73	1.59	1.04	1.36	2.19	1.18	0.49	0.98	5.59	2.58	24.74
1994	2.54	1.15	5.5	2.98	1.39	2.6	3.63	2.63	1.53	0.8	0.52	0.42	25.69
1995	0.46	6.54	4.19	1.13	0.31	0.31	0.4	0.26	0.15	0.45	0.75	0.86	15.81
1996	9.29	18.99	7.28	0.85	1.56	3.83	2.87	3.96	2.64	1.29	1.39	1.04	54.99
1997	2.06	0.95	0.19	0.39	0.37	4.75	1.89	0.33	0.22	0.31	0.68	0.59	12.73
1998	0.31	0.45	0.49	0.65	0.84	1.74	1.92	0.92	0.26	0.23	0.39	1.13	9.33
1999	3.46	1.35	0.18	5	2.23	5.25	2.11	0.29	0.14	0.12	0.09	0.12	20.34
2000	0.32	3.81	6.88	2.29	0.77	0.99	1.92	1.04	0.32	0.48	1.68	1.58	22.08
2001	1.21	3.61	1.54	0.82	0.4	0.16	0.29	0.37	0.76	3.91	2.97	4.59	20.63
2002	1.78	0.32	0.73	0.36	0.35	15.7	6.06	2.59	1.77	0.94	0.73	0.46	31.79
2003	1.18	0.62	0.37	0.65	0.74	1.36	1.14	0.75	0.57	0.53	0.77	1.68	10.36
Average	**2.83**	**2.78**	**1.92**	**1.49**	**1.44**	**2.15**	**1.99**	**2.15**	**1.49**	**1.64**	**2.44**	**2.71**	**25.03**

Natural flow in the K40C catchment

Units in million m^3

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	TOTAL
1920	0.6	0.78	3.93	1.56	3.77	5.57	3.66	1.37	0.75	0.97	0.78	1.74	25.48
1921	1.08	1.62	4.09	3.35	1.34	1.79	7.29	3.77	1.12	2.68	1.93	1.89	31.95
1922	3.63	6	1.91	1.78	0.97	0.45	2.38	3.19	1.72	0.62	0.66	0.54	23.85
1923	0.98	2.32	1.12	0.72	0.73	0.43	0.68	0.7	0.63	0.38	2.12	3.85	14.66
1924	1.86	1.73	3.08	1.6	0.39	3.11	2.08	0.9	1.25	0.77	2.3	13.21	32.28
1925	6.02	1.6	1.75	0.8	0.41	2.56	1.24	0.49	1.38	1.4	1.06	1.08	19.79
1926	2.06	5.32	1.72	0.32	1.65	0.79	0.2	1.46	0.79	0.29	0.97	0.69	16.26
1927	0.74	0.74	0.38	0.54	1.04	5.5	3.28	0.79	0.45	0.35	0.87	1.64	16.32
1928	0.92	5.2	3.87	0.84	0.77	1.08	0.75	0.95	0.78	2.31	2.73	2.22	22.42
1929	1.5	0.61	0.95	1.05	7.2	3.77	1.04	1.91	1.55	1.31	2.52	2.23	25.64
1930	1.74	0.67	0.96	3.45	1.55	0.53	1.94	0.95	0.31	2.09	1.6	2.45	18.24
1931	4.71	1.7	17.12	10.68	5.73	2.31	0.51	1.16	1.22	0.9	0.62	11.58	58.24
1932	6.93	2.04	0.5	0.09	0.78	1.83	1.48	1.11	0.7	0.47	6.07	2.61	24.61
1933	0.44	2.37	0.88	0.56	1.18	2.55	0.96	0.24	0.22	2.55	1.76	1.23	14.94
1934	7.04	5.17	1.11	0.51	1.92	0.98	2.22	19.73	8.14	1.59	1.6	3.81	53.82
1935	3.13	4.36	3.55	1.34	1.74	1.49	0.57	2.35	1.16	2.11	1.14	2.55	25.49
1936	1.79	6.45	2.85	0.93	1.74	5.5	1.9	0.16	0.37	1.77	1.15	2.67	27.28
1937	1.86	2.26	2.42	1.81	0.46	0.77	1.28	0.67	0.42	0.4	0.65	1.7	14.7
1938	1.99	4.15	2.39	0.47	4.01	3.51	1.02	0.17	0.05	3.98	7.25	4.55	33.54
1939	1.84	1.3	1.02	3.37	8.49	4.29	1.03	0.49	0.4	0.49	0.33	1.76	24.81
1940	1.36	1.28	0.42	0.84	1.14	0.72	6.27	2.47	1.42	0.87	0.42	0.95	18.16
1941	3.44	2.84	5.38	5.99	1.85	2.94	1.54	2.66	1.62	0.83	1.01	0.74	30.84
1942	2.28	1.79	3.02	3.92	1.64	3.32	1.45	0.34	0.27	0.26	1.95	6.61	26.85
1943	3.88	8.19	4.89	0.86	0.8	2.03	1.17	8.1	3.98	3.41	1.96	5.28	44.55
1944	2.65	0.66	0.5	0.35	0.18	0.19	0.15	7.5	5.62	1.86	1.56	1.09	22.31
1945	3.65	1.51	0.73	1.39	1.69	7.01	2.61	0.28	0.22	0.5	0.55	1.03	21.17
1946	0.87	0.44	0.3	0.39	0.46	3.84	1.78	1.05	1.13	4.54	1.88	3.47	20.15
1947	2.32	1.27	0.41	4.36	2.15	0.75	3.39	1.43	0.33	0.41	0.39	1.88	19.09
1948	5.83	2.79	2.12	3.41	2.4	0.62	1.26	2.31	0.93	0.19	0.34	1.42	23.62
1949	1.06	8.53	2.93	0.22	0.67	0.76	0.58	0.43	0.19	4.47	3.27	2.34	25.45
1950	3.86	14.97	7.99	12.15	4.31	1.16	0.48	0.74	1.85	7.11	4.56	4.01	63.19
1951	1.47	0.17	0.11	2.73	2	0.61	1.51	1.75	1.19	1.19	3.79	9.55	26.07
1952	4.62	1.5	2.04	1.12	3.56	1.38	1.13	0.57	5.52	5.23	7.73	4.2	38.6
1953	10.82	6.68	2.18	0.45	0.1	1.47	2.18	4.83	2.45	2.47	20.28	7.8	61.71
1954	0.95	7.13	2.44	2.37	11.82	4.5	0.73	0.57	0.81	0.9	0.8	1.36	34.38
1955	2.9	6.36	1.97	1	1.69	3.9	1.88	4.89	1.99	0.3	0.31	0.95	28.14
1956	6.02	3.55	3.44	1.33	2.55	2.4	0.84	0.84	2.09	1.15	2.18	5.09	31.48
1957	2.75	0.55	0.53	0.73	0.43	3.43	2.11	2.78	1.52	0.44	2.49	1.25	19.01
1958	1.18	0.69	0.76	6.91	3.37	3.91	6.08	2.96	0.72	2.35	6.94	2.91	38.78
1959	6.68	2.52	1.34	3.75	1.25	6.7	3.45	1.72	1.44	1.16	0.67	3.22	33.9
1960	1.62	1.4	2.4	1.13	0.69	4.61	3.2	2.21	0.94	0.48	0.99	1.12	20.79
1961	1.77	1.21	0.74	2.93	1.54	3.76	1.92	0.46	0.19	0.21	12.69	4.91	32.33
1962	5.18	5.35	1.45	2.72	1.16	14.39	5.48	0.88	0.53	1.55	1.13	0.48	40.3
1963	1.03	0.59	2.24	2.71	1.34	1.15	1.34	0.62	3.78	1.71	2.4	11.11	30.02
1964	4.01	1.54	0.51	0.34	0.3	3.22	1.49	1.56	1.12	0.82	0.55	0.4	15.86
1965	9.34	9.7	4.31	2.31	2.75	0.86	0.95	2.08	0.95	0.3	3.29	2.34	39.18
1966	0.8	0.33	1.82	0.66	2.35	3.7	11.69	9.8	2.89	1.74	1.49	1.65	38.92
1967	1.24	1.64	0.65	0.15	0.14	1.94	1.18	1.01	7.29	2.89	1.8	2.31	22.24
1968	2.23	4.48	1.46	0.96	0.83	2.15	1.11	0.29	2.01	1.29	0.87	0.91	18.59
1969	2.07	0.8	0.08	0.46	2.36	0.96	0.15	0.11	0.19	0.35	3.91	2.05	13.49
1970	1.53	0.6	9.39	3.36	2.23	2.94	3.77	3.9	1.71	8.87	9.11	2.54	49.95
1971	0.7	3.12	1.08	0.55	4.61	2.65	0.82	0.93	0.99	0.82	2.36	1.31	19.94
1972	0.43	0.37	0.3	0.4	0.32	0.67	1.62	1	0.59	0.54	0.64	0.86	7.74
1973	0.57	1.46	0.76	2.88	2.82	3.44	1.22	2.9	1.41	0.33	3.39	2.17	23.35
1974	0.83	1.62	0.56	1.31	0.83	1.35	0.82	0.35	0.55	1.21	2.22	4.72	16.37
1975	1.77	1.34	1.44	0.65	0.79	1.72	0.67	1.15	0.99	2.32	1.52	0.94	15.3
1976	9.32	7.82	2.64	0.41	6.65	3.79	0.77	9.04	3.73	0.5	1.18	2.64	48.49

1977	1.53	2.24	0.91	0.53	0.2	0.26	0.58	0.41	1.21	0.72	0.95	0.84	10.38
1978	1.49	3.41	1.62	1.71	0.95	0.42	0.21	1.82	1.29	4.76	4.36	3.96	26
1979	1.44	0.29	0.18	1.03	0.43	0.18	1.03	0.72	1.17	0.75	0.65	2.08	9.95
1980	4.71	4.36	3.49	10.2	3.71	7.72	8.64	20.32	7.64	1.28	11.14	4.63	87.84
1981	4.87	2.09	2.07	1.11	0.95	1.55	11.69	4.17	1.74	2.23	1.21	4.16	37.84
1982	3.67	1.13	0.43	0.22	0.56	0.46	0.44	0.76	5.96	10.22	3.39	2.17	29.41
1983	4.03	2.84	1.56	0.64	0.45	2.41	0.99	0.34	0.41	2.72	1.35	0.42	18.16
1984	3.24	1.44	1.58	2.49	2.78	1.15	1.59	0.83	0.74	2.36	1.23	0.48	19.91
1985	7.58	4.65	4.12	2.19	0.66	0.44	0.32	0.15	0.11	0.33	5.8	2.76	29.11
1986	5.35	2.43	0.69	1.3	0.9	0.99	6.52	2.37	0.93	0.6	1.91	9.91	33.9
1987	3.59	0.29	0.68	0.55	0.3	0.36	2.7	1.82	1.11	0.65	1.36	1.35	14.76
1988	1.15	0.55	0.62	0.48	0.27	0.46	3.93	1.58	0.35	0.57	0.45	0.38	10.79
1989	8.08	7.92	1.89	0.35	4	1.56	3.15	2.05	3.58	1.6	0.62	0.59	35.39
1990	2.84	1.96	0.55	0.7	1.29	0.74	0.37	0.33	0.69	1.01	0.75	0.38	11.61
1991	4.61	1.69	3.1	1.36	1.72	1.41	0.64	1.38	1.25	4.99	3.98	1.32	27.45
1992	10.47	5.63	0.91	2.87	1.52	0.85	4.7	3.29	1.17	0.48	0.52	13.57	45.98
1993	5.12	1.36	2.47	2.4	1.47	1.59	2.63	1.12	0.37	1.26	5.67	2.5	27.96
1994	3.7	1.42	6.4	3.6	1.77	3.63	4.81	3.27	1.44	0.6	0.44	0.41	31.49
1995	0.49	7.68	4.97	1.39	0.36	0.41	0.42	0.21	0.13	0.6	0.85	0.87	18.38
1996	10.63	19.53	8.04	1.08	2.01	4.99	3.81	4.23	2.98	1.25	1.69	1.05	61.29
1997	3.03	1.2	0.15	0.69	0.59	5.56	1.99	0.32	0.22	0.45	0.97	0.67	15.84
1998	0.32	0.74	0.84	1.23	1.44	2.72	2.58	0.9	0.18	0.31	0.5	1.14	12.9
1999	4.06	1.4	0.16	5.65	2.72	6.08	2.19	0.19	0.11	0.11	0.09	0.16	22.92
2000	0.62	4.78	7.71	2.65	1.03	1.31	2.3	0.96	0.21	0.69	2.21	1.67	26.14
2001	1.36	4.37	1.83	1.1	0.5	0.15	0.46	0.44	1.05	4.07	3.15	5.01	23.49
2002	1.79	0.39	1.38	0.59	0.48	17.35	6.4	3.41	1.86	0.83	0.74	0.43	35.65
2003	1.72	0.76	0.5	1.03	1.4	2.51	1.6	0.76	0.57	0.57	0.84	2.31	14.57
Average	**3.16**	**3.09**	**2.26**	**1.94**	**1.86**	**2.63**	**2.27**	**2.23**	**1.51**	**1.65**	**2.47**	**2.82**	**27.90**

Natural flow in the K40D catchment
Units in million m^3

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	TOTAL
1920	0.75	0.84	3.76	1.56	3.61	5.46	3.69	1.6	0.96	1.15	0.99	1.83	26.2
1921	1.26	1.62	3.91	3.16	1.34	1.73	7.43	4.03	1.4	2.77	2.2	2.11	32.96
1922	3.69	6.03	2.01	1.65	0.97	0.51	2.3	3.21	1.98	0.84	0.8	0.69	24.68
1923	1.06	2.24	1.13	0.73	0.74	0.49	0.74	0.82	0.78	0.52	2.11	3.89	15.25
1924	2.11	1.76	2.91	1.54	0.44	2.95	2.12	1.09	1.4	0.96	2.34	13.98	33.6
1925	6.43	1.72	1.68	0.81	0.45	2.42	1.32	0.64	1.46	1.59	1.3	1.28	21.1
1926	2.13	5.31	1.79	0.35	1.53	0.83	0.28	1.42	0.9	0.42	1.05	0.85	16.86
1927	0.86	0.81	0.43	0.54	1	5.46	3.35	0.98	0.58	0.47	0.96	1.75	17.19
1928	1.11	5.2	3.74	0.86	0.76	1.07	0.84	1.07	0.96	2.37	2.92	2.48	23.38
1929	1.74	0.76	0.93	1	7.27	3.81	1.17	1.97	1.75	1.55	2.67	2.47	27.09
1930	1.95	0.82	0.93	3.24	1.54	0.6	1.89	1.09	0.45	2.07	1.81	2.58	18.97
1931	4.78	1.87	17.91	10.88	5.63	2.35	0.63	1.2	1.37	1.11	0.82	12.09	60.64
1932	7.18	2.17	0.6	0.13	0.73	1.73	1.54	1.28	0.89	0.63	6.19	2.89	25.96
1933	0.63	2.25	0.89	0.56	1.12	2.42	1.04	0.35	0.31	2.48	1.97	1.47	15.49
1934	7.26	5.19	1.18	0.52	1.78	1.02	2.17	20.86	8.76	1.92	1.85	3.91	56.42
1935	3.28	4.35	3.41	1.32	1.64	1.48	0.68	2.31	1.32	2.17	1.34	2.57	25.87
1936	1.95	6.57	2.9	0.93	1.64	5.43	2.04	0.26	0.43	1.79	1.35	2.71	28
1937	2.03	2.26	2.29	1.7	0.49	0.74	1.29	0.81	0.56	0.52	0.78	1.77	15.24
1938	2.1	4.09	2.33	0.5	3.85	3.38	1.13	0.27	0.1	3.84	7.62	4.84	34.05
1939	2.11	1.41	1.03	3.18	8.57	4.33	1.17	0.64	0.53	0.62	0.45	1.72	25.76
1940	1.48	1.33	0.47	0.79	1.1	0.77	6.34	2.7	1.54	1.06	0.59	1.05	19.22
1941	3.42	2.81	5.31	5.86	1.89	2.81	1.63	2.69	1.84	1.07	1.2	0.94	31.47
1942	2.28	1.81	2.87	3.7	1.63	3.2	1.55	0.49	0.38	0.35	1.93	6.78	26.97
1943	3.98	8.4	4.85	0.87	0.77	1.92	1.26	8.38	4.31	3.6	2.29	5.46	46.09
1944	2.92	0.84	0.55	0.38	0.22	0.23	0.21	7.63	5.82	2.19	1.81	1.34	24.14
1945	3.66	1.63	0.76	1.29	1.6	7.08	2.8	0.43	0.31	0.59	0.69	1.14	21.98
1946	1.02	0.55	0.35	0.41	0.49	3.7	1.87	1.2	1.31	4.67	2.14	3.49	21.2
1947	2.48	1.38	0.48	4.2	2.12	0.81	3.3	1.58	0.48	0.53	0.52	1.87	19.75
1948	5.89	2.92	2.04	3.2	2.28	0.68	1.24	2.33	1.09	0.29	0.42	1.46	23.84
1949	1.21	8.78	3.08	0.27	0.66	0.79	0.68	0.55	0.27	4.38	3.45	2.58	26.7
1950	3.96	15.66	8.11	12.5	4.51	1.19	0.57	0.81	1.91	7.45	4.93	4.14	65.74
1951	1.63	0.25	0.13	2.51	1.9	0.68	1.49	1.85	1.4	1.41	3.94	10.18	27.37
1952	4.97	1.63	1.94	1.09	3.39	1.43	1.17	0.68	5.56	5.46	8.39	4.58	40.29
1953	11.37	6.83	2.16	0.49	0.14	1.35	2.13	4.87	2.74	2.68	21.61	8.5	64.87
1954	1.2	7.28	2.55	2.19	12.14	4.73	0.87	0.71	0.95	1.07	1	1.5	36.19
1955	2.92	6.42	2.07	0.94	1.58	3.75	1.99	4.95	2.23	0.47	0.42	1.04	28.78
1956	6.12	3.6	3.29	1.32	2.4	2.31	0.96	0.96	2.16	1.37	2.27	5.19	31.95
1957	2.9	0.67	0.53	0.71	0.47	3.27	2.16	2.84	1.76	0.63	2.44	1.41	19.79
1958	1.28	0.79	0.77	6.93	3.37	3.8	6.1	3.21	0.95	2.34	7.34	3.31	40.19
1959	6.92	2.73	1.3	3.53	1.26	6.76	3.56	1.88	1.67	1.4	0.88	3.2	35.09
1960	1.8	1.43	2.25	1.11	0.71	4.51	3.23	2.35	1.16	0.65	1.13	1.3	21.63
1961	1.87	1.3	0.79	2.73	1.51	3.63	2.02	0.62	0.29	0.29	13.22	5.32	33.59
1962	5.27	5.3	1.52	2.54	1.16	14.99	5.85	1.07	0.7	1.62	1.33	0.66	42.01
1963	1.09	0.68	2.09	2.51	1.32	1.17	1.4	0.77	3.75	1.91	2.48	11.77	30.94
1964	4.46	1.56	0.54	0.35	0.33	3.05	1.57	1.64	1.31	1.03	0.74	0.54	17.12
1965	9.65	9.95	4.26	2.17	2.59	0.9	0.96	2.09	1.13	0.45	3.24	2.54	39.93
1966	1.03	0.44	1.68	0.65	2.18	3.52	12.14	10.42	3.31	1.96	1.76	1.86	40.95
1967	1.44	1.66	0.69	0.19	0.17	1.8	1.24	1.14	7.48	3.06	1.83	2.42	23.12
1968	2.38	4.45	1.52	0.91	0.83	2.05	1.2	0.42	1.96	1.46	1.09	1.1	19.37
1969	2.12	0.91	0.14	0.43	2.19	0.99	0.23	0.17	0.25	0.43	3.87	2.28	14.01
1970	1.69	0.72	9.63	3.49	2.09	2.8	3.72	3.98	2.01	9.39	9.79	2.95	52.26
1971	0.85	3	1.1	0.55	4.47	2.63	0.95	1.06	1.16	1.02	2.44	1.54	20.77
1972	0.61	0.44	0.34	0.42	0.35	0.69	1.6	1.15	0.76	0.69	0.8	1.02	8.87
1973	0.72	1.42	0.78	2.69	2.66	3.31	1.33	2.87	1.6	0.5	3.33	2.37	23.58
1974	1.06	1.6	0.59	1.19	0.83	1.31	0.91	0.48	0.65	1.33	2.36	4.85	17.16
1975	1.93	1.31	1.36	0.67	0.78	1.65	0.75	1.18	1.14	2.4	1.78	1.18	16.13
1976	9.69	7.96	2.64	0.46	6.68	3.77	0.88	9.35	4.07	0.71	1.26	2.69	50.16

1977	1.74	2.22	0.94	0.55	0.24	0.29	0.63	0.52	1.27	0.86	1.07	1.01	11.34
1978	1.57	3.31	1.62	1.59	0.95	0.49	0.29	1.76	1.44	4.91	4.69	4.19	26.81
1979	1.7	0.42	0.23	0.95	0.45	0.23	1.02	0.84	1.28	0.92	0.81	2.12	10.97
1980	4.74	4.33	3.35	10.42	3.87	7.88	8.84	21.66	8.33	1.6	11.83	5.09	91.94
1981	4.98	2.24	1.98	1.09	0.94	1.5	12.14	4.54	1.81	2.38	1.49	4.21	39.3
1982	3.77	1.31	0.5	0.25	0.55	0.51	0.52	0.86	6.06	10.86	3.86	2.28	31.33
1983	4.07	2.87	1.55	0.67	0.49	2.28	1.06	0.46	0.53	2.7	1.55	0.59	18.82
1984	3.16	1.52	1.5	2.3	2.62	1.21	1.6	0.97	0.88	2.42	1.46	0.65	20.29
1985	7.78	4.69	3.97	2.1	0.7	0.5	0.4	0.22	0.16	0.4	5.86	3.03	29.81
1986	5.49	2.57	0.76	1.22	0.9	1.01	6.61	2.57	1.03	0.74	1.94	10.43	35.27
1987	3.98	0.43	0.67	0.56	0.34	0.4	2.59	1.95	1.34	0.86	1.47	1.54	16.13
1988	1.33	0.68	0.64	0.49	0.31	0.49	3.83	1.72	0.5	0.69	0.59	0.5	11.77
1989	8.3	8.03	2	0.38	3.83	1.61	3.07	2.2	3.68	1.85	0.82	0.75	36.52
1990	2.81	1.99	0.62	0.69	1.22	0.79	0.47	0.43	0.79	1.16	0.94	0.53	12.44
1991	4.57	1.78	2.92	1.33	1.62	1.4	0.76	1.44	1.42	5.16	4.29	1.65	28.34
1992	10.95	5.75	0.98	2.68	1.49	0.9	4.66	3.43	1.44	0.68	0.67	14.19	47.82
1993	5.56	1.41	2.31	2.23	1.43	1.56	2.59	1.29	0.53	1.34	5.92	2.84	29.01
1994	3.74	1.55	6.45	3.51	1.69	3.5	4.77	3.43	1.74	0.83	0.6	0.54	32.35
1995	0.6	7.83	4.88	1.37	0.42	0.45	0.49	0.3	0.19	0.66	0.99	1.04	19.22
1996	11.08	20.49	8.23	1.11	1.88	4.86	3.81	4.31	3.24	1.57	1.86	1.28	63.72
1997	3.03	1.3	0.22	0.65	0.61	5.53	2.1	0.42	0.31	0.53	1.09	0.84	16.63
1998	0.45	0.76	0.83	1.15	1.37	2.6	2.58	1.07	0.29	0.38	0.61	1.24	13.33
1999	4.05	1.51	0.22	5.58	2.72	6.1	2.34	0.31	0.17	0.16	0.13	0.21	23.5
2000	0.67	4.7	7.72	2.7	1.02	1.3	2.27	1.11	0.33	0.76	2.26	1.9	26.74
2001	1.55	4.31	1.86	1.06	0.53	0.21	0.5	0.54	1.13	4.11	3.4	5.36	24.56
2002	2.07	0.49	1.28	0.59	0.5	18.11	6.84	3.44	2.1	1.09	0.94	0.59	38.04
2003	1.69	0.84	0.53	0.97	1.33	2.39	1.68	0.94	0.74	0.72	1	2.37	15.2
Average	**3.32**	**3.18**	**2.26**	**1.90**	**1.83**	**2.62**	**2.35**	**2.38**	**1.68**	**1.81**	**2.67**	**3.03**	**29.04**

I9 REFERENCES

Department of Water Affairs and Forestry. (2007a). Outeniqua Coast Water Situation Study. Supporting Report: Existing Bulk Water Infrastructure and Water Use. Report prepared by UWP and BKS Consulting Engineers.

Department of Water Affairs and Forestry. (2007b). Outeniqua Coast Water Situation Study. Supporting Report: Hydrology. Report prepared by M Roux.

Department of Water Affairs and Forestry. (2007c). Outeniqua Coast Water Situation Study. Supporting Report: Agricultural Developments. Report prepared by Gorra Water.

Mallory, SJL. (2005). The modelling of water restrictions applied in complex bulk water supply systems and the application of these techniques to operationalising the ecological Reserve; 12th South African National Hydrology Symposium, 2005.

Mallory SJL and Desai A. (2008). The Water Resources Modelling Platform. User Guide. Available on www.waterforafrica.com

Midgley DC., Pitman WV and Middleton BJ. (19940. Surface Water Resources of South Africa 1990. Volume VI. Drainage Regions U,V,W,X - Eastern Escarpment– Appendices and Book of Maps. WRC Report Number 298/6.1/94.

Ninham Shand. (2007). Knysna Bulk Water Supply Planning Study: Main Report

Roux M. (2007). Personal communication, Department of Water Affairs and Forestry.