P WMA 12/T30/00/5212/7

water & sanitation

Department:
Water and Sanitation
REPUBLIC OF SOUTH AFRICA

DIRECTORATE: OPTIONS ANALYSIS

FEASIBILITY STUDY FOR THE MZIMVUBU WATER PROJECT

RESERVE DETERMINATION

VOLUME 1: RIVER

OCTOBER 2014

FEASIBILITY STUDY FOR THE MZIMVUBU WATER PROJECT

APPROVAL

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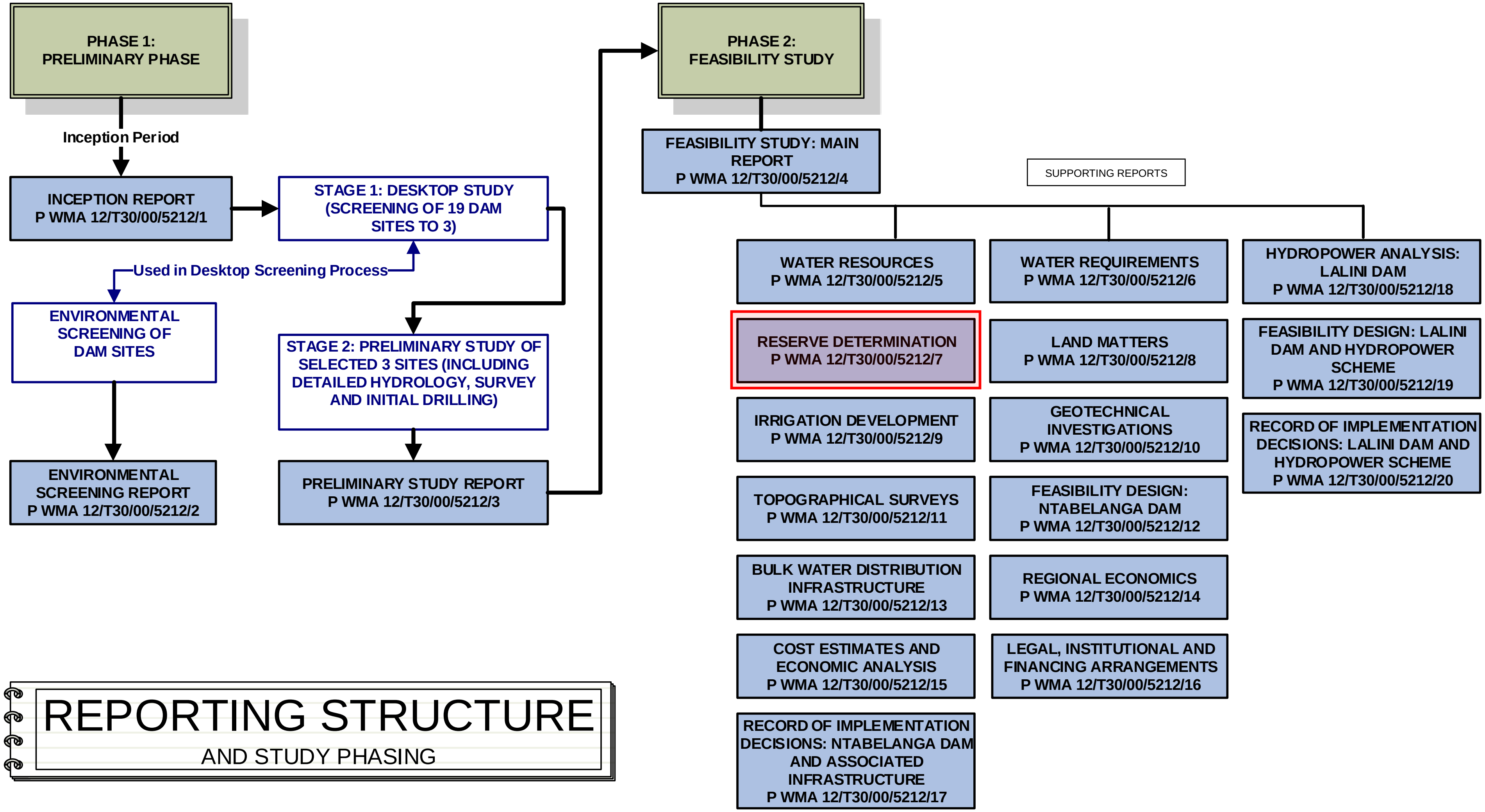
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REFERENCE

This report is to be referred to in bibliographies as:

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DWS Report No: P WMA 12/T30/00/5212/7

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Note on Departmental Name Change:

In 2014, the Department of Water Affairs changed its name to the Department of Water and Sanitation, which happened during the course of this study. In some cases this was after some of the study reports had been finalized. The reader should therefore kindly note that references to the Department of Water Affairs and the Department of Water and Sanitation herein should be considered to be one and the same.

Note on Spelling of Laleni:

The settlement named Laleni on maps issued by the Surveyor General is locally known as Lalini and both names therefore refer to the same settlement.

EXECUTIVE SUMMARY

BACKGROUND

The National Water Act (NWA) No. 36 of 1998 requires that before water use authorisations can be granted to utilise a particular water resource, it is necessary to determine the reserve for the relevant ecological component of the resource that will be impacted by the proposed water use. This requires the implementation of Resource Directed Measures (RDM) to protect the water resources of the country.

The construction of the Ntabelanga dam has been proposed in the Tsitsa catchment in quaternary catchment T35E. The proposed dam will have both direct (i.e. hydraulics) and indirect impacts (i.e. geomorphology, habitat integrity and response variables) on the downstream aquatic ecosystem. These impacts necessitate that the reserve (ecological and basic human needs) are determined for the catchment to ensure adequate protection of the water resources.

Therefore, an Intermediate level Ecological Water Requirement assessment was undertaken in the Tsitsa River in order to determine the effects of reduced flows in the system. This report provides the results of the preliminary determination of the quantity and quality requirements of the reserve on an Intermediate Level for the Tsitsa River. Activities and tasks for this ecological reserve determination study were undertaken in accordance with the appropriate approaches and methodologies for rivers as prescribed by the Resource Directed Measures chief directorate of the Department of Water and Sanitation (DWS).

RESULTS

The water resources of the Tsitsa River at the EWR site is currently in a C category (moderately modified state), mainly due to water quality impacts (a result of increased sedimentation in the system), and localised disturbances (e.g. alien invasive plants and concomitant bank erosion). These changes were observed in both abiotic (i.e. the Desktop Reserve Model (DRM), the Physicochemical Assessment Index (PAI) and Index of Habitat Integrity (IHI)) and biotic (i.e. Macroinvertebrate Response Assessment Index (MIRAI), Fish Response Assessment Index (FRAI) and Specific Pollution sensitivity Index (SPI)) assessments. The overall confidence in these results is medium.

The system has a moderate Ecological Importance and Sensitivity. This is primarily driven by:

a) The unique Barbus anoplus-type minnow likely to be present in system as high waterfalls both up and downstream create barriers to fish movement, thus enabling the development of an Evolutionary Significant Unit;
b) Oligoneuridae were sampled during the survey (these macroinvertebrates are dependent on high velocities); and
c) Perlidae and Prosopistomatidae being present in the system.

The Recommended Ecological Category (REC) is a C.

The results as obtained with the Desktop Reserve Model (SPATSIM, version 2.12) and accepted by the various specialists for the recommended ecological category are summarised in the following table.

Table 1: Summarised key EWR details for the Tsitsa River/Reserve

Quaternary Catchment	***T35E***
EWR Site Co-ordinates	*30.606°S; E 29.755°E*
Ecological Category	*C*
VMAR for Quaternary Catchment Area	*428.49*
Total EWR	*87.249 (20.36 %MAR)*
Maintenance Low flows	*50.517 (11.79 %MAR)*
Drought Low flows	*23.991 (5.60 %MAR)*
Maintenance High flows	*36.732 (8.57 %MAR)*
Overall confidence	*Medium*

CONCLUSIONS AND RECOMMENDATIONS

The Tsitsa River is moderately modified: impacted by both catchment scale processes (e.g. sedimentation) and localised impacts (e.g. alien invasive vegetation). It is critical that the ecological water requirements per this report are met. This will allow management to maintain the REC of a C.

It is recommended that a baseline water quality monitoring programme be initiated. The results from this programme will inform the EcoSpecs and Thresholds of Potential Concern (TPC) in this report and allow for potential re-calibration once sufficient baseline data has been collected.

Furthermore, it is recommended that the biomonitoring programme include quarterly sampling of:

- *Macroinvertebrates (per the SASS5 protocol (Dickens and Graham, 2002) by a Department of Water and Sanitation Accredited SASS5 practioner);*
- *Benthic diatoms; and*
- *Fish.*

These measures will allow for analysis of ecological trends in the system in response to the proposed dam.

This report is based on scenarios and models run at the time of respective workshops. Additional scenarios may need to be run in the future and appropriate modifications made to this report accordingly and if appropriate.

Please note that a further reserve determination study has been undertaken of the Tsitsa River at the proposed Lalini hydroelectric scheme site below the Tsitsa Falls. This additional study was undertaken following this Ntabelanga Dam site study under the separate EIA PSP contract.

The findings and EWR recommendations of that additional study may be found in DWS Report: Rapid Reserve Determination: Tsitsa River at Lalini No. P WMA 12/T30/00/5314/17.

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ASGISA-EC	Accelerated and Shared Growth Initiative for South Africa – Eastern Cape
ASPT	Average Score per Taxon
CAPEX	Capital Expenditure
CD: RDM	Chief Directorate: Resource Directed Measures
CFRD	Concrete-faced Rockfill dam
CMA	Catchment Management Agency
CTC	Cost to Company
CV	Coefficient of Variability
DAFF	Department of Agriculture, Forestry and Fisheries
DBSA	Development Bank of Southern Africa
DEA	Department of Environment Affairs
DM	District Municipality
DME	Department of Minerals and Energy
DoE	Department of Energy
DRDAR	Department of Rural Development and Agrarian Reform
DRDLR	Department of Rural Development and Land Reform
DRM	Desktop Reserve Model
DWA	Department of Water Affairs
DWAF	Department of Water Affairs and Forestry
DWS	Department of Water and Sanitation
EA	Environmental Authorisation
EAP	Environmental Assessment Practitioner
EC	Eastern Cape
ECRD	Earth core rockfill dam
EF	Earthfill (dam)
EIA	Environmental Impact Assessment
EIS	Ecological Importance and Sensitivity
EMP	Environmental Management Plan
EPWP	Expanded Public Works Programme
ESIA	Environmental and Social Impact Assessment
EWR	Environmental Water Requirements
FRAI	Fish Response Assessment Index
FROC	Frequency of Occurance
FSL	Full Supply Level
GERCC	Grout enriched RCC
GN	Government Notices
GW	Gigawatt
GWh/a	Gigawatt hour per annum
HFSR	Habitat Flow Stressor Response
IAPs	Invasive Alien Plants
IB	Irrigation Board
IFC	International Finance Corporation
IHAS	Integrated Habitat Assessment System
IPP	Independent Power Producer
IRR	Internal Rate of Return
IVRCC	Internally vibrated RCC
ISO	International Standards Organisation
kW	Kilowatt

LM	Local Municipality
ℓ/s	Litres per second
MAP	Mean Annual Precipitation
MAR	Mean Annual Runoff
MEC	Member of the Executive Council
MIG	Municipal Infrastructure Grant
million m^3	Million cubic metres
MIRAI	Macroinvertebrate Response Assessment Index
NEMA	National Environmental Management Act
NERSA	National Energy Regulator of South Africa
NHRA	National Heritage Resources Act
NOCL	Non-overspill crest level
NWA	National Water Act
NWPR	National Water Policy Review
NWRMS	National Water Resources Management Strategy
O&M	Operations and Maintenance
OPEX	Operational Expenditure
PAI	Physico-chemical Assessment Index
PES	Present Ecological State/Ecostatus
PICC	Presidential Infrastructure Co-Ordinating Committee
PPA	Power Purchase Agreement
PPP	Public Private Partnership
PSC	Project Steering Committee
PSP	Professional Services Provider
RBIG	Regional Bulk Infrastructure Grant
RCC	Roller-compacted concrete
RDM	Resource Directed Measures
REC	Recommended Ecological Category
REIPPPP	Renewable Energy Independent Power Producer Procurement Programme
RQO	Resource Quality Objectives
RWI	Regional Water Institution
RWU	Regional Water Utilities
SASS5	South African Scoring System (version 5)
SAWS	South African Weather Service
SEZ	Special Economic Zone
SIP	Strategic Integrated Project
SMC	Study Management Committee
SPATSIM	Spatial and Time Series Information Modelling Software
SPV	Special Purpose Vehicle
TCTA	Trans Caledon Tunnel Authority
ToR	Terms of Reference
UOS	Use of System
URV	Unit Reference Value
VEGRAI	Vegetation Response Assessment Index
WEF	Water Energy Food
WMA	Water Management Area
WRYM	Water Resources Yield Model
WSA	Water Services Authority
WSP	Water Services Provider
WTE	Water Trade Entity
WUA	Water User Association

LIST OF UNITS

Description	Standard unit
Elevation	m a.s.l.
Height	m
Distance	m, km
Dimension	mm, m
Area	m^2 , ha or km^2
Volume (storage)	m^3
Yield, Mean Annual Runoff	m^3/a
Rotational speed	rpm
Head of Water	m
Pressure	Pa
Diameter	mm or m
Temperature	ºC

Description	Standard unit
Velocity, speed	m/s, km/hr
Discharge	m^3/s
Mass	kg, tonne
Force, weight	N
Gradient (V:H)	%
Slope (H:V) or (V:H)	1:5 (H:V) or 5:1 (V:H)
Volt	V
Power	W
Energy used	kWh
Acceleration	m/s^2
Density	kg/m^3
Frequency	Hz

1. INTRODUCTION

The Mzimvubu River catchment in the Eastern Cape Province of South Africa is situated in one of the poorest and least developed regions of the country. Development of the area to accelerate the social and economic upliftment of the people was therefore identified as one of the priority initiatives of the Eastern Cape Provincial Government.

Harnessing the water resources of the Mzimvubu River, the only major river in the country which is still largely unutilised, is considered by the Eastern Cape Provincial Government as offering one of the best opportunities in the Province to achieve such development. In 2007, a special-purpose vehicle (SPV) called ASGISA-Eastem Cape (Pty) Ltd (ASGISA-EC) was formed in terms of the Companies Act to initiate planning and to facilitate and drive the Mzimvubu River Water Resources Development.

The five pillars on which the Eastern Cape Provincial Government and ASGISA-EC proposed to model the Mzimvubu River Water Resources Development are:

- Forestry;
- Irrigation;
- Hydropower;
- Water transfer; and
- Tourism.

The Department of Water and Sanitation (DWS) commissioned the Mzimvubu Water Project with the overarching aim of developing water resources schemes (dams) that can be multi-purpose reservoirs in order to provide benefits to the surrounding communities and to provide a stimulus for the regional economy, in terms of irrigation, forestry, domestic water supply and the potential for hydropower generation amongst others.

1.1 Study Locality

The Mzimvubu River Catchment is situated in the Eastern Cape (EC) Province of South Africa which consists of six District Municipalities (DM) and two Metropolitan Municipalities (Buffalo City and Nelson Mandela Bay). These include Cacadu DM in the west across to the Alfred Nzo DM in the east with the two Metropolitan Areas being located around the two major centres of the province, East London and Port Elizabeth, both of which border the Indian Ocean.

The Mzimvubu River Catchment is situated within three of the DM's namely the Joe Gqabi DM in the north-west, the OR Tambo DM in the South and the Alfred Nzo DM in the east and north east. A locality map of the whole catchment area and its position in relation to the DM's in the area is provided in Figure 1-1 overleaf.

1.2 Study Stages

The study commenced in January 2012 and was completed by October 2014 in three stages as follows:

- Inception;
- Phase 1 – Preliminary Study; and
- Phase 2 – Feasibility Study.

The purpose of the study was not to repeat or restate the research and analyses undertaken on the several key previous studies described below, but to make use of that information previously collected, to update and add to this information, and to undertake more focussed and detailed investigations and feasibility level analyses for the dam site options identified as being the most promising and cost beneficial.

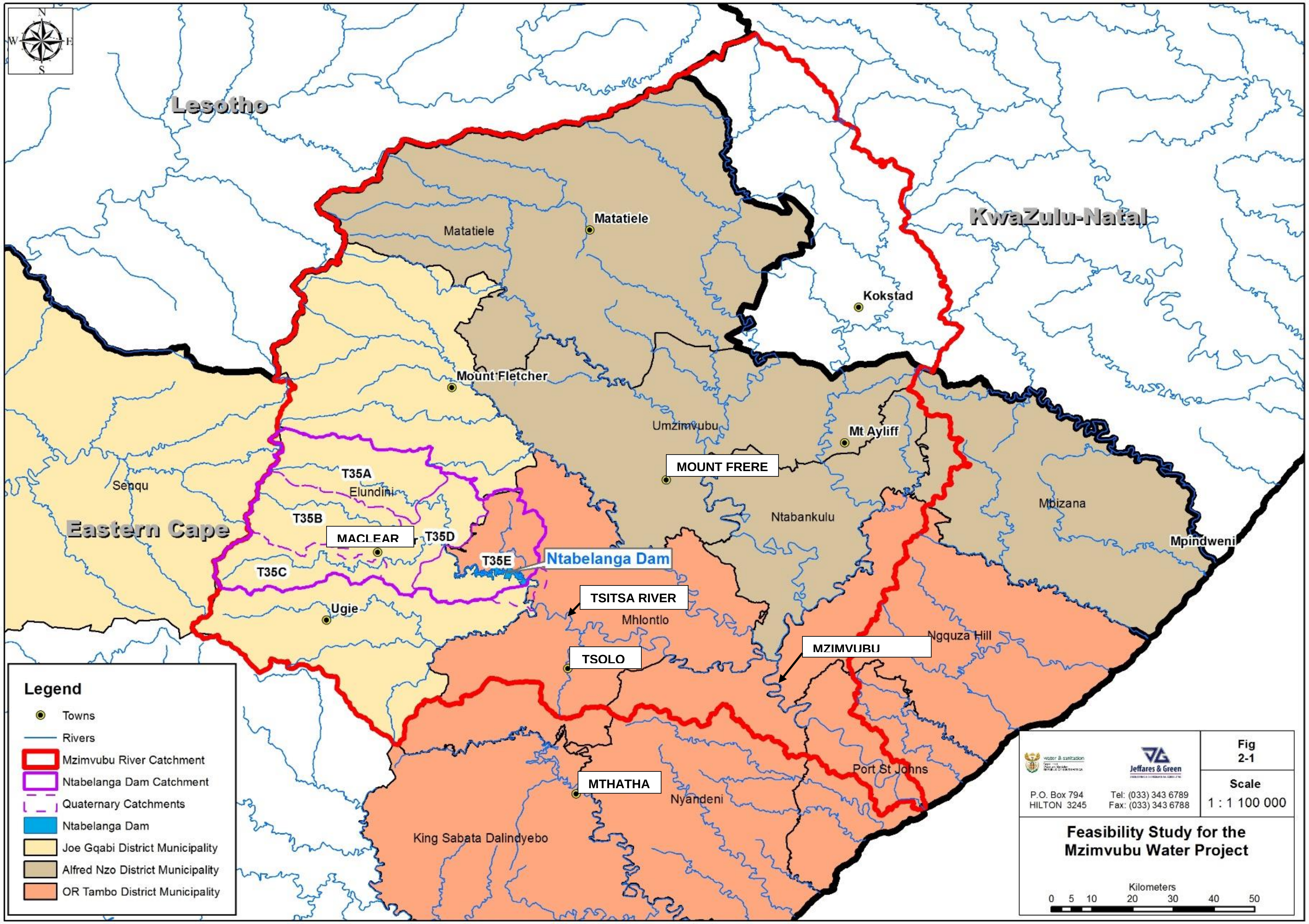

Figure 1-1: Locality Map of Mzimvubu Catchment

1.2.1 Inception Phase

The aim of the inception phase was to finalise the Terms of Reference (TOR) as well as to include, *inter alia*, the following:

- A detailed review of all the data and information sources available for the assignment;
- A revised study methodology and scope of work;
- A detailed review of the proposed project schedule, work plan and work breakdown structure indicating major milestones;
- Provision of an updated organogram and human resources schedule; and
- Provision of an updated project budget and monthly cash flow projections.

The inception phase has been completed and culminated in the production of an inception report (DWS Report Number P WMA 12/T30/00/5212/1) which also constitutes the final TOR for the study.

1.2.2 Preliminary Study Phase

The preliminary report describes the activities undertaken during the preliminary study phase, summarizes the findings and conclusions, and provides recommendations for the way forward and scope of work to be undertaken during the feasibility study phase.

The Preliminary Study Phase was divided into two stages:

- Desktop Study; and
- Preliminary Study.

The aim of the desktop study was, through a process of desktop review, analyses of existing reports and data, and screening, to determine the three best development options from the pre-identified 19 development options (from the previous investigation). This process is described in Section 2 of this report.

The aim of the preliminary study was to gather more information with regard to the three selected development options as well as to involve the Eastern Cape Provincial Government and key stakeholders in the process of selecting the single best development option to be taken forward into Phase 2 of the study.

The main activities undertaken during of the second stage of Phase 1 were as follows:

- Stakeholder involvement;
- Environmental screening;
- Water requirements (including domestic water supply, irrigation and hydropower);
- Hydrological investigations;
- Geotechnical investigations;
- Topographical survey investigations, and
- Selection process.

1.2.3 Phase 2 – Feasibility Study

The preliminary study recommended a preferred dam site and scheme development to be taken forward to Feasibility Study level.

The key activities undertaken during the Feasibility Study are as follows:

- Detailed hydrology (over and above that undertaken during the Preliminary Study);
- Reserve determination;
- Water requirements investigation (including agricultural and domestic water supply investigations);
- Topographical survey (over and above that undertaken during the Preliminary Study);
- Geotechnical investigation (more detailed investigations than during the Preliminary Study);
- Dam design;
- Land matters;
- Public participation;
- Regional economics; and
- Legal, institutional and financial arrangements.

An Environmental Impact Assessment was undertaken in a separate study that ran in parallel to this one;

1.2.4 Additional Detailed Investigations for Lalini Dam and Hydropower Scheme

Further detailed investigations were undertaken for a second dam on the Tsitsa at Lalini (just above the Tsitsa Falls) which would be operated conjunctively with the Ntabelanga Dam to generate significant hydropower for supply into the national grid. The feasibility design of the Lalini Dam and hydropower scheme is described in Report No. P WMA 12/T30/00/5212/19.

1.3 Purpose of Report

This report summarises the approach and findings of specialist studies undertaken for an ecological reserve determination of the Tsitsa River at the section of the river below the proposed Ntabelanga Dam site.

A similar study was undertaken for the Lalini Dam site separately, and is included in the suite of reports produced for the Environmental Impact Assessment.

1.4 Background to Ecological Reserve Determination

1.4.1 National Water Act

Chapter 3 of the National Water Act (NWA) (Act No. 36, 1998) requires the implementation of Resource Directed Measures (RDM) to protect the water resources of the country, based on the guiding principles of sustainability and equity. In terms of the Act, before the required authorization to utilise a particular water resource can be granted, it is necessary to determine the reserve for the relevant ecological component of the resource that will be impacted by the proposed water use.

According to the Act, all reserve determinations that are currently determined and approved by the Department of Water and Sanitation (DWS) are preliminary reserve determinations and the associated recommended class is a preliminary class (section 17(1)), until the Classification of the water resources has been undertaken.

The ecological component of the reserve is defined as the quantity, quality and reliability of water required to “protect aquatic ecosystems in order to secure ecologically sustainable development and use of the relevant water resource” (National Water Act, 1998).

1.4.2 Resource Directed Measures (RDM)

a) Classification

The NWA makes provision in section 12 for the development of a national classification system for the classification of all significant water resources. The classification system is based on ecological, social and economic considerations when decisions are made as to the management class of a water resource.

b) Reserve

A suite of methods has been developed for determining the ecological reserve depending on the level of accuracy and confidence in the results required. These are outlined in Volume 2 of the RDM method manuals (DWAF, 1999) and consist of approaches for a Rapid, Intermediate and a Comprehensive ecological reserve method. The results of reserve determinations are also linked to a level of confidence (very low to high), based on the availability of information and accuracy of the determination.

The application of the appropriate RDM method to ensure that the necessary level of confidence in the results is obtained for the particular water resource under consideration depends on a number of factors. These include:

- The Ecological Importance and Sensitivity (EIS) of the catchment;
- The degree to which the catchment is already utilised;
- The potential impact of the proposed water use(s) to be authorised and possible future use; and
- The need to establish a catchment management plan.

The ecological reserve is not intended to protect the aquatic ecosystem *per se*, but to maintain aquatic ecosystems in such a way that they can continue to provide the goods and services to society. The reserve (ecological and basic human needs) is the only right to water; all other water uses are subject to authorizations.

A summary of the generic steps which form part of the procedure to determine the ecological reserve for aquatic ecosystems is provided in Figure 1-2.

c) Resource Quality Objectives

Resource Quality Objectives (RQOs) are defined as clear goals (numerical or descriptive statements) relating to the quality of a water resource and are set in accordance to the management class (preliminary class) specified for the resource to ensure the water resource is protected. The purpose of RQOs is to set clear objectives for the resource against which water use licenses and the related impacts can be evaluated and managed to achieve a balance between the need to protect and utilise the resource.

1.4.3 Reserve Determination Procedures

The reserve refers to the quantity and quality of water required to (i) supply basic human needs and (ii) protect aquatic ecosystems.

The ecological component of the reserve (i.e. water to protect aquatic ecosystems), refers to water quantity and water quality within the following four components:

- Groundwater;
- Wetlands;
- Rivers; and
- Estuaries.

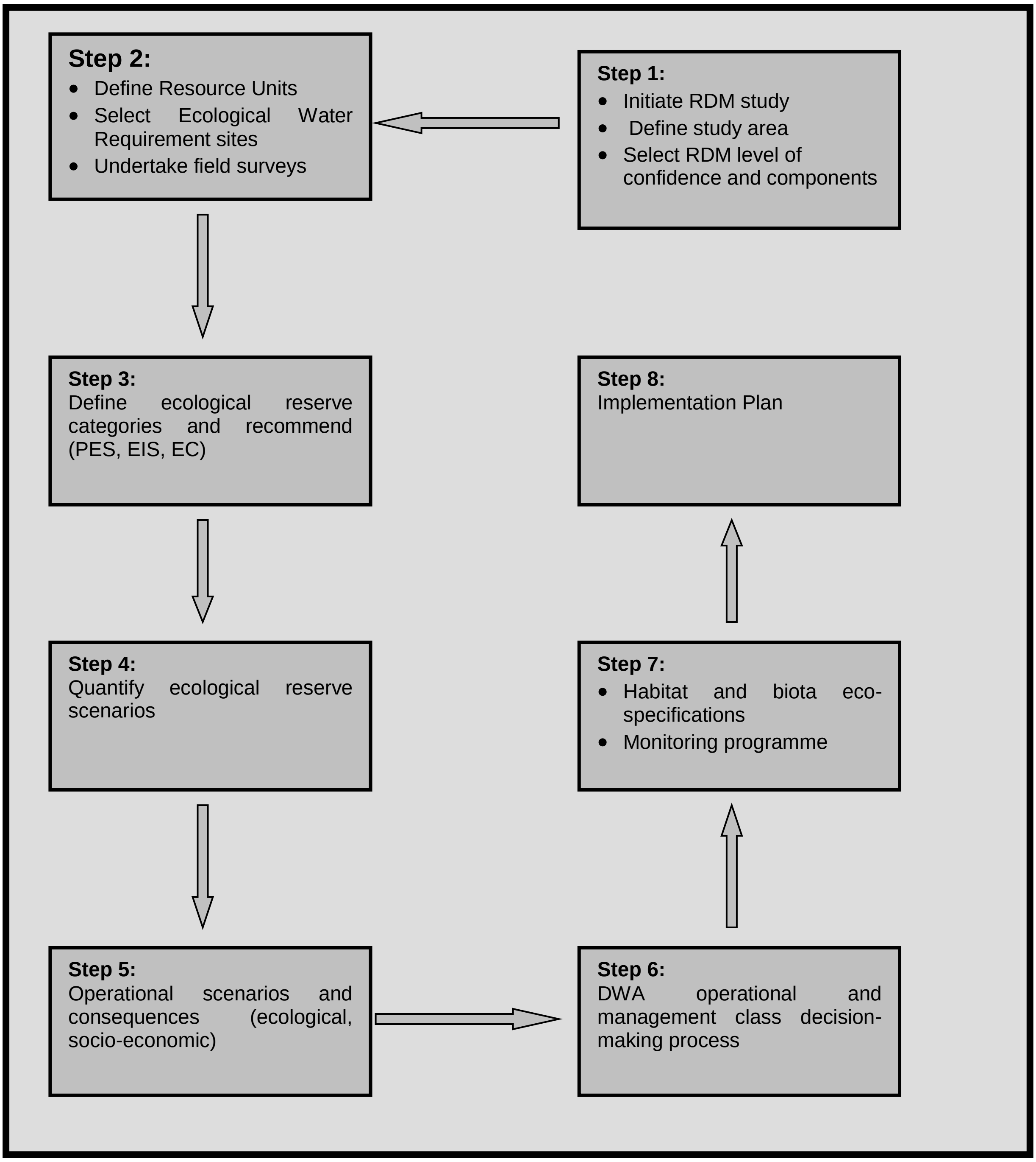

Figure 1-2: Generic procedure for the determination of the ecological reserve

The water quantity component for a river will typically refer to the flows and flow patterns (magnitude, timing and duration) needed to maintain a river ecosystem within acceptable limits of change, or the specified ecological category.

The DWS requires that a standard procedure be followed in order to determine the appropriate level of ecological reserve determination as set out in the RDM method manuals (DWAF, 1999) for each component of the water resource under consideration.

1.4.4 Purpose of the Intermediate Ecological Reserve Determination Study

The development of a dam on the Mzimvubu system in secondary catchment T3 has been initiated by the Department of Water and Sanitation (DWS). Initially, nineteen potential dam sites had been identified within the system during the Water Resource study in Support of the ASGISA-EC Mzimvubu Development Project finalised in 2010 by DWS. The localities of these potential dam sites are shown in Fugure 1-2.

The purpose of the Feasibility Study for the Mzimvubu Water Project undertaken by Jeffares and Green is to eliminate those dams that (i) are not economically viable, (ii) would not provide adequate yield for developments, or (iii) that are situated in ecologically sensitive or important areas.

A preliminary desktop based assessment was undertaken to reduce the number of the 19 potential dam sites to a more manageable number which can go forward into further feasibility stages of dam site selection and reserve determination studies. The main criteria used during the initial elimination were:

- Potential yield from the dam;
- Economics (e.g. capital cost);
- Accessibility to the proposed dam;
- Hydropower potential;
- Job creation; and
- Ecological considerations (importance, sensitivity, present state, sedimentation).

Details of the ecological assessments are given in the Environmental Screening Report Number P WMA 12/T30/00/5212/2.

This elimination process resulted in five potential dam sites that were investigated in more detail during phase 1 of the project to identify the final dam site to undertake the intermediate reserve study. The identified dams were:

i. Somabadi Dam in T33E on the Kinira River (Dam 7);
ii. Thabeng Dam in T33D on the Kinira River (Dam 6);
iii. Mpindweni Dam in T34G/T34H on the Tina River (Dam 11);
iv. Ntabelanga Dam in T35E on the Tsitsa River (Dam 14); and
v. Laleni Dam in T35L on the Tsitsa River (Dam 17).

Rapid level III reserve determinations studies were undertaken during phase 1 on the Kinira, Tsitsa and Tina Rivers to provide the necessary ecological information for the final selection of one dam site. The detailed assessment of the rapid studies to select the final dam is attached as Appendix A. This was a draft report, and findings from this were incorporated into this report.

The final dam site selected from an ecological perspective through the phase 1 studies was the Ntabelanga Dam (Dam 14) on the Tsitsa River in quaternary catchment T35E. An intermediate reserve determination study was undertaken downstream of this proposed dam. All information collated on the Tsitsa River during phase 1 was used and additional surveys undertaken to provide the final Ecological Water Requirements (EWR).

This report summarises the tasks undertaken during the intermediate study and provides the results from this study as well as recommendations if construction of the dam proceeds.

Professional Services Provider (PSP) GroundTruth cc was appointed to conduct all the tasks and activities during the process to eliminate dams from an ecological perspective and the final intermediate study. This report provides the results of the determination of the quantity and quality requirements of the reserve for the surface water component of the Tsitsa River, a tributary of the Mzimvubu River in quaternary catchment T35E.

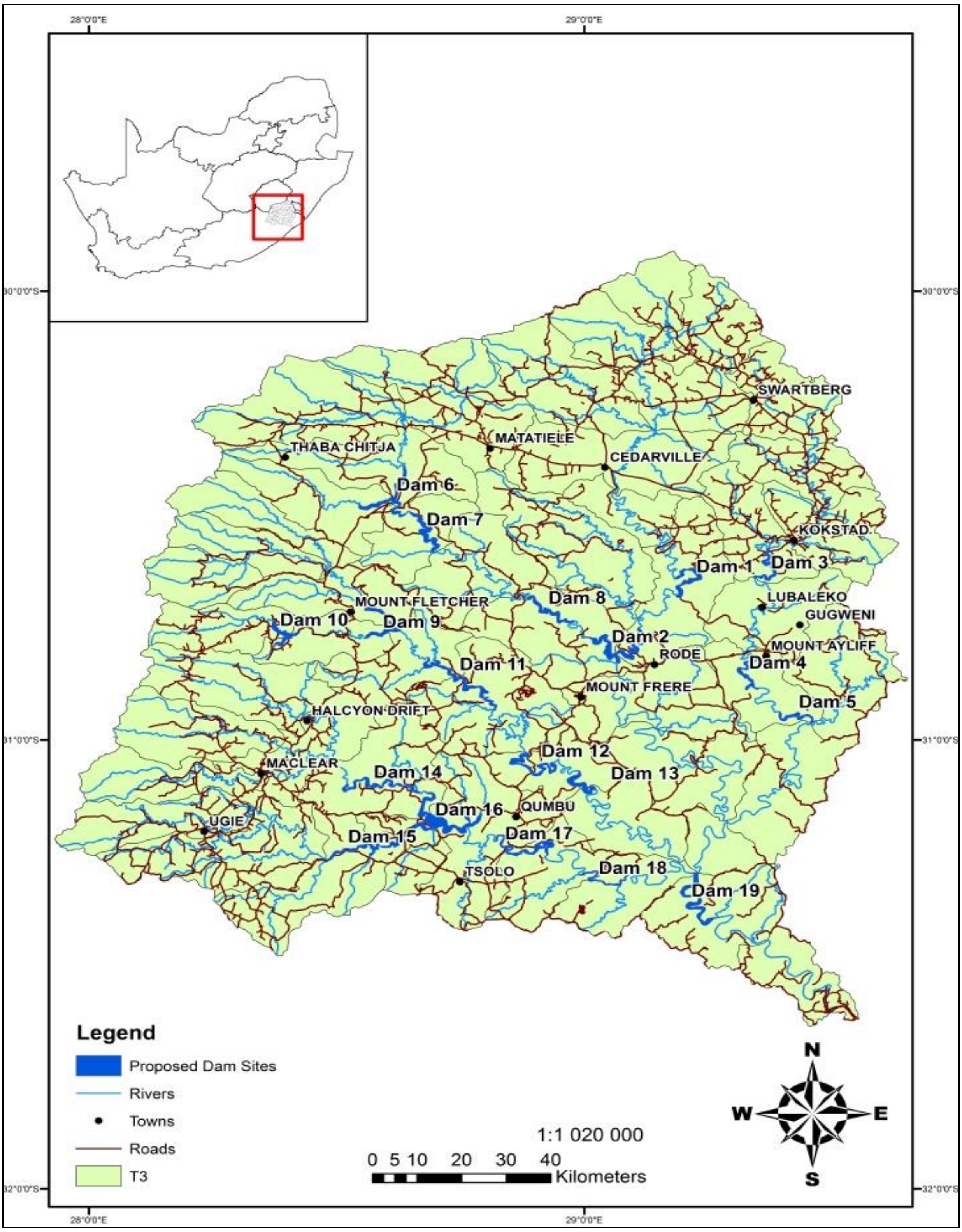

Figure 1-3: Map of the Mzimvubu system indicating the 19 proposed dams

1.5 Scope of Work for the Proposed Study

The purpose of the study was to determine the EWR for the surface water resources of the final selected dam site (Tsitsa River in quaternary catchment T35E) on an intermediate level of detail.

The following main tasks were undertaken as part of the intermediate study:

- Undertake field surveys for the fish, macro-invertebrates, geomorphology, riparian vegetation and hydraulics (flow measurement and profiling) on the Kinira River at the EWR site selected for the rapid III study (phase 1);
- Use the reference conditions as described during phase 1 and re-assess the Present Ecological State (PES), Ecological Importance and Sensitivity (EIS) and the Recommended Ecological Category (REC) for the EWR site on the Kinira River;
- Determine the ecological water requirements of the Tsitsa River at the EWR site using the final set of hydrology and following the Habitat Flow Stressor Response (HFSR) approach;
- Determine the ecological consequences for a number of operational scenarios and dam sizes of the proposed Ntabelanga Dam;
- Determine the ecological specification and provide recommendation and monitoring requirements if construction of the proposed dam proceeds; and
- Prepare a report detailing the process followed, approaches, results and recommendations of the study.

1.6 Study Approach

The following main activities were undertaken to meet the objectives of the study:

Three field surveys were undertaken during July 2012 (moderate flows), April 2013 (high flows) and again in July 2013 (low flows) to collect data on fish, macro-invertebrates, geomorphology and riparian vegetation and to undertake the hydraulic measurements.

Integration of the results from the field survey, to determine the EcoStatus and ecological water requirements (Habitat Flow Stressor Response (HFSR) and Spatial and Time Series Information Modelling (SPATSIM)) of the river at the EWR site were done during a specialist workshop in April 2013.

The ecological consequences assessment for various dam sizes and operation of the dam was done in August 2013.

Due to the high flow events sampled during July 2012 and April 2013, an additional field survey was undertaken in July 2013 to capture the low/base flow situation in this reach of river. The PES and REC was revised based on the additional information obtained on macroinvertebrates sampled during the low flow sampling. The HFSR indices were also revised to incorporate the new information.

The initial hydrology that was used during the HFSR workshop in April 2013 and the ecological consequences workshop in August 2013 was updated in September 2013 and the stress indices for macroinvertebrates had been checked for the final EWR results that are presented in this report.

The activities and tasks for this ecological reserve determination study were undertaken in accordance with the appropriate approaches and methodologies for rivers as prescribed by the CD: RDM of DWS, namely:

- The methodology as set out in DWAF (1999): Resource Directed Measures for Protection of Water Resources; Volume 3: River Ecosystems Version 1.0 (Revised water quality methodology, 2002);
- The revised methods as outlined in Louw and Hughes (2002), the Habitat Flow Stressor Response (HFSR) manual of IWR Source-to-Sea (2004) and the EcoClassification manual of Kleynhans et al (2005);
- The Desktop reserve and the Flow Stressor Response models within SPATSIM will be used for the integration of data produced from the surveys;
- The Ecostatus suite of methods will be used for the ecological components;
- DWAF (2002): Hazard-based water quality ecological specifications for the Ecological reserve in fresh water Resources. Report No. N/0000/REQ0000. Institute for Water Quality Studies, Department of Water Affairs and Forestry. Author: Jooste S; and
- 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. Draft 2, March 2008.

1.7 Structure of the Report

This report is divided into 5 main chapters and applicable appendices, supported by detail specialist reports, where necessary. The main chapters are:

Chapter 1 provides the general background to RDM and the study approach.
Chapter 2 describes the study protocol followed for the assessment of the Tsitsa River.
Chapter 3 provides the results of the field surveys, specialist workshop, and the final recommended ecological reserve for the Tsitsa River.
Chapter 4 presents the main conclusions and recommendations.
Chapter 5 cites the references used in this report.

2. STUDY PROTOCOL

This section of the report provides the protocol followed for the ecological reserve determination of the Tsitsa River in quaternary catchment T35E.

2.1 Study Team

The specialists involved in the assessment are listed in Table 2-1.

Table 2-1: Study team for the rapid ecological reserve determination

Team Member	Affiliation	Specialisation/Task
Stassen R	JMM Stassen	Co-ordination, SPATSIM
Graham, M	GroundTruth cc	Macroinvertebrates
Gray, R	Jeffares & Green	Hydraulics
Kleynhans, M	Aurecon	Hydraulics
Hlongwane, L	Digby Wells	Geomorphology
Bok, A	Bok & Associates	Fish
de Villiers, A	GroundTruth	Riparian Vegetation
Quayle, L	Institute of Natural Resources	Water Quality

2.2 Study Area

The study area of the Tsitsa River falls within the Mzimvubu to Keiskamma Water Management Area (WMA) and comprises quaternary catchment T35E with a total catchment area of approximately 2 016 km^2. The Tsitsa River is a major tributary of the Mzimvubu River.

The natural Mean Annual Runoff (MAR) at the EWR site in quaternary catchment T35E is 428.5 million m^3 (Jeffares and Green, 2013). The closest gauging weir (T3H006), with a catchment area of 4 268 km^2 is situated after the confluence of the Inxu River (major tributary of the Tsitsa River). The record period at the gauging weir is from 1951 to present. However, a large percentage of the data is missing, mainly for the period 1951 to 1985 and only the latter period could be used. As this weir is too far downstream from the EWR site and the Inxu River contributes substantially to the flow at the weir, the data could not be used during the EWR assessment.

The town of Maclear and smaller rural villages are situated in the upper catchment. Forestry plantations and irrigation, mainly in the Mooi River catchment are present. No other large development (irrigation schemes or dams) are currently in the catchment.

The selected EWR site on the Tsitsa River is in quaternary catchment T35E, just downstream of the proposed Ntabelanga Dam. The details of the site are indicated in Table 2-2 and Figure 2-1.

Table 2-2: Tsitsa EWR site information in quaternary catchment T35E

EWR site	River	Quaternary	Latitude	Longitude	MAR (10^{6}m^3)
MzimEWR1	Tsitsa	T35E	S 31.148°	E 28.674°	428.5

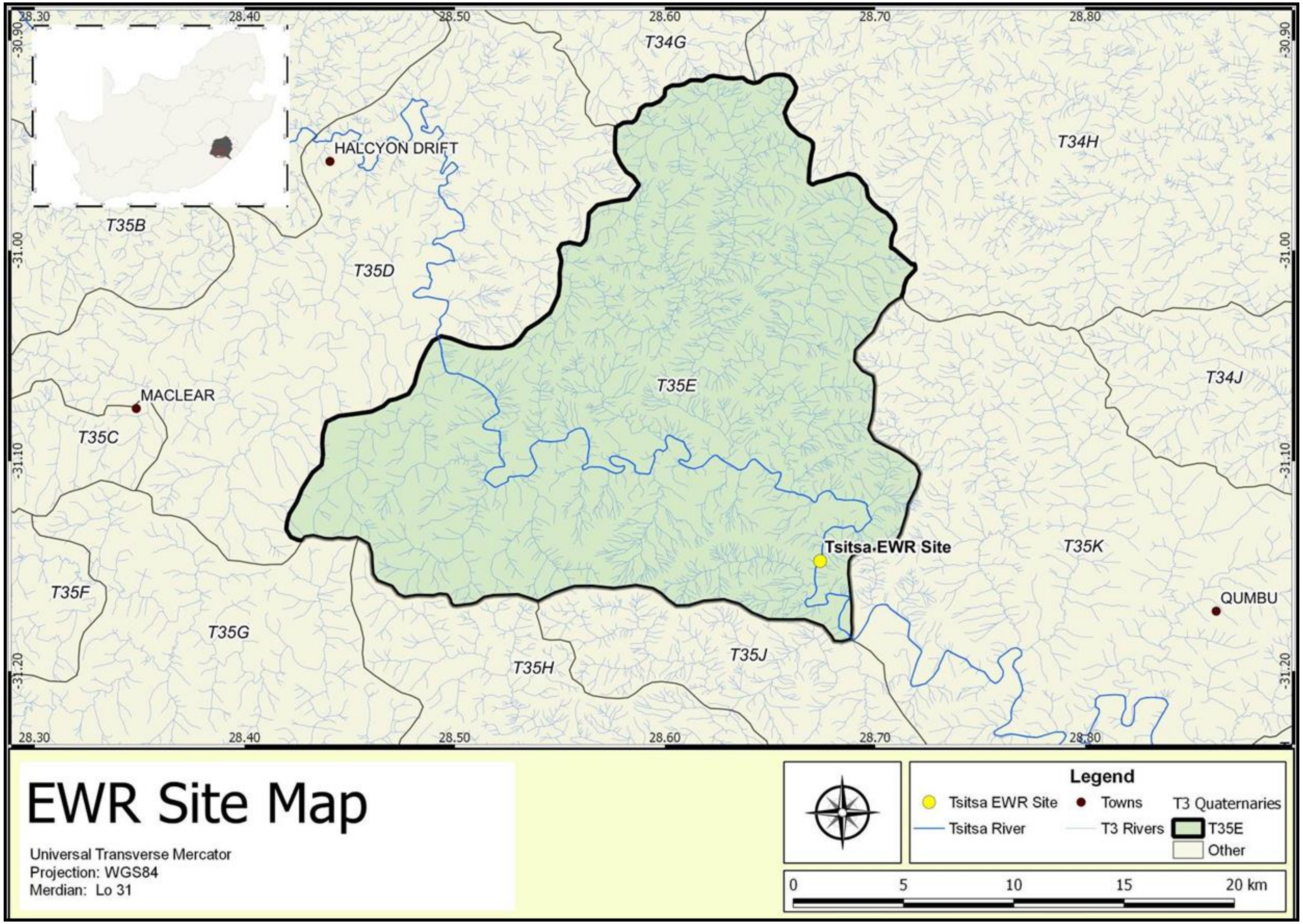

Figure 2-1: Study area of the Tsitsa River in T35E

2.3 Site Visit

The tasks undertaken during the first site visit on 17 July 2012 included:

- A visual "survey" of the river reaches directly upstream and downstream of the probable EWR sites;
- Finding suitable EWR Sites. This was governed by the suitability of the river channel for accurate hydraulic modelling and flow measurement, as well as the presence of habitats critical for ecosystem functioning, such as riffles. The sites should also be representative of the catchment to allow scaling of the results to other relevant points in the catchment;
- The specialists assessed the present condition of their study component in relation to the considered reference condition, which allowed the allocation of the PES for the specific component;
- A cross-sectional profile of the river channel was surveyed using a Total Station by the hydraulic specialist. Hydraulic data for calibration purposes was collected and the river flow was determined with the aid of a current meter at the EWR site;
- The fish specialist sampled fish in all suitable aquatic habitats in the vicinity of the EWR site using an electro-fish shocker and nets, and noted any man-induced habitat modifications impacting on fish fauna;
- The macroinvertebrate specialist surveyed aquatic macroinvertebrates occurring within the range of instream habitats at the site using the SASS5 methodology. A habitat assessment of the site pertaining to SASS was also conducted;
- In situ water quality data and diatom samples were collected at the EWR site;
- The fluvial geomorphologist surveyed the stream morphology (riffles, pools and in stream islands), habitat quality (substrate embeddedness), boundary conditions (erosion, sedimentation and channel stability), in stream disturbance (weirs, bridges, river crossings and dams), historical and current landuse activities (agriculture, residential), impacts of current and historical land use (erosion) valley form (confined or unconfined), channel pattern (single thread, anastomosing or meandering), morphometry (channel width and channel depth) and sediment flow pattern (bed load and suspended load). The habitat assessment was used to during the ecological classification process (measure of deviation of the current state from a pre-determined reference condition). The sedimentation features and the sediment flow patterns were used to calculate the system flood requirements.; and
- The riparian vegetation specialist assessed the condition of the marginal and non-marginal riparian vegetation zones.

The flow during the first site visit was moderate and not low as expected for July. This was due to a cold front with snow and heavy rains that has moved through the catchment.

Two other site visits were undertaken, one in April 2013 to undertake sampling for the post high flow event (moderate to high flows) and in July 2013 to undertake the low flow sampling.

2.4 Specialist Workshop (EcoClassification Workshop)

The results of the field assessments of the various habitat and biotic components to obtain the EcoStatus and the recommended ecological category (EC) were compiled after the completion of the site visits. This assessment took place during the ecoclassification workshop with input from all the specialists. The process included the determination of the following:

- Reference conditions: - it is those conditions that occur under natural conditions before anthropogenic impacts;
- Present ecological state (PES) or EcoStatus: - the determination of the current state of the resource through rule-based models for the driver components (geomorphology – GAI, hydrology – HAI and water quality – PAI) and for the biological response components (fish – FRAI, macro-invertebrates – MIRAI and vegetation – VEGRAI). A rule-based model is then used to derive the EcoStatus or overall/integrated condition/health of the resource by integrating the driver and response status;
- Trends: - this is the reaction of the components to changes in the catchment and can be stable, negative or positive;
- Ecological Importance and Sensitivity (EIS): - the ecological importance is defined by Kleynhans (1999), and is regarded as an expression of the water resource's ability to maintain the ecological diversity and functioning on local and wider scales. The ecological sensitivity refers to the river's ability to recover from disturbance. The EIS model (Kleynhans 1999, updated 2002) was used to determine the EIS; and
- Recommended Ecological Category (REC): - the PES and EIS is used in the decision on the REC as well as the feasibility to realistically be able to maintain or improve the current condition of the water resource.

3. RESULTS

The results of the ecological reserve determination of the Tsitsa River at the EWR site are presented in this section. The Tsitsa River in quaternary catchment T35E falls within an area of moderate to high relief dominated by grassland. The river is situated in the South Eastern Uplands ecoregion level I and in eco-region level II (16.03).

3.1 EWR Site Selection and Evaluation

A number of possible EWR sites downstream of the proposed dam were visited by the project team during the first field visit in July 2012. The site chosen then for the rapid assessment was also used during the intermediate study. The final site selected for this assessment is just downstream of the proposed dam and is characterised by a cobble-dominated riffle with limited marginal vegetation. A run area is immediately upstream of the site with a large pool downstream of the cross section that was surveyed. The details of the river at the EWR site can be seen in Figure 3-1.

Figure 3-1: View of the EWR site on the Tsitsa River in T35E

The chosen site was evaluated by the various specialists in terms of advantages and disadvantages as well as given a confidence score to provide clues for undertaking field verification. The scores allocated were from 0-5, with 0 = no confidence and 5 = high confidence that the EWR site provides sufficient indicators. The results of this evaluation are given in Table 3-1.

Table 3-1: Tsitsa River EWR site evaluation

Component	Confidence Score*	Advantages	Disadvantages
Hydraulics	3	Good section for flow measurements near to habitat cross section.	Hydraulics
Fish	3	All representative hydraulic habitats present, including scarce riffles.	Limited marginal vegetation cover for fish at medium and low flows, backwaters badly silted up.
Macroinvertebrates	3	Good stones and GSM habitat. Riffles, runs and pools present.	Limited marginal vegetation.
Geomorphology	4	• Single thread siniuos channel • The morphology of the site is representative of the river reach • The non-flow related impacts of landuse activities are representative of the catchment. • The sediment transport requirements can be used in conjunction with morphological features to determine the flood requirements	• The cobbles and boulders are embedded due to high sediment accumulation within the active channel. • Active channel undercutting on both sides of the channel. • Active erosion dongas high up in the catchment.
Riparian vegetation	4	Distinct marginal and non-marginal zones on the left-hand bank with near natural vegetation.	Right-hand bank highly eroded, with marginal and non-marginal zones not clearly delimited by natural vegetation.

** Confidence scores: 0 = no confidence; 5 = high confidence*

3.2 Data Collected

3.2.1 Hydraulics

The EWR cross section (Figure 3-2) was selected during the first site visit in July 2012. The GPS co-ordinates captured for the cross section are, Right Bank Peg 31.14806 S, 28.67384 E. During each site visit (including three visits in July 2012, April 2013 and July 2013) the following activities were undertaken:

- A survey of the cross sectional profile of the site;
- Longitudinal water slope was surveyed;
- Discharge was measured; and
- EWR site photographs were taken.

There was very limited riffle habitat available during the site selection trip and, this, coupled with access constraints made the selection of a site difficult. Due to these constraints the selected site has limitations from a hydraulic perspective (situated at the exit of a bend in the river). However, the site, and thus hydraulic results for the site, was considered sufficient for use in this study.

Velocity data was measured by means of a flow metre taking measurements at 60 % of depth, which was assumed to be the average velocity for that specific column of water. The topographical measurements were collected using a Total Station and downloaded for conversion into an appropriate co-ordinate system for further analyses. The hydraulic data collected during the site visits are listed in Table 3.2.

Table 3-2: Hydraulics data measured at the EWR site

Date	Discharge Q (m^3/s)	Maximum flow depth (m)
18 July 2012	7.106	0.746
16 April 2013	10.188	0.910
18 July 2013	2.550	0.650

Figure 3-2: Aerial View of the Upper Tsitsa Cross Section (MzimEWR1)

3.2.2 Derivation of the Rating Curve

Modelling was carried out using the three measured stage-discharge pairs, as well as two modelled points (zero flow and a hypothetical flood flow condition) to develop a stage discharge curve. The following data was required in the use of the modelling:

- y – maximum flow depth;
- n – resistance coefficient;
- S – slope;
- Q – discharge;
- A – area; and
- WP – wetted perimeter.

The accuracy of the rating curve is dependent on the number of measured points used in its creation and the hydraulic stability of the selected cross section under high flow conditions (it is rarely possible to measure these during high flow conditions). The measured and modelled data are shown in Table 3-3 below.

Table 3-3: Hydraulic data used to extend observed rating data at the EWR site

EWR site	Discharge, *Q* (m^3/s)	Maximum flow depth (m)	Manning's resistance, *n*	Surface Slope, *S* m/m)	Ave. Velocity, V (m/s)
MzimEWR1	2.550	0.65	0.404	0.026	0.19
	7.106	0.75	0.188	0.019	0.41
	10.188	0.91	0.226	0.018	0.42
	274.396	3.00	0.035	0.002	2.23

The depth-discharge relationship (Hirschowitz PM, Birkhead AL, James CS) was determined using the following equation as it is most widely accepted for use in Southern Africa:

$$y = aQ^b + c \quad (1)$$

where:

- y is the maximum depth;
- Q is the discharge (m³3/s); and
- a, b and c are coefficients.

The coefficients used in equation (1) are shown in Table 3-4 below.

Table 3-4: Regression coefficients in equation (1)

EWR site	Regression coefficients		
	a	***b***	***c***
MzimEWR1	0.4095	0.3543	0.000

The cross section of the EWR site in the Tsitsa River and the stage discharge relationships developed from the modelling are shown in Figure 3-3: Cross-sectional view of the EWR site on the Tsitsa River Figure 3-3 and Figure 3-4 respectively.

In addition to the above, the hydraulics was further modelled using the HABFLO (HABitat FLOw) program (Hirschowitz *et al*, 2007).

The program is used to predict statistical distributions of hydraulic habitat for fish and invertebrates based on inputs such as cross section survey, observed velocities, observed depths, rating curve and specific hydraulic parameters relating to the substrate and vegetation in the river reach.

The hydraulic habitat predictions for fish were used in this study and were based on accepted combinations of depth and velocity in Southern Africa (James and King, 2010).

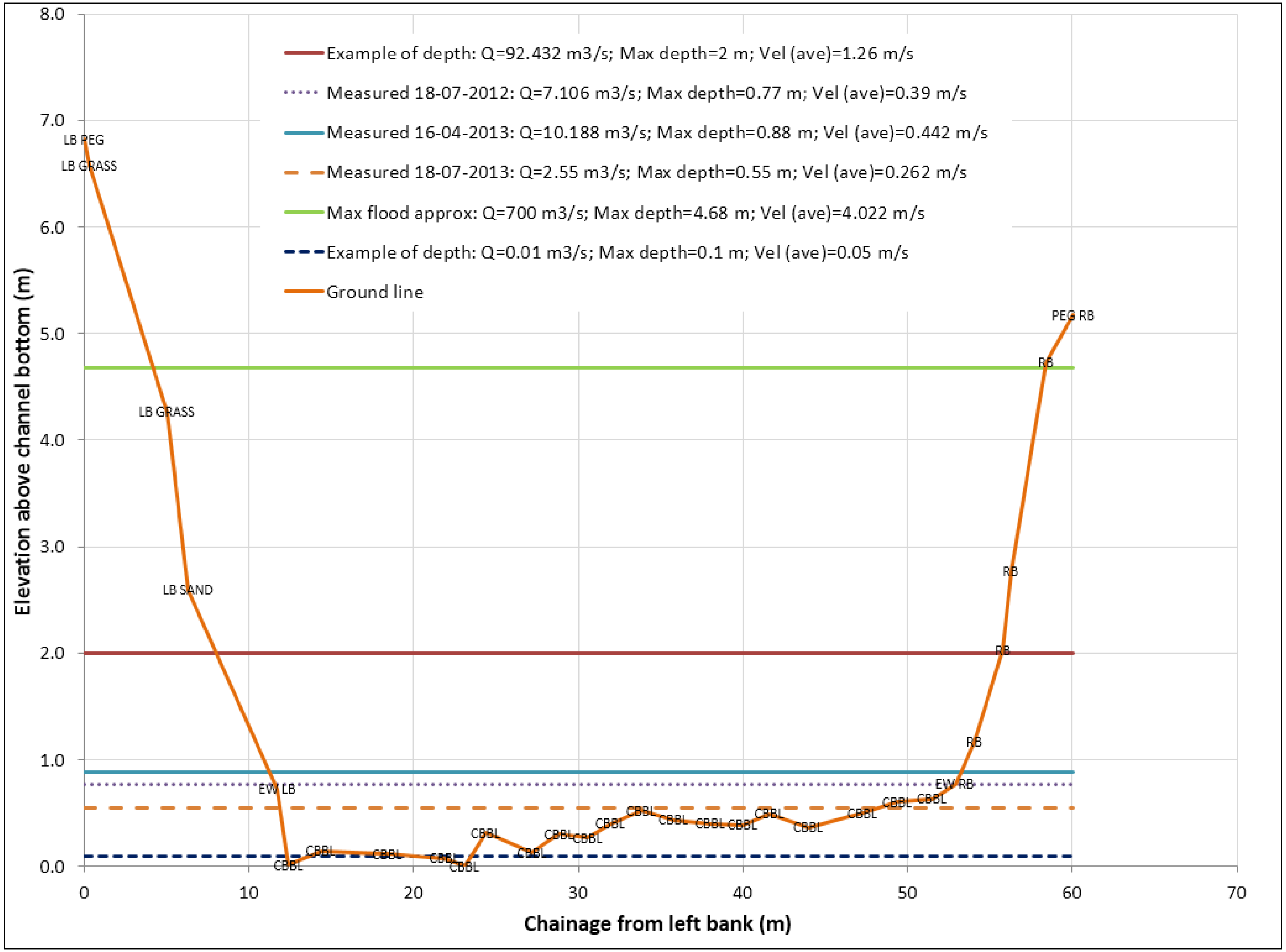

Figure 3-3: Cross-sectional view including the three sampled water levels

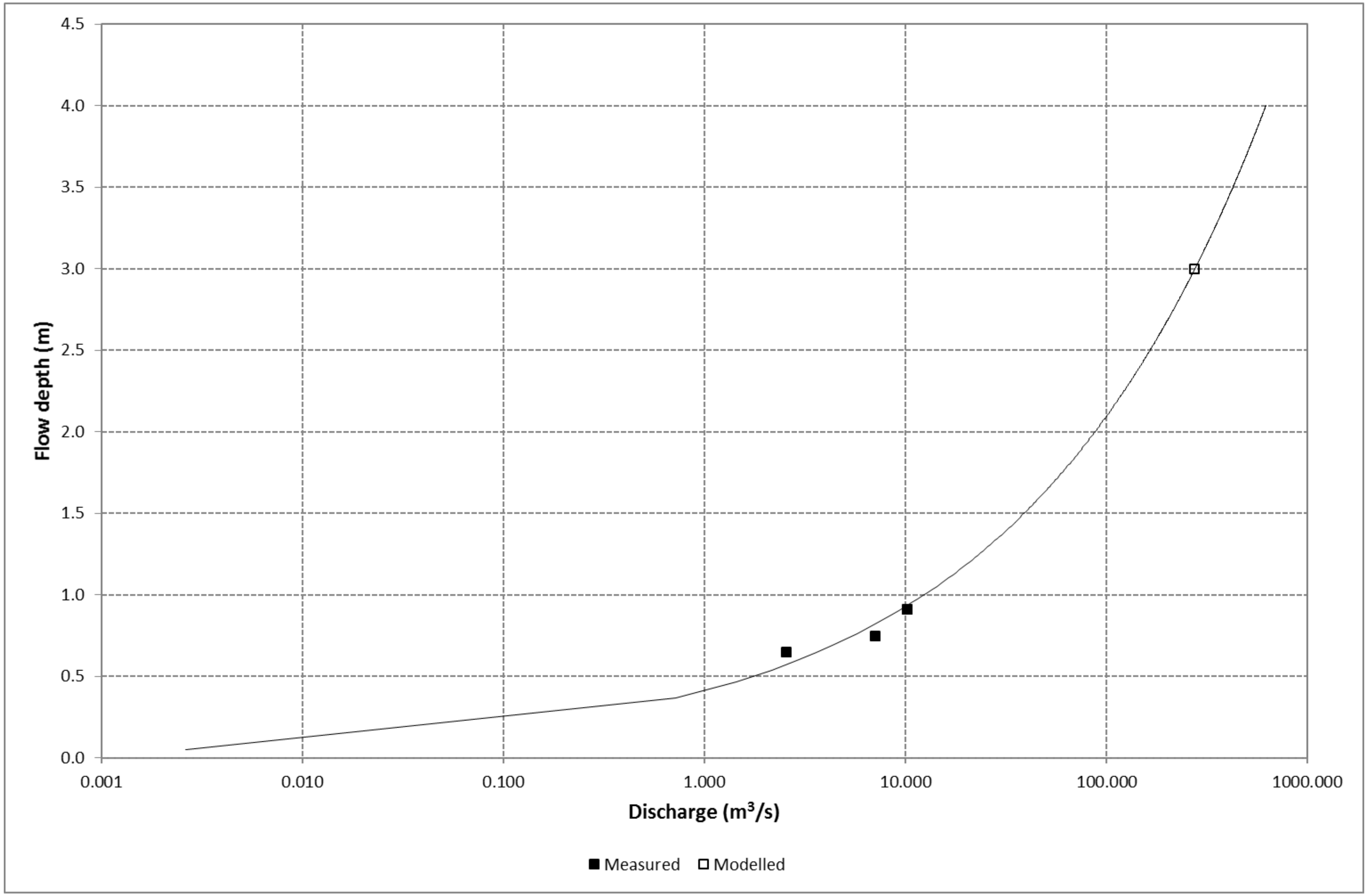

Figure 3-4: Calibrated cross sectional profile for the Tsitsa EWR site

Six classes were modelled in this study (see Figure 3-5 for parameter ranges in the fish habitat modelling), namely:

- SVS – Slow-Very Shallow;
- SS – Slow-Shallow;
- SD – Slow-Deep;
- FS – Fast- Shallow;
- FI – Fast-Intermediate; and
- FD – Fast-Deep.

The invertebrate habitat distributions used as input into the model were obtained from the geomorphology results (for sedimentation habitat). The vegetation inputs (proportion of vegeration in the habitat, stem diametres, spacings and lengths) were assumed based on visual assessments during the site visit.

Table 3-5 presents the inputs used for the invertebrate habitat distributions in the hydraulic modelling. The following four classes were used:

- SCS – Slow-Course Sediment;
- FCS – Fast-Course Sediment;
- SFS – Slow-Fine Sediment; and
- FFS – Fast-Fine Sediment.

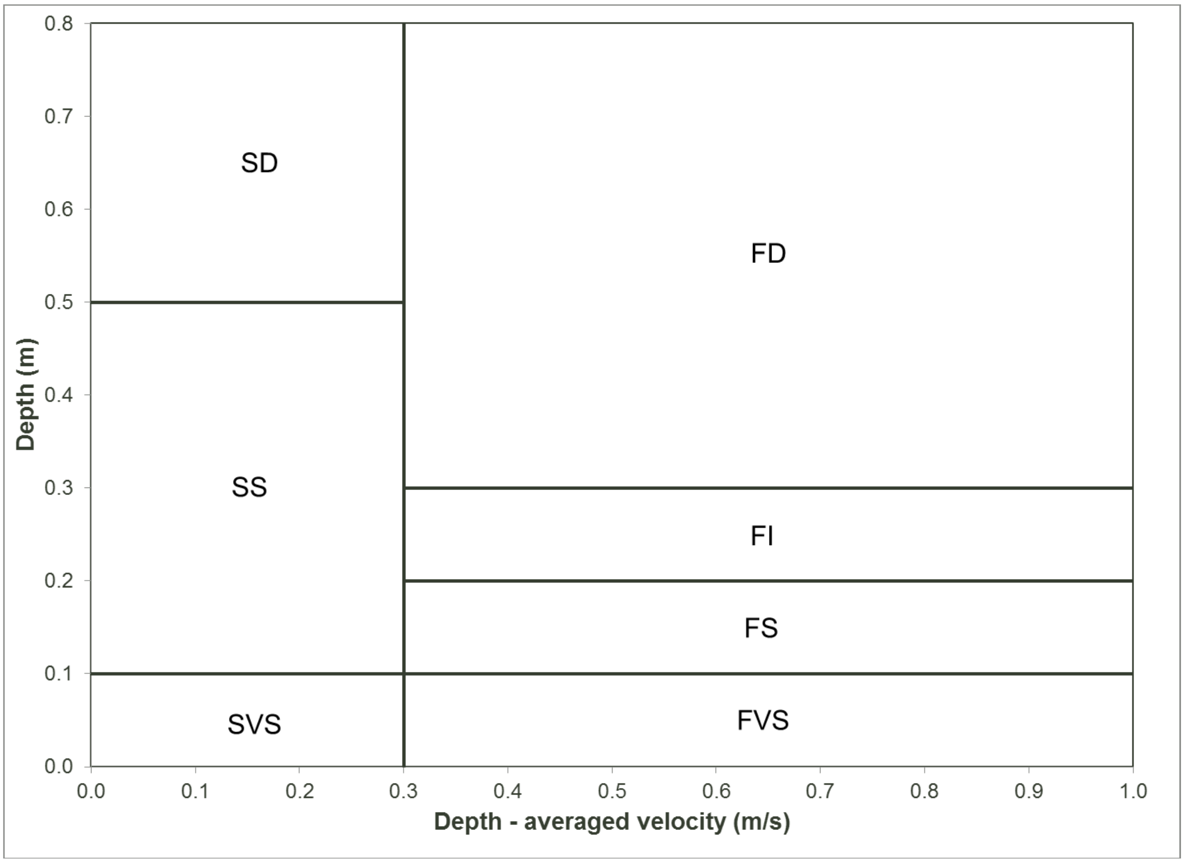

Figure 3-5: Velocity – depth (habitat) classes used to define hydraulic habitat for fish

Table 3-5: Invertebrate Habitat Distributions used in HABFLO

Invertebrate Habitat-Types		
Min Range (m^3/s)	**Max Range (m^3/s)**	**Class**
0.0	0.3	SCS
0.3	10.0	FCS
0.0	0.3	SFS
0.3	10.0	FFS
Invertebrate Vegetation Habitat Data		
Min Depth (m)	**Max Depth (m)**	**Vegetation Width**
0.52	1.45	4.00
0.37	0.83	0.65
0.83	1.46	8.00
Invertebrate Site-Sediment Classification		
Depth (m)	**% Fine Sediment**	**% Course Sediment**
0.57	12	88
1.80	47	53
Invertebrate Vegetation Characteristics		
Stem Diameter (m)	**Stem Spacing (m)**	**Average Height of Stems (m)**
0.008	0.050	2.000

3.2.3 Hydraulic results

The fish habitat distributions modelled by HABFLO are presented in Figure 3-6.

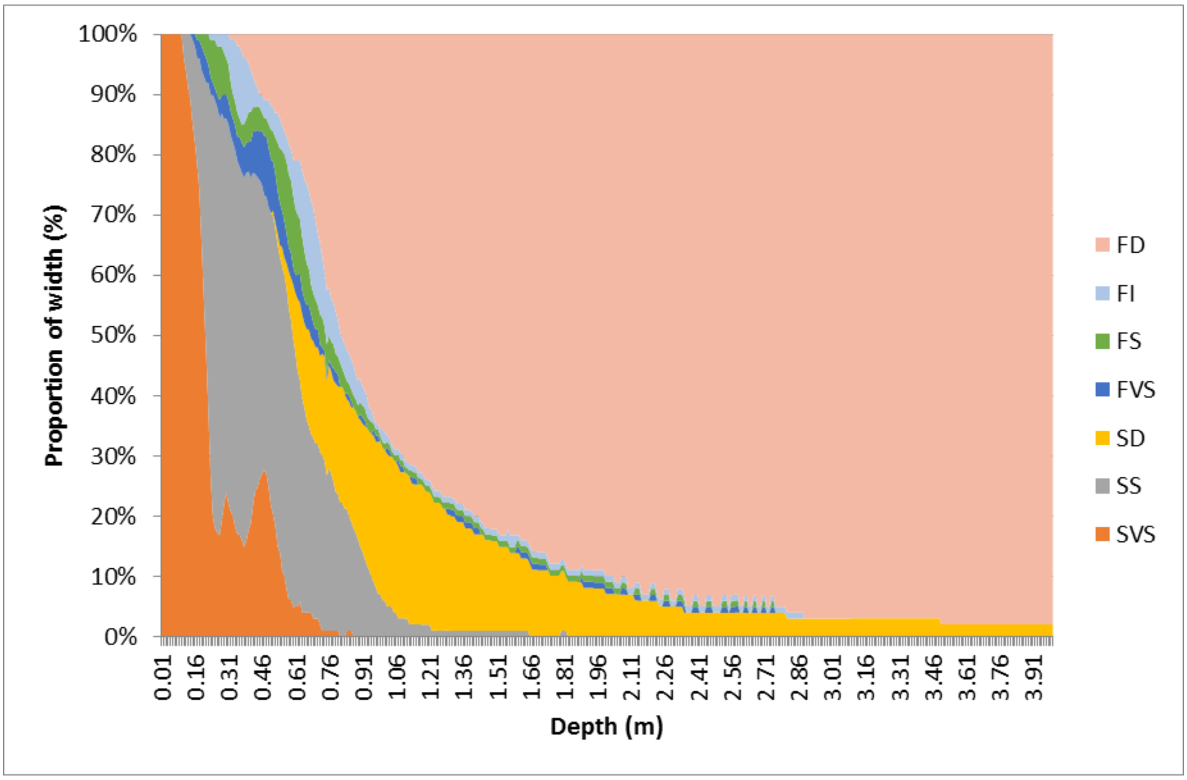

Figure 3-6: Fish habitat distribution versus maximum depth in the channel

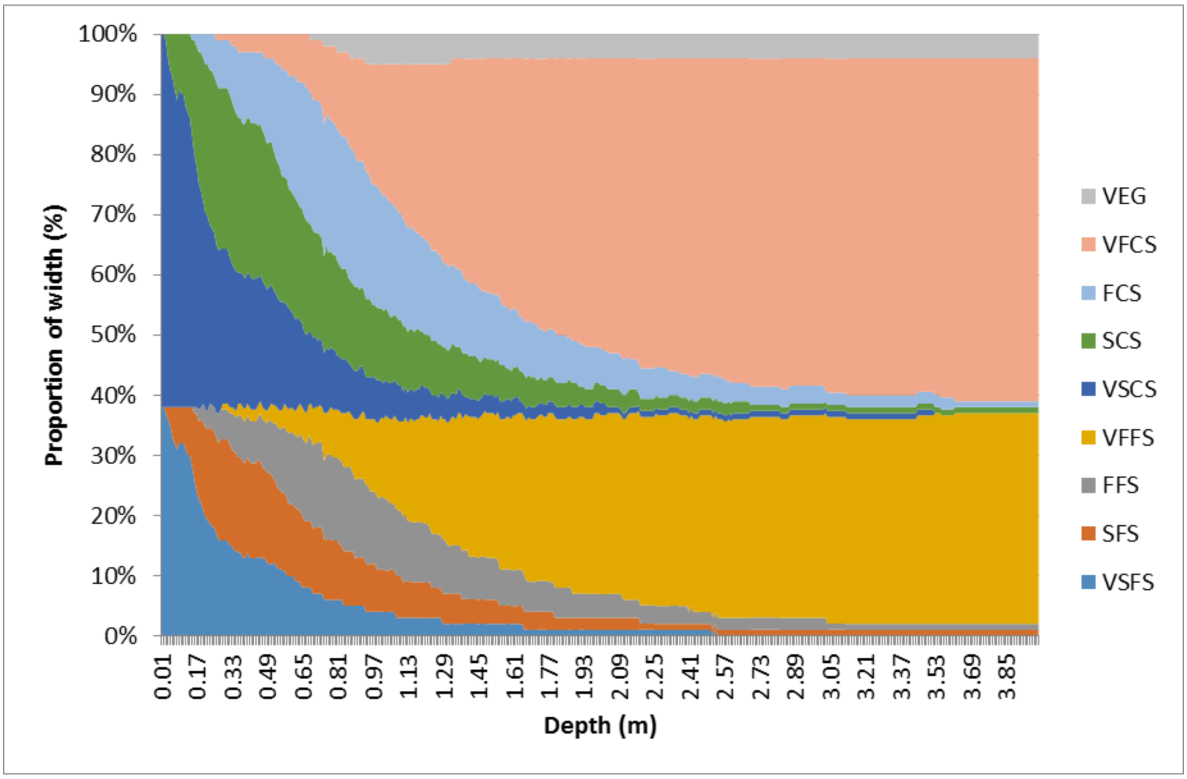

Figure 3-7: Invertebrates habitat distribution versus maximum depth in the channel

The modelled predictions appear to provide a reasonable correlation between the results obtained from the three measured samples, thus indicating that the model should be able to predict habitat distributions to a reasonable level of accuracy, at least for depth. Tabulated output from HABFLO are provided in Appendix B. The confidence rating in the hydraulic modelling results for the EWR site ranges from 0=none to 5=high and is indicated in Table 3-6.

Table 3-6: Confidence in the hydraulic modelled results

EWR site	Limits of measured discharge range (m^3/s)	Confidence rating for discharge range		Comments
	$Q_{measured}$	$Q < Q_{measured}$	$Q > Q_{measured}$	
MzimEWR1	10.188	3	3	Although the rating curve provides a reasonable fit to the measured and modelled flows, there could be some improvement with more observed values. This is especially so in the lower flow range.

3.2.4 Fish

Fish surveys were undertaken during all three the site visits at the selected EWR site on the Tsitsa River in T35E. Electro-narcosis (conducting an electric current into the water, which immobilises the fish momentarily) was applied at all available biotopes. A minnow seine net was also used in suitable pools and backwaters.

The Ecological Category was determined using historical fish data and from the sampling that took place during the surveys of the Tsitsa River. The data were given moderate confidence and weighting scores in determining the overall category for the site.

An Expected and Observed Frequency of Occurrence (FROC) of fish species were compiled based on the historical data obtained for the site and using the reference frequency of occurrence for fish species in South Africa (Kleynhans et al 2007). These FROC values were used to interrogate the Fish Response Assessment Index (FRAI) to evaluate changes from reference conditions.

The FRAI is a rule-based model developed by DWS (Kleynhans et al., 2007) and is an assessment index based on the environmental intolerances and preferences of the reference fish assemblage and the response of the constituent species of the assemblage to particular groups of environmental determinants or drivers. These intolerance and preference attributes are categorized into metric groups with constituent metrics that relates to the environmental requirements and preferences of individual species.

Assessment of the response of the species metrics to changing environmental conditions occur either through direct measurement (surveys) or are inferred from changing environmental conditions (habitat). Evaluation of the derived response of species metrics to habitat changes are based on knowledge of species ecological requirements. Usually the FRAI is based on a combination of fish sample data and available habitat for fish. Changes in environmental conditions are related to fish stress and form the basis of ecological response interpretation and to determine the Present Ecological Category of the fish assemblage.

No fish were collected during any of the visits. This is possibly due to the following:

- Very low densities of fish present in the river reach;
- Highly turbid water during sampling which reduced the effectiveness of the electrofisher; and
- Strong currents in the riffle habitat during sampling that made fish (including eels) capture difficult.

3.2.5 *Macroinvertebrates*

Macroinvertebrate diversity and abundances were measured by a Department of Water and Sanitation SASS5 practioner during three site visits (17 July 2012, 16 April 2013 and 18 July 2013) using the South African Scoring System Version 5 (SASS5; Dickens and Graham, 2002). Historic sampled data and specialist knowledge were used to determine reference conditions. The following assessment methods were used collect and/or analyse the data:

- The South African Scoring System Version 5 (SASS5). This index measures aquatic macroinvertebrate presence data at a family taxon level. Each taxon is allocated a value between 1 and 15 according to its perceived sensitivity to water quality changes (with 1 being the least sensitive and 15 the most sensitive). Results are expressed as index scores: the SASS Score and the Average Score per Taxon (ASPT);
- The Invertebrate Habitat Assessment System (IHAS) was used in assessing the instream and riparian habitat (McMillan, 1998). Sections of the site characterisation manual (Dallas, 2005) were used to assist in characterising the site and interpreting data; and
- The Macroinvertebrate Response Assessment Index (MIRAI; Thirion, 2008) uses SASS and pre-determined reference condition data to determine the Present Ecological State (PES) of a site. The model considers the three main drivers of a river, namely: i) flow conditions, ii) geomorphology and iii) water quality. These drivers create the instream habitats that affect instream biotic communities. Therefore, the ecological category generated by the MIRAI reflects the influence of the various drivers on the site and the macroinvertebrate community response.

Appendix C describes the results of the invertebrate assessment.

3.2.6 Geomorphology

The geomorphological assessment was conducted on the 18th of July 2012 during which a number of EWR sites were visited within the catchment area. This provided an opportunity to assess the Mzimvubu catchment area and identify dominant land use activities and the non-flow related impacts of land use activities within the catchment as well as the active channel.

Findings indicate that agricultural activities within the steep slopes in the catchment area have resulted in extensive erosion within the entire catchment. Erosion high up in the catchment has resulted in the mobilisation of fine sediment and deposition with the main channel. Sediment deposition in the active channel has resulted in the anchoring of cobbles and boulders to the active channel floor.

A number of in stream sedimentation features have developed as a result of the increased suspended sediment load within the water column. The increased in the suspended sediment load transport has resulted in the increase in turbidity and imbededness of the substrate.

Some localised erosion of the sediment benches was also identified at the EWR site. Most of the identified impacts are non-flow related, however as result of land use activities within the catchment. The local catchment has not been developed extensively however the most dominant land use activity within the catchment are rural dwellings and subsistence farming. Furthermore there are no major in stream developments such as major dams within the catchment.

Appendix D provides the detail results of the geomorphological assessment.

d) Riparian Vegetation

Riparian vegetation was assessed using the Vegetation Response Assessment Index (level 3; Kleynhans *et al.*, 2007). As a result, assessments included: distinguishing between marginal and non-marginal zones; determining the condition of each vegetation zone; describing the indigenous woody and non-woody vegetation; describing riparian vegetation degradation; and assessing the extent of alien vegetation infestation at the site.

Riparian vegetation at the site was subdivided into marginal and non-marginal zones in order to: i) assess vegetation changes from the reference state within each zone and ii) determine each zone's contribution to the instream habitat integrity of the system. The marginal zone was considered to be the active zone at the water's edge; and the non-marginal zone the area that would be inundated at least once every three years.

Each zone was assessed separately and weighted in terms of its contribution (in the reference state) to the instream habitat integrity of the river. Furthermore, each zone was assessed in terms of intensity and extent of vegetation removal, alien vegetation infestation, and changes in water quantity and quality from the reference.

Furthermore, VEGRAI level 3 required that changes in cover, abundance and species composition of both the woody and non-woody vegetation from the reference state were assessed within each zone. The contributions of woody and non-woody vegetation to the instream habitat integrity were assessed individually and scored in relation to each another.

Appendix E describes the detail results of the riparian vegetation assessment.

3.2.7 Hydrology

The Tsitsa River is a major tributary of the Mzimvubu River in quaternary catchment T35E with a natural MAR of 428.5 million m^3 at the selected EWR site. Updated hydrology (Jeffares & Green, 2013) was used for the final analysis. The detailed hydrological modelling for the EWR site is described in a separate report (Jeffares and Green, 2013).

The EWR site is situated in the lower reaches of quaternary catchment T35E just upstream of the confluence with the Inxu River. The main tributaries of the Tsitsa River upstream of the EWR site are the Tsitsana, Pot and Mooi Rivers contributing to the MAR at the EWR site.

The only gauging weir in Tsitsa River is T3H006 that is situated downstream of the EWR site. The data from this weir could not be used during the assessments due to the substantial contribution of the Inxu River. However, the data from the weir was used as a check for the flood peaks specified by the geomorphologist and riparian vegetation specialist.

3.2.8 Physicochemical Data

There are two DWS water quality monitoring points located within the dam catchment area, one at Maclear (T3H009), and one at Halcyon Drift (T3H012). The site at Halcyon drift however has only been sampled 8 times between 1980 and 1982 and thus does not provide sufficient information to generate a picture of water quality in the upper Tsitsa. It has thus been disregarded.

The site at Maclear is located on the Mooi River at the bottom of quaternary catchment T35C and has been sampled 737 times between 1971 and 2013. This provides a good indication of water quality in the upper Mooi River. The site is however approximately 75 km upstream of the EWR site and does not take into account the impact on water quality of the town of Maclear, (and particularly of its WWTW which is located downstream of the site) or the significant contributions of water and potential pollutants from the Little Pot River and the upper Tsitsa River.

Data from this site (1975 – 1985) have however been used to assess reference condition for this catchment as it is located in the same ecoregion (South Eastern Uplands) as the EWR site and is in reasonably close proximity.

Site T3H006 is located approximately 50km downstream of the dam site and has been sampled over 200 times between 1971 and the present day and thus contains a good history of water quality in the area. Unfortunately this site is located downstream of the Tsita's confluence with two additional tributaries which drain areas outside the dam site's catchment (Inxu and the Nqado).

These tributaries both carry pollutants from two urban centres, Ugie and Tsolo, and the data from this site thus in all probability does not accurately reflect water quality at the EWR site, which is located upstream of these tributaries. This is particularly true from a nutrient perspective. The very limited data from a monitoring point at the Tsolo WWTW indicates very high phosphate concentrations (5mg/l) and elevated conductivities (73ms/m). This consequently limits the confidence in the data available for a present ecological state assessment for the EWR site.

Some in-situ water quality measurements were taken during the field visits to the EWR site. These are reported below in Table 3-7.

In addition, SASS river health bio-monitoring was performed and diatom samples collected to provide biological indicator data covering the EWR site (Table 3-8). All the data collected feed into the physico chemical driver assessment index (PAI) model for the determination of the physico-chemical category rating.

Table 3-7: Water quality results for the *in-situ* sampling undertaken at the EWR site

Metric	Unit	April 2013	July 2013
Water temperature	ºC	18.31	12.34
Electrical conductivity	mS/m	64	89
pH	pH units	7.19	6.97
TDS	g/l		0.075
Dissolved Oxygen	mg/l	9.57	11.03
Water clarity	cm	49	100
Water temperature	ºC	18.31	12.34

Table 3-8: Biological indicator data

Metric	Value		River health category	
	April 2013	July 2013	April 2013	July 2013
SASS ASPT score	6.63	6.68	C	B
SASS Score	126	147		
Diatoms at EWR site (SPI)	14.7	17.1	B	A/B

3.3 Information Availability

The available information for the EWR site is summarized in Table 3-9. The summary is linked to reserve determination levels for the various scores. Data availability on a Rapid reserve level has a score of 3-2, the Intermediate level a score of 3 and the Comprehensive level a score of 4.

Table 3-9: Information availability for the EWR site

Component	Information Availability					Description Of Information
	0	1	2	3	4	
Hydraulics	█					Little to no hydraulic data was available for the site.
Hydrology		█				Updated hydrology from Jeffares and Green, 2013 available was used during the assessment. Gauge T3H006 on the Tsitsa River was not used as the flow at the gauge include the contribution of the Inxu River.
Fish			█			Data from the River Health Programme and PES EI ES databases, including fish surveys downriver in T35K in 2003 (Kotze & Niehaus, 2003) are available.
Macroinvertebrates			█			Data from the River Health Programme and PES EI ES databases were available.
Geomorphology			█			Data from the River Health Programme and PES EI ES databases available. However very limited fluvial geomorphological information for the catchment area.
Riparian vegetation		█				Reference condition information was derived from Mucina and Rutherford (2006) using the method prescribed in Kleynhans *et al.* (2007).

Component	Information Availability					Description Of Information
	0	1	2	3	4	
Physico-chemical			■			Two DWS monitoring sites providing meaningful data are located in the vicinity of the EWR site. One in the upper catchment above the site (T3H009) and one below the site (T3H006). This data is however used indicatively as it contains pollutants from outside the EWR site's catchment. In-situ readings have been taken for Temp, DO, Conductivity and Clarity. Two sets of biological indicator data (SASS and Diatoms) are likewise available.

3.4 Specialist Workshop (Ecoclassification)

The results of the specialist workshop are summarized per sub-section for the following:

- Reference conditions;
- Present Ecological State (EcoStatus) per component;
- Ecological Importance and Sensitivity;
- Integrated PES (EcoStatus);
- Trends; and
- Recommended Ecological Category.

3.4.1 Reference Conditions

Reference conditions usually reflect the natural, un-impacted/pre-development conditions and are used as a baseline against which surveyed data can be compared to reflect the degree of change from the natural/un-impacted state of a resource.

Reference conditions for EWR sites are usually derived from un-impacted rivers in the same catchment area, aerial photographs, knowledge of the catchment and historical information, where available. The reference conditions for the EWR site in the Weza River per specialist component are summarized in Table 3-10.

Table 3-10: Description of reference conditions for the Tsitsa EWR site

Component	Description of Reference Conditions
Fish	Based on available information, this river reach has a naturally low species diversity, with only 2 indigenous fish species expected, namely the chubbyhead barb (*Barbus cf. anoplus)* and the longfin eel (*Anguilla mossambica*).
Macroinvertebrates	SASS5 scores: The total SASS5 score should be >224 and the Average Score Per Taxon (ASPT) should be >7.7. Reference taxa include: *Baetidae* >2spp, *Oligoneuridae*, *Heptageniidae*, *Prosopistomatidae* and *Perlidae*.
Geomorphology	The EWR site is located in predominantly mountainous stream where the reference state would have been characterised by mobile bed load transported material with very limited sediment suspended sediment within the water column. The bed load transportable material would have been comprised of large boulders, cobbles and very course gravel with limited fine suspended solids. The sedimentation features would have consisted of sediment benches with very limited in stream sedimentation features. The active channel is confined between two hills therefore the extent of the macro-channel is limited. This would also limit the lateral connectivity of the active channel and the uplands. Localised erosion of the sediment benches have further reduced the lateral connectivity between the active channel and the upland. The longitudinal connectivity

<table>
<tr><th>Component</th><th colspan="3">Description of Reference Conditions</th></tr>
<tr><td></td><td colspan="3">of the channel is well preserved due to the lack of major dams in the upper reaches of the system.</td></tr>
<tr><td>Riparian vegetation</td><td colspan="3">The marginal zone would have been dominated by a sedge-grassland vegetation type. This vegetation type would have had a greater basal cover and fewer sand banks in between than found in the present state. Boulders would have been scattered along the banks with woody individuals in between.
The non-marginal zone would have been grassland. Boulders would have been scattered in between. Clustered stands of Acacia karroo, Buddleja salviifolia, Diospyros lycioides, Leucosidea sericea, Searsia dentata and Rhamnus prinoides would have been present in areas that deterred or retarded the spread of fires.
The non-marginal zone played the primary role in driving the overall ecological condition of the system. Both zones would have been relatively similar in terms of their basal cover; however, the non-marginal zone would have had a greater surface area and would have had a slightly higher abundance of woody species whose roots would help with bank stabilisation.</td></tr>
<tr><td>Hydrology</td><td colspan="3">Natural flows at the EWR site were available for the period 1920 to 2009 as provided by R Gray of Jeffares and Green</td></tr>
<tr><td rowspan="6">Physico-chemical</td><td rowspan="5">Physical Variables</td><td>pH:</td><td>Reference condition data (1971 – 1985) from the upper Mooi River at Maclear indicates frequent periods where the pH falls below 6 (5th %tile = 5.7). Since 1989, this has not occurred and the pH has barely fallen below 7. Given that there have not been any significant developments in the catchment which may have resulted in this change, it is assumed that this change has come about due to changes in the method used for measuring pH, and that reference site data is not valid. Reference condition is thus set as per the pH natural benchmarks from DWS 2008 guidelines: ≥ 6.5 (5th percentile) and ≤ 8.0 (95th percentile)</td></tr>
<tr><td>EC:</td><td>Reference site data indicates low conductivities (95th %tile = 9.5mS/m). RC set at ≤ 30 mS/m as per DWS (2008) benchmark</td></tr>
<tr><td>Temperature:</td><td>No historical temperature records are available for this site. DWS (2008) benchmark tables are used for a low confidence, qualitative assessment of temperature RC.</td></tr>
<tr><td>Clarity:</td><td>There are no clarity/turbidity records available for reference condition assessment. Reference condition is taken as that qualitatively described in the DWS (2008) benchmark tables.</td></tr>
<tr><td>Oxygen:</td><td>No dissolved oxygen records are available for this site. DWS guideline benchmark tables (2008) have been utilised to characterise the site's reference condition.</td></tr>
<tr><td>Nutrients:</td><td>PO_4</td><td>Reference site indicates low SRP concentrations. RC set at <0.005 mg/ ℓ (50th percentile /median) as per DWS</td></tr>
</table>

Component	Description of Reference Conditions		
			(2008) benchmarks
		TIN	Reference site indicates low TIN concentrations. RC set at <0.25 mg/ ℓ (50th percentile/median) as per DWS (2008) benchmarks.
	Toxins:	All	No toxic parameters are monitored as part of the NCMP in this catchment. Reference condition is thus taken as that described in the DWS (2008) guidelines benchmark tables.

3.4.2 *Present Ecological State*

The PES is determined making use of the recognised models for each component as published in a series of volumes under the lead volume Kleynhans and Louw, (2008). The PES for the fish, macroinvertebrates, riparian vegetation, geomorphology, hydrology and physico-chemical are provided below:

a) Fish

No fish species of the 2 expected species were collected during the surveys. Historical fish data for the river, including data from fish surveys by the fish team in similar habitats in adjacent tributaries, were used to determine the FROC. These FROC results were used to inform the FRAI which was used to determine the PES.

The FRAI results indicated that fish are in a D (45.1%) ecological category. This is mainly due to serious catchment degradation resulting from overgrazing and destruction of natural vegetation, particularly in the riparian zone. The resulting soil erosion and river bank destabilization has resulted in massive sedimentation and modification of aquatic habitats.

The most impacted metric drivers were fish cover and physic-chemical conditions (turbidity). The paucity of marginal vegetation compared to the reference state has a significant negative impact as this is the required spawning habitat of *Barbus cf. anoplus* and provides cover from predation.

The detailed FRAI tables are presented in Appendix F.

b) Macroinvertebrates

The three modification metrics of the MIRAI, namely flow modification, habitat and water quality, were each ranked and weighted and then rated according to macroinvertebrate community changes from the reference condition. This information was then modelled to derive the Present Ecological Category of the site. Results below are for the low flow (and therefore critical period) sampling occasion on the 18th of July 2013.

The macroinvertebrate Ecological Category is a B/C (77.5%). This means the river is in a good ecological condition. The B/C category could be attributed to increased sediment loading as a result of both catchment related processed (e.g. overgrazing) and localised impacts (e.g. bank erosion as a result of alien invasive plant infestation).

The most impacted driver metric was habitat integrity (28.7%), followed by water quality (23.1%) and flow modification (14.8%). Table 3-11 provides the summary of the data interpretation and the PES for the macroinvertebrates. Taxa characterising this site included *Libellulidae*, *Simuliidae*, *Baetidae* >2spp and *Perlidae*.

Table 3-11: Macroinvertebrate Ecological Category, MIRAI

Invertebrate EC Metric Group		Metric Group Calculated Score	Calculated Weight	Weighted Score Of Group	Rank Of Metric Group	%Weight For Metric Group
Flow Modification	FM	85.2	*0.296*	25.2401	3	80
Habitat	H	71.3	*0.333*	23.7607	2	90
Water Quality	WQ	76.9	*0.370*	28.4747	1	100
Connectivity & Seasonality	CS	100.0	*0.000*	0		
Invertebrate EC				77.4754		270
Invertebrate EC Category				B/C		

According to flow modification assessments, taxa with a preference for very fast flowing water were the most important group; and taxa with a preference for slow flowing water ranked the least important group in the system. Taxa with a preference for standing water were most impacted group (1.5).

According to habitat modification assessments, taxa with a preference for loose cobbles were the most important group; and taxa with a preference for bedrock and boulders were the least important group in the system. Taxa with a preference for vegetation were the most impacted group (3). This could be attributed to the removal of marginal vegetation as a result of bank erosion. Taxa with a preference for gravels, sand and mud, and for the water column or surface water were the least impacted groups (0.5).

According to water quality assessments, the ASPT was the most important parameter; and taxa with a very low requirement for unmodified physicochemical conditions the least important group in the system. The ASPT and SASS Scores, and taxa with a very low requirement for unmodified physicochemical conditions were the most impacted parameters (1.5); whereas taxa with a moderate requirement for unmodified physicochemical conditions were the least impacted (0.5).

Appendix C provides the detail tables for the flow, habitat and water quality modification metrics and the scoring sheet.

c) Riparian Vegetation

The riparian vegetation ecological category is a C/D, this means the river is in a moderately modified ecological condition. The C/D category could be attributed to bank erosion and alien invasive plant infestation. Therefore, the impacts are primarily non-flow related.

The marginal zone: The marginal zone was characterised by sand banks and boulders with non-woody vegetation scattered in between. The right- and left-hand banks were markedly different as a result of severe alien invasion on the right-hand bank. *Arundinella nepalensis, Cynodon dactylon* and a variety of *Cyprus spp*. and *Juncus spp*. dominated the marginal zone. *Acacia mearnsii* and *A. dealbata* formed sections of dense stands on the right-hand bank. Indigenous woody and non-woody cover and abundances were affected by erosion and the establishment of alien vegetation.

The non-marginal zone: The non-marginal zone had distinct vegetation communities on the right- and left-hand banks. The right-hand bank was heavily infested by *Acacia mearnsii* and *A. dealbata* with bank collapse severe in certain sections. Indigenous vegetation was restricted to small gaps in the alien stands where the bank structure was still intact. In contrast, the left-hand bank was more natural, with grassland dominating the non-marginal zone. Scattered *Diospyros lycioides* individuals and boulders were present along this bank.

Indigenous woody and non-woody vegetation cover, abundance and species composition on the right-hand bank were removed by erosion and the establishment of alien vegetation. Vegetation on the left-hand bank were affected primarily by an altered fire regime in the catchment.

Table 3-12: Riparian vegetation ecological category, VEGRAI 3

Level 3 Assessment					
Metric Group	**Calculated Rating**	**Weighted Rating**	**Confidence**	**Rank**	**% Weight**
Marginal	66.4	11.1	4.2	2.0	20.0
Non Marginal	57.9	48.3	4.2	1.0	100.0
Level 3 Vegrai (%)				59.4	
Vegrai EC				**C/D**	
Average Confidence				4.2	

Appendix E provides the detail tables for marginal and non-marginal vegetation zone scoring sheet.

d) Geomorphology

The EWR site is located within a predominantly rural catchment where the most dominant land use activities are low density residential areas and subsistence farming. The subsistence farming in the area is characterized by cattle and crop plantation within the undulating hills that dominate the catchment. Due to the prevalence of steep slopes within the catchment area significant amount of sediment is washed from the surrounding land into the active channel. Afforestation and water abstraction reduces the capacity of the stream to transport sediment downstream therefore resulting in the storage of sediment within the active channel.

The Fluvial geomorphology is a (PES: C) due to the accumulation of sediment within the active channel as a result of increased sediment input from the catchment area. In stream sediment features have developed and grown therefore altering (to some degree) the in stream flow patterns. The sediment accumulation within the active channel has resulted in smothering of riffles and rapids which has increased imbededness of the gravel, cobbles and boulders and therefore reducing the amount and quality of habitat available to in stream biota.

Table 3-13: Fluvial geomorphology ecological category, GAI

PES	Trend	Period	Reason	Confidence
C	Negative	5 years	The increased sediment input into the active channel will result in further deterioration of habitat quality	3

e) Hydrology

Forestry, small dams and irrigation abstractions are the main impacts in the upper catchment, especially in the Mooi and Pot Rivers. The rest of the upper catchment is rural, with Maclear the only large town upstream of the EWR site. The details of the flow and the Hydrological Assessment Index are presented in Table 3-14 below.

Table 3-14: HAI scores for the Tsitsa EWR site

Hydrology Driver Assessment Index				
Hydrology Metrics	**Rank**	**%wt**	**Rating**	**Confidence**
Low Flows	3.00	80.00	2.00	3.00
Zero Flow Duration	1.00	100.00	0.00	4.00
Seasonality	2.00	90.00	0.50	4.00
Moderate Events	2.00	85.00	1.00	3.00
Event Hydrology(High Flows-Floods)	4.00	70.00	0.00	2.00
Hydrology Score	**86.35**			
Hydrology Ecological Category	**B**			
Boundary EC				
Note: Moderate events include freshets, 1:1 and 1:2 year flood events				

f) Physico-chemical

The PES category assigned to this site is a **B**. The following information sources were interrogated to inform population of the PAI model and to derive an overall physico-chemical condition for the Tsitsa EWR site:

Assessment of catchment activities and land use. Site observations during the EWR site field visits. In-situ physico-chemical sampling at the site. Sampling of biological indicators of water quality at the site.Historical water quality records from the DWS National Chemical Monitoring Programme

The results of these analyses are given in Table 3-15 below.

Table 3-15: Physico-chemical results at the EWR site

River		**Tsitsa**			
EWR Site		**MzimEWR1**			
Confidence		**Moderate - Low**			
Constituent		**PES Value**	**No. of samples (N)**	**Category / Rating**	**Comment**
Salts	Electrical Conductivity (mS/m)	7.6 (mS/m) Mean of two in-situ readings	2	0 [A]	Data available for salts for this site from DWS site T3H006 is influenced by salinity impacts from outside of the EWR site's catchment. Aggregation of salts data from this monitoring site is thus not considered meaningful for this EWR site. EC data from in-situ readings is thus used to provide a low-confidence assessment of salinity at the EWR site (N=2). Given that the 95th percentile of the reference data EC was 9.5 mS/m, the site is considered to be in a natural state from a salinity perspective.
Nutrients	PO_4 (mg/l)	0.0165	132	Adjusted category 1[B]	Nutrient data available for this site from monitoring point T3H006 suggest a moderate change from reference condition in phosphate concentrations and a natural condition in TIN concentrations. This data is however likely to be influenced by discharges from at least two WWTWs (Tsolo and Ugie) which fall outside the EWR and Dam sites' catchment. Based on the activity which is known to occur in the

River		Tsitsa			
EWR Site		MzimEWR1			
Confidence		Moderate - Low			
Constituent		**PES Value**	**No. of samples (N)**	**Category / Rating**	**Comment**
	TIN (mg/l)	0.179	102		catchment, and based on the biological indicators sampled and observed on site, a moderate to low confidence assessment of a small change from natural (class 1[B]) is assigned.
Physical Variables	pH	8.6	53	1 [B]	Data analysis from both monitoring points in the catchment indicate a 95th %tile pH value which is slightly elevated (8.2) with respect to natural (8.0). A category of "Small change" is assigned: 1 [B].
	Temperature (°C)	26.01	1	0.5 [A/B]	No temperature data is available (historical or current) for the DWS sites within the vicinity of the EWR site. Existing benchmark tables were consulted for a low confidence, qualitative rating (DWAF, 2008). No activities that may significantly modify temperature are noted upstream, with the exception of forestry and the shading of water courses by invasive alien trees.
	Dissolved Oxygen (mg/l)	10.3 (mg/l)	2	0 [A]	No dissolved oxygen data is available for monitoring sites in the EWR site's catchment. In-situ readings of DO taken during site visits (n = 2) indicate near natural conditions and few activities are noted in the catchment which are likely to influence this. The Maclear WWTW is located some 70Km upstream and any oxygen depletion is likely to have re-set by the time water arrives at the EWR site.
	Turbidity	N/A	0	3 [D]	Unfortunately no turbidity or total suspended solids data is available for the catchment. This is a significant concern given the erodible nature of the duplex soil types found in the region and the large-scale erosion problems which characterise this area. One third (538,381 ha) of the Mzimvubu Catchment is exposed to high erosion risk and the average erosion rate predicted is excessive at 33 t/ha/yr (Le Roux et al 2008). This is seasonal though and is driven by rainfall events. In-situ dry season clarity tube measurement shows clear water (100cm visibility). A qualitative assessment based on the DWA guidelines (2008) renders a class of "Large Change": 3 [D].
Response variables	SASS score	ASPT 6.6 SASS 136.5	2	1.5 [B/C]	Two SASS samples were taken during the site visits and have been used to provide additional information regarding water quality at this site, against which to compare and adjust the outputs of the PAI model
	Diatoms (SPI)	15.9	2	0.5 [A/B]	Two diatom samples were collected and have been used evaluate the water quality assessment.
Toxics		No data available	0	0 [A]	No toxics data is available for this site from the DWS chemical monitoring

River		Tsitsa			
EWR Site		MzimEWR1			
Confidence		Moderate - Low			
Constituent		PES Value	No. of samples (N)	Category / Rating	Comment
					programme. Based on the Diatom and SASS data, and on the assessment of catchment activities, it is unlikely that toxins are a concern in this catchment.
Overall Site Classification				B	The PAI model result was determined from DWS WQ data, water and biological indicator sampling during site visits and qualitative catchment indicators. This assessment classes the site as having undergone a small change from natural (B).

g) Status

The PES per component as derived from the various models, the rationale and an indication if it is flow or non-flow related impacts are provided in Table 3-16.

Table 3-16: The PES, with reasons for this classification, of the various components

Component	PES	Flow/ Non-flow	Explanation
Hydrology	B (86.4)	F	Impacts on the low flows and moderate events due to forestry, small dams and irrigation in upper catchment
Fish	D (45.1)	NF	The main impacts on fish are associated with the increased sediment input due to catchment and riparian zone degradation, resulting in modification and destruction of critical fish habitat.
Macroinvertebrates	B/C	NF	The main driver in the system affecting the macroinvertebrate community is increased sediment loading as a result of catchment-scale (over grazing) and localised (bank erosion as a result of alien vegetation) impacts.
Geomorphology	C	NF	The reduction in the amount and quality of available habitat is due to the increased sediment input into the active channel as a result of the dominant land use activities in the catchment area.
Riparian vegetation	C/D	NF	Impacts are localised and primarily the result of alien invasive plant infestation and bank erosion.
Physico-chemical	B (88.2)	F & N/F	The most significant impacts on water quality are largely related to erosion problems in the catchment. This is not flow related. Impacts due to discharges from sewerage works are mitigated and diluted over the length of the river and could be considered to be flow related.

The assessments of the various biophysical components impacting on the present ecological status of the river can be integrated, with the overall classification given as an EcoStatus score.

To determine the EcoStatus, the macroinvertebrates (MIRAI) and fish (FRAI) results are combined to determine the instream category. The Vegetation Response Assessment Index (VEGRAI) category and confidence is then included in the assessment index and the integrated EcoStatus is calculated.

The integrated PES or EcoStatus of the Tsitsa River at the EWR site is a C category (moderately modified) and is presented in

Table 3-17 below. The main negative impacts on the Tsitsa River at the EWR site is increased sedimentation, erosion gulleys and collapsing of the river banks.

Table 3-17: Ecostatus for the Tsitsa River at EWR site in T35E

INSTREAM BIOTA	**Importance Score**	**Weight**	**EC %**	**EC**
FISH				
1. What is the natural diversity of **fish** species with different flow requirements	1	80		
2. What is the natural diversity of **fish** species with a preference for different cover types	1	100		
3. What is the natural diversity of **fish** species with a preference for different flow depth classes	1	100		
4. What is the natural diversity of **fish** species with various tolerances to modified water quality	1	60		
Fish Ecological Category	4	340	**45.1**	**D**
AQUATIC INVERTEBRATES				
1. What is the natural diversity of invertebrate biotopes	4	100		
2. What is the natural diversity of invertebrate taxa with different velocity requirements	3	90		
3. What is the natural diversity of invertebrate taxa with different tolerances to modified water quality	2	70		
Aquatic Invertebrate Ecological Category	**9**	260	**77.5**	**C/B**
Instream Ecological Category (No confidence)		600	**71.2**	**C**
INSTREAM ECOLOGICAL CATEGORY WITH CONFIDENCE	**Confidence rating**	**Proporitons**	**Modified weights**	
Confidence rating for **fish** information	0.5	0.14	6.44	
Confidence rating for **macro-invertebrate** information	3	0.86	66.43	
	3.5	1.00	72.87	
Instream Ecological Cateogory	**EC**		**C**	
RIPARIAN VEGETATION	**EC %**	**EC**		
Riparian Vegetation Ecological Category	**59.4**	**C/D**		
ECOSTATUS				
Confidence rating for instream biological information	2.6429	0.40	28.99	
Confidence rating for riparian vegetation zone information	4	0.60	35.77	
	6.6429	1.00	64.76	
Ecostatus	**EC**		**C**	

3.4.3 Ecological Importance and Sensitivity

The EIS for the Tsitsa River was determined as moderate as shown in Table 0-18. The Evolutionary Significant Unit (*Barbus cf. anoplus*) is potentially present in the system. Furthermore, *Oligoneuridae* (that are dependent on high velocities) were sampled during the high flow survey. *Perlidae* and *Prosopistomatidae* (that are sensitive to water quality changes) are also present at the EWR site.

Two waterfalls are present in the system, namely the large Tsitsa Falls downstream (below N2 road) and the smaller falls upstream (below R56 road) of the EWR site. These falls act as barriers that could result in the creation of an evolutionary significant unit. DNA analyses of fish from this river reach and comparison with chubbhead bard populations upstream of the Upper Tsista falls and in adjacent rivers, will be required to resolve this issue. Until this information is available, the precautionary principle is prudent.

Table 3-18: Ecological Importance and Sensitivity of the Tsitsa River

Determinants	Present Score (0-4)	Comment
Biota (Riparian and Instream)		
Rare and endangered	0	None
Unique (endemic, isolated)	3	Unique *Barbus anoplus*-type minnow likely to be present in system as high waterfalls both up and downstream create barriers to fish movement , thus enabling the development of an Evolutionary Significant Unit.
Intolerant (flow and flow related water quality)	3	*Oligoneuridae* dependant on high velocities was sampled during high flow survey. *Perlidae* and *Prosopistomatidae* present in the system
Species/taxon richness	2	22 invertebrate families. ASPT=6.7 SASS=147 0 of 3 expected fish species sampled.
Riparian And Instream Habitats		
Diversity of types	2	Cobbles, boulders, marginal vegetation, gravel, mud and sand (GSM), riffle, pools
Refugia	2	Pools might serve as refugia for BANO and eels during low/no flows
Sensitivity to flow changes	2	Presence of pools and isolated riffle sections
Sensitivity to flow related water quality changes	1	-
Migration route/corridor (instream and riparian)	1	Limited due to Tsitsa Falls downstream, although longfin eel (*Anguilla mossambica*) have been recorded upstream of this barrier (Kotze & Niehaus 2003)
Importance of conservation and natural areas	0	None
Median Of Determinants	**2**	
Ecological Importance and Sensitivity		**Moderate**

4 – Very high; 3 – High; 2 – Moderate; 1 – Marginal/Low; 0 - None

3.4.4 Trends

The trend in ecological status gives an idea whether the present state is realistic and would stay the same if the management of the catchment were to continue in the same way that gave rise to the present state.

Thus the definition of the trend is *"…viewed as a directional change in the attributes of the drivers and biota (as a response to drivers) at the time of the PES assessment. A trend can be absent (close to natural or in a changed state but stable), negative (moving away from reference conditions) or positive (moving back towards natural - when alien vegetation is cleared, for instance). The ultimate objective is to determine if the biota have adapted to the current habitat template or are still in a state of flux",* Kleynhans and Louw (2008).

The ecological trends are presented in Table 3-19 below.

Table 3-19: Ecological trends for the Tsitsa River at the EWR site

Component	Trend	Reason	Confidence (0-5)*
Fish	Decline	Current negative impacts could intensify due to population growth leading to further catchment degradation and increased alien plant infestation, resulting in elevated sediment inputs.	2
Macro-invertebrates	Decline	Current negative impacts could intensify due to population growth leading to further catchment degradation and increased alien plant infestation, resulting in elevated sediment inputs.	2
Riparian Vegetation	Decline	Bank erosion is likely to be exacerbated by continued alien plant infestation in the system.	2
Fluvial geomorphology	Decline	Reduced stream capacity to transport increased sediment input into the active channel will result in a change in the flow patterns associated with the stream	3
Hydrology	Stable	No recent changes to forestry areas, increases in small dams or irrigation use	3
Physico-chemical	Decline	If current management remains constant, increasing erosion problems and expansion of urban areas with poorly performing WWTWs will increasingly impact water quality.	3

** 0 – no confidence to 5 – high confidence*

3.4.5 Integration of Results (EcoStatus) and Recommended Ecological Category

The EcoStatus of the Tsitsa River EWR site is in a C category. This EcoStatus score can be modified, if necessary, by the ecological importance and sensitivity assessment to give the final attainable REC.

During the final allocation of the REC, if the resource is degraded (i.e. has a low PES) but has a high ecological importance and sensitivity (EIS), the REC can be upgraded if it is potentially feasible to do so. The EIS for the Tsitsa River is moderate and after discussions between the various specialists, it was decided to maintain the C category as the Recommended Ecological Category.

3.4.6 Ecological Water Requirements (Quantity)

The above information together with the hydraulic cross-section were utilised during the Habitat Flow Stressor Response (HFSR) process to determine the stress indices for low flows and the flood requirements for the fish, macroinvertebrates, geomorphology and riparian vegetation.

Stress indices are set for fish and macroinvertebrates to aid in the determination of low flow requirements. The stress index describes the consequences of flow reduction on flow dependent biota. It therefore describes the habitat conditions for fish and macroinvertebrate indicator species or guild for various low flows. These habitat conditions for different flows are rated from 10 (zero flows, high stress) to 0 (no stress), which is optimum habitat for the indicator species.

The fish were not included in the determination of the flow requirements as none were sampled and those species expected to be present are relatively insensitive to flow. Thus, only macroinvertebrates were used to determine the stress index. This is an unusual situation brought about by the poor natural fish species diversity in the river, and the low requirement for flowing water by those species that are present.

The optimum base flows for the wet and dry season were determined from the reference flow and is summarised in Table 3-20.

Table 3-20: Optimum base flows for the Tsitsa EWR site in m^3/s

High flow month	Optimum base flow	Low flow month	Optimum base flow	Measured			REC
				Jul 12	Apr 13	Jul 13	
Feb	14.62	Aug	7.34	7.1	10.6	2.55	C

The Desktop reserve Model (DRM) and Flow Stressor Response Model in SPATSIM, version 2.12 were used to calculate the final Ecological Water Requirements for the REC of a C. The reference flow used was the natural simulated flows with the mean annual runoff 428.49 million m^3.

The measured discharges were used as the departure point as no stress was observed for the macroinvertebrates during the site visits. The stress-flow relationships were determined for flows lower than these using the hydraulic cross-section, available habitats and velocities. The base flows for the low flow month of August were considered during the determination of the stress curve. The selected stress values and associated flows are provided in Table 3-21 and the final integrated stress curve is shown in Figure 3-8.

Table 3-21: Selected stress values, flows and rationale for macroinvertebrates

Stress	Flow (m^3/s)	Rationale
0	10.600	Observed April 2013
1	7.100	Observed July 2012
2	4.459	
3	2.550	Observed July 2013
5	0.445	
8	0.034	
9	0.001	
10	0.000	

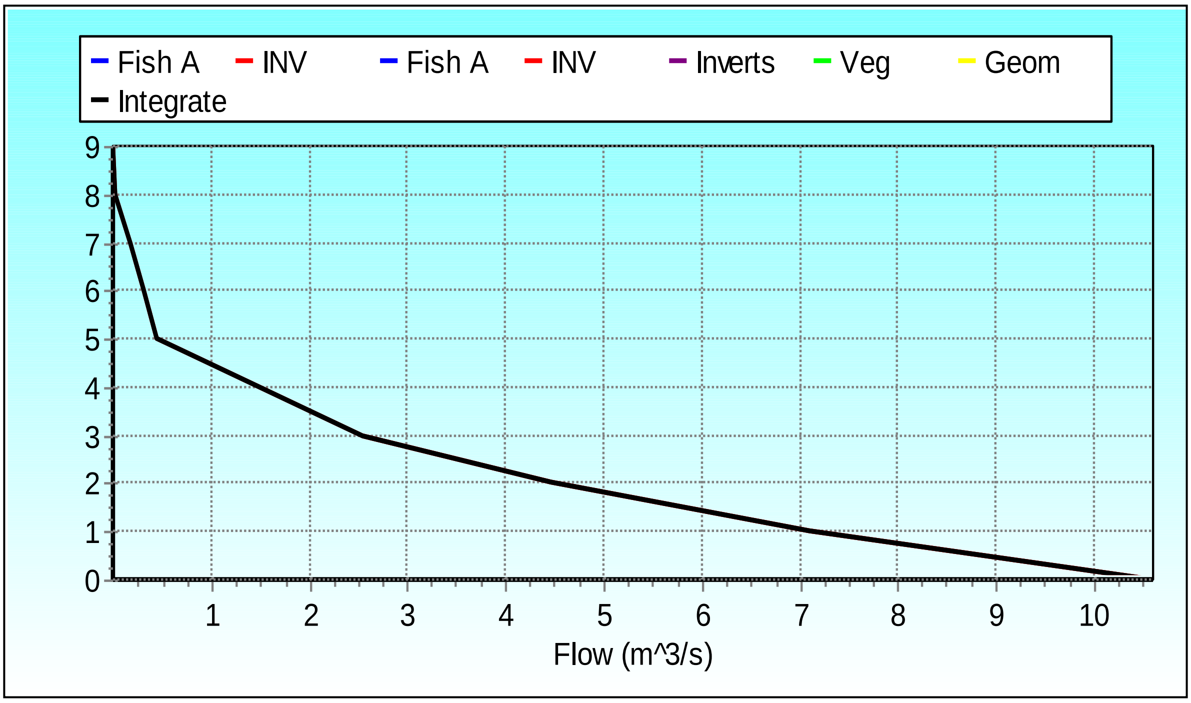

Figure 3-8: Final stress curve for the Tsitsa River EWR site

The information of the above stress curve was used to convert the flows into stress duration curves for the EWR site for the dry season (August) and wet season (February) indicating the actual required flows for the macroinvertebrates are shown in Figure 3-9 and Figure 3-10 below.

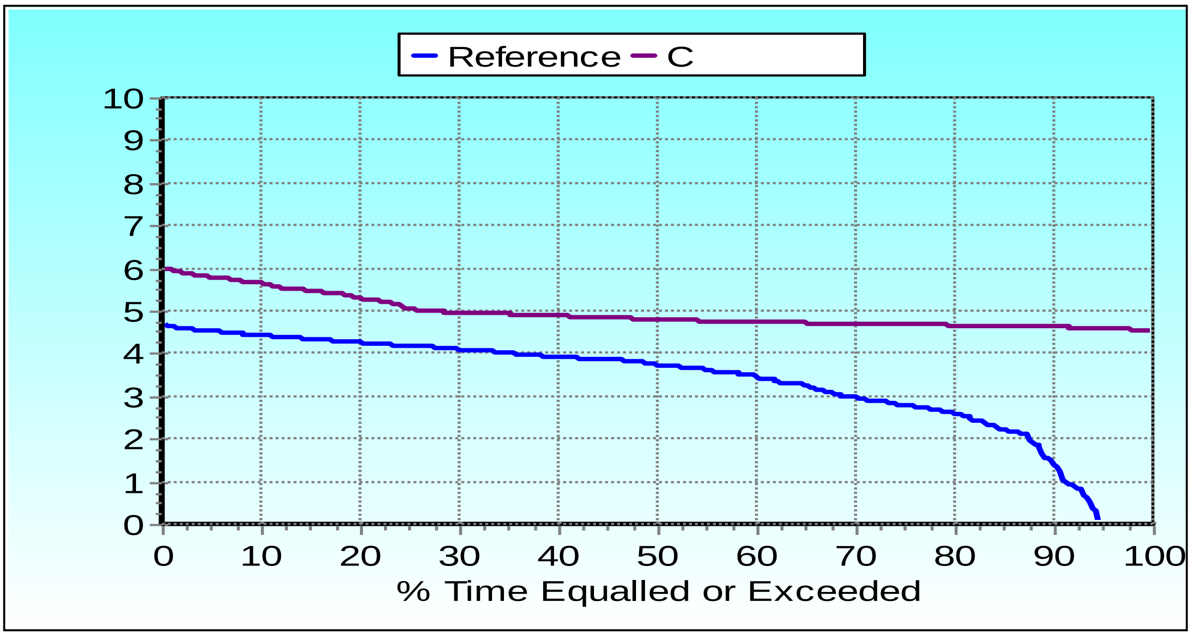

Figure 3-9: Stress duration curve – dry season (August)

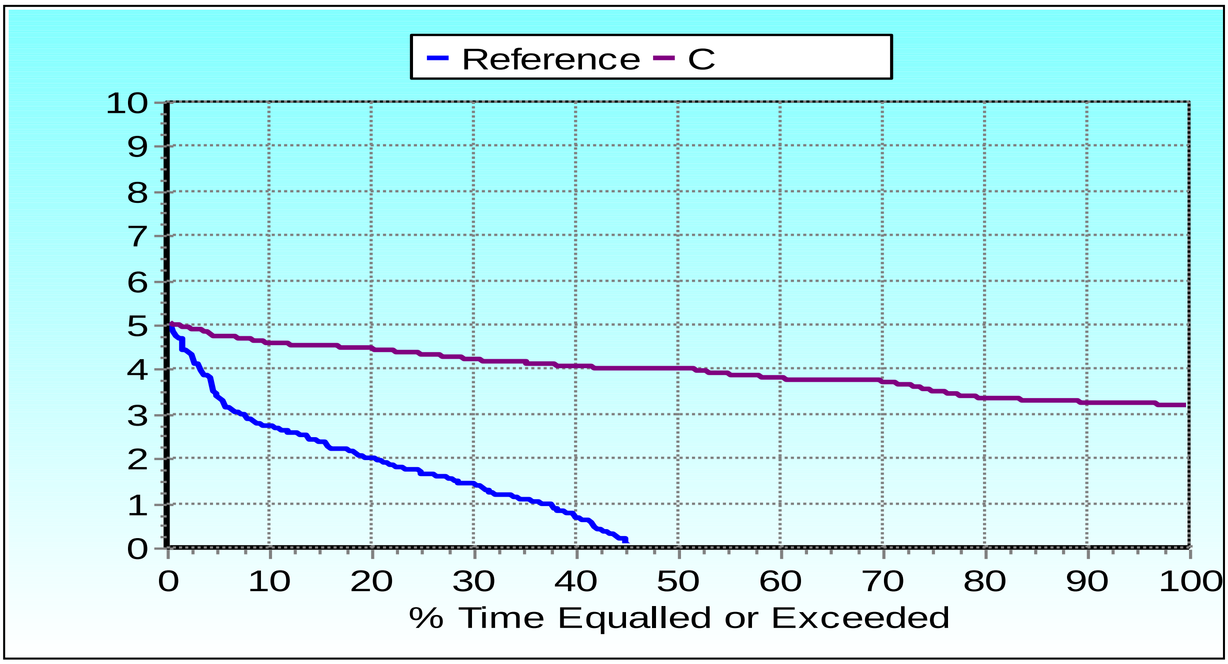

Figure 3-10: Stress duration curve – wet season (February)

The flood requirements for the Tsitsa River were specified by the macroinvertebrates, geomorphology and riparian vegetation specialists and include small freshets to provide specific cues as well as larger floods for clearing of the river channel. The individual requirements were integrated for inclusion in the final EWR results and are summarised in Table 3-22.

Table 3-22: Flood requirements for the Tsitsa River at the EWR site

Floods	Flood size (range)	Fish	Inverts	Vegetation	Geomorph	Integrated*	Actual Flood Value in SPATSIM
Class 1	0-7 Average	Same as inverts	3 cumecs Dec, Jan 2 days			3 cumecs Dec, Jan 2 days	**3**
			5-7 cumecs Sep, Oct 3 days			7 cumecs Sep, Oct 3 days	**7**
Class 2	7-10 Average	Same as inverts	10 cumecs Nov, Feb 3 days		12 cumecs Nov, Feb 3 days	10 cumecs Nov, Feb 3 days	**10**
Class 3	10-70 Peak			70 cumecs Feb 5 days	70 cumecs Feb 5 days	70 cumecs Feb 2 days	**50**
Class 4	70-150			150 cumecs Mar 5 days	150 cumecs Mar 5 days	150 cumecs Mar 5 days	**100**

** The freshets as defined in the DRM for April have been included.*

The final ecological water requirements were generated by the DRM in SPATSIM using the stress duration curves and the integrated flood requirements and are summarised in Table 3-23.

Table 3-23: Summary of the EWR results (flows in million m^3 per annum)

Quaternary Catchment	T35E
EWR Site Co-ordinates	S 30.606; E 29.755
Ecological Category	C
VMAR for Quaternary Catchment Area	428.49
Total EWR	87.249 (20.36 %MAR)
Maintenance Low flows	50.517 (11.79 %MAR)
Drought Low flows	23.991 (5.60 %MAR)
Maintenance High flows	36.732 (8.57 %MAR)
Overall confidence	Medium

The EWR results are used to produce the final Ecological reserve quantity results in the format of an assurance table or EWR rule curves. These curves specify the frequency of occurrence relationships of the defined maintenance and drought flow requirements for each month of the year. The tables thus specify the % of time that defined flows should equal or exceed the flow regime required to satisfy the ecological reserve. The detail tables of the requirements are provided in Appendix G.

3.4.7 Ecological Water Requirements (quality)

The Physico-Chemical Driver Assessment Index (PAI) model was used to rate the degree of change of each water quality variable category (e.g. nutrients) from the Reference Condition/natural state to the present condition (PES). The PAI table covering the physico-chemical PES for the EWR site on the Tsitsa River is given in Table 3.22, with interpretation of the table following thereafter.

In summary the most significant changes from Reference Condition/natural state is in the suspended solids component, while catchment land use activities and other discharges upstream in the catchment increase the concentrations of nutrients slightly. It is expected that the releases from the proposed dam will have a strong influence on water quality at the EWR site, particularly in providing water with a reduced sediment load.

The EcoSpecs in Table 3-24 have been derived based on the present state and reference condition of water quality at the site, in conjunction with the rating categories which are referred to during the PAI modelling.

Table 3-24: PAI table for the Tsitsa River in T35E

Metric	Rating	Threshold Exceeded?	Conf	Default Weights	Adjusted Ranks	Adjusted Weights
pH	1.00	N	2.00	50.00		
Salts	0.00	None Specified	1.00	50.00		
Nutrients	1.00	None Specified	1.00	65.00		
Water Temperature	0.50	N	2.00	60.00		
Water clarity	3.00	None Specified	2.00	50.00		
Oxygen	0.00	N	2.00	75.00		
Toxics	0.00	N	1.00	100.00		

Metric	Rating	Threshold Exceeded?	Conf	Default Weights	Adjusted Ranks	Adjusted Weights
PC Modification Rating With Threshold Applied (Max)	0.66	**Mean Conf →**	1.57			
Calculated PC Modification Rating Without Threshold And With Default Weights	0.66					
Calculated P-C Rating Without Threshold And Based On Adjusted Weights	0.66					
Final PC Modification Rating	0.66					
P-C Category %	P-C Category					
65.20	C					

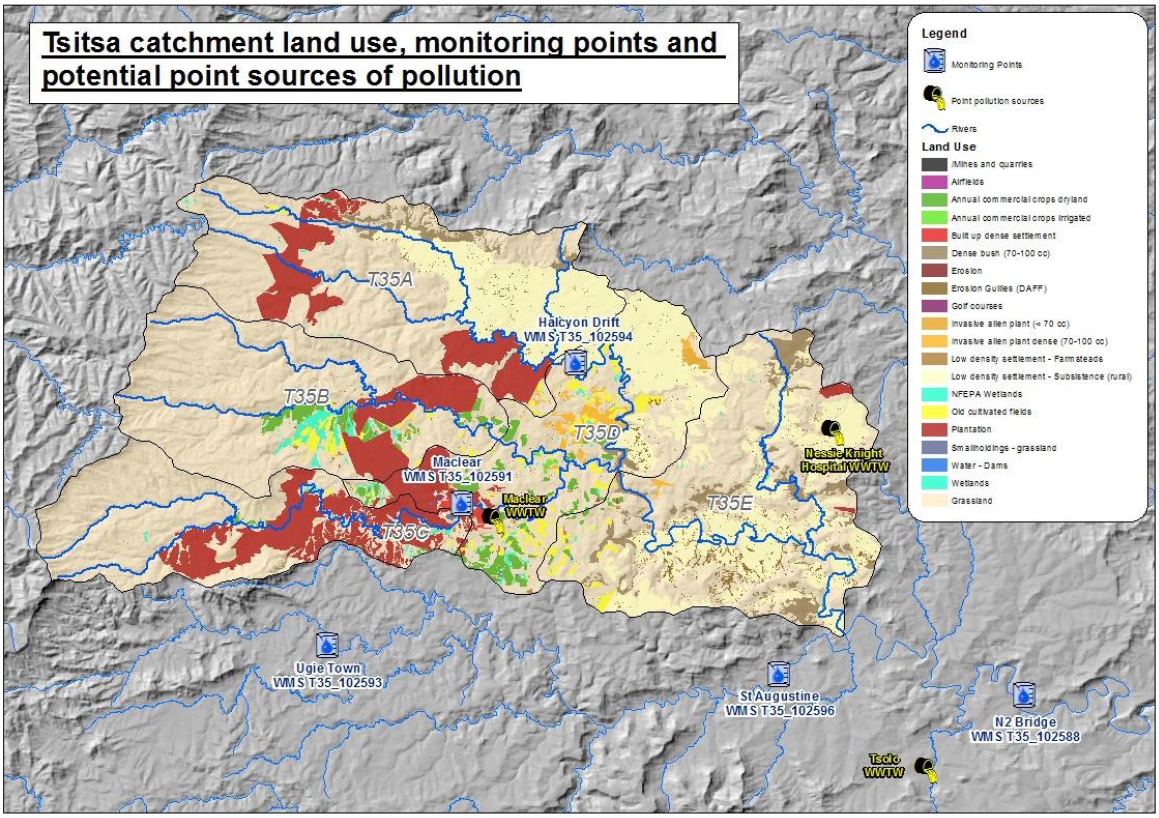

Figure 3-11: Map of land use and monitoring points in the Tsitsa catchment

Interpretation of the PAI table is as follows:

a) pH

Historical data (1971 – 1985, n=88) from the Mooi River catchment upstream of Maclear shows pH ranging from 5.4 to 8.4, with a 5th percentile value of 5.8. While this is considered the reference site for this study, pH data appears significantly different over this period from the period after 1990 (5th percentile 7.1). No apparent major changes in activities are noted in the catchment that may have resulted in this change, and it is assumed therefore that a change in the method used by the DWS in measuring pH must account for this difference. This data has thus been disregarded and the guideline benchmark values for reference (DWA 2008) used.

When compared against the benchmark values, pH data from the upper Mooi River between 1990 and the present indicates a 5th – 95th percentile range of 7.1 – 8.07. This is classified as constituting a small change from natural – category B (1). Data from the monitoring site below the EWR site (T3H006) shows a range of 7.3 – 8.3 over the same period, and is also classified as Category B (1). Although neither of these sites are ideal in representing the EWR site, the agreement between them provides confirmation that the pH at the EWR site is likely to have undergone a small change from natural and is thus assigned a B (1) category.

b) Salts

The data available to represent the EWR site contains sufficient data to aggregate salts, however this step is considered meaningless given the impact of the two urban areas (Tsolo and Ugie) and the two tributaries draining their regions (Inxu and Nqado) which fall outside of the EWR site's catchment and which will contribute salinity impacts to the monitoring site. Consequently in-situ readings of EC taken during site visits have been used to give a low confidence indication of salinity levels at the EWR site. These readings suggest a very low level of salinity, one which is certainly less than the benchmark guideline values reported in the Water Quality Reserve Determination Method (DWA 2008). This is consistent with the assessment of land use in the catchment which identifies very few activities which could impact the concentration of dissolved salts and thus the conductivity of the water. Conductivity is thus assigned a category A (0).

c) Nutrients

Nutrient data from the DWS monitoring site below the EWR site (T3H006) shows a phosphate concentration lying on the boundary between a B and a C category. This data however is not considered an accurate representation of the water quality at the EWR site because of reasons stated above. An assessment of land use in the catchment and an assessment of biological indicators suggest that a small change in nutrient concentrations is likey to have occurred. Two WWTWs (Maclear and Nessie Knight Hospital) discharge into the catchment and commercial agricultural activities, though limited in scale, are likely to impact phosphate levels. Nutrients are thus assigned a B (1) score in the PAI model.

d) Temperature

There is no historical temperature data recorded at the DWS NCMP sites within vicinity of the EWR site. Though two temperature readings were taken during site visits, these are meaningless unless they can be compared against daily fluctuations which naturally characterise the temperature of the water at the site. As a result, a conclusion regarding the PES for temperature at the site is drawn from an assessment of the activities and characteristics of the catchment above the site.

No significant temperature altering activities are noted as taking place in this rural catchment. Alien wattle trees are seen to populate some of the river banks and dense forestry stands may also have a slight impact on the temperature of the water flowing alongside it. In addition high turbidity periods may additionally play a role in altering the water temperature slightly. Temperature is thus assigned an A/B (0.5) category indicating an almost natural situation.

e) Water clarity

Unfortunately no turbidity or total suspended solids data is available for the catchment. This is a significant concern given the large-scale erosion problems which characterise this area. These have been documented in several studies. Le Roux et al (2008) used a national scale model (USLE interfaced in a GIS) to assess erosion potential across the country and it was found that one third (538,381 ha) of the Mzimvubu Catchment is exposed to high erosion risk. Additionally, the average erosion rate predicted is excessive at 33 t/ha/yr with over 10 million tons of soil eroding annually.

In a separate study, Le Roux and Sumner (2012) assessed the factors influencing the formation of continuous and dis-continuous erosion gullies in the Tsitsa catchment. They describe the erodible nature of duplex soil types found in the region, and they note that their field observations indicated a high proportion of cultivated and grassland areas are affected by gulley erosion due to the influence of livestock through grazing and trampling.

Site visit observations however indicate that turbidity is not a permanent problem and that clear water is present at times. Based on this assessment, and compared to the qualitative descriptions included in the DWS benchmark guidelines (DWA 2008), turbidity ranks as the determinant most likely to have been significantly modified from reference condition, and is assigned a category of D (3).

f) Dissolved Oxygen

There is no DWS data for dissolved oxygen at any of the sites in the catchment. Two in-situ measurements were taken during field visits and compared against the benchmark tables of the WQ reserve guideline document (DWA 2008) these reflect a natural condition. With no reason to suspect otherwise, given the activities occurring in the catchment, the site is assigned a category of A (0).

g) Toxics

No toxin data is available for the catchment. Biological survey data (diatoms and SASS) indicates that toxins are unlikely to be present in concentrations that could affect the ecology of the river. In addition land cover in the catchment is predominantly grassland with few potential sources of toxins present. Toxins are thus considered to be in a natural state and assigned a category A (0).

h) Final P-C Category Rating

According to the Generic Ecological Categories for Ecostatus (Kleynhans 2008) the score of 60-79 is C category.

The PAI model result was determined from DWS historical data, water and biological indicator sampling during the site visit and qualitative catchment indicators revealing a system which has undergone small change from its natural condition which is normally represented by a final P-C Category Rating of C. This site classification indicates that few developmental pressures are currently impacting the site while soil erosion is the predominant cause of water quality deterioration.

3.5 Ecological Consequences of Scenarios

A number of scenarios were identified to assess the likely impact of the proposed dam and releases for a possible second dam upstream of the Tsitsa Falls just below the N2 road. The scenarios assessed are listed in Table 3-25 below.

Table 3-25: Operational scenarios for the Tsitsa River at EWR site

Scenario	Description	Full Supply Capacity ($10^6 m^3$)
Nat	Natural	No dam
Prs	Present day flows without EWR (present day is almost natural flows)	No dam
Sc1	0.1 MAR Ntabelanga Dam with full EWR, without hydropower releases.	41.5
Sc2	0.5 MAR Ntabelanga Dam with full EWR, without hydropower releases	207.5
Sc3	1.2 MAR Ntabelanga Dam with full EWR, without hydropower releases	489.7
Sc4	1.2 MAR Ntabelanga Dam with full EWR, with constant releases for hydropower	489.7

The hydrological changes associated with each of the identified scenarios were modelled and used as the primary driver of change. The EWR of the Tsitsa River was assessed in terms of how this change in hydrology will impact on the level of stress being experienced in the system and the state of the various response variables.

The flows as provided for the operational scenarios were converted into m^3/s and seasonal distribution plots were prepared. The seasonal distribution plot is shown in Figure 3-12 and the flow duration plots for August and February in Figures 3-13 and 3-14.

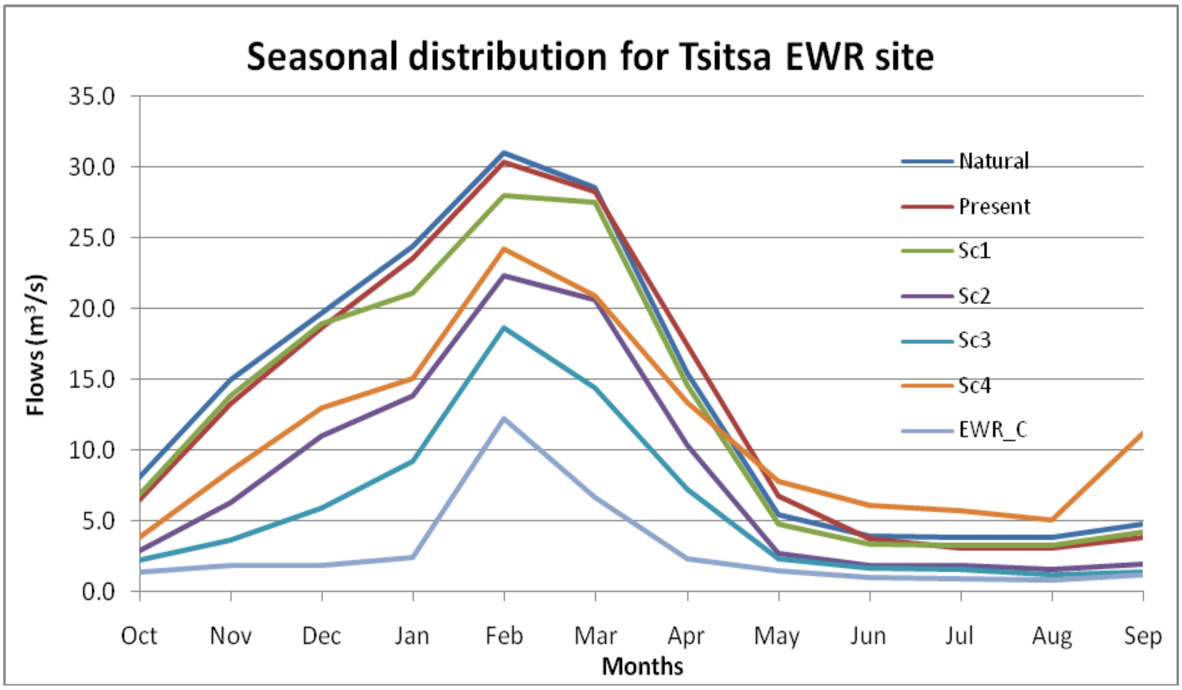

Figure 3-12: Seasonal distribution plots of scenarios at Tsitsa River EWR site

From the above figure it is clear that the EWR could on average be supplied for all the scenarios.

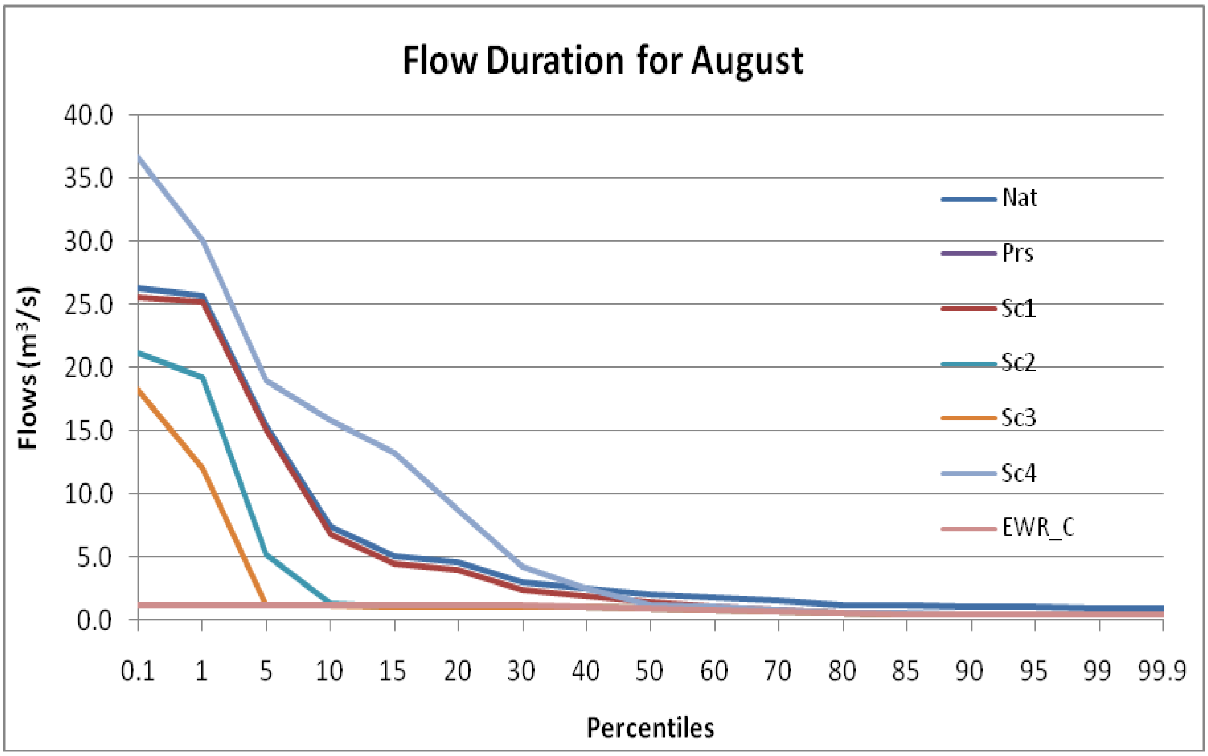

Figure 3-13: Flow duration curves for August for the scenarios

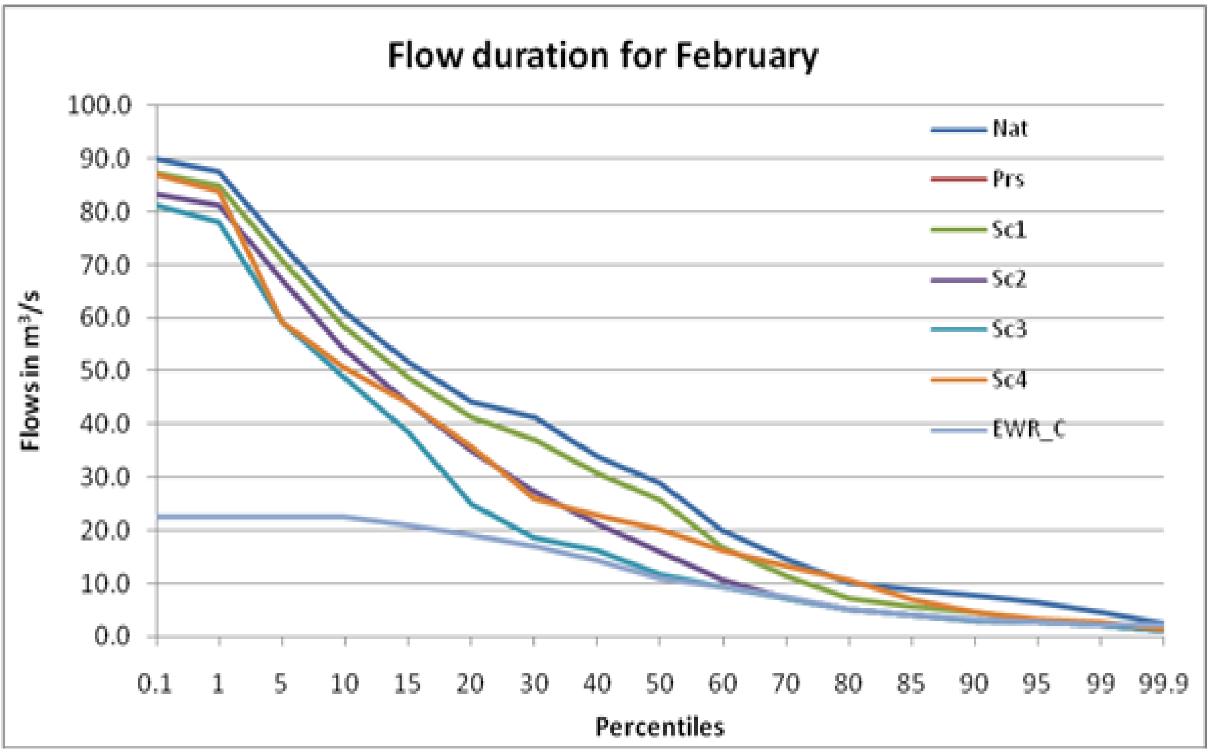

Figure 3-14: Flow duration curves for February for the scenarios

The flow duration curves of the scenarios for both months show that the EWR could be supplied for most of the time. Table 3-26 and Table 3-27 show the percentiles for August and February for the various scenarios and indicate where the EWR could not be met.

Table 3-26: Percentiles for August per scenario at EWR site

Percentiles	Nat	Prs	Sc1	Sc2	Sc3	Sc4	EWR_C
0.1	26.27	28.98	25.62	21.19	18.20	36.65	1.13
1	25.69	23.77	25.24	19.21	12.03	30.10	1.13
5	15.43	11.78	15.06	5.15	1.12	19.05	1.13
10	7.34	7.58	6.79	1.26	1.12	15.88	1.12
15	5.08	4.84	4.44	1.11	1.11	13.22	1.12
20	4.56	3.41	3.97	1.11	1.11	8.79	1.11
30	3.06	2.46	2.44	1.07	1.08	4.26	1.08
40	2.56	1.72	1.92	1.01	1.01	2.52	1.01
50	2.03	1.37	1.40	0.91	0.92	1.25	0.91
60	1.74	1.05	1.11	0.77	0.78	1.08	0.77
70	1.51	0.88	0.87	0.64	0.64	0.85	0.64
80	1.22	0.63	0.57	0.53	0.54	0.62	0.53
85	1.16	0.60	0.50	0.49	0.50	0.54	0.49
90	1.12	0.51	0.47	0.47	0.47	0.52	0.46
95	1.03	0.47	0.46	0.46	0.46	0.49	0.45
99	0.94	0.34	0.44	0.44	0.44	0.48	0.44
99.9	0.93	0.29	0.44	0.44	0.44	0.48	0.44

For present day flows, both 99-99.9% of the time the EWR is not meet, however, this is not a serious concern since this situation will only happen during dry period.

Table 3-27: Percentiles for February per scenario at EWR site

Percentiles	Nat	Prs	Sc1	Sc2	Sc3	Sc4	EWR_C
0.1	90.04	87.05	87.40	83.34	81.24	87.02	22.62
1	87.68	82.94	85.08	81.16	78.02	83.71	22.62
5	73.78	73.13	71.12	67.19	59.24	59.25	22.62
10	61.28	58.34	58.40	53.95	48.71	50.55	22.58
15	51.64	51.31	48.88	44.00	38.56	43.83	21.01
20	44.23	44.02	41.35	35.07	24.94	35.66	19.14
30	41.44	37.54	37.04	27.23	18.58	25.97	17.06
40	33.89	34.04	30.84	21.39	16.25	22.82	14.53
50	28.79	28.21	25.81	16.12	11.86	20.07	10.91
60	19.83	20.13	16.84	10.76	9.47	16.11	9.47
70	14.62	15.33	11.56	7.41	7.41	13.28	7.43
80	10.24	10.48	7.17	5.14	5.14	10.62	5.15
85	8.71	9.69	5.59	3.99	3.99	6.70	4.10
90	7.64	9.06	4.57	3.18	3.18	4.53	3.18
95	6.40	6.48	3.16	2.81	2.81	3.17	2.71
99	4.59	4.14	2.21	2.21	2.21	2.50	2.26
99.9	2.45	1.69	1.20	1.20	1.20	1.26	2.22

The highlighted rows indicate the flows that do not meet the EWR from 70%tile i.e. mostly in scenario two (2) and three (3). Considering that for scenario 4 the EWR is not met only at 99%, and this is during dry period. This is not a major concern, therefore scenario 4 is recommended.

The Table 3-28 provides a description of the ecological consequences per component.

Table 3-28: Ecological consequences per scenario at the Tsitsa River EWR site

EC					Ecological Consequences	
Prs	**Sc1**	**Sc2**	**Sc3**	**Sc4**	**Dry season**	**Wet season**
GEOMORPHOLOGY						
B	B	B/C	C			
Morphological change EWR site is c.16 km downstream of the dam site, with no major tributary inputs. Reduction in magnitude of annual flood and sediment trapping would lead to bed armouring – loss of sand and fine gravels. Reduction in availability of coarser sediment likely to be insignificant, at least in the medium term as sediment will continue to be supplied from the channel bed upstream. Increased bedrock exposure – and possible channel widening. Bank erosion below dam could increase silt on bed in the short term, but once banks have stabilized the trend would be towards armouring. Increase in terrestrial vegetation on banks (see vegetation response) could increase bank stability if there was an increase in woody shrubs or long rooted trees. Increase in aliens such as *Acacia mearnsii* would lead to bank instability– more shrub species would stablise banks, but are unlikely to cause channel narrowing due to lack of available fine sediment to form lateral bars or islands. Strong bedrock influence decreases potential for change. *Impact of flow changes on available substrate (assuming no change from present)* On the cross-section, the bed is dominated by bedrock from 30 m to 50 m. Fines over bedrock occur from 30-35 m and coarse gravel from 35 to 44 m, but in the deepest part of the channel there is only bedrock. Up to 30 m there is a significant amount of coarse gravel and cobble overlying bedrock. This is the shallowest part of the channel, exposed at low flows. Reduced baseflows, especially in winter, will therefore severely reduce the amount of inundated coarse gravel and cobble habitat.						
RIPARIAN VEGETATION						
C/D	C/D	D	D	C/D	Reduced water depth has minimal impact on root wetting.	Reduction in flood magnitude and frequency may cause an increase in woody species (including alien species) in the marginal and lower zones. A corresponding decrease in basal cover of non-woody vegetation is anticipated.
Reduction in high flows and floods are likely to result in an increase in woody species (both indigenous and alien) in the marginal and non-marginal zones. This may result in a decrease in Ecological Category from a C/D to a D.						
FISH						
A/B	A/B	B	B/C		Fish spawning occurs in wet season so limited impact expected	Little change once the dam is overflowing. If there is a decrease in indigenous non-woody vegetation (sedges, etc.) in lower marginal zone, the loss of spawning habitat could reduce fish numbers.
Flow data show a loss in fast-deep habitat but this is not negative to the fish present at the river site. Oxygen, temperature, toxics and nutrients will also change slightly in negative direction. However this is not substantial and both fish species expected to be present are moderately tolerant of modified water quality, so does not impact on the outcome of the FRAI model. However, a reduction in invertebrate biomass could potentially lead to a secondary reduction in fish biomass. This predicted change is of low confidence and is thus not included in the FRAI model.						

MACROINVERTEBRATES						
B/C	B/C	C	B/C		Reduced flows in the dry season may result in an increase in sedimentation in the instream habitat. This could reduce habitat availability for species with a preference for stones and bedrock substrates.	Change in allocthonous organic inputs due to shift from grasslands to woody vegetation (including aliens) has negative implications for natural invert fauna.
Habitat integrity is the main driver affecting macroinvertebrate community condition in the system. Therefore, flow modification is unlikely to have a significant impact on the invertebrate community if sufficient fast flowing water is available within the reach throughout the year.						
ECOSTATUS						
B	B		C		This scenario results in a drop of one category in the EcoStatus mainly due to changes in the river structure, the riparian vegetation and the fish. Water quality changes would be slight.	

4. CONCLUSIONS AND RECOMMENDATIONS

4.1 Conclusions

4.1.1 General

The overall conclusion of this EWR report is that the state of the Mzimvubu EWR site is in a fairly modified condition. Drivers in the system were both at a catchment scale (e.g. overgrazing and concomitant erosion and sedimentation) and localised (e.g. alien invasive riparian vegetation and concomitant bank erosion and sedimentation).

4.1.2 Water Quantity

The hydrology of the Tsitsa River has been re-calibrated using the WRSM2000 model and the flows from gauging weir T3H006 at the N2 Road Bridge. The flows at the gauging weir also include the flow contribution of the Inxu River, a major tributary of the Tsitsa River. No gauging weirs are situated on the Inxu River to determine the contribution. Sedimentation is a major problem at T3H006 and this can influence the accuracy of the measured flows that were used for calibration. Thus, the confidence in the hydrology is low.

4.1.3 Water Quality

The catchment above the EWR site, and thus above the dam site is a predominantly rural landscape with few land uses which are likely to cause water quality problems. Water quality concerns that do exist in the catchment are dominated by suspended solids. Human accelerated erosion in the catchment is significant due to the erodible duplex soils present and the heavy utilisation of the grassland areas by livestock and subsistence agriculture. Some nutrient enrichment is likely given that there are two WWTWs discharging into the catchment.

With respect to the EWR site, the construction of a dam immediately upstream is likely to improve the situation with respect to sediment and nutrients as the dam is likely to trap a large proportion of these pollutants.

There are however other potential negative impacts of a dam on water quality, though these can be mitigated through the implementation of a release management plan that ensures environmental flows are released from close to the surface, above the thermocline and that water being released is well oxygenated. This can be achieved through the incorporation of a variable depth off-take facility in the design of the dam.

4.1.4 Fish

The current negative impacts on fish species at the EWR site are not flow related, but due to habitat modification and destruction associated with elevate sediment input due to catchment degradation and reduction in marginal vegetation. The limited changes in water quality due to the dam are expected to have little impact, as the fish species present are moderately tolerant of changes in water quality. These fish are also moderately tolerant of low or even no-flow conditions. High rivers flows in summer are required to provide *Barbus cf anoplus* with flooded marginal vegetation for spawning purposes. In general, the negative impact of the proposed dam on existing fish populations is thus not anticipated to be significant.

4.1.5 Macroinvertebrates

The macroinvertebrate community at the EWR site was impacted by changes in the instream habitat (i.e. sedimentation). Sedimentation was the result of catchment processes (e.g. overgrazing) and localised impacts (e.g. bank erosion). Therefore, these impacts were non-flow related. However, reduced volumes and velocities may result in increased sediment deposition at the site, thereby resulting in further deterioration in the instream habitat from a macroinvertebrate perspective.

4.1.6 *Geomorphology*

The fluvial geomorphological Present Ecological Stratus in the catchment is due to non-flow related impacts associated with the current and historical land use activities. Overgrazing, crop plantations within steep slopes and water abstraction are some of the landuse activities that have resulted in the reduction of sediment transport capacity and increased sediment input into the active channel. The sediment accumulation within the active channel has resulted in smothering of riffles and rapids which has increased embededness of the gravel, cobbles and boulders and therefore reducing the amount and quality of habitat available to in stream biota.

4.1.7 *Riparian Vegetation*

The riparian vegetation at the EWR site was impacted by alien vegetation. Infestation was not homogenous, with severe infestation present on the right-hand bank and near natural vegetation on the left-hand bank. Furthermore, bank erosion (as a result of low basal cover on the right-hand bank resulted in bank slip. Therefore, impacts were non-flow related. However, reduced flooding in the system may favour woody vegetation, and in particular alien invasive species, at the expense of the more natural grassland-sedge species.

4.2 Recommendations

4.2.1 *Water Quantity*

It is strongly recommended that EWR quantities, as specified in this report, be maintained. It is also recommended that a gauging weir be constructed below the proposed dam to monitor the EWR compliance and to provide accurate measured flows for future calibration of the Tsitsa River.

4.2.2 *Water Quality*

Water quality is currently not a major concern in this catchment; however recommendations can be made to ensure that issues do not arise subsequent to the construction of the dam:

i. It is vital that a variable depth off-take facility is incorporated into the design of the dam. This will enable the dam controller to release water to fulfil the environmental flows that is of optimal quality and will reduce the probability of negative impacts on the downstream environment.

ii. It is important to monitor downstream temperature, oxygen and toxicity impacts of the dam and apply an adaptive management strategy to the release process to minimise impacts on the downstream ecology.

4.2.3 *Fish*

The most important flow requirements for fish are the summer high flows that inundate marginal vegetation, providing a suitable substrate for *Barbus cf anoplus* to spawn successfully, as well as forming flooded backwaters for larval feeding. These freshets and floods will also facilitate fish (including eel) migration upstream over critical riffle areas and prevent habitat fragmentation. However, the flow requirement for the fish will easily be met if those flows recommended for the macroinvertebrates (and riparian vegetation) in this study are provided.

4.2.4 *Macroinvertebrates*

It is recommended that the system receive sufficient volumes of water to maintain key fast flowing habitats in the system. These habitat types are important for a number of sensitive and important macroinvertebrate (e.g. *Perlidae* and *Oligoneuridae*). Furthermore, the natural flooding regime should be emulated in order to flush out sediments that may accumulate in the low flow months and alter the instream habitat.

4.2.5 Geomorphology

It is recommended that landscape management strategy with emphasis on erosion control is developed and implemented. This landscape management strategy should concentrate on addressing upland erosion and sediment input into the active channel through a change in the mind-set of the local community and stabilising the existing erosion dongas.

The proposed dam should be managed such that the flow from the dam emulates the natural flooding regime (frequency and intensity of floods). The maintenance floods and elevated base flows during the dry season are very important in maintaining the capacity of the stream to transport sediment.

4.2.6 Riparian Vegetation

It is recommended that releases from the dam emulate the natural flooding regime (frequency and intensity of floods) per this report. Freshets and larger floods are important in maintaining a healthy riparian vegetation community by retarding ingress of woody vegetation and controlling recruitment and successional processes in the non-marginal zone.

4.3 Eco-specs and Monitoring requirements

4.3.1 Water Quantity

The hydrological Ecospecs are included in the water quantity aspects of the Ecological reserve as provided in Appendix G. These Ecospecs are in the format of a summary table with the requirements specified for the various flow components and an assurance table or EWR rule curve. The curves specify the frequency of occurrence relationships of the defined maintenance and drought flow requirements for each month of the year. The tables thus specify the % of time that defined flows should equal or exceed the flow regime required to satisfy the ecological reserve. The following descriptors of the hydrological characteristics should be used:

- Total Mean Annual Maintenance Low flow volume;
- Total Mean Annual Drought flow volume;
- Monthly mean Maintenance Low and Drought flows;
- Monthly exceedence curves for the low flows (excluding floods) and for the complete flow regime; and
- Duration, magnitude (in daily average peak), volume and timing of intra-annual floods (see Table 3-22).

4.3.2 Water Quality

Current DWS water quality monitoring sites are not able to isolate the catchment above the EWR site, as discharges from urban areas and other polluting activities outside of the catchment are carried by tributaries that reach the nearest monitoring point. For this reason monitoring for the EWR site should be introduced at the site itself, and not left to depend on the results of the NCMP at site T3H006. In addition, the range of determinants currently monitored by the NCMP is insufficient to assess the impact of the proposed dam adequately.

The impacts of dams on downstream water quality are well documented and vary considerably with the type of structure (the release mechanism in particular) and the management of releases. The most significant impacts of dams involve the release of water from deep beneath the surface, where cold, anoxic water is present. This results in downstream changes in temperature, oxygen levels and increases in concentrations of toxic substances such as ammonia and manganese. If however water is released from above the thermocline, impacts on downstream water quality can to a large degree be mitigated.

The water quality EcoSpecs are therefore developed based on the most likely threats to water quality in this catchment, and on the likely impacts of the dam.

a) Nutrients

The second current threat to water quality in the catchment is nutrients (particularly SRP). The waste water treatment facilities at Maclear and at Nessie Knight Hospital have the potential to elevate nutrient levels. Nutrients, like suspended solids, are likely to be trapped and sequestered in the dam. It is important however to monitor this determinant given the impact of other WWTWs downstream (see monitoring requirements within Table 4-1).

b) Physical variables

i. pH is important as it has a strong influence on the interactions of other constituents and high or low pH values can increase the toxicity of other constituents (particularly Ammonia). pH must thus be routinely monitored.
ii. Due to the acknowledged difficulty associated with determining aggregated inorganic salt concentrations, Electrical Conductivity (EC), which is easily measurable, has been included as a convenient substitute measure of inorganic salts in the EcoSpecs for this site.
iii. From a catchment perspective, the most significant threat to water quality is the potential for large quantities of sediment to be introduced into the river system due to significant erosion problems, and the large areas observed with poor vegetative cover known to exist in the catchment. Unfortunately turbidity has not been monitored by DWS in the past, and thus no records of past levels are available. Although it is likely that the construction of a dam will significantly reduce the turbidity levels encountered at the EWR site, monitoring of this determinant should be initiated. A recommended method is the use of a clarity tube, a cost effective and simple instrument which allows quick and repeatable measurements of water clarity. The EcoSpecs and TPC for this study have been determined in terms of this method.
iv. Dissolved Oxygen (DO) levels play a critical role within the aquatic ecosystem and can be significantly impacted by the release of dam water and by organic pollution from WWTWs. DO levels must thus be monitored routinely.
v. Temperature is an important constituent in that it can affect the toxicity of other constituents (such as Ammonia), and can also impact on biodiversity through the loss of temperature sensitive species. Temperature is also one of the most likely determinands to be impacted by the release of dam water. Unfortunately no water temperature monitoring is currently occurring near the site, meaning that there is no baseline data against which to compare monitoring going forward. Temperature must thus be monitored monthly in order to obtain a baseline data set from which to compare changes related to catchment activities. It is also important to monitor temperature at the time of sampling for ammonia as temperature plays an important role in determining the position of the equilibrium between NH_3 and NH_4 and thus the concentration of toxic ammonia present.

c) Biological response variables

Biotic response indicators have been included as per the requirement for the macro invertebrate EcoSpec.

i)

d) Toxics

It is known that the release of anoxic dam water increases the concentration of ammonia (NH3) downstream of the dam. Free ammonia is toxic to many forms of life in aquatic ecosystems and concentrations should be monitored monthly. Free ammonia can be estimated from Total Ammonia (N) based on the DWS water quality guidelines matrix using temperature and pH readings taken at the site and time of sampling.

Manganese is also toxic to certain forms of aquatic life and concentrations downstream of a dam can also be elevated by anoxic water releases. This should thus also be monitored monthly.

A bi-annual (two times per year) sample should be analysed for the full spectrum of toxics as listed in the DWS Water Quality guideline (DWAF 2008). Should individual toxics be noted as being of concern, monthly monitoring of these should be initiated.

e) EcoSpecs

In the case of several of the determinants listed below, no baseline data is available from which to gauge present state or the direction of trends. The most important recommendation to make is that baseline monitoring of these variables be initiated. Once sufficient baseline data have been collected, the EcoSpecs and TPCs should be re-evaluated.

Table 4-1 below sets out the water qualtity EcoSpecs for the EWR site as well as the recommended monitoring programme.

Table 4-1: Water Quality Ecospecs, TPCs and sampling frequency

Category	Parameter	EcoSpec	TPC	Monitoring/Frequency
Nutrients	SRP	0.015 mg/ℓ @ 50th percentile.	50th percentile value should not exceed 0.01 mg/ ℓ	Monthly
	TIN	0.25 mg/ℓ @ 50th percentile	50th percentile value should not exceed 0.2 mg/ ℓ.	Monthly
Inorganic Salts	EC	30 mS/m @ 95th percentile	95th percentile should not exceed 24 mS/m	Monthly
Physical Variables	pH	6.5 – 8.8 5th and 95th percentiles must not fall outside of this range.	5th percentile should not be less than 6.7 and the 95th percentile should not be greater than 8.6	Monthly
	Clarity	Clarity should not display more than a small negative change from baseline conditions. Recommended that clarity tube method be implemented	Initiate baseline monitoring of this parameter using a clarity tube to determine current / baseline clarity levels.	Monthly
	Temperature	Baseline daily and seasonal temperature fluctuations must be established for the EWR site. Temperature measurements should not fall more than 3^0C outside of baseline range for the season and time of day concerned.	Temperature measurements should not fall more than 1.5^0C outside of baseline range for the season and time of day concerned.	Initially continuous (hourly) monitoring is recommended using a temperature logger to establish daily and seasonal fluctuations. Thereafter monthly monitoring
Toxins	Ammonia (NH3)	The 95th percentile should not exceed 43.75µg/l	The 95th percentile should not exceed 39.4µg/l	Monthly
	Manganese	The 95th percentile should not exceed 180µg/l	The 95th percentile should not exceed 160µg/l	Monthly
	Full spectrum of toxins listed in the DWS WQ reserve determination guideline (2008)	Values should not exceed the B [1] category boundary value	Values should not approach within 10% 0f the B [1] category boundary value.	Bi-annually. If TPC is approached for any of the determinands, monthly monitoring should be initiated for that determinand.
Response indicators	SASS (ASPT score)	As per Invert Ecospecs	As per Invert Ecospecs	As per Invert Ecospecs

4.3.3 Fish

Fish surveys should be undertaken at least once annually during low flow conditions, preferably at the beginning of summer, when water temperatures are rising but water turbidity is relatively low.

4.3.4 Macroinvertebrates

Macroinvertebrates community health must be monitored at a quarterly basis using the SASS5 protocol (Dickens and Graham, 2002). Sampling must be done by an accredited SASS5 practitioner to ensure that results are reliable, defensible and comparable. Furthermore, it is recommended that benthic diatoms be sampled quarterly to provide ancillary information on water quality in the river.

4.3.5 Geomorphology

Suitable monitoring sites that are representative of the river reach as well as the landuse impacts on the channel should be identified and monitored through fixed point photography and habitat monitoring.

The bed load material should be surveyed every 5 years post implementation of the proposed dam to ensure that the active channel flow pattern does not change completely as these changes will have a detrimental impacts on the in stream biota.

4.3.6 Riparian Vegetation

Riparian vegetation should be monitored on an annual basis to determine the impacts of the dam on the downstream vegetation.

All alien CARA 1 vegetation must be removed from the dam property.

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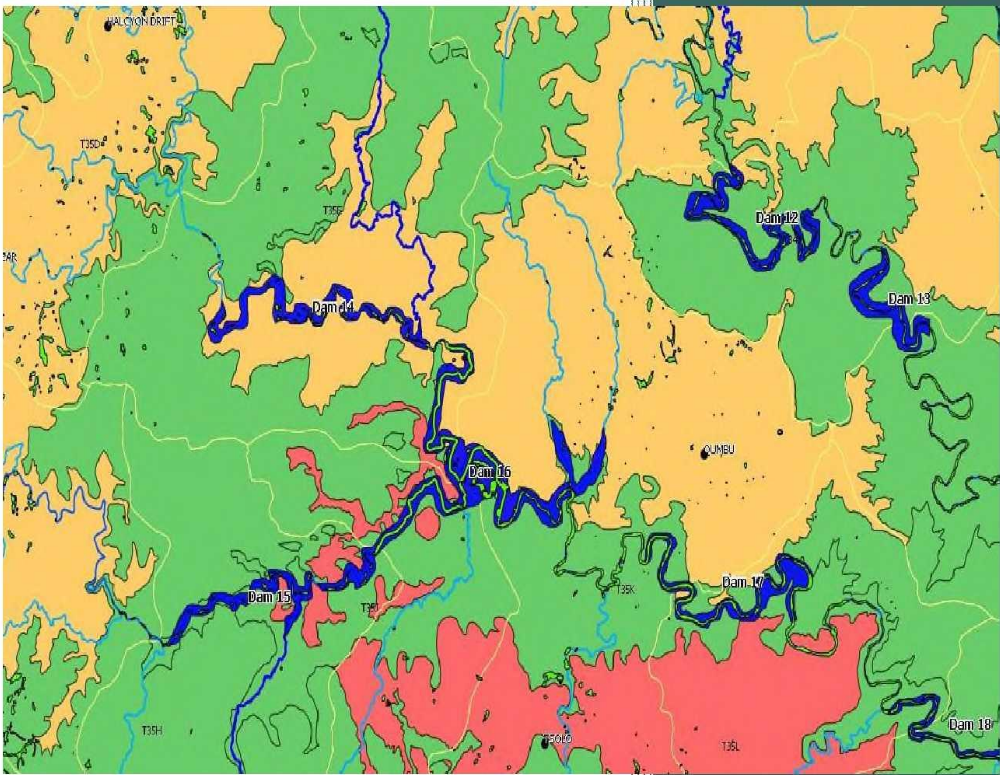
APPENDIX A

MZIMVUBU EWR
DRAFT PHASE 1 REPORT

Draft Phase 1 Report

Mzimvubu Water Resources Development Project:

Ecological Water Requirements – Phase 1



Reference: GT0354-5062012-01

Date: March 2013

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1. Introduction

1.1 Background

The construction of a dam on the Mzimvubu system (situated in secondary catchment T3) has been initiated by the Department of Water Affairs (DWA). Nineteen potential dam sites (**Error! Reference source not found.**) have initially been identified within the system during the Water Resource study in Support of the ASGISA-EC Mzimvubu Development Project finalised in 2010 by BKS for DWA.

The purpose of the current study (Water Resources Development Project) undertaken by Jeffares and Green is to eliminate those dams that are not economically viable, won't provide adequate yield for developments, e.g. irrigation or that are situated in ecologically sensitive or important areas. A preliminary desktop based assessment was undertaken to reduce the number of the 19 potential dam sites to a more manageable number which can go forward into further feasibility stages of dam site selection and Reserve determination studies. The main criteria used during the initial elimination were:

- Potential yield from the dam
- Economics (URV, capital cost)
- Accessibility to the proposed dam
- Hydropower potential
- Job creation
- Ecological considerations (importance, sensitivity, present state, sedimentation)

The above elimination process resulted in five potential dam sites that would be investigated in more detail during phase 1 of the project to identify the final dam site to undertake the detail studies. The identified dams were:

i. Somabadi Dam in T33E on the Kinira River (Dam 7)
ii. Thabeng Dam in T33D on the Kinira River (Dam 6)
iii. Mpindweni Dam in T34G/T34H on the Tina River (Dam 11)
iv. Ntabelange Dam in T35E on the Tsitsa River (Dam 14)
v. Laleni Dam in T35L on the Tsitsa River (Dam 17)

Rapid level III Reserve determinations studies were undertaken during phase 1 to provide the necessary ecological information to be used during the selection of the final dam site. This report summarises the tasks undertaken during the rapid studies and the results from these studies as well as a recommendation as to the prefeerd dam from an ecological perspective.

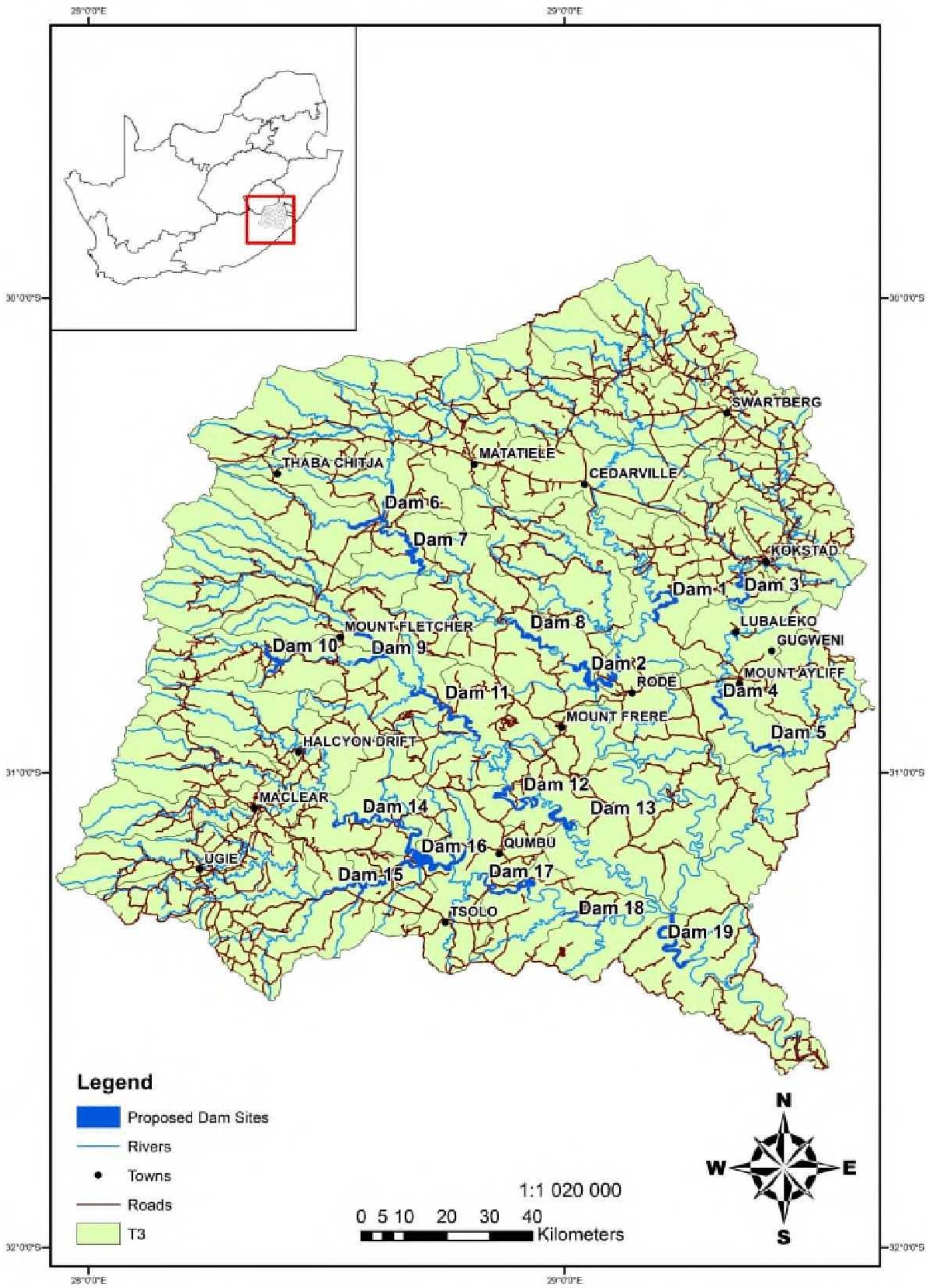

Figure 1: Map of the study area indicating the locations of the 19 proposed dams within the Mzimvubu system.

2. *Methodology*

2.1 Study approach

The following main activities undertaken to meet the objectives of phase 1 of the study were:

- A field visit was undertaken from 16 to 19 July 2012 (moderate flows) to select Ecological Water Requirement (EWR) sites and to collect data on fish, macroinvertebrates, *in situ* water quality, geomorphology and hydraulics (cross-section and discharge).
- The integration of the results from the field surveys, to determine the ecostatus and ecological water requirements of the rivers at the EWR sites were done during a specialist workshop on 28 and 29 August 2012.
- Provide recommendations as to the preferred dam option with the least ecological consequences as determined during the rapid assessments.

2.2 Process for Reserve determination

The activities and tasks for these ecological assessments were undertaken in accordance with the appropriate approaches and methodologies for rivers as prescribed by the CD: RDM of DWA, namely:

- *The methodology as set out in DWAF (1999): Resource Directed Measures for Protection of Water Resources; Volume 3: River Ecosystems Version 1.0 (Revised water quality methodology, 2002).*
- *The revised methods as outlined in Louw and Hughes (2002) for the 8 step process, the Habitat Flow Stressor Response (HFSR) manual of 2005 and 2008 and the*
- *Detailed ecoclassification manuals for fish, macroinvertebrates and habitat integrity (2007, 2009).*
- *The ecological water requirements for the rapid EWR sites were estimated using the Hughes Desktop Reserve Model (DRM) (DWAF, 1999) for the Recommended Ecological Category (REC).*
- *SPATSIM (Spatial and Time Series Information Modelling) (Hughes and Forsythe, 2006) was used as a framework to determine the EWR results.*

3. Study protocol

This section of the report provides the protocol followed for the rapid assessments that were undertaken for the proposed dams on the Tsitsa, Tina and Kinira Rivers.

3.1 Study team

The specialists involved in the rapid assessment during the field visit and the specialist workshop are listed in Table 1.

Table 1: Study team for the rapid assessments in the Mzimvubu catchment

Team Member	Affiliation	Specialization/Task
Stassen, R	JMM Stassen	SPATSIM, integration
Graham, M	GroundTruth cc	Macroinvertebrates, habitat integrity
Kleynhans, M	Aurecon	Hydraulics
Gray, R	Jeffares & Green	Hydraulics
Bok, A	Bok & Associates	Fish, habitat integrity
Hlongwane, L	Digby Wells	Geomorphology

3.2 Study area and site visit

The study area for the rapid assessments was the main stem Tsitsa, Tina and Kinira Rivers below the proposed dams. It was anticipated that one EWR site would be selected on the rivers below the proposed dams. The following were decided regarding the site selection and surveys due to limited available budget:

i. Kinira River (Dam 6 and Dam 7) – one EWR site to be selected below the 2 dams in T33F or T33G as both the dams are situated in the same ecoregion

ii. Tina River (Dam 11) – one EWR site to be selected below the dam in T34H or T34J

iii. Upper Tsitsa River (Dam 14) – one EWR site to be selected on the short river reach before the confluence with the Inxu River

iv. Lower Tsitsa River (Dam 17) – The Tsitsa Falls are situated almost immediately downstream of this dam in T35L and the impact of the dam will be below the falls. One EWR site to be selected on the Tsitsa River in T35M

Three EWR sites were selected, one each in the Kinira, Tina and upper Tsitsa Rivers. Due to the inaccessibility of the Tsitsa River below the falls, no EWR site could be selected. The details of the sites selected are provided in Table 2.

Table 2: EWR site information

EWR site	River	Date	Latitude	Longitude	Quaternary catchment	MAR* ($10^6 m^3$)	Discharge (m^3/s)
MzimEWR1	Tsitsa	17/7/2012	S 31.148°	E 28.674°	T35E	406.76	7.106
MzimEWR2	Tina	18/7/2012	S 31.072°	E 28.913°	T34J	404.43	4.876
MzimEWR3	Kinira	19/7/2012	S 30.758°	E 28.994°	T33G	407.08	3.009

* WR2005 hydrology (1920-2004)

The following tasks were undertaken during the site visit:

- A visual "survey" of the river reaches directly upstream and downstream of the proposed dams to select an EWR site per river reach. This was governed by the suitability of the river channel for accurate hydraulic modelling and flow measurement, as well as the presence of habitats critical for ecosystem functioning, such as riffles;
- The specialists assessed the present condition of their study component in relation to the considered reference condition, which allowed the allocation of the PES for the specific component;
- A cross-sectional profile of the river channel was surveyed by the hydraulic specialist, hydraulic data for calibration purposes was collected and the river flow was determined with the aid of a flow meter;
- The fish specialist sampled fish in all suitable aquatic habitats in the vicinity of the EWR site using an electro-fish shocker and nets, and noted any man-induced habitat modifications impacting on fish fauna;
- The macroinvertebrate specialist surveyed the aquatic macroinvertebrates occurring within the range of instream habitats at the locality using the SASS5 methodology. A habitat assessment of the site pertaining to SASS was also conducted;
- The geomorphologist collected information on the sediment in the system for further analysis; and
- In situ water chemistry data was collected namely temperature, electrical conductivity, dissolved oxygen, pH and clarity. Diatom samples were taken for further analysis.

The flows in the rivers were much higher than expected for this period of the year (winter), especially in the Tsitsa and Tina Rivers. This was due to a cold front with rain and snow that has moved through the catchment the week prior to the field surveys. These higher flows might have impacted on the fish and macroinvertebrates sampling results.

3.3 Specialist workshop

The hydraulics, fish, macroinvertebrate and geomorphology data collected during the site visit was interpreted with the various models in preparation of the specialist workshop. The results of the field assessments of the various habitat and biotic components are used during the workshop to obtain the Ecostatus/Present Ecological Status (PES) and the recommended ecological category (REC). This assessment took place during the ecoclassification workshop on 28 and 29 August 2012. The process included the determination of the following:

Reference conditions:- i.e. those conditions that occur under natural conditions before anthropogenic impacts.

Present ecological state (PES) or ecostatus:- the determination of the current state of the resource through rule-based models for the driver components (geomorphology – GAI, hydrology – HAI and water quality – PAI) and for the biological response components (fish – FRAI, macro-invertebrates – MIRAI and vegetation – VEGRAI). A rule-based model is then used to derive the ecostatus or overall/integrated condition/health of the resource by integrating the driver and response status. Only the FRAI and MIRAI models are used during a rapid ecological assessment.

Ecological Importance and Sensitivity (EIS):- the ecological importance is defined by Kleynhans (1999), and is regarded as an expression of the water resource's ability to maintain the ecological diversity and functioning on local and wider scales. The ecological sensitivity refers to the river's ability to recover from disturbance. The EIS model (Kleynhans 1999, updated 2002) was used to determine the EIS.

Habitat Integrity (HI):- the Habitat Integrity model (Kleynhans, 1996) was used to evaluate the habitat integrity of both the instream and riparian components in the vicinity of the EWR sites. This assessment model is based on the qualitative assessment (allocation of scores) for various impact criteria on both the instream and riparian zones.

Recommended Ecological Category (REC):- the PES and EIS is used in the decision on the REC as well as the feasibility to realistically be able to maintain or improve the current condition of the water resource.

Ecological Water Requirements: -The Desktop Reserve Model (DRM) (SPATSIM, version 2.12) was used to calculate the Ecological Water Requirements (quantity) for the recommended ecological category at the rapid III EWR site. These EWR flow data were converted to hydraulic conditions at the EWR site (i.e. depths and flow velocities at discharges measured in m^3/s) using a hydraulic model to be evaluated by the ecologists. Where the modelled requirements were not adequate to provide the envisaged protection, the DRM was adjusted accordingly.

An additional tasks that were undertaken during the workshop was to provide information and recommendations for the selection of the final dam site.

4. Results

4.1 Specialist workshop

All current and historical information on fish, macroinvertebrates, etc was used to prepare for the specialist workshop. This information was used to populate the various models (FRAI – fish, MIRAI – macroinvertebrates, EIS – ecological importance and sensitivity, Ecostatus – determination of the present state, HABFLOW – hydraulics and the DRM – determination of the EWRs.

A summary of the results per EWR site are provided in Table 3. The detail results, motivations and rationale per EWR site will be provided in the integrated EWR report after the intermediate Reserve has been determined on the selected river.

Table 3: Summary of specialist workshop results

EWR site	River	Quarter-nary	PES	EIS	REC	%EWR	MAR* (10^6m^3)
MzimEWR1	Tsitsa River	T35E	D	Low	D	16.0	406.76
MzimEWR2	Tina River	T34J	B/C	Moderate	B/C	29.6	404.43
MzimEWR3	Kinira River	T33G	C	Moderate	C	25.6	407.08

4.2 Dam elimination process

The following criteria were used to provide information for the final dam selection:

- Present Ecological State (PES)
- Ecological Importance and Sensitivity (EIS)
- Fish migration
- Potential for ecological improvement due to sediment reduction
- Potential for negative ecological impacts downstream (hydropower, irrigation)

The ecological ratings that were used are 1 – unsuitable for a dam, 2 – moderately suitable for a dam and 3 – suitable for a dam. It was further assumed that the dams will be operated for optimum downstream ecological improvement. The higher the score the more suitable the river for the construction of a dam. The scores for the three rivers using the above criteria is presented in Table 4.

Table 4: Suitability scores per river

Criteria	Tsitsa	Tina	Kinira
PES	3	2	2
EIS	3	2	2
Fish migration	3	1	1
Potential for improvement	2	2	3
Potential for improvement through catchment management	3	1	2
Potential for downstream impact – hydropower	2	1	1
Potential for downstream impact – irrigation	2	3	3
Sum	***18***	***12***	***14***
Median	***3***	***2***	***2***
Average	***2.6***	***1.7***	***2.0***

The assessment shows that a dam on the Tsitsa River (T35E) will be the most suitable.

5. Conclusions and recommendations

Rapid assessments were undertaken on the Tsitsa, Tina and Kinira Rivers downstream of the proposed dams to provide information for the selection of the final dam site.

Field surveys were undertaken in July 2012 and the specialist workshop to determine the PES, EIS, REC and ecological water requirements was held in August 2012. An additional component of this workshop was to provide ecological considerations for the final dam selection process.

The three rivers assessed are currently moderately to largely modified with the Tsitsa River in a D category, the Tina River in a B/C category and the Kinira River in a C category.

The results of the final assessment to identify the dam with the least ecological impacts showed that a dam on the upper Tsitsa River (Dam 14, Ntabelange Dam) will be most suitable.

APPENDIX B

HYDRAULICS RESULTS

Perim	AvVel	Vel98%	Dist_FishHT's(%)							Dist_InvertHT's(%)									#Int	Vveg	Vint
(m)	(m/s)	(m/s)	SVS	SS	SD	FVS	FS	FI	FD	VSFS	SFS	FFS	VFFS	VSCS	SCS	FCS	VFCS	VEG			
0.2	0.01	0.05	100	0	0	0	0	0	0	38	0	0	0	62	0	0	0	0	0	0	0
0.6	0.02	0.07	100	0	0	0	0	0	0	38	0	0	0	62	0	0	0	0	0	0	0
0.9	0.03	0.10	100	0	0	0	0	0	0	37	1	0	0	61	1	0	0	0	0	0	0
1.3	0.03	0.12	100	0	0	0	0	0	0	36	2	0	0	58	4	0	0	0	0	0	0
1.6	0.04	0.14	100	0	0	0	0	0	0	35	3	0	0	56	6	0	0	0	0	0	0
2.0	0.05	0.16	100	0	0	0	0	0	0	33	5	0	0	55	7	0	0	0	0	0	0
2.4	0.05	0.18	100	0	0	0	0	0	0	32	6	0	0	53	9	0	0	0	0	0	0
2.7	0.06	0.20	100	0	0	0	0	0	0	31	7	0	0	51	11	0	0	0	0	0	0
4.1	0.05	0.18	100	0	0	0	0	0	0	32	6	0	0	53	9	0	0	0	0	0	0
5.5	0.05	0.19	100	0	0	0	0	0	0	32	6	0	0	52	10	0	0	0	0	0	0
6.8	0.06	0.19	96	4	0	0	0	0	0	32	6	0	0	52	10	0	0	0	0	0	0
8.4	0.06	0.20	93	6	0	0	0	0	0	31	7	0	0	50	12	0	0	0	0	0	0
9.9	0.06	0.22	91	9	0	0	0	0	0	30	8	0	0	49	13	0	0	0	0	0	0
11.7	0.07	0.22	89	11	0	0	0	0	0	30	8	0	0	48	14	0	0	0	0	0	0
12.0	0.07	0.26	85	14	0	1	0	0	0	28	10	0	0	45	16	1	0	0	0	0	0
12.4	0.08	0.28	82	16	0	2	0	0	0	26	11	1	0	42	19	1	0	0	0	0	0
12.7	0.09	0.31	79	18	0	3	1	0	0	24	13	1	0	40	20	2	0	0	0	0	0
13.0	0.10	0.33	74	22	0	3	1	0	0	23	13	2	0	38	22	3	0	0	0	0	0
13.3	0.10	0.36	65	29	0	4	2	0	0	22	14	2	0	36	23	3	0	0	0	0	0
13.6	0.11	0.38	56	37	0	4	3	0	0	21	15	3	0	34	24	4	0	0	0	0	0
13.9	0.12	0.40	47	45	0	4	4	0	0	20	15	3	0	33	25	5	0	0	0	0	0
14.2	0.12	0.43	37	54	0	3	5	0	0	19	15	3	0	32	25	5	0	0	0	0	0
14.5	0.13	0.45	27	63	0	3	6	1	0	19	16	4	0	30	26	6	0	0	0	0	0
14.8	0.14	0.47	20	70	0	2	7	1	0	18	16	4	0	29	26	6	0	0	0	0	0
15.1	0.14	0.49	18	71	0	2	8	1	0	18	16	4	0	29	26	7	0	0	0	0	0
15.5	0.15	0.51	17	70	0	2	8	2	0	17	16	4	0	28	27	7	1	0	0	0	0
15.8	0.15	0.53	17	70	0	3	9	2	0	16	16	5	0	27	27	8	1	0	0	0	0
16.8	0.15	0.53	19	67	0	3	8	2	0	16	17	5	0	27	27	8	1	0	0	0	0
17.8	0.16	0.54	22	64	0	4	7	3	0	16	17	5	1	26	27	8	1	0	0	0	0
18.8	0.16	0.55	24	62	0	4	6	4	0	16	17	5	1	26	27	8	1	0	0	0	0
19.1	0.16	0.56	22	63	0	4	6	5	0	16	17	5	1	26	27	8	1	0	0	0	0
19.2	0.17	0.59	21	63	0	4	5	7	1	15	17	5	1	25	27	9	1	0	0	0	0

Perim	AvVel	Vel98%	Dist_FishHT's(%)							Dist_InvertHT's(%)									#Int	Vveg	Vint
(m)	(m/s)	(m/s)	SVS	SS	SD	FVS	FS	FI	FD	VSFS	SFS	FFS	VFFS	VSCS	SCS	FCS	VFCS	VEG			
19.3	0.18	0.61	20	62	0	4	4	9	1	15	16	6	1	24	27	9	2	0	0	0	0
19.4	0.19	0.63	18	62	0	4	4	10	1	14	16	6	1	23	26	10	2	0	0	0	0
19.6	0.19	0.65	17	62	0	4	4	11	2	14	16	6	1	23	26	11	2	0	0	0	0
19.7	0.20	0.68	17	61	0	5	3	12	2	14	16	7	2	22	26	11	3	0	0	0	0
20.2	0.20	0.68	16	61	0	5	3	12	3	14	16	7	2	22	26	11	3	0	0	0	0
20.7	0.21	0.70	15	62	0	5	4	11	4	13	16	7	2	22	25	12	3	0	0	0	0
22.4	0.20	0.70	16	61	0	5	4	10	4	13	16	7	2	22	26	12	3	0	0	0	0
24.1	0.20	0.68	18	60	0	5	5	8	5	14	16	7	2	22	26	11	3	0	0	0	0
25.4	0.20	0.69	19	58	0	6	5	7	6	13	16	7	2	22	26	11	3	0	0	0	0
26.7	0.20	0.70	22	55	0	7	4	5	7	13	16	7	2	22	26	12	3	0	0	0	0
28.0	0.21	0.70	24	52	0	7	4	4	8	13	16	7	2	22	26	12	3	0	0	0	0
29.3	0.21	0.70	25	52	0	8	4	3	9	13	16	7	2	22	26	12	3	0	0	0	0
30.3	0.21	0.71	26	49	0	8	4	2	10	13	16	7	2	21	25	12	3	0	0	0	0
31.2	0.21	0.72	27	48	0	9	3	3	10	13	16	8	2	21	25	12	3	0	0	0	0
32.2	0.22	0.74	28	46	0	10	3	3	11	13	15	8	2	21	25	13	3	0	0	0	0
33.2	0.22	0.74	27	46	0	10	3	3	11	13	15	8	2	21	25	13	4	0	0	0	0
34.2	0.23	0.76	25	47	0	10	4	4	11	12	15	8	2	20	24	14	4	0	0	0	0
34.8	0.23	0.78	22	49	0	9	5	4	12	12	15	9	2	20	24	14	4	0	0	0	0
35.5	0.24	0.79	20	49	1	8	5	4	12	12	15	9	3	20	24	14	4	0	0	0	0
36.1	0.24	0.82	18	49	1	8	6	4	13	12	14	9	3	19	23	15	4	0	0	0	0
36.3	0.25	0.83	15	50	2	7	8	5	13	12	14	10	3	19	23	16	5	0	0	0	0
36.5	0.26	0.87	14	49	2	7	9	5	14	11	13	10	3	18	22	16	5	0	0	0	0
36.7	0.26	0.87	11	50	3	6	10	4	15	11	13	10	3	18	22	17	5	0	0	0	0
37.0	0.27	0.91	10	50	3	6	11	4	16	11	13	11	3	18	21	18	6	0	0	0	0
37.2	0.28	0.93	8	50	4	5	12	4	17	11	13	11	4	17	21	18	6	0	0	0	0
37.4	0.28	0.95	6	48	6	4	12	5	18	10	13	11	4	17	21	18	6	0	0	0	0
37.6	0.29	0.98	6	46	7	4	12	5	19	10	12	12	4	17	20	19	7	0	0	0	0
37.9	0.30	0.99	5	45	9	3	12	6	21	10	12	12	4	16	20	19	7	0	0	0	0
38.6	0.30	1.00	5	42	10	3	11	8	21	10	12	12	4	16	20	20	7	0	0	0	0
39.3	0.31	1.02	5	39	12	4	10	9	21	9	12	12	4	15	20	20	7	0	0	0	0
40.0	0.31	1.05	6	37	13	5	9	10	21	9	12	12	5	15	19	20	8	0	0	0	0
40.1	0.32	1.05	4	36	14	4	9	11	23	9	12	13	5	14	19	21	8	0	0	0	0

Perim	AvVel	Vel98%	Dist_FishHT's(%)							Dist_InvertHT's(%)									#Int	Vveg	Vint
(m)	(m/s)	(m/s)	SVS	SS	SD	FVS	FS	FI	FD	VSFS	SFS	FFS	VFFS	VSCS	SCS	FCS	VFCS	VEG			
40.3	0.33	1.07	4	34	14	4	8	12	24	8	12	13	5	14	19	21	8	0	0	0	0
40.4	0.34	1.10	4	32	15	4	7	13	25	8	11	13	5	13	19	22	8	0	1	0.05	0.13
40.5	0.34	1.10	4	31	16	4	6	13	26	8	11	13	5	13	19	22	9	0	1	0.05	0.13
40.6	0.35	1.12	4	30	16	4	5	14	28	8	11	14	5	12	18	22	9	0	1	0.05	0.13
40.7	0.35	1.13	3	30	16	3	5	14	29	8	11	14	6	12	18	22	9	1	1	0.05	0.14
40.8	0.36	1.15	3	29	16	3	5	13	31	7	11	14	6	12	18	22	10	1	1	0.05	0.14
40.9	0.36	1.16	3	29	16	3	4	12	33	7	11	14	6	12	17	22	10	1	1	0.05	0.14
41.1	0.36	1.16	2	29	16	2	5	12	35	7	11	14	6	11	18	22	10	1	1	0.05	0.14
41.2	0.37	1.16	1	29	17	1	5	10	37	7	11	14	6	11	17	22	10	1	1	0.06	0.14
41.3	0.37	1.17	1	28	17	1	4	9	39	7	11	14	6	11	17	22	11	1	1	0.06	0.14
41.4	0.38	1.19	1	26	16	1	5	9	43	6	10	13	8	10	16	22	13	2	1	0.06	0.15
41.6	0.38	1.20	1	27	17	1	4	8	42	6	10	14	7	11	17	22	11	2	1	0.06	0.15
41.7	0.39	1.21	1	26	17	1	4	7	44	6	10	14	7	10	16	22	12	2	1	0.06	0.15
41.8	0.39	1.24	1	25	17	2	4	7	45	6	10	14	8	10	16	22	12	2	1	0.06	0.15
41.8	0.40	1.25	1	23	18	2	3	7	46	6	10	14	8	10	16	22	13	2	1	0.06	0.15
41.9	0.40	1.25	1	23	18	2	3	6	48	6	10	14	8	10	16	22	13	2	1	0.06	0.15
42.0	0.41	1.25	0	22	19	0	4	5	49	6	10	14	8	9	16	22	13	3	1	0.06	0.15
42.0	0.41	1.27	0	22	19	0	3	5	50	6	9	14	8	9	15	22	13	3	1	0.06	0.16
42.1	0.42	1.28	0	21	19	0	3	5	51	6	9	14	8	9	15	22	14	3	1	0.06	0.16
42.1	0.42	1.31	1	20	18	1	2	5	52	5	9	14	9	9	15	22	14	3	1	0.06	0.16
42.2	0.43	1.31	1	19	19	1	2	5	53	5	9	14	9	9	15	22	14	3	1	0.06	0.16
42.3	0.43	1.33	1	18	19	1	2	5	54	5	9	14	9	8	14	22	15	3	1	0.06	0.16
42.3	0.44	1.33	0	18	20	0	2	5	55	5	9	14	9	8	14	22	15	4	1	0.06	0.16
42.4	0.44	1.34	0	17	20	0	2	4	56	5	9	13	9	8	14	22	15	4	1	0.06	0.16
42.5	0.45	1.35	0	16	20	0	2	4	57	5	8	13	10	8	14	22	16	4	1	0.06	0.16
42.5	0.45	1.38	0	15	21	1	2	4	57	5	8	13	10	8	14	21	17	4	1	0.06	0.16
42.6	0.46	1.39	0	14	21	1	2	3	58	5	8	13	10	8	13	21	17	4	1	0.06	0.17
42.6	0.47	1.40	0	13	22	1	2	3	59	5	8	13	11	8	13	21	17	4	1	0.06	0.17
42.7	0.47	1.40	0	12	23	0	2	3	61	5	8	13	11	7	13	21	17	4	1	0.06	0.17
42.8	0.48	1.42	0	11	23	0	2	2	62	4	8	13	11	7	13	21	18	5	1	0.06	0.17
42.8	0.48	1.42	0	10	24	0	2	2	63	4	8	13	11	7	13	21	18	5	1	0.06	0.17
42.9	0.49	1.45	0	9	24	1	1	1	63	4	8	12	12	7	13	20	19	5	2	0.06	0.17

Perim	AvVel	Vel98%	Dist_FishHT's(%)							Dist_InvertHT's(%)											
(m)	(m/s)	(m/s)	SVS	SS	SD	FVS	FS	FI	FD	VSFS	SFS	FFS	VFFS	VSCS	SCS	FCS	VFCS	VEG	#Int	Vveg	Vint
43.0	0.49	1.46	0	8	24	1	1	1	64	4	8	12	12	7	12	20	20	5	2	0.06	0.17
43.0	0.50	1.47	0	7	25	1	1	1	64	4	8	12	12	7	12	20	20	5	2	0.06	0.17
43.1	0.51	1.47	0	7	25	0	1	1	65	4	7	12	12	7	12	20	20	5	2	0.06	0.17
43.1	0.51	1.49	0	6	25	0	1	2	65	4	7	12	13	7	12	20	21	5	2	0.06	0.18
43.2	0.52	1.49	0	6	25	0	1	2	66	4	7	12	13	6	12	19	21	5	2	0.06	0.18
43.3	0.52	1.52	0	5	25	1	1	1	66	4	7	12	13	6	12	19	22	5	2	0.06	0.18
43.3	0.53	1.53	0	5	25	1	1	1	67	4	7	12	14	6	12	19	22	5	2	0.06	0.18
43.4	0.54	1.53	0	5	25	0	1	1	68	4	7	12	14	6	12	19	23	5	2	0.06	0.18
43.5	0.54	1.54	0	4	25	0	1	1	68	4	7	11	14	6	11	19	23	5	2	0.06	0.18
43.5	0.55	1.56	0	4	25	0	1	1	69	4	7	11	14	6	11	19	23	5	2	0.06	0.18
43.6	0.55	1.58	0	3	25	1	1	1	68	4	7	11	15	6	11	18	24	5	2	0.06	0.18
43.7	0.56	1.59	0	3	24	1	1	1	69	3	7	11	15	6	11	18	24	5	2	0.06	0.18
43.7	0.57	1.60	0	3	24	1	1	1	69	3	7	11	15	6	11	18	25	5	2	0.06	0.19
43.8	0.57	1.60	0	3	24	0	1	1	70	3	7	11	15	6	11	18	25	5	2	0.06	0.19
43.8	0.58	1.61	0	3	24	0	1	1	71	3	6	11	16	5	11	18	26	5	2	0.06	0.19
43.9	0.59	1.62	0	2	24	0	1	1	70	3	6	11	16	5	10	17	26	5	2	0.06	0.19
44.0	0.59	1.65	0	2	23	1	1	1	70	3	6	10	16	5	10	17	27	5	2	0.06	0.19
44.0	0.60	1.67	0	2	23	1	1	1	71	3	6	10	17	5	10	17	27	5	2	0.06	0.19
44.1	0.61	1.68	0	2	23	1	1	1	71	3	6	10	17	5	10	17	27	5	2	0.06	0.19
44.2	0.61	1.68	0	2	23	0	1	1	72	3	6	10	17	5	10	17	28	5	2	0.06	0.19
44.2	0.62	1.69	0	2	23	0	1	1	72	3	6	10	17	5	10	16	28	5	2	0.06	0.19
44.3	0.63	1.70	0	2	23	0	1	1	73	3	6	10	17	5	10	16	28	5	2	0.06	0.19
44.3	0.63	1.70	0	2	22	0	1	1	73	3	6	10	18	5	9	16	29	5	2	0.06	0.2
44.4	0.64	1.71	0	2	22	0	1	1	74	3	6	10	18	5	9	16	29	5	2	0.06	0.2
44.4	0.65	1.73	0	2	22	0	1	1	74	3	6	10	18	5	9	16	30	5	2	0.06	0.2
44.5	0.65	1.74	0	1	22	0	1	1	74	3	6	10	18	5	9	16	30	5	2	0.06	0.2
44.5	0.66	1.75	0	1	21	0	1	1	75	3	6	9	19	4	9	15	30	5	2	0.06	0.2
44.6	0.67	1.76	0	1	21	0	1	1	75	3	5	9	19	4	9	15	31	5	2	0.06	0.2
44.6	0.67	1.77	0	1	21	0	1	1	75	3	5	9	19	4	9	15	31	5	2	0.06	0.2
44.7	0.68	1.78	0	1	21	0	1	1	76	3	5	9	19	4	9	15	31	5	2	0.06	0.2
44.7	0.69	1.79	0	1	20	0	1	1	76	3	5	9	19	4	9	15	32	5	2	0.06	0.2
44.8	0.69	1.81	0	1	20	0	1	1	76	3	5	9	20	4	8	15	32	5	2	0.06	0.2

Perim	AvVel	Vel98%	Dist_FishHT's(%)							Dist_InvertHT's(%)											
(m)	(m/s)	(m/s)	SVS	SS	SD	FVS	FS	FI	FD	VSFS	SFS	FFS	VFFS	VSCS	SCS	FCS	VFCS	VEG	#Int	Vveg	Vint
44.8	0.70	1.84	0	1	19	1	1	1	76	2	5	9	20	4	8	14	33	5	2	0.06	0.2
44.9	0.71	1.85	0	1	19	1	1	1	76	2	5	9	20	4	8	14	33	5	2	0.06	0.21
44.9	0.71	1.86	0	1	19	1	1	1	77	2	5	8	20	4	8	14	33	5	2	0.06	0.21
45.0	0.72	1.87	0	1	19	1	1	1	77	2	5	8	21	4	8	14	34	5	2	0.06	0.21
45.1	0.73	1.88	0	1	18	1	1	1	77	2	5	8	21	4	8	13	34	4	2	0.06	0.21
45.1	0.74	1.89	0	1	18	1	1	1	78	2	5	8	21	4	8	13	34	4	2	0.06	0.21
45.2	0.74	1.90	0	1	18	1	1	1	78	2	5	8	21	4	8	13	35	4	2	0.06	0.21
45.2	0.75	1.91	0	1	18	1	1	1	78	2	5	8	22	4	7	13	35	4	2	0.06	0.21
45.3	0.76	1.92	0	1	17	1	1	1	79	2	5	8	22	4	7	13	35	4	2	0.06	0.21
45.3	0.76	1.94	0	1	17	1	1	1	79	2	4	8	22	4	7	13	36	4	2	0.06	0.21
45.4	0.77	1.95	0	1	17	1	1	1	79	2	4	8	22	3	7	12	36	4	2	0.06	0.21
45.4	0.78	1.96	0	1	17	1	1	1	80	2	4	8	22	3	7	12	36	4	2	0.06	0.21
45.5	0.79	1.97	0	1	16	1	1	1	80	2	4	7	23	3	7	12	37	4	2	0.06	0.21
45.5	0.79	1.98	0	1	16	1	1	1	80	2	4	7	23	3	7	12	37	4	2	0.06	0.21
45.6	0.80	1.99	0	1	16	1	1	1	80	2	4	7	23	3	7	12	37	4	2	0.06	0.21
45.6	0.81	1.96	0	1	16	0	1	1	81	2	4	7	23	3	7	12	37	4	2	0.06	0.22
45.7	0.82	1.97	0	1	16	0	1	1	82	2	4	7	23	3	7	12	38	4	2	0.06	0.22
45.7	0.82	1.99	0	1	15	0	1	1	82	2	4	7	23	3	6	12	38	4	2	0.06	0.22
45.8	0.83	2.00	0	1	15	0	1	1	82	2	4	7	23	3	6	11	38	4	2	0.06	0.22
45.8	0.84	2.01	0	1	15	0	1	1	82	2	4	7	24	3	6	11	38	4	2	0.06	0.22
45.9	0.85	2.03	0	1	15	0	1	1	83	2	4	7	24	3	6	11	39	4	2	0.06	0.22
46.0	0.85	2.03	0	1	15	0	1	1	83	2	4	7	24	3	6	11	39	4	2	0.06	0.22
46.0	0.86	2.04	0	1	15	0	1	1	83	2	4	7	24	3	6	11	39	4	2	0.06	0.22
46.1	0.87	2.05	0	1	14	0	1	1	83	2	4	7	24	3	6	11	39	4	2	0.06	0.22
46.1	0.88	2.06	0	1	14	0	1	1	84	2	4	7	24	3	6	11	40	4	2	0.06	0.22
46.2	0.88	2.06	0	1	14	0	1	1	84	2	4	7	25	3	6	11	40	4	2	0.06	0.22
46.2	0.89	2.07	0	1	14	0	1	1	84	2	3	6	25	3	6	11	40	4	2	0.06	0.22
46.3	0.90	2.08	0	1	14	0	1	2	83	2	3	6	25	3	6	10	41	4	2	0.05	0.22
46.3	0.91	2.09	0	1	13	0	1	2	84	2	3	6	25	3	6	10	41	4	2	0.05	0.22
46.4	0.91	2.09	0	1	13	0	1	2	84	2	3	6	25	3	5	10	41	4	2	0.05	0.22
46.4	0.92	2.10	0	1	13	0	1	2	84	2	3	6	25	3	5	10	41	4	2	0.05	0.22
46.5	0.93	2.14	0	1	13	1	1	1	84	2	3	6	25	3	5	10	42	4	2	0.05	0.22

Perim	AvVel	Vel98%	Dist_FishHT's(%)							Dist_InvertHT's(%)									#Int	Vveg	Vint
(m)	(m/s)	(m/s)	SVS	SS	SD	FVS	FS	FI	FD	VSFS	SFS	FFS	VFFS	VSCS	SCS	FCS	VFCS	VEG			
46.5	0.94	2.15	0	1	13	1	1	1	84	2	3	6	26	3	5	10	42	4	2	0.05	0.22
46.6	0.95	2.18	0	1	12	1	1	1	84	2	3	6	26	3	5	10	42	4	2	0.05	0.23
46.6	0.95	2.19	0	1	12	1	1	1	84	2	3	6	26	3	5	9	42	4	2	0.05	0.23
46.7	0.96	2.20	0	1	12	1	1	1	84	2	3	6	26	2	5	9	43	4	2	0.05	0.23
46.7	0.97	2.21	0	1	12	1	1	1	85	2	3	6	26	2	5	9	43	4	2	0.05	0.23
46.8	0.98	2.22	0	0	12	1	1	1	85	1	3	6	26	2	5	9	43	4	2	0.05	0.23
46.8	0.99	2.23	0	0	11	1	1	1	85	1	3	5	26	2	5	9	43	4	2	0.05	0.23
46.9	0.99	2.23	0	0	11	1	1	1	85	1	3	5	27	2	5	9	43	4	2	0.05	0.23
47.0	1.00	2.24	0	0	11	1	1	1	85	1	3	5	27	2	5	9	44	4	2	0.05	0.23
47.0	1.01	2.25	0	0	11	1	1	1	86	1	3	5	27	2	5	9	44	4	2	0.05	0.23
47.1	1.02	2.26	0	0	11	1	1	1	86	1	3	5	27	2	5	9	44	4	2	0.05	0.23
47.1	1.03	2.30	0	0	11	1	1	1	86	1	3	5	27	2	4	9	44	4	2	0.05	0.23
47.2	1.03	2.32	0	0	11	1	1	1	86	1	3	5	27	2	4	8	44	4	2	0.05	0.23
47.2	1.04	2.31	0	0	11	0	1	1	87	1	3	5	27	2	4	8	44	4	2	0.05	0.23
47.3	1.05	2.32	0	0	10	0	1	1	87	1	3	5	27	2	4	8	45	4	2	0.05	0.23
47.3	1.06	2.33	0	0	10	0	1	1	87	1	3	5	27	2	4	8	45	4	2	0.05	0.23
47.4	1.07	2.34	0	0	10	0	1	1	87	1	3	5	28	2	4	8	45	4	2	0.05	0.23
47.4	1.08	2.35	0	0	10	0	1	1	87	1	3	5	28	2	4	8	45	4	2	0.05	0.23
47.5	1.08	2.36	0	0	10	0	1	1	87	1	3	5	28	2	4	8	45	4	2	0.05	0.23
47.5	1.09	2.37	0	1	10	0	1	1	88	1	2	5	28	2	4	8	45	4	2	0.05	0.23
47.6	1.10	2.38	0	1	10	0	1	1	88	1	2	5	28	2	4	8	46	4	2	0.05	0.23
47.6	1.11	2.39	0	1	9	0	1	1	88	1	2	5	28	2	4	8	46	4	2	0.05	0.23
47.7	1.12	2.40	0	0	9	0	1	1	88	1	2	5	28	2	4	8	46	4	2	0.05	0.23
47.7	1.13	2.45	0	0	9	0	1	1	88	1	2	5	28	2	4	8	46	4	2	0.05	0.24
47.8	1.13	2.46	0	0	9	0	1	1	88	1	2	5	28	2	4	8	46	4	2	0.05	0.24
47.9	1.14	2.46	0	0	9	0	1	1	88	1	2	5	28	2	4	7	46	4	2	0.05	0.24
47.9	1.15	2.47	0	0	9	0	1	1	88	1	2	5	28	2	4	7	46	4	2	0.05	0.24
48.0	1.16	2.48	0	0	9	0	1	1	89	1	2	4	29	2	4	7	47	4	2	0.05	0.24
48.0	1.17	2.52	0	0	9	1	1	1	88	1	2	4	29	2	4	7	47	4	2	0.05	0.24
48.1	1.18	2.53	0	0	8	1	1	1	88	1	2	4	29	2	4	7	47	4	2	0.05	0.24
48.1	1.19	2.54	0	0	8	1	1	1	88	1	2	4	29	2	3	7	47	4	2	0.05	0.24
48.2	1.19	2.55	0	0	8	1	1	1	88	1	2	4	29	2	3	7	47	4	2	0.05	0.24

Perim	AvVel	Vel98%	Dist_FishHT's(%)							Dist_InvertHT's(%)									#Int	Vveg	Vint
(m)	(m/s)	(m/s)	SVS	SS	SD	FVS	FS	FI	FD	VSFS	SFS	FFS	VFFS	VSCS	SCS	FCS	VFCS	VEG			
48.2	1.20	2.56	0	0	8	1	1	1	88	1	2	4	29	2	3	7	47	4	2	0.05	0.24
48.3	1.21	2.56	0	0	8	1	1	1	88	1	2	4	29	2	3	7	48	4	2	0.05	0.24
48.3	1.22	2.57	0	0	8	1	1	1	89	1	2	4	29	2	3	7	48	4	2	0.05	0.24
48.4	1.23	2.58	0	0	8	1	1	1	89	1	2	4	29	2	3	7	48	4	2	0.05	0.24
48.4	1.24	2.61	0	0	8	1	1	1	89	1	2	4	29	2	3	7	48	4	2	0.05	0.24
48.5	1.25	2.63	0	0	8	1	1	1	89	1	2	4	30	2	3	6	48	4	2	0.05	0.24
48.5	1.25	2.65	0	0	8	1	1	1	89	1	2	4	30	2	3	6	48	4	2	0.05	0.24
48.6	1.26	2.67	0	0	7	1	1	1	89	1	2	4	30	2	3	6	48	4	2	0.05	0.24
48.6	1.27	2.68	0	0	7	1	1	1	89	1	2	4	30	2	3	6	49	4	2	0.05	0.24
48.7	1.28	2.70	0	0	7	1	1	1	89	1	2	4	30	2	3	6	49	4	2	0.05	0.24
48.8	1.29	2.71	0	0	7	1	1	1	89	1	2	4	30	2	3	6	49	4	2	0.04	0.24
48.8	1.30	2.69	0	0	7	0	1	1	90	1	2	4	30	1	3	6	49	4	2	0.04	0.24
48.8	1.31	2.70	0	0	7	0	1	1	91	1	2	4	30	1	3	6	49	4	2	0.04	0.24
48.9	1.32	2.71	0	0	7	0	1	1	91	1	2	4	30	1	3	6	49	4	2	0.04	0.24
48.9	1.33	2.74	0	0	7	1	1	1	90	1	2	4	30	1	3	6	49	4	2	0.04	0.24
49.0	1.33	2.75	0	0	7	1	1	1	90	1	2	4	30	1	3	6	49	4	2	0.04	0.24
49.0	1.34	2.77	0	0	7	1	1	1	91	1	2	4	30	1	3	6	49	4	2	0.04	0.24
49.0	1.35	2.76	0	0	7	0	0	1	92	1	2	4	30	1	3	6	50	4	2	0.04	0.24
49.1	1.36	2.78	0	0	7	0	0	1	92	1	2	3	30	1	3	6	50	4	2	0.04	0.24
49.1	1.37	2.81	0	0	7	0	0	1	92	1	2	3	30	1	3	6	50	4	2	0.04	0.24
49.2	1.38	2.85	0	0	6	1	1	1	91	1	2	3	31	1	3	6	50	4	2	0.04	0.24
49.2	1.39	2.87	0	0	6	1	1	1	91	1	2	3	31	1	3	5	50	4	2	0.04	0.24
49.3	1.40	2.89	0	0	6	1	1	1	92	1	2	3	31	1	3	5	50	4	2	0.04	0.24
49.3	1.41	2.88	0	0	6	0	0	1	93	1	2	3	31	1	3	5	50	4	2	0.04	0.24
49.3	1.42	2.90	0	0	6	0	0	1	93	1	2	3	31	1	3	5	50	4	2	0.04	0.24
49.4	1.43	2.91	0	0	6	0	0	1	93	1	2	3	31	1	2	5	50	4	2	0.04	0.24
49.4	1.43	2.93	0	0	6	0	0	1	93	1	1	3	31	1	2	5	51	4	2	0.04	0.24
49.5	1.44	2.98	0	0	6	1	1	1	92	1	1	3	31	1	2	5	51	4	2	0.04	0.24
49.5	1.45	2.99	0	0	6	1	1	1	92	1	1	3	31	1	2	5	51	4	2	0.04	0.24
49.6	1.46	3.00	0	0	6	1	1	1	92	1	1	3	31	1	2	5	51	4	2	0.04	0.24
49.6	1.47	2.99	0	0	6	0	0	1	93	1	1	3	31	1	2	5	51	4	2	0.04	0.24
49.6	1.48	3.01	0	0	5	0	0	1	93	1	1	3	31	1	2	5	51	4	2	0.04	0.24

Perim	AvVel	Vel98%	Dist_FishHT's(%)							Dist_InvertHT's(%)									#Int	Vveg	Vint
(m)	(m/s)	(m/s)	SVS	SS	SD	FVS	FS	FI	FD	VSFS	SFS	FFS	VFFS	VSCS	SCS	FCS	VFCS	VEG			
49.7	1.49	3.03	0	0	5	0	0	1	93	1	1	3	31	1	2	5	51	4	2	0.04	0.24
49.7	1.50	3.08	0	0	5	1	1	1	93	1	1	3	32	1	2	5	51	4	2	0.04	0.24
49.8	1.51	3.09	0	0	5	1	1	1	93	1	1	3	32	1	2	5	52	4	2	0.04	0.24
49.8	1.52	3.10	0	0	5	1	1	1	93	1	1	3	32	1	2	5	52	4	2	0.04	0.24
49.9	1.53	3.08	0	0	5	0	0	1	94	1	1	3	32	1	2	5	52	4	2	0.04	0.24
49.9	1.54	3.10	0	0	5	0	0	1	94	1	1	3	32	1	2	5	52	4	2	0.04	0.24
49.9	1.55	3.12	0	0	5	0	0	1	94	1	1	3	32	1	2	5	52	4	2	0.04	0.24
50.0	1.56	3.17	0	0	5	1	1	1	93	1	1	3	32	1	2	4	52	4	2	0.04	0.24
50.0	1.57	3.19	0	0	5	1	1	1	93	1	1	3	32	1	2	4	52	4	2	0.04	0.24
50.1	1.58	3.20	0	0	5	1	1	1	93	1	1	3	32	1	2	4	52	4	2	0.04	0.24
50.1	1.58	3.22	0	0	4	1	1	1	94	1	1	3	32	1	2	4	52	4	2	0.04	0.24
50.2	1.59	3.20	0	0	4	0	0	1	95	1	1	3	32	1	2	4	52	4	2	0.04	0.24
50.2	1.60	3.22	0	0	4	0	0	1	95	1	1	3	32	1	2	4	53	4	2	0.04	0.24
50.2	1.61	3.23	0	0	4	0	0	1	95	1	1	3	32	1	2	4	53	4	2	0.04	0.24
50.3	1.62	3.28	0	0	4	1	1	1	94	1	1	3	32	1	2	4	53	4	2	0.04	0.24
50.3	1.63	3.30	0	0	4	1	1	1	94	1	1	3	32	1	2	4	53	4	2	0.04	0.24
50.4	1.64	3.31	0	0	4	1	1	1	94	1	1	2	32	1	2	4	53	4	2	0.04	0.24
50.4	1.65	3.28	0	0	4	0	0	1	95	1	1	3	32	1	2	4	53	4	2	0.04	0.24
50.5	1.66	3.30	0	0	4	0	0	1	95	1	1	2	32	1	2	4	53	4	2	0.04	0.24
50.5	1.67	3.33	0	0	4	0	0	1	95	1	1	2	32	1	2	4	53	4	2	0.03	0.24
50.5	1.68	3.39	0	0	4	1	1	1	94	1	1	2	32	1	2	4	53	4	2	0.03	0.24
50.6	1.69	3.41	0	0	4	1	1	1	94	1	1	2	33	1	2	4	53	4	2	0.03	0.24
50.6	1.70	3.44	0	0	4	1	1	1	94	1	1	2	33	1	2	4	53	4	2	0.03	0.24
50.7	1.71	3.42	0	0	4	0	0	1	95	1	1	2	33	1	2	4	53	4	2	0.03	0.24
50.7	1.72	3.44	0	0	4	0	0	1	95	1	1	2	33	1	2	4	53	4	2	0.03	0.24
50.8	1.73	3.46	0	0	4	0	0	1	95	1	1	2	33	1	2	4	53	4	2	0.03	0.24
50.8	1.74	3.48	0	0	4	0	0	1	95	1	1	2	33	1	2	4	53	4	2	0.03	0.24
50.8	1.75	3.53	0	0	4	1	1	1	94	0	1	2	33	1	2	4	53	4	2	0.03	0.24
50.9	1.76	3.52	0	0	4	1	1	1	94	1	1	2	33	1	2	4	53	4	2	0.03	0.24
50.9	1.77	3.55	0	0	4	1	1	1	94	0	1	2	33	1	2	4	53	4	2	0.03	0.24
51.0	1.78	3.54	0	0	4	0	0	1	95	0	1	2	33	1	2	4	53	4	2	0.03	0.24
51.0	1.79	3.60	0	0	4	1	1	1	94	0	1	2	33	1	2	4	53	4	2	0.03	0.24

Perim	AvVel	Vel98%	Dist_FishHT's(%)							Dist_InvertHT's(%)											
(m)	(m/s)	(m/s)	SVS	SS	SD	FVS	FS	FI	FD	VSFS	SFS	FFS	VFFS	VSCS	SCS	FCS	VFCS	VEG	#Int	Vveg	Vint
51.0	1.80	3.63	0	0	4	1	1	1	94	0	1	2	33	1	2	4	54	4	2	0.03	0.24
51.1	1.81	3.68	0	0	4	1	1	1	93	0	1	2	33	1	2	4	54	4	2	0.03	0.24
51.1	1.82	3.70	0	0	4	1	1	1	93	0	1	2	33	1	2	3	54	4	2	0.03	0.24
51.2	1.83	3.68	0	0	4	0	0	1	95	0	1	2	33	1	2	4	54	4	2	0.03	0.24
51.2	1.84	3.70	0	0	4	0	0	1	95	0	1	2	33	1	2	3	54	4	2	0.03	0.24
51.2	1.85	3.75	0	0	4	1	1	1	94	0	1	2	33	1	2	3	54	4	2	0.03	0.24
51.2	1.86	3.77	0	0	4	1	1	1	95	0	1	2	33	1	2	3	54	4	2	0.03	0.24
51.3	1.87	3.75	0	0	4	0	0	1	95	0	1	2	33	1	2	3	54	4	2	0.03	0.23
51.3	1.88	3.75	0	0	4	0	0	1	95	0	1	2	33	1	2	3	54	4	2	0.03	0.23
51.3	1.89	3.82	0	0	4	1	1	1	95	0	1	2	33	1	2	3	54	4	2	0.03	0.23
51.3	1.90	3.85	0	0	4	1	1	1	95	0	1	2	33	1	2	3	54	4	2	0.03	0.23
51.4	1.91	3.83	0	0	4	0	0	1	96	0	1	2	33	1	2	3	54	4	2	0.03	0.23
51.4	1.92	3.86	0	0	4	0	0	1	96	0	1	2	33	1	1	3	54	4	2	0.03	0.23
51.4	1.93	3.92	0	0	4	1	1	1	95	0	1	2	33	1	1	3	54	4	2	0.03	0.23
51.4	1.94	3.94	0	0	4	1	1	1	95	0	1	2	33	1	1	3	54	4	2	0.03	0.23
51.5	1.95	3.93	0	0	4	0	0	1	96	0	1	2	33	1	1	3	54	4	2	0.03	0.23
51.5	1.96	3.94	0	0	4	0	0	1	96	0	1	2	33	1	1	3	54	4	2	0.03	0.23
51.5	1.97	4.00	0	0	4	1	1	1	95	0	1	2	33	1	1	3	54	4	2	0.03	0.23
51.5	1.98	4.02	0	0	4	1	1	1	95	0	1	2	33	1	1	3	54	4	2	0.03	0.23
51.6	1.99	4.00	0	0	4	0	0	1	96	0	1	2	33	1	1	3	54	4	2	0.03	0.23
51.6	2.00	4.00	0	0	4	0	0	1	96	0	1	2	33	1	1	3	54	4	2	0.03	0.23
51.6	2.01	4.03	0	0	4	0	0	1	96	0	1	2	33	1	1	3	54	4	2	0.03	0.22
51.6	2.03	4.06	0	0	4	0	0	1	96	0	1	2	33	1	1	3	54	4	2	0.02	0.22
51.7	2.04	4.09	0	0	4	0	0	1	96	0	1	2	33	1	1	3	54	4	2	0.02	0.22
51.7	2.05	4.11	0	0	3	0	0	1	96	0	1	2	33	1	1	3	54	4	2	0.02	0.22
51.7	2.06	4.14	0	0	3	0	0	1	96	0	1	2	33	1	1	3	54	4	2	0.02	0.22
51.7	2.07	4.17	0	0	3	0	0	1	96	0	1	2	33	1	1	3	55	4	2	0.02	0.22
51.8	2.08	4.19	0	0	3	0	0	1	96	0	1	2	33	1	1	3	55	4	2	0.02	0.22
51.8	2.09	4.21	0	0	3	0	0	1	96	0	1	2	33	1	1	3	55	4	2	0.02	0.22
51.8	2.10	4.24	0	0	3	0	0	1	96	0	1	2	33	1	1	3	55	4	2	0.02	0.22
51.9	2.11	4.26	0	0	3	0	0	1	96	0	1	2	34	1	1	3	55	4	2	0.02	0.22
51.9	2.12	4.28	0	0	3	0	0	1	96	0	1	2	34	1	1	3	55	4	2	0.02	0.21

Perim	AvVel	Vel98%	Dist_FishHT's(%)							Dist_InvertHT's(%)											
(m)	(m/s)	(m/s)	SVS	SS	SD	FVS	FS	FI	FD	VSFS	SFS	FFS	VFFS	VSCS	SCS	FCS	VFCS	VEG	#Int	Vveg	Vint
51.9	2.13	4.27	0	0	3	0	0	0	97	0	1	2	34	1	1	3	55	4	2	0.02	0.21
51.9	2.14	4.30	0	0	3	0	0	0	97	0	1	2	34	1	1	3	55	4	2	0.02	0.21
52.0	2.15	4.33	0	0	3	0	0	0	97	0	1	2	34	1	1	3	55	4	2	0.02	0.21
52.0	2.16	4.35	0	0	3	0	0	0	97	0	1	2	34	1	1	3	55	4	2	0.02	0.21
52.0	2.17	4.38	0	0	3	0	0	0	97	0	1	2	34	1	1	3	55	4	2	0.02	0.21
52.0	2.19	4.41	0	0	3	0	0	0	97	0	1	2	34	1	1	3	55	4	2	0.02	0.21
52.1	2.20	4.43	0	0	3	0	0	0	97	0	1	2	34	1	1	3	55	4	2	0.02	0.2
52.1	2.21	4.46	0	0	3	0	0	0	97	0	1	2	34	1	1	3	55	4	2	0.02	0.2
52.1	2.22	4.48	0	0	3	0	0	0	97	0	1	2	34	1	1	3	55	4	2	0.02	0.2
52.2	2.23	4.50	0	0	3	0	0	0	97	0	1	2	34	1	1	3	55	4	2	0.02	0.2
52.2	2.24	4.53	0	0	3	0	0	0	97	0	1	2	34	1	1	3	55	4	2	0.02	0.2
52.2	2.25	4.55	0	0	3	0	0	0	97	0	1	2	34	1	1	3	55	4	2	0.02	0.2
52.2	2.26	4.57	0	0	3	0	0	0	97	0	1	2	34	1	1	3	55	4	2	0.02	0.2
52.3	2.27	4.60	0	0	3	0	0	0	97	0	1	2	34	1	1	3	55	4	2	0.02	0.2
52.3	2.28	4.59	0	0	3	0	0	0	97	0	1	2	34	1	1	2	55	4	2	0.02	0.2
52.3	2.29	4.62	0	0	3	0	0	0	97	0	1	1	34	1	1	2	55	4	2	0.02	0.2
52.3	2.31	4.65	0	0	3	0	0	0	97	0	1	1	34	1	1	2	55	4	2	0.02	0.2
52.4	2.32	4.68	0	0	3	0	0	0	97	0	1	1	34	1	1	2	55	4	2	0.02	0.2
52.4	2.33	4.71	0	0	3	0	0	0	97	0	1	1	34	1	1	2	55	4	2	0.02	0.2
52.4	2.34	4.73	0	0	3	0	0	0	97	0	1	1	34	1	1	2	55	4	2	0.02	0.2
52.5	2.35	4.76	0	0	3	0	0	0	97	0	1	1	34	1	1	2	55	4	2	0.02	0.2
52.5	2.36	4.82	0	0	3	0	0	0	96	0	1	1	34	1	1	2	55	4	2	0.02	0.2
52.5	2.37	4.85	0	0	3	0	0	0	96	0	1	1	34	1	1	2	55	4	2	0.02	0.2
52.5	2.38	4.87	0	0	3	0	0	0	96	0	1	1	34	1	1	2	55	4	2	0.02	0.2
52.6	2.39	4.89	0	0	3	0	0	0	96	0	1	1	34	1	1	2	56	4	2	0.02	0.2
52.6	2.41	4.91	0	0	3	0	0	0	96	0	1	1	34	1	1	2	56	4	2	0.02	0.2
52.6	2.42	4.93	0	0	3	0	0	0	96	0	1	1	34	1	1	2	56	4	2	0.02	0.2
52.6	2.43	4.92	0	0	3	0	0	0	96	0	1	1	34	1	1	2	56	4	2	0.02	0.2
52.7	2.44	4.95	0	0	3	0	0	0	96	0	1	1	34	1	1	2	56	4	2	0.02	0.2
52.7	2.45	4.98	0	0	3	0	0	0	96	0	1	1	34	1	1	2	56	4	2	0.02	0.2
52.7	2.46	5.01	0	0	3	0	0	0	96	0	1	1	34	1	1	2	56	4	2	0.02	0.2
52.8	2.47	5.04	0	0	3	0	0	0	96	0	1	1	34	1	1	2	56	4	2	0.02	0.21

Perim	AvVel	Vel98%	Dist_FishHT's(%)							Dist_InvertHT's(%)												
(m)	(m/s)	(m/s)	SVS	SS	SD	FVS	FS	FI	FD	VSFS	SFS	FFS	VFFS	VSCS	SCS	FCS	VFCS	VEG	#Int	Vveg	Vint
52.8	2.48	5.07	0	0	3	0	0	0	96	0	1	1	34	1	1	2	56	4	2	0.02	0.21
52.8	2.50	5.09	0	0	3	0	0	0	96	0	1	1	34	1	1	2	56	4	2	0.02	0.21
52.8	2.51	5.11	0	0	3	0	0	0	96	0	1	1	34	1	1	2	56	4	2	0.02	0.21
52.9	2.52	5.13	0	0	3	0	0	0	96	0	1	1	34	1	1	2	56	4	2	0.02	0.21
52.9	2.53	5.15	0	0	3	0	0	0	96	0	1	1	34	1	1	2	56	4	2	0.02	0.21
52.9	2.54	5.18	0	0	3	0	0	0	96	0	1	1	34	1	1	2	56	4	2	0.02	0.21
52.9	2.55	5.19	0	0	3	0	0	0	96	0	1	1	34	1	1	2	56	4	2	0.02	0.21
53.0	2.56	5.22	0	0	3	0	0	0	96	0	1	1	34	1	1	2	56	4	2	0.02	0.21
53.0	2.58	5.24	0	0	3	0	0	0	96	0	1	1	34	1	1	2	56	4	2	0.02	0.21
53.0	2.59	5.22	0	0	3	0	0	0	96	0	1	1	34	1	1	2	56	4	2	0.02	0.21
53.1	2.60	5.25	0	0	3	0	0	0	96	0	1	1	34	1	1	2	56	4	2	0.02	0.21
53.1	2.61	5.29	0	0	3	0	0	0	96	0	1	1	34	1	1	2	56	4	2	0.02	0.21
53.1	2.62	5.32	0	0	3	0	0	0	96	0	1	1	34	1	1	2	56	4	2	0.02	0.21
53.1	2.63	5.35	0	0	3	0	0	0	96	0	1	1	34	1	1	2	56	4	2	0.02	0.21
53.2	2.65	5.37	0	0	3	0	0	0	96	0	1	1	34	1	1	2	56	4	2	0.02	0.21
53.2	2.66	5.40	0	0	3	0	0	0	96	0	1	1	34	1	1	2	56	4	2	0.02	0.21
53.2	2.67	5.42	0	0	3	0	0	0	96	0	1	1	34	1	1	2	56	4	2	0.02	0.21
53.3	2.68	5.45	0	0	3	0	0	0	96	0	1	1	34	1	1	2	56	4	2	0.02	0.21
53.3	2.69	5.47	0	0	3	0	0	0	96	0	1	1	34	1	1	2	56	4	2	0.02	0.21
53.3	2.70	5.49	0	0	3	0	0	0	96	0	1	1	34	1	1	2	56	4	2	0.02	0.21
53.3	2.72	5.52	0	0	3	0	0	0	96	0	1	1	34	1	1	2	56	4	2	0.02	0.22
53.4	2.73	5.55	0	0	3	0	0	0	96	0	1	1	34	1	1	2	56	4	2	0.02	0.22
53.4	2.74	5.57	0	0	3	0	0	0	96	0	1	1	34	1	1	2	56	4	2	0.02	0.22
53.4	2.75	5.58	0	0	3	0	0	0	96	0	1	1	34	1	1	2	56	4	2	0.02	0.22
53.4	2.76	5.57	0	0	3	0	0	0	96	0	1	1	35	1	1	2	56	4	2	0.02	0.22
53.5	2.77	5.60	0	0	3	0	0	0	96	0	1	1	35	1	1	2	56	4	2	0.02	0.22
53.5	2.79	5.64	0	0	3	0	0	0	96	0	1	1	35	1	1	2	56	4	2	0.02	0.22
53.5	2.80	5.66	0	0	3	0	0	0	96	0	1	1	35	1	1	2	56	4	2	0.02	0.22
53.6	2.81	5.70	0	0	3	0	0	0	96	0	1	1	35	1	1	2	56	4	2	0.02	0.22
53.6	2.82	5.73	0	0	2	0	0	0	96	0	1	1	35	1	1	2	56	4	2	0.02	0.22
53.6	2.83	5.76	0	0	2	0	0	0	96	0	1	1	35	1	1	2	56	4	2	0.02	0.22
53.6	2.85	5.78	0	0	2	0	0	0	96	0	1	1	35	1	1	2	56	4	2	0.02	0.22

Perim	AvVel	Vel98%	Dist_FishHT's(%)							Dist_InvertHT's(%)											
(m)	(m/s)	(m/s)	SVS	SS	SD	FVS	FS	FI	FD	VSFS	SFS	FFS	VFFS	VSCS	SCS	FCS	VFCS	VEG	#Int	Vveg	Vint
53.7	2.86	5.81	0	0	2	0	0	0	96	0	1	1	35	0	1	2	56	4	2	0.02	0.22
53.7	2.87	5.83	0	0	2	0	0	0	96	0	1	1	35	0	1	2	56	4	2	0.02	0.22
53.7	2.88	5.86	0	0	2	0	0	0	96	0	1	1	35	0	1	2	56	4	2	0.02	0.22
53.7	2.89	5.89	0	0	2	0	0	0	96	0	1	1	35	0	1	2	57	4	2	0.02	0.22
53.8	2.91	5.91	0	0	2	0	0	0	96	0	1	1	35	0	1	2	57	4	2	0.02	0.22
53.8	2.92	5.94	0	0	2	0	0	0	96	0	1	1	35	0	1	2	57	4	2	0.02	0.22
53.8	2.93	5.96	0	0	2	0	0	0	96	0	1	1	35	0	1	2	57	4	2	0.02	0.22
53.9	2.94	5.94	0	0	2	0	0	0	96	0	1	1	35	0	1	2	57	4	2	0.02	0.22
53.9	2.95	5.97	0	0	2	0	0	0	96	0	1	1	35	0	1	2	57	4	2	0.02	0.22
53.9	2.97	6.01	0	0	2	0	0	0	96	0	1	1	35	0	1	1	57	4	2	0.02	0.22
53.9	2.98	6.04	0	0	2	0	0	0	96	0	1	1	35	0	1	1	57	4	2	0.02	0.23
54.0	2.99	6.08	0	0	2	0	0	0	96	0	1	1	35	0	31	1	57	4	2	0.02	0.23
54.0	3.00	6.11	0	0	2	0	0	0	96	0	1	1	35	0	1	1	57	4	2	0.02	0.23
54.0	3.02	6.14	0	0	2	0	0	0	96	0	1	1	35	0	1	1	57	4	2	0.02	0.23
54.0	3.03	6.17	0	0	2	0	0	0	96	0	1	1	35	0	1	1	57	4	2	0.02	0.23
54.1	3.04	6.20	0	0	2	0	0	0	96	0	1	1	35	0	1	1	57	4	2	0.02	0.23
54.1	3.05	6.22	0	0	2	0	0	0	96	0	1	1	35	0	1	1	57	4	2	0.02	0.23
54.1	3.06	6.25	0	0	2	0	0	0	96	0	1	1	35	0	1	1	57	4	2	0.02	0.23
54.2	3.08	6.28	0	0	2	0	0	0	96	0	1	1	35	0	1	1	57	4	2	0.02	0.23
54.2	3.09	6.30	0	0	2	0	0	0	97	0	1	1	35	0	1	1	57	4	2	0.02	0.23
54.2	3.10	6.32	0	0	2	0	0	0	97	0	1	1	35	0	1	1	57	4	2	0.02	0.23
54.2	3.11	6.34	0	0	2	0	0	0	97	0	1	1	35	0	1	1	57	4	2	0.02	0.23
54.3	3.13	6.36	0	0	2	0	0	0	97	0	1	1	35	0	1	1	57	4	2	0.02	0.23
54.3	3.14	6.34	0	0	2	0	0	0	97	0	1	1	35	0	1	1	57	4	2	0.02	0.23
54.3	3.15	6.38	0	0	2	0	0	0	97	0	1	1	35	0	1	1	57	4	2	0.02	0.23
54.4	3.16	6.41	0	0	2	0	0	0	97	0	1	1	35	0	1	1	57	4	2	0.02	0.23
54.4	3.18	6.44	0	0	2	0	0	0	97	0	1	1	35	0	1	1	57	4	2	0.02	0.23
54.4	3.19	6.48	0	0	2	0	0	0	97	0	1	1	35	0	1	1	57	4	2	0.02	0.23
54.4	3.20	6.51	0	0	2	0	0	0	97	0	1	1	35	0	1	1	57	4	2	0.02	0.23
54.5	3.21	6.53	0	0	2	0	0	0	97	0	1	1	35	0	1	1	57	4	2	0.02	0.23
54.5	3.23	6.56	0	0	2	0	0	0	97	0	1	1	35	0	1	1	57	4	2	0.02	0.23
54.5	3.24	6.59	0	0	2	0	0	0	97	0	1	1	35	0	1	1	57	4	2	0.02	0.23

Perim	AvVel	Vel98%	Dist_FishHT's(%)							Dist_InvertHT's(%)											
(m)	(m/s)	(m/s)	SVS	SS	SD	FVS	FS	FI	FD	VSFS	SFS	FFS	VFFS	VSCS	SCS	FCS	VFCS	VEG	#Int	Vveg	Vint
54.5	3.25	6.62	0	0	2	0	0	0	97	0	1	1	35	0	1	1	57	4	2	0.02	0.24
54.6	3.26	6.65	0	0	2	0	0	0	97	0	1	1	35	0	1	1	57	4	2	0.02	0.24
54.6	3.28	6.67	0	0	2	0	0	0	97	0	1	1	35	0	1	1	57	4	2	0.02	0.24
54.6	3.29	6.69	0	0	2	0	0	0	97	0	1	1	35	0	1	1	57	4	2	0.02	0.24
54.7	3.30	6.72	0	0	2	0	0	0	97	0	1	1	35	0	1	1	57	4	2	0.02	0.24
54.7	3.31	6.74	0	0	2	0	0	0	97	0	1	1	35	0	1	1	57	4	2	0.02	0.24
54.7	3.33	6.77	0	0	2	0	0	0	97	0	1	1	35	0	1	1	57	4	2	0.02	0.24
54.7	3.34	6.79	0	0	2	0	0	0	97	0	1	1	35	0	1	1	57	4	2	0.02	0.24
54.8	3.35	6.77	0	0	2	0	0	0	97	0	1	1	35	0	1	1	57	4	2	0.02	0.24
54.8	3.36	6.80	0	0	2	0	0	0	97	0	1	1	35	0	1	1	57	4	2	0.02	0.24
54.8	3.38	6.84	0	0	2	0	0	0	97	0	1	1	35	0	1	1	57	4	2	0.02	0.24
54.8	3.39	6.88	0	0	2	0	0	0	97	0	1	1	35	0	1	1	57	4	2	0.02	0.24
54.9	3.40	6.91	0	0	2	0	0	0	97	0	1	1	35	0	1	1	57	4	2	0.02	0.24
54.9	3.42	6.94	0	0	2	0	0	0	97	0	1	1	35	0	1	1	57	4	2	0.02	0.24
54.9	3.43	6.97	0	0	2	0	0	0	97	0	1	1	35	0	1	1	57	4	2	0.02	0.24
55.0	3.44	7.00	0	0	2	0	0	0	97	0	1	1	35	0	1	1	57	4	2	0.02	0.24

APPENDIX C

INVERTEBRATE ASSESSMENT

Table C-1: SASS5 Datasheet for the Tsitsa River intermediate EWR site (17 July 2012)

SASS Version 5 Score Sheet

Version date: Sept 2005

Date (dd:mm:yr):	17-Jul-12		(dd.ddddd)	**Biotopes Sampled (tick & rate)**	Rating (1 - 5) / Time (min)
RHP Site Code:		**Grid reference (dd mm ss.s) Lat:**	S	Stones In Current (SIC)	
Collector/Sampler:	Mark Graham	**Long:**	E	Stones Out Of Current (SOOC)	
River:	Tsitsa	**Datum (WGS84/Cape):**		Bedrock	
Level 1 Ecoregion:		**Altitude (m):**		Aquatic Veg	
Quaternary Catchment:	T35E	**Zonation:**		MargVeg In Current	
	Temp (°C):	**Routine or Project? (circle one)**	Flow:	MargVeg Out Of Current	
Site Description:	pH:	Project Name:	Clarity (cm):	Gravel	
	DO (mg/L):	GT0354	Turbidity:	Sand	
	Cond (mS/m):		Colour:	Mud	
	Riparian Disturbance:			Hand picking/Visual observation	
	Instream Disturbance:				

Taxon	QV	S	Veg	GSM	TOT	Taxon	QV	S	Veg	GSM	TOT	Taxon	QV	S	Veg	GSM	TOT
PORIFERA (Sponge)	5					HEMIPTERA (Bugs)						DIPTERA (Flies)					
COELENTERATA (Cnidaria)	1					Belostomatidae* (Giant water bugs)	3					Athericidae (Snipe flies)	10				
TURBELLARIA (Flatworms)	3					Corixidae* (Water boatmen)	3					Blepharoceridae (Mountain midges)	15				
ANNELIDA						Gerridae* (Pond skaters/Water striders)	5					Ceratopogonidae (Biting midges)	5				
Oligochaeta (Earthworms)	1					Hydrometridae* (Water measurers)	6					Chironomidae (Midges)	2	A			A
Hirudinea (Leeches)	3					Naucoridae* (Creeping water bugs)	7	A			A	Culicidae* (Mosquitoes)	1				
CRUSTACEA						Nepidae* (Water scorpions)	3					Dixidae* (Dixid midge)	10				
Amphipoda (Scuds)	13					Notonectidae* (Backswimmers)	3					Empididae (Dance flies)	6				
Potamonautidae* (Crabs)	3					Pleidae* (Pygmy backswimmers)	4					Ephydridae (Shore flies)	3				
Atyidae (Freshwater Shrimps)	8					Veliidae/M...veliidae* (Ripple bugs)	5	A			A	Muscidae (House flies, Stable flies)	1	1			1
Palaemonidae (Freshwater Prawns)	10					MEGALOPTERA (Fishflies, Dobsonflies & Alderflies)						Psychodidae (Moth flies)	1				
HYDRACARINA (Mites)	8					Corydalidae (Fishflies & Dobsonflies)	8					Simuliidae (Blackflies)	5	A	A		B
PLECOPTERA (Stoneflies)						Sialidae (Alderflies)	6					Syrphidae* (Rat tailed maggots)	1				
Notonemouridae	14					TRICHOPTERA (Caddisflies)						Tabanidae (Horse flies)	5				
Perlidae	12	A			A	Dipseudopsidae	10					Tipulidae (Crane flies)	5				
EPHEMEROPTERA (Mayflies)						Ecnomidae	8					GASTROPODA (Snails)					
Baetidae 1sp	4					Hydropsychidae 1 sp	4	1			1	Ancylidae (Limpets)	6				
Baetidae 2 sp	6	A			A	Hydropsychidae 2 sp	6					Bulininae*	3				
Baetidae > 2 sp	12					Hydropsychidae > 2 sp	12					Hydrobiidae*	3				
Caenidae (Squaregills/Cainfles)	6	A			A	Philopotamidae	10					Lymnaeidae* (Pond snails)	3				
Ephemeridae	15					Polycentropodidae	12					Physidae* (Pouch snails)	3				
Heptageniidae (Flatheaded mayflies)	13					Psychomyiidae/Xiphocentronidae	8					Planorbinae* (Orb snails)	3				
Leptophlebiidae (Prongills)	9	A			A	Cased caddis:						Thiaridae* (=Melanidae)	3				
Oligoneuridae (Brushlegged mayflies)	15					Barbarochthonidae SWC	13					Viviparidae* ST	5				
Polymitarcyidae (Pale Burrowers)	10					Calamoceratidae ST	11					PELECYPODA (Bivalvles)					
Prosopistomatidae (Water specs)	15					Glossosomatidae SWC	11					Corbiculidae (Clams)	5				
Teloganodidae SWC (Spiny Crawlers)	12					Hydroptilidae	6					Sphaeriidae (Pill clams)	3				
Tricorythidae (Stout Crawlers)	9					Hydrosalpingidae SWC	15					Unionidae (Perly mussels)	6				
ODONATA (Dragonflies & Damselflies)						Lepidostomatidae	10					SASS Score		80	5	21	80
Calopterygidae ST,T (Demoiselles)	10					Leptoceridae	6					No. of Taxa		5.71	5	4.2	5.71
Chlorocyphidae (Jewels)	10					Petrothrincidae SWC	11					ASPT		14.0	1.0	5.0	14.0
Synlestidae (Chlorolestidae)(Sylphs)	8					Pisuliidae	10					Other biota:					
Coenagrionidae (Sprites and blues)	4					Sericostomatidae SWC	13										
Lestidae (Emerald Damselflies/Spreadwings)	8					COLEOPTERA (Beetles)											
Platycnemidae (Stream Damselflies)	10					Dytiscidae/Noteridae* (Diving beetles)	5	A		1	A						
Protoneuridae (Threadwings)	8					Elmidae/Dryopidae* (Riffle beetles)	8	1			1						
Aeshnidae (Hawkers & Emperors)	8					Gyrinidae* (Whirligig beetles)	5					Comments/Observations:					
Corduliidae (Cruisers)	8					Haliplidae* (Crawling water beetles)	5										
Gomphidae (Clubtails)	6	1		A	A	Helodidae (Marsh beetles)	12										
Libellulidae (Darters/Skimmers)	4	A		A	A	Hydraenidae* (Minute moss beetles)	8										
LEPIDOPTERA (Aquatic Caterpillars/Moths)						Hydrophilidae* (Water scavenger beetles)	5										
Crambidae (Pyralidae)	12					Limnichidae (Marsh-Loving Beetles)	10										
						Psephenidae (Water Pennies)	10										

Table C-2: SASS5 Datasheet for the Tsitsa River intermediate EWR site (16 April 2013)

SASS Version 5 Score Sheet

Version date: Sept 2005

Date (dd:mm:yr):	16-Apr-13		(dd.ddddd)	**Biotopes Sampled (tick & rate)**	Rating (1 - 5) / Time (min)
RHP Site Code:		Grid reference (dd mm ss.s) Lat:	S	Stones In Current (SIC)	
Collector/Sampler:	Mark Graham and Andrew de Villiers	Long:	E	Stones Out Of Current (SOOC)	
River:	Tsitsa	Datum (WGS84/Cape):		Bedrock	
Level 1 Ecoregion:		Altitude (m):		Aquatic Veg	
Quaternary Catchment:	T35E	Zonation:		MargVeg In Current	
	Temp (°C):	Routine or Project? (circle one)	Flow:	MargVeg Out Of Current	
Site Description:	pH:	Project Name:	Clarity (cm):	Gravel	
	DO (mg/L):	GT0354	Turbidity:	Sand	
	Cond (mS/m):		Colour:	Mud	
	Riparian Disturbance:			Hand picking/Visual observation	
	Instream Disturbance:				

Taxon	QV	S	Veg	GSM	TOT	Taxon	QV	S	Veg	GSM	TOT	Taxon	QV	S	Veg	GSM	TOT
PORIFERA (Sponge)	5					**HEMIPTERA (Bugs)**						**DIPTERA (Flies)**					
COELENTERATA (Cnidaria)	1					Belostomatidae* (Giant water bugs)	3					Athericidae (Snipe flies)	10				
TURBELLARIA (Flatworms)	3		A		A	Corixidae* (Water boatmen)	3		A			Blepharoceridae (Mountain midges)	15				
ANNELIDA						Gerridae* (Pond skaters/Water striders)	5					Ceratopogonidae (Biting midges)	5			1	1
Oligochaeta (Earthworms)	1			1	1	Hydrometridae* (Water measurers)	6					Chironomidae (Midges)	2		A	1	A
Hirudinea (Leeches)	3					Naucoridae* (Creeping water bugs)	7		1	1	A	Culicidae* (Mosquitoes)	1				
CRUSTACEA						Nepidae* (Water scorpions)	3					Dixidae* (Dixid midge)	10				
Amphipoda (Scuds)	13					Notonectidae* (Backswimmers)	3					Empididae (Dance flies)	6				
Potamonautidae* (Crabs)	3					Pleidae* (Pygmy backswimmers)	4					Ephydridae (Shore flies)	3				
Atyidae (Freshwater Shrimps)	8					Veliidae/M...veliidae* (Ripple bugs)	5	A	B		B	Muscidae (House flies, Stable flies)	1				
Palaemonidae (Freshwater Prawns)	10					**MEGALOPTERA (Fishflies, Dobsonflies & Alderflies)**						Psychodidae (Moth flies)	1				
HYDRACARINA (Mites)	8					Corydalidae (Fishflies & Dobsonflies)	8					Simuliidae (Blackflies)	5	A	A		B
PLECOPTERA (Stoneflies)						Sialidae (Alderflies)	6					Syrphidae* (Rat tailed maggots)	1				
Notonemouridae	14					**TRICHOPTERA (Caddisflies)**						Tabanidae (Horse flies)	5				
Perlidae	12	A			A	Dipseudopsidae	10					Tipulidae (Crane flies)	5				
EPHEMEROPTERA (Mayflies)						Ecnomidae	8					**GASTROPODA (Snails)**					
Baetidae 1sp	4					Hydropsychidae 1 sp	4	A				Ancylidae (Limpets)	6				
Baetidae 2 sp	6		B	B		Hydropsychidae 2 sp	6					Bulininae*	3				
Baetidae > 2 sp	12	B			B	Hydropsychidae > 2 sp	12					Hydrobiidae*	3				
Caenidae (Squaregills/Cainfles)	6		A		A	Philopotamidae	10					Lymnaeidae* (Pond snails)	3				
Ephemeridae	15					Polycentropodidae	12					Physidae* (Pouch snails)	3				
Heptageniidae (Flatheaded mayflies)	13					Psychomyiidae/Xiphocentronidae	8					Planorbinae* (Orb snails)	3				
Leptophlebiidae (Prongills)	9		1		1	**Cased caddis:**						Thiaridae* (=Melanidae)	3				
Oligoneuridae (Brushlegged mayflies)	15	A			A	Barbarochthonidae SWC	13					Viviparidae* ST	5				
Polymitarcyidae (Pale Burrowers)	10					Calamoceratidae ST	11					**PELECYPODA (Bivalvles)**					
Prosopistomatidae (Water specs)	15		1			Glossosomatidae SWC	11					Corbiculidae (Clams)	5				
Teloganodidae SWC (Spiny Crawlers)	12					Hydroptilidae	6					Sphaeriidae (Pill clams)	3				
Tricorythidae (Stout Crawlers)	9					Hydrosalpingidae SWC	15					Unionidae (Perly mussels)	6				
ODONATA (Dragonflies & Damselflies)						Lepidostomatidae	10					**SASS Score**		65	83	35	**126**
Calopterygidae ST,T (Demoiselles)	10					Leptoceridae	6					**No. of Taxa**		8	13	7	**19**
Chlorocyphidae (Jewels)	10					Petrothrincidae SWC	11					**ASPT**		8.1	6.4	5.0	**6.6**
Synlestidae (Chlorolestidae)(Sylphs)	8					Pisuliidae	10					**Other biota:**					
Coenagrionidae (Sprites and blues)	4		A		A	Sericostomatidae SWC	13										
Lestidae (Emerald Damselflies/Spreadwings)	8					**COLEOPTERA (Beetles)**											
Platycnemidae (Stream Damselflies)	10					Dytiscidae/Noteridae* (Diving beetles)	5										
Protoneuridae (Threadwings)	8					Elmidae/Dryopidae* (Riffle beetles)	8	A	1	1	A						
Aeshnidae (Hawkers & Emperors)	8					Gyrinidae* (Whirligig beetles)	5					**Comments/Observations:**					
Corduliidae (Cruisers)	8					Haliplidae* (Crawling water beetles)	5										
Gomphidae (Clubtails)	6			A	A	Helodidae (Marsh beetles)	12										
Libellulidae (Darters/Skimmers)	4	A	1		A	Hydraenidae* (Minute moss beetles)	8										
LEPIDOPTERA (Aquatic Caterpillars/Moths)						Hydrophilidae* (Water scavenger beetles)	5										
Crambidae (Pyralidae)	12					Limnichidae (Marsh-Loving Beetles)	10										
						Psephenidae (Water Pennies)	10										

Table C-3: SASS5 Datasheet for the Tsitsa River intermediate EWR site (18 July 2013)

SASS Version 5 Score Sheet — Version date: Sept 2005

Date (dd:mm:yr):	18-Jul-13		(dd.ddddd)	**Biotopes Sampled (tick & rate)**	Rating (1 - 5) / Time (min)
RHP Site Code:		Grid reference (dd mm ss.s) Lat:	S	Stones In Current (SIC)	
Collector/Sampler:	Juan Tedder	Long:	E	Stones Out Of Current (SOOC)	
River:	Tsitsa	Datum (WGS84/Cape):		Bedrock	
Level 1 Ecoregion:		Altitude (m):		Aquatic Veg	
Quaternary Catchment:	T35E	Zonation:		MargVeg In Current	
	Temp (°C):	Routine or Project? (circle one)	Flow:	MargVeg Out Of Current	
Site Description:	pH:	Project Name:	Clarity (cm):	Gravel	
	DO (mg/L):	GT0354	Turbidity:	Sand	
	Cond (mS/m):		Colour:	Mud	
	Riparian Disturbance:			Hand picking/Visual observation	
	Instream Disturbance:				

Taxon	QV	S	Veg	GSM	TOT	Taxon	QV	S	Veg	GSM	TOT	Taxon	QV	S	Veg	GSM	TOT
PORIFERA (Sponge)	5					**HEMIPTERA (Bugs)**						**DIPTERA (Flies)**					
COELENTERATA (Cnidaria)	1					Belostomatidae* (Giant water bugs)	3					Athericidae (Snipe flies)	10		A		A
TURBELLARIA (Flatworms)	3		1		1	Corixidae* (Water boatmen)	3	A			A	Blepharoceridae (Mountain midges)	15				
ANNELIDA						Gerridae* (Pond skaters/Water striders)	5					Ceratopogonidae (Biting midges)	5		1		1
Oligochaeta (Earthworms)	1					Hydrometridae* (Water measurers)	6					Chironomidae (Midges)	2	A		A	A
Hirudinea (Leeches)	3					Naucoridae* (Creeping water bugs)	7	A		A	B	Culicidae* (Mosquitoes)	1				
CRUSTACEA						Nepidae* (Water scorpions)	3					Dixidae* (Dixid midge)	10				
Amphipoda (Scuds)	13					Notonectidae* (Backswimmers)	3					Empididae (Dance flies)	6				
Potamonautidae* (Crabs)	3					Pleidae* (Pygmy backswimmers)	4					Ephydridae (Shore flies)	3				
Atyidae (Freshwater Shrimps)	8					Veliidae/M...veliidae* (Ripple bugs)	5		1		1	Muscidae (House flies, Stable flies)	1				
Palaemonidae (Freshwater Prawns)	10					**MEGALOPTERA (Fishflies, Dobsonflies & Alderflies)**						Psychodidae (Moth flies)	1				
HYDRACARINA (Mites)	8					Corydalidae (Fishflies & Dobsonflies)	8					Simuliidae (Blackflies)	5	B		A	B
PLECOPTERA (Stoneflies)						Sialidae (Alderflies)	6					Syrphidae* (Rat tailed maggots)	1				
Notonemouridae	14					**TRICHOPTERA (Caddisflies)**						Tabanidae (Horse flies)	5				
Perlidae	12	B		B	B	Dipseudopsidae	10					Tipulidae (Crane flies)	5	1			1
EPHEMEROPTERA (Mayflies)						Ecnomidae	8					**GASTROPODA (Snails)**					
Baetidae 1sp	4					Hydropsychidae 1 sp	4			1		Ancylidae (Limpets)	6				
Baetidae 2 sp	6		B	A		Hydropsychidae 2 sp	6	B			B	Bulininae*	3				
Baetidae > 2 sp	12	B			B	Hydropsychidae > 2 sp	12					Hydrobiidae*	3				
Caenidae (Squaregills/Cainfles)	6		A			Philopotamidae	10					Lymnaeidae* (Pond snails)	3				
Ephemeridae	15					Polycentropodidae	12					Physidae* (Pouch snails)	3				
Heptageniidae (Flatheaded mayflies)	13					Psychomyiidae/Xiphocentronidae	8					Planorbinae* (Orb snails)	3				
Leptophlebiidae (Prongills)	9	1	1		A	**Cased caddis:**						Thiaridae* (=Melanidae)	3				
Oligoneuridae (Brushlegged mayflies)	15					Barbarochthonidae SWC	13					Viviparidae* ST	5				
Polymitarcyidae (Pale Burrowers)	10					Calamoceratidae ST	11					**PELECYPODA (Bivalvles)**					
Prosopistomatidae (Water specs)	15	1			1	Glossosomatidae SWC	11					Corbiculidae (Clams)	5				
Teloganodidae SWC (Spiny Crawlers)	12					Hydroptilidae	6					Sphaeriidae (Pill clams)	3				
Tricorythidae (Stout Crawlers)	9	A			A	Hydrosalpingidae SWC	15					Unionidae (Perly mussels)	6				
ODONATA (Dragonflies & Damselflies)						Lepidostomatidae	10					**SASS Score**		102	54	42	147
Calopterygidae ST,T (Demoiselles)	10					Leptoceridae	6		1		1	**No. of Taxa**		14	9	7	22
Chlorocyphidae (Jewels)	10					Petrothrincidae SWC	11					**ASPT**		7.3	6.0	6.0	6.7
Synlestidae (Chlorolestidae)(Sylphs)	8					Pisuliidae	10					**Other biota:**					
Coenagrionidae (Sprites and blues)	4		A		A	Sericostomatidae SWC	13										
Lestidae (Emerald Damselflies/Spreadwings)	8					**COLEOPTERA (Beetles)**											
Platycnemidae (Stream Damselflies)	10					Dytiscidae/Noteridae* (Diving beetles)	5										
Protoneuridae (Threadwings)	8					Elmidae/Dryopidae* (Riffle beetles)	8	A			A						
Aeshnidae (Hawkers & Emperors)	8					Gyrinidae* (Whirligig beetles)	5	A			A	**Comments/Observations:**					
Corduliidae (Cruisers)	8					Haliplidae* (Crawling water beetles)	5										
Gomphidae (Clubtails)	6			A	A	Helodidae (Marsh beetles)	12										
Libellulidae (Darters/Skimmers)	4	B			B	Hydraenidae* (Minute moss beetles)	8										
LEPIDOPTERA (Aquatic Caterpillars/Moths)						Hydrophilidae* (Water scavenger beetles)	5										
Crambidae (Pyralidae)	12					Limnichidae (Marsh-Loving Beetles)	10										
						Psephenidae (Water Pennies)	10										

Table C-4: Tsitsa River Flow Modification Metrics

FLOW MODIFICATION METRICS. WITH REFERENCE TO VELOCITY PREFERENCES, WHAT ARE THE CHANGES TO THE FOLLOWING OBSERVED OR EXPECTED TO BE?	RATING	RANKING OF METRICS	% Weight
Presence of taxa with a preference for very fast flowing water	0.5	1	100
Abundance and/or frequency of occurrence of taxa with a preference for very fast flowing water			
Presence of taxa with a preference for moderately fast flowing water	0.5	2	70
Abundance and/or frequency of occurrence of taxa with a preference for moderately fast flowing water			
Presence of taxa with a preference for slow flowing water	0.5	4	35
Abundance and/or frequency of occurrence of taxa with a preference for slow flowing water			
Presence of taxa with a preference for standing water	1.5	3	65
Abundance and/or frequency of occurrence of taxa with a preference for standing water			
Overall % change in flow dependance of assemblage			15

Table C-5: Tsitsa River Habitat Modification Metrics

HABITAT MODIFICATION METRICS. WITH REFERENCE TO INVERTEBRATE HABITAT PREFERENCES, WHAT ARE THE CHANGES TO THE FOLLOWING OBSERVED OR EXPECTED TO BE?	RATING	RANKING OF METRICS	%WEIGHT
Has the occurrence of invertebrates with a preference for bedrock/boulders changed relative to expected?	2	5	5
Has the abundance and/or frequency of occurrence of any of the taxa with a preference for bedrock/boulders changed?			
Has the occurrence of invertebrates with a preference for loose cobbles changed relative to expected?	1.5	1	100
Has the abundance and/or frequency of occurrence of any of the taxa with a preference for loose cobbles changed?			
Has the occurrence of invertebrates with a preference for vegetation changed relative to expected?	3	3	30
Has the abundance and/or frequency of occurrence of any of the taxa with a preference for vegetation changed?			
Has the occurrence of invertebrates with a preference for sand, gravel or mud changed relative to expected?	0.5	4	20
Has the abundance of any of the taxa with a preference for sand, gravel or mud changed relative to expected?			
Has the occurrence of invertebrates with a preference for the water column or water surface changed relative to expected?	0.5	2	40
Has the abundance and/or frequency of occurrence of any of the taxa with a preference for the water column/water surface changed?			
Overall % change in flow dependanceof assemblage			29

Table C-6: Tsitsa River Habitat Modification Metrics

WATER QUALITY METRICS. WITH REFERENCE TO WATER QUALITY REQUIREMENTS, WHAT ARE THE CHANGES TO THE FOLLOWING OBSERVED OR EXPECTED TO BE?	RATING	RANKING OF METRICS	% WEIGHT
Has the number of taxa with a high requirement for unmodified physico-chemical conditions changed?	1	3	90
Has the abundance and/or frequency of occurrence of the taxa with a high requirement for unmodified physico-chemical			
Has the number of taxa with a moderate requirement for unmodified physico-chemical conditions changed?	0.5	4	80
Hasthe abundance and/or fequency of occurrence of the taxa with a moderate requirement for modified physico-chemical			
Has the number of taxa with a low requirement for unmodified physico-chemical conditions changed?	1	5	70
Has the abundance and/or frequency of occurrence of the taxa with a low requirement for unmodified physico-chemical			
Has the number of taxa with a very low requirement for unmodified physico-chemical conditions changed?	1.5	6	30
Has the abundance and/or frequency of occurrence of the taxa with a very low requirement for unmodified physico-chemical			
How does the total SASS score differ from expected?	1.5	2	95
How does the total ASPT score differ from expected?	1.5	1	100
Overall change to indicators of modified water quality			23

Table C-7: Tsitsa River Macroinvertebrate Ecological Category, MIRAI

INVERTEBRATE EC METRIC GROUP		METRIC GROUP CALCULATED SCORE	CALCULATED WEIGHT	WEIGHTED SCORE OF GROUP	RANK OF METRIC GROUP	%WEIGHT FOR METRIC GROUP
FLOW MODIFICATION	**FM**	85.2	*0.296*	25.2401	3	80
HABITAT	**H**	71.3	*0.333*	23.7607	2	90
WATER QUALITY	**WQ**	76.9	*0.370*	28.4747	1	100
CONNECTIVITY & SEASONALITY	**CS**	100.0	*0.000*	0		
						270
INVERTEBRATE EC				77.4754		
INVERTEBRATE EC CATEGORY				C		

APPENDIX D

GEOMORPHOLOGY ASSESSMENT

GEOMORPHOLOGICAL DATA SHEET: CLASSIFICATION

RIVER SYSTEM	uMzimvubu	**RECORDER**	Lindo
RIVER	Tsitsa River	**DATE**	18-Jul-12
SITE	Tsitsa EWR s	**LAT**	31.075641°
QUATERNARY CATCHMENT		**LONG**	28.897821°
MAP REFERENCE		**ALTITUDE**	
		GRADIENT	Steep

CHANNEL CLASSIFICATION

Channel pattern	Single-thread	single thread		multiple thread			
	Sinuous	sinuous	straight	sinuous	straight		
Reach type	bedrock	bedrock			mixed or alluvial		
	pool-riffle	bedrock fall	bedrock cascade	flat bedrock	pool-rapid	pool-riffle	plain bed
		pool-rapid	anastomosing/ anabranching		step-pool	flat bed	regime
Dominant floor (top row) and sediment type (bottom row)	bedrock with		bedrock	mixed	alluvial	fixed boulder	
	boulder	bedrock	boulder	cobble	gravel	sand	silt & clay

CHANNEL CONFINEMENT	**Score (/5)**
broad flood plain	**5**
confined valley flood plain	**4**
flood plain confined on one side	**3.5**
incised channel (often with flood benches)	**3**
Alternating slopes (bedrock cliff opposite moderate slope)	**2**
gorge with narrow valley floor	**1.5**
V-shaped valley	**1**
ravine	**0.5**
Score	**1**
confidence	**3**

MORPHOLOGICAL UNITS			tick
bedrock	*in-channel features*	waterfall	
		rock steps	
		rapid	x
		bedrock pool	
		bedrock pavement	
	bedrock island/ core bar		
alluvial	*in-channel features*	backwater	
		bedrock run	x
		step	
		rapid	
		plane bed	
		riffle	x
		run	
		shallow pool	x
		deep pool	x
		flat' sand bed	
		backwater	
	alluvial bars	point bar	
		lateral bar	x
		mid-channel bar	
		tributary bar	x
		lee bar	
	secondary channels		x
	vegetated islands		x

Figure D-1: GAI Tsitsa Classification Tab

MORPHOLOGICAL CHANGE	This assesses the change in morphology of the river, relative to the reference condition. ***The reference condition is not a static state, but a consideration of the natural rates and extents of change.***		
Do you think that there been a change in the type and abundance of habitat, relative to the reference condition, due to:	**(rate 0 to 10)**	**Degree to which this change is flow related (1-100)**	**Confidence (1-5)**
FIELD ASSESMENT CRITERIA			
a) changes to the material on the channel bed & bars?	3	1	3
b) change in bank and/or riparian zone substrate (due to flow changes)	1	1	3
c) change in the width or depth of the channel?	1	1	3
DESKTOP ASSESSMENT CRITERIA (using historical aerial photography & previous site info)			
d) change in the number of secondary channels? *(reach scale)*	2	1	3
e) change in the sinuosity of the channel?	2	1	3
f) change in the number of bars or islands?	4	1	3

Figure D-2: GAI Tsitsa Metrics Tab

WEIGHTING OF DRIVER METRICS:

	Rank	Weight
SYSTEM CONNECTIVITY	2	100
REACH SEDIMENT BUDGET	1	90
CHANNEL PERIMETER RESISTANCE	3	60
MORPHOLOGICAL CHANGE	4	30

EXAMPLES FOR WEIGHTING FOR DIFFERENT RIVER TYPES

Bedrock pool rapid

	Rank	*Weight*
SYSTEM CONNECTIVITY	*3*	*60*
REACH SEDIMENT BUDGET	*1*	*100*
CHANNEL PERIMETER RESISTANCE	*2*	*80*
MORPHOLOGICAL CHANGE	*4*	*10*

Mixed pool riffle

	Rank	*Weight*
SYSTEM CONNECTIVITY	*2*	*80*
REACH SEDIMENT BUDGET	*1*	*100*
CHANNEL PERIMETER RESISTANCE	*3*	*60*
MORPHOLOGICAL CHANGE	*4*	*20*

Alluvial flat bed

	Rank	*Weight*
SYSTEM CONNECTIVITY	*1*	*100*
REACH SEDIMENT BUDGET	*2*	*90*
CHANNEL PERIMETER RESISTANCE	*3*	*60*
MORPHOLOGICAL CHANGE	*4*	*30*

Figure D-3: GAI Tsitsa Weightings Tab

FINAL GEOMORPHIC DRIVER STATUS	*This model (GAI level III) is designed for use by trained river specialists, for the purposes of determining the PES and geomorphic drivers of monitoring sites. Although the data/information driving this model will assist in Reserve studies, additional ESSENTIAL data are required for flow determinations.*						
GEOMORPHOLOGY DRIVERS							
COMPONENTS	**RANK**	**RELATIVE WEIGHTING (%)**	**RATING**	**WEIGHT**	**Weighed score**	**flow related (event hydrology ;high flows, floods)**	**CONFIDENCE**
System Connectivity	2	100	0.33	0.36	0.12	1.00	3.00
Reach sediment balance	1	90	3.00	0.32	0.96	1.00	3.00
Channel perimeter resistance	3	60	2.40	0.21	0.51	1.00	3.00
Morphological change	4	30	1.11	0.11	0.12	0.79	2.38
TOTALS		280.00		1.00	1.72		
System Driver status:					**1.72**		
Driver status:(%): >89=A; 80-89=B; 60-79=C; 40-59=D; 20-39=E; <20=F					**65.67**		
HABITAT DRIVER CATEGORY					**C**		
FLOW RELATED (%)						**0.99**	**2.93**

Figure D-4: GAI Tsitsa final PES tab

APPENDIX E

RIPARIAN VEGETATION ASSESSMENT

Table E-1: Description of the riparian vegetation present and reference states

Zones	Impacts	Response Metrics	Description of PRESENT STATE	Description of REFERENCE STATE
Marginal	Vegetation Removal Exotic Vegetation Water Quantity Water Quality	Cover Abundance Species Composition	The marginal zone was characterised by sand banks and boulders with a non-woody cover scattered in between. The right- and left-hand banks were markedly different as a result of the severe alien invasion on the right-hand bank. *Arundinella nepalensis, Cynodon dactylon* and a variety of *Cyprus spp.* and *Juncus spp*. dominated this zone. *Acacia mearnsii and A. dealbata* formed a canopy over sections of the marginal zone on the right-hand-bank.	The marginal zone would have been dominated by a sedge-grassland vegetation type. This vegetation type would have had a greater basal cover and fewer sand banks in between. Boulders would have been scattered along the bank with woody individuals being.
Non-marginal	Vegetation Removal Exotic Vegetation Water Quantity Water Quality	Cover Abundance Species Composition	The non-marginal zone had distinct vegetation communities on the right- and left-hand banks. The right-hand bank was severely infested with Acacia mearnsii and A. dealbata and had high sediment loads that formed sand banks. Indigenous vegetation was restricted to small gaps in the alien stands where the bank structure was still intact. The left-hand bank was more natural, with grassland dominating the non-marginal zone. Scattered *Diospyros lycioides* individuals and boulders were present.	The non-marginal zone would have been dominated by grassland. Boulders would have been scattered in between with little to no sand banks present. Clustered stands of *Acacia karroo, Buddleja salviifolia, Diospyros lycioides, Leucosidea sericea, Searsia dentata* and *Rhamnus prinoides* would have been present in areas that deterred or retarded the spread of fires.

Table E-2: Changes in marginal zone vegetation

	MODIFICATION RATINGS				
CAUSES OF MODIFICATION	**INTENSITY**	**EXTENT**	**CONFIDENCE**	**NOTES: (give reasons for each assessment)**	
REMOVAL	3.0	1.0	5.0	Vegetation in the marginal zone was removed by erosion and livestock.	
EXOTIC INVASION	2.0		5.0	Alien invasive species dominated the right-hand bank.	
WATER QUANTITY	1.0	1.0	5.0	Water removal from the system was minimal.	
WATER QUALITY	2.0	3.0	5.0	Water quality was affected by high sediment loads as a result of severe over-grazing in the catchment.	
AVERAGE			5.0		
		RESPONSE METRIC RATINGS			
VEGETATION COMPONENTS	**RESPONSE METRIC**	**CONSIDER? (Y/N)**	**RATING**	**CONFIDENCE**	**NOTES: (give reasons for each assessment)**
WOODY	COVER	Y	0.5	5.0	Indigenous woody cover was removed by erosion and the establishment of alien vegetation.
	ABUNDANCE	Y	0.5	5.0	Indigenous woody vegetation was removed by erosion and the establishment of alien vegetation.
	SPECIES COMPOSITION	Y	1.0	5.0	Species composition was markedly affected on the right-hand bank as a result of both erosion and the presence of alien invasive vegetation.
			0.7	5.0	
NON-WOODY	COVER	Y	2.0	5.0	Non-woody vegetation cover was affected by both erosion and the presence alien invasive vegetation.
	ABUNDANCE	Y	2.0	5.0	Non-woody vegetation abundances were affected by both erosion and the presence alien invasive vegetation.
	SPECIES COMPOSITION	Y	1.5	5.0	Non-woody species composition was changed as a result of shading from alien invasive vegetation, bank instability and an altered fire regime.
			1.8	3.3	

Table E-3: Summary of changes in marginal zone vegetation

VEGETATION COMPONENTS	CONSIDER? (Y/N)	RANK	WEIGHT	RATING	WEIGHTED RATING	MEAN CONFIDENCE	NOTES: (give reasons for each assessment)
WOODY	Y	2.0	15.0	0.7	0.10	5.0	The woody vegetation played a secondary role in affecting the ecological condition of the vegetation.
NON-WOODY	Y	1.0	100.0	1.8	1.83	3.3	The non-woody vegetation played the primary role in stabilising the bank and affecting the ecological condition of the vegetation. The system would have originally been a non-woody dominated system.
					1.93	4.2	
CHANGE (%) IN MARGINAL ZONE CONDITION			**33.6**				

Table E-4: Changes in non-marginal zone vegetation

	MODIFICATION RATINGS			
CAUSES OF MODIFICATION	**INTENSITY**	**EXTENT**	**CONFIDENCE**	**NOTES: (give reasons for each assessment)**
REMOVAL	3.0	3.0	5.0	Vegetation in the non-marginal zone was removed by erosion and livestock.
EXOTIC INVASION	3.0		5.0	Alien invasive species dominated the right-hand bank.
WATER QUANTITY	1.0	1.0	5.0	Water removal from the system was minimal.
WATER QUALITY	1.5	2.0	5.0	Water quality was affected by high sediment loads as a result of severe over-grazing in the catchment.
AVERAGE			5.0	

		RESPONSE METRIC RATINGS			
VEGETATION COMPONENTS	**RESPONSE METRIC**	**CONSIDER? (Y/N)**	**RATING**	**CONFIDENCE**	**NOTES: (give reasons for each assessment)**
WOODY	COVER	Y	1.5	5.0	Indigenous woody cover was removed by erosion and the establishment of alien vegetation.
	ABUNDANCE	Y	1.0	5.0	Indigenous woody vegetation was removed by erosion and the establishment of alien vegetation.
	SPECIES COMPOSITION	Y	1.5	5.0	Species composition was markedly affected on the right-hand bank as a result of both erosion and the presence of alien invasive vegetation.
			1.3	5.0	
NON-WOODY	COVER	Y	2.5	5.0	Non-woody vegetation cover was affected by both erosion and the presence alien invasive vegetation.
	ABUNDANCE	Y	2.5	5.0	Non-woody vegetation abundances were affected by both erosion and the presence alien invasive vegetation.
	SPECIES COMPOSITION	Y	2.0	5.0	Non-woody species composition was changed as a result of shading from alien invasive vegetation, bank instability and an altered fire regime.
			2.3	3.3	

Table E-5: Summary of changes in non-marginal zone vegetation

VEGETATION COMPONENTS	CONSIDER? (Y/N)	RANK	WEIGHT	RATING	WEIGHTED RATING	MEAN CONFIDENCE	NOTES: (give reasons for each assessment)
WOODY	Y	2.0	30.0	1.3	0.40	5.0	The woody vegetation played a secondary role in affecting the ecological condition of the vegetation.
NON-WOODY	Y	1.0	100.0	2.3	2.33	3.3	The non-woody vegetation played the primary role in stabilising the bank and affecting the ecological condition of the vegetation. The system would have originally been a non-woody dominated system.
					2.73	4.2	
CHANGE (%) IN MARGINAL ZONE CONDITION			**42.1**				

APPENDIX F

FISH ASSESSMENT

Table F-1: Automated and Adjusted FRAI percentage and ecological categories for the Tsitsa River

AUTOMATED	
FRAI (%)	42.5
EC: FRAI	D
ADJUSTED	
FRAI (%)	45.6
EC: FRAI	D

Table F-2: FRAI metric group weightings for the Tsitsa River

WEIGHT OF METRIC GROUPS	
METRIC GROUP	**WEIGHT (%)**
VELOCITY-DEPTH	72.22
COVER	100.00
FLOW MODIFICATION	75.00
PHYSICO-CHEMICAL	91.67
MIGRATION	41.67
IMPACT OF INTRODUCED	47.22

Table F-3: FRAI reference frequency of occurrence and observed species lists for the Tsitsa River

ABBREVIATIONS: REFERENCE SPECIES (INTRODUCED SPECIES EXCLUDED)	SCIENTIFIC NAMES: REFERENCE SPECIES (INTRODUCED SPECIES EXCLUDED)	REFERENCE FREQUENCY OF OCCURRENCE	EC:OBSERVED & HABITAT DERIVED FREQUENCY OF OCCURRENCE
BANO	BARBUS ANOPLUS WEBER, 1897	2.00	1.00
AMOS	ANGUILLA MOSSAMBICA PETERS 1852	1.00	0.00

APPENDIX G

DESKTOP RESERVE MODEL RESULTS

Table G-1: Summary of EWR estimates – Tsitsa River

```
        Desktop Version 2, Printed on 9/20/2013
        Summary of IFR estimate for: MzimEWR1 Generic Name
        Determination based on defined BBM Table with site specific assurance
rules.

        Annual Flows (Mill. cu. m or index values):
        MAR                 =  428.491
        S.Dev.              =  177.946
        CV                  =    0.415
        Q75                 =    6.550
        Q75/MMF             =    0.183
        BFI Index           =    0.347
        CV(JJA+JFM) Index =      2.117

        ERC = C

        Total IFR           =   87.249 (20.36 %MAR)
        Maint. Lowflow      =   50.517 (11.79 %MAR)
        Drought Lowflow     =   23.991 ( 5.60 %MAR)
        Maint. Highflow     =   36.732 ( 8.57 %MAR)

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

        Month    Natural Flows           Modified Flows (IFR)
                                         Low flows    High Flows Total Flows
               Mean    SD      CV     Maint.  Drought    Maint.    Maint.
         Oct   8.104   8.647   0.398    1.037   0.522     0.406     1.443
         Nov  14.965  13.888   0.358    1.431   0.704     0.600     2.031
         Dec  19.684  16.765   0.318    1.731   0.597     0.135     1.866
         Jan  24.418  18.723   0.286    2.110   1.013     0.135     2.245
         Feb  31.259  21.809   0.288    2.757   1.313     9.107    11.864
         Mar  28.566  20.355   0.266    2.742   1.302     3.823     6.565
         Apr  15.404  13.421   0.336    2.309   1.105     0.001     2.310
         May   5.476   5.331   0.363    1.445   0.709     0.000     1.445
         Jun   3.961   5.093   0.496    1.085   0.546     0.000     1.085
         Jul   3.828   6.013   0.587    0.921   0.469     0.000     0.921
         Aug   3.860   5.081   0.492    0.857   0.440     0.000     0.857
         Sep   4.742   7.236   0.589    0.887   0.455     0.420     1.307
```

* Natural MAR at EWR site based on updated hydrology from Jeffares and Green, 2013 for period 1920-2009

Table G-2: Summary of EWR rules – Tsitsa River

Desktop Version 2, Printed on 9/20/2013
Summary of IFR rule curves for : MzimEWR1 Generic Name
Determination based on defined BBM Table with site specific assurance rules.
Regional Type : T Region

ERC = C

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

% Points

Month	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	1.854	1.835	1.790	1.702	1.548	1.324	1.056	0.805	0.636	0.571
Nov	2.605	2.580	2.520	2.397	2.182	1.864	1.479	1.116	0.870	0.776
Dec	2.501	2.482	2.439	2.351	2.189	1.927	1.561	1.143	0.788	0.616
Jan	3.142	3.080	3.003	2.889	2.679	2.409	2.028	1.589	1.213	1.039
Feb	22.816	19.780	17.239	15.002	11.043	9.578	7.533	5.198	3.214	2.290
Mar	12.220	10.637	9.310	8.096	6.127	5.129	3.923	2.786	2.015	1.720
Apr	3.079	3.049	2.982	2.846	2.611	2.268	1.859	1.476	1.217	1.118
May	1.926	1.908	1.866	1.782	1.638	1.426	1.174	0.938	0.778	0.717
Jun	1.423	1.406	1.364	1.282	1.150	0.977	0.798	0.658	0.578	0.552
Jul	1.207	1.191	1.155	1.084	0.971	0.826	0.677	0.561	0.496	0.474
Aug	1.124	1.111	1.078	1.014	0.911	0.776	0.637	0.527	0.465	0.444
Sep	1.670	1.652	1.612	1.532	1.392	1.188	0.945	0.717	0.563	0.504

Reserve flows without High Flows

Month	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	1.382	1.369	1.340	1.281	1.178	1.029	0.851	0.684	0.571	0.527
Nov	1.908	1.891	1.852	1.772	1.631	1.423	1.171	0.934	0.773	0.712
Dec	2.342	2.324	2.284	2.203	2.055	1.812	1.474	1.089	0.761	0.608
Jan	2.858	2.840	2.800	2.718	2.564	2.310	1.953	1.541	1.188	1.025
Feb	3.733	3.708	3.653	3.541	3.334	2.998	2.530	1.995	1.540	1.328
Mar	3.656	3.623	3.547	3.390	3.115	2.708	2.216	1.752	1.437	1.317
Apr	3.077	3.048	2.980	2.844	2.610	2.267	1.858	1.475	1.217	1.117
May	1.926	1.908	1.866	1.782	1.638	1.426	1.174	0.938	0.778	0.717
Jun	1.423	1.406	1.364	1.282	1.150	0.977	0.798	0.658	0.578	0.552
Jul	1.207	1.191	1.155	1.084	0.971	0.826	0.677	0.561	0.496	0.474
Aug	1.124	1.111	1.078	1.014	0.911	0.776	0.637	0.527	0.465	0.444
Sep	1.182	1.171	1.147	1.097	1.010	0.884	0.733	0.592	0.496	0.460

Natural Duration curves*

Month	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	19.276	11.884	9.263	6.761	4.850	3.678	3.103	2.229	1.915	1.086
Nov	38.434	23.989	18.873	14.236	9.711	7.203	6.211	4.213	2.774	1.358
Dec	41.323	33.397	26.975	20.154	12.978	10.984	8.218	6.071	3.338	0.616
Jan	55.843	37.896	31.384	23.432	17.761	15.046	12.791	10.801	6.579	2.117
Feb	62.037	45.722	41.877	34.664	29.270	20.056	14.864	10.342	7.726	4.931
Mar	58.147	39.259	32.855	29.760	24.373	18.836	16.760	13.303	9.017	4.357
Apr	30.930	21.300	18.765	15.976	11.551	10.039	7.353	5.378	3.472	1.408
May	10.260	8.893	5.772	4.368	3.883	3.334	2.800	2.165	1.736	1.284
Jun	6.790	5.120	3.503	2.967	2.299	1.979	1.771	1.570	1.343	1.030
Jul	6.411	4.055	3.517	2.434	2.024	1.829	1.591	1.411	1.217	0.907
Aug	10.088	4.846	3.088	2.599	2.035	1.747	1.516	1.221	1.120	0.937
Sep	12.257	5.806	4.240	3.322	2.419	2.118	1.732	1.404	1.038	0.814

* Natural MAR at EWR site based on updated hydrology from Jeffares and Green, 2013 for period 1920-2009