CLASSIFICATION OF SIGNIFICANT WATER RESOURCES IN THE CROCODILE (WEST), MARICO, MOKOLO AND MATLABAS CATCHMENTS (WP 10506)

EVALUATION OF SCENARIOS REPORT

FINAL

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LIST OF ABBREVIATIONS AND ACRONYMS

CD: RDM	Chief Directorate: Resource Directed Measures
DBSA	Development Bank of South Africa
DWA	Department of Water Affairs
EEAs	Environmental Economic Accounting
EIS	Ecological Importance and Sensitivity
ESBC	Ecologically Sustainable Base Configuration
ERE	Environmental and Resource Economics
EWR	Ecological Water Requirements
GDP	Gross Domestic Product
HN	Hydro-node
IUA	Integrated Unit of analysis
ISP	Internal Strategic Perspective
IWRM	Integrated Water Resource Management
MC	Management Class
MEA	Millennium Ecosystems Assessment
NWA	National Water Act
PES	Present Ecological State
PGM	Platinum Group Metals
PSC	Project Steering Committee
REC	Recommended Ecological Category
RDM	Resource Directed Measures
RQOs	Resource Quality Objectives
RWQOs	Resource Water Quality Objectives
SAM	Social Accounting Matrix
SAWQGs	South African Water Quality Guidelines
SEEAW	System of Environmental Economic Accounting for Water
SNA	System of National Accounts
TWQR	Target Water Quality Range
WDCS	Waste Discharge Charge System
WMA	Water Management Area
WRC	Water Research Commission
WRCS	Water Resource Classification System
WRYM	Water Resources Yield model
WRPM	Water Resource Planning Model

GLOSSARY

Some key terms and definitions as for Water Resource Classification as applied in the study:

Ecological Importance and Sensitivity (EIS)	Key indicators in the ecological classification of water resources. Ecological importance relates to the presence, representativeness and diversity of species of biota and habitat. Ecological sensitivity relates to the vulnerability of the habitat and biota to modifications that may occur in flows, water levels and physico-chemical conditions.
Ecological Water Requirements (EWR)	The flow patterns (magnitude, timing and duration) and water quality needed to maintain a riverine ecosystem in a particular condition. This term is used to refer to both the quantity and quality components.
Ecological Water Requirement Sites	Specific points on the river as determined through the site selection process. An EWR site consists of a length of river which may consist of various cross-sections for both hydraulic and ecological purposes. These sites provide sufficient indicators to assess environmental flows and assess the condition of biophysical components (drivers such as hydrology, geomorphology and physico-chemical conditions) and biological responses (*viz*. fish, invertebrates and riparian vegetation).
Integrated Unit of Analysis (IUAs)	The basic unit of assessment for the classification of water resources. The IUAs incorporate socio-economic zones and are defined by catchment area boundaries.
Internal Strategic Perspective (ISP)	Represents the Department of Water Affairs' (DWAF) view on how Integrated Water Resource Management (IWRM) should be practiced in a particular area. the methodology used is described in the document entitled: "*Methodology followed for the Development of Reconciliation Strategies for the All Town Study Northern Region*"
Management Class (MC)	The MC is representative of those attributes that the DWA (as the custodian) and society require of different water resources (consultative process). The process requires a wide range of trade-offs to assessed and evaluated at a number of scales. Final outcome of the process is a set of desired characteristics for use and ecological condition each of the water resources in a given catchment. The WRCS defines three management classes, Class I, II, and III based on extent of use and alteration of ecological condition from the predevelopment condition.

Present Ecological State (PES)	The current state or condition of a water resource in terms of its biophysical components (drivers) such as hydrology, geomorphology and water quality and biological responses *viz*. fish, invertebrates, riparian vegetation). The degree to which ecological conditions of an area have been modified from natural (reference) conditions.
Recommended Ecological Category (REC)	The Recommended Ecological Category is the future ecological state (Ecological Categories A to D) that can be recommended for a resource unit depending on the EIS and PES. The REC is determined based on ecological criteria and considers the EIS, the restoration potential of the system and attainability there-of.
River Node (Hydro-node)	These are modelling point's representative of an upstream reach or area of an aquatic eco-system (rivers, wetlands, estuaries and groundwater) for which a suite of relationships apply.
Scenario	Scenarios, in the context of water resource management and planning, are plausible definitions (settings) of factors (variables) that influence the water balance and water quality in a catchment and the system as a whole. Each scenario represents an alternative future condition, generally reflecting a change to the present condition.
Significant Water Resources	Water resources that are deemed to be significant from a water resource use perspective, and/or for which sufficient data exist to enable an evaluation of changes in their ecological condition in response to changes in their quality and quantity of water. Water resources are deemed to be significant based on factors such as, but not limited to, aquatic importance, aquatic ecosystems to protect and socio-economic value.
Sub-nodes	Finer scale of modelling points defined within a particular IUA at which flows and water qualities will be set to protect a particular ecological subarea that is identified as important and sensitive.
Sub-quaternary catchments	A finer subdivision of the quaternary catchments (the catchment areas of tributaries of main stem rivers in quaternary catchments). The update of the PES and EIS (2010) status has been determined per sub-

	quaternary.
Trade-offs	Balancing of all factors in relation to the water resource and/or and IUA(s) that are not necessarily attainable at the same which may involve a giving up of one benefit, advantage, etc. in order to gain another regarded as more desirable. This may include balancing of those factors between use and protection (which may or may not be conflicting), between downstream impacts and upstream uses and vice versa, between possible use of resources within a catchment and between catchments, and between possible resource uses between different parts of the country. Decisions on these trade-offs will have different implications for different stakeholders at local, regional and national levels.
Water Resource Planning Model (WRPM)	The Water Resources Planning Model (WRPM) is a planning model capable of modelling demands which increase with time as well as changing system configuration. It can be used both as a planning tool to assess the likely implementation dates of new schemes or resources and also as an operational tool for the month to month operation of a system. The WRPM was used in the scenarios assessments for the classification of water resources in the Crocodile (West), Marico, Matlabas and Mokolo catchments.
Water Resource Yield Model (WRYM)	The WRYM is a network based water resources model used to analyse complex water systems under various operating and growth scenarios. The WRYM is used to assess the long-term yield capabilities of a water resource system for a given operating policy. It is used to analyse a system at constant development level, i.e. the system and the water requirements remain constant throughout the simulation period.

EXECUTIVE SUMMARY

Background

Chapter 3 of the National Water Act (NWA, Act 106 of 1998) provides for the protection of water resources through the implementation of resource directed measures which includes the classification of water resources, setting the Reserve and resource quality objectives. In 2010, the Department of Water Affairs (DWA) identified the need to undertake the classification of significant water resources in the Crocodile (West)**,** Marico**,** Matlabas and Mokolo catchments in accordance with the Water Resource Classification System (WRCS).

To classify a water resource, the WRCS lays out a set of procedures grouped together in 7 steps that when applied to a specific catchment will result in the determination of a Management Class (MC). Determining the class of a water resource requires that the costs and benefits associated with utilisation versus protection of a water resource is assessed, taking into account the social, economic and ecological landscape in a catchment.

The ultimate goal of the study is the implementation of the WRCS which has as its final product the selection of one of three MCs for the twenty Integrated Units of Analysis (IUAs) that were identified in the Crocodile West/Marico WMA and the Mokolo and Matlabas catchments' study area. The MCs will essentially describe the desired condition of the resource, and conversely, the degree to which it can be utilised. The MCs will, therefore, ensure that a balance is maintained between the need to protect and sustain water resources on one hand and the need to develop and use them on the other. This process will specify one of three MCs for each IUA, which will then be translated into Resource Quality Objectives (RQOs) that will specify the actual targets and ranges for maintenance of a specific class of water resource. The RQO development process is a separate process that will only be initiated in 2014 and will run on the outcome of the classification study.

As such, classification is not carried out in isolation, but is integrated within the overall planning for water resource protection, development and use. The basis for determining the MC is the determination of an ecological sustainable level of protection that is required for water resources and integrating this with the economic and social goals. Once appropriate levels of ecological protection are established for the water resources; the measures required to achieve these protection levels, can then be assessed in terms of the overall implications to the IUAs and the WMA. This forms the scenario evaluation component of the WRCS process. The study process is now in its final stages in terms of the WRCS process, the evaluation of scenarios, the results of which are set out in this report.

Approach

A scenario can be defined as "a story of what could happen in the future", and is used to understand different ways that future events might unfold. Scenarios, in the context of water resource management and planning, are plausible definitions (settings) or factors (variables) that influence the water balance and water quality in a catchment and the system as a whole.

Each scenario represents an alternative future condition, generally reflecting a change to the present condition. Analysis thereof gives the ability to compare the implications of one scenario against another, with the ultimate aim to make a selection of the preferred scenario.

Establishment of MCs for the IUAs of the Crocodile West/Marico WMA and Mokolo and Matlabas catchments requires integration of the following suite of components into scenario analysis:

- Water availability in the catchment (water quantity);
- Ecological water requirements (protection of a sustainable level of ecology);
- Economic and social drivers;
- Ecosystem services; and
- Water quality.

In terms of the classification, a range of scenarios were established in order to understand what the result would be in terms of system yield by implementing a certain level of ecological protection required to ensure sustainable use of the catchment water resources (consideration of ecological, water quality and quantity needs).

Each scenario defines a certain ecological condition (Ecological Category [EC] of A, B, C or D) for each water resource; and the water requirement to maintain that category.

To facilitate the classification decision making process for the Crocodile West/Marico WMA and Mokolo and Matlabas catchments, the catchment scenarios for the different catchments that were evaluated as part of the analysis are summarised below. A combination of the following scenarios was evaluated, depending on the availability of data at each specific site. The hydrology supplied by the DWA through the various reconciliation and hydrology studies was used and no new hydrology was run. IUAs 8, 9 and 10 (Molopo and Ngotwane catchments) are catchments that rely on groundwater.

In addition to the scenarios set out below, model runs were done for the present day water use without EWR. It should also be noted that where the PES = REC, only one scenarios was included.

Catchment	Scenarios description
Molopo and Ngotwane	ESBC: Ecological = PES, present water use 1) Reductions in groundwater (outflow from dolomitic eye), PES, present water use 2) Reductions in groundwater (outflow from dolomitic eye), REC, present water use 3) Reductions in groundwater (outflow from dolomitic eye), PES, future water use Water quality – Mafikeng and Dinokana WWTW, metals Water requirements for wetland (less diverted for domestic use)
Klein Marico	ESBC: Ecological = PES ecological category, present water use Scenario 1: PES ecological category, future water use Scenario 2: REC ecological category, present water use Scenario 3: REC ecological category, future water use. Possible future urban expansion in towns, leading to marginal increased demands for domestic water

Catchment	Scenarios description
Groot Marico	ESBC: Ecological = PES, present water use Present water use, no EWR 1) PES, future water use – additional RDP housing; capacity of new WWTW: 500 kl/d; no return flows; 2) C category at MAR_EWR3, present water use, 3) C category at MAR_EWR3: future water use, 4) D category at MAR_EWR3: present water use; 5) PES without floods and freshets and present water use
Crocodile West	ESBC: Ecological = PES, present water use Present water, no EWR 1) PES=REC, future water use (mining – Rustenburg area, transfer of water to Mokolo – MCWAP) Water quality – nutrients, AMD
Mokolo	ESBC: Ecological = PES, present water use Present water use, no EWR 1) REC, present water use Possible return-flows downstream Lephalale.
Matlabas	ESBC: Ecological = PES, present water use 1) REC, present water use

Results

Scenario evaluation included assessment of different ecological categories and water user requirements, in different configurations to obtain results that reflect:

- A water balance (yield required to maintain ecological protection level and water use requirements – results in water surplus or deficit in the IUA)
- Ecological consequences, and
- An economic implication (cost-benefit analysis of the regional economy and social well-being).

Where there is a water deficit, the various interventions identified in the relevant Reconciliation Strategies, Hydrology studies and Internal Strategic Perspectives (ISP) to achieve the required water supply were applied in the economic analysis.

Conclusion and Recommendations

The scenarios and evaluation results were presented to the PSC at a meeting held on the 21st August 2013, the aim being to describe the overall scenario evaluation results and select recommended scenarios and their associated Management Class for proposal to the Minister. Based on the technical evaluation and assessment of the identified criteria, the scenarios were assessed in terms of EWR implementation, water quality implications, WMA water balance and economic and social implications to determine the most likely options to take forward.

Based on the scenario evaluation and consultation with the stakeholders, it was recommended that the go forward options are the following scenarios:

- Crocodile West catchment: scenarios which supply the PES ecological category, which in the context of the Crocodile West catchment is equal to the REC ecological category, and meets the future growth in water requirements (2030) in the catchment;
- Marico catchment: the scenario in the Klein Marico is the REC with present water use (2015); the scenario in the Groot Marico is the REC with present water use (2015);
- Mokolo catchment: PES with future water use (2030); and
- Matlabas, Molopo and Ngotwane: the ESBC is to be maintained.

	IUA	Catchment area	Recommended Management Class	% contribution to achieve the MC			Implications of implementation
				Surface water	Ground water	Wetlands	
CROCODILE (WEST)	**1**	Upper Crocodile/Hennops/ Hartebeespoort	III	75	15	10	**Preferred Scenario: Ecological category = REC + future water use as per the Crocodile-West Reconciliation Strategy** Future Water Requirements driven by: • Future urban expansion in Gauteng, leading to significantly increased return flows; • Additional future mining activities in the Rustenburg area, primarily related to platinum mining; and • Future water use requirements around Lephalale, which would necessitate a water transfer from the Crocodile directly to Lephalale • Water supply, does not constrain the future growth and development of the economy, with the exception of agriculture. • The Recommended (REC) ecological category for the Crocodile West catchment is achievable. • From 2018 onwards, the augmentation of the water supply system through using the surplus water stored in dams would start reducing dam water levels in especially the Hartbeespoort Dam, Roodeplaat Dam and Rietvlei Dam during the dry winter seasons. • There are potential future costs associated with the treatment of AMD and nutrient loads in the Crocodile West River. • With this scenario the economy grows and there is no net loss of river and wetland ecosystem services.
	2	Magalies	II	60	33	7	
	3	Crocodile/ Roodekopjes	III	95	5	0	
	4	Hex/Waterkloofspruit/ Vaalkop	II	77	9	14	
	5	Elands/Vaalkop	II	75	5	20	
	12	Bierspruit	III	80	20	0	
	13	Lower Crocodile	III	68	25	7	
	14	Tolwane/Kulwane/ Moretele/Klipvoor	III	65	15	20	

<table>
<tr><th rowspan="2"></th><th rowspan="2">IUA</th><th rowspan="2">Catchment area</th><th rowspan="2">Recommended Management Class</th><th colspan="3">% contribution to achieve the MC</th><th rowspan="2">Implications of implementation</th></tr>
<tr><th>Surface water</th><th>Ground water</th><th>Wetlands</th></tr>
<tr><td rowspan="6">MARICO</td><td>6a</td><td>Klein Marico/ Kromellemboog</td><td>II</td><td>75</td><td>25</td><td>0</td><td>Preferred Scenario: Ecological category = REC + present water use

Future water use and river flows are driven by:
• Possible future urban expansion in towns, leading to marginal increased demands for domestic water
• No large scale additional future use is envisaged and additional future water uses are to be achieved through water demand management and well planned and managed groundwater supply schemes.
• In this scenario the water economy stays stable and there is no net loss of river and wetland ecosystem services.</td></tr>
<tr><td>6b</td><td>Groot Marico/Marico Bosveld Dam</td><td>II</td><td>90</td><td>10</td><td>0</td><td rowspan="5">Preferred Scenario: PES, AIP clearing, present water use (incl emerging farmers)

• No additional significant future water supply is possible in the Groot Marico;
• The key water source here is the dolomitic outflow, and this supply is current used at a maximum rate, both in the Groot Marico and towards the south towards Lichtenburg; and
• In this scenario the water economy stays stable and there is no net loss of river and wetland ecosystem services.</td></tr>
<tr><td>7</td><td>Kaaloog-se-Loop</td><td>I</td><td>35</td><td>35</td><td>30</td></tr>
<tr><td>8</td><td>Malmaniesloop</td><td>III</td><td>0</td><td>70</td><td>30</td></tr>
<tr><td>9</td><td>Molopo</td><td>II</td><td>5</td><td>70</td><td>25</td></tr>
<tr><td>10</td><td>Dinokana Eye/Ngotwane Dam</td><td>III</td><td>15</td><td>70</td><td>15</td></tr>
</table>

	IUA	Catchment area	Recommended Management Class	% contribution to achieve the MC			Implications of implementation
				Surface water	Ground water	Wetlands	
	11a	Groot Marico/Molatedi Dam	III	80	20	0	**Preferred Scenario: ESBC: Ecological = PES, present water use** • Groundwater supply adequate; and • In this scenario the water economy stays stable and there is no net loss of river and wetland ecosystem services.
	11b	Groot Marico/seasonal tributaries	III	75	20	5	
MOKOLO	**15**	Upper Mokolo	II	74	10	16	**Preferred Scenario: PES with future water use (2030)** • The Lephalale area is forecast to experience a very significant growth in coal mining, power generation and industrial economic activity; • This will not directly affect the Mokolo River; • The water required for this expansion is significant; • These water requirements are to be met through a water

	IUA	Catchment area	Recommended Management Class	% contribution to achieve the MC			Implications of implementation
				Surface water	Ground water	Wetlands	
	16	Lower Mokolo	II	60	20	20	transfer from the Crocodile West River, directly to the Lephalale; • Extensive coal mining IUA 16 could affect aquifers and could lead to AMD in future; • The aesthetic appeal of IUA 16 may be negatively affected; and • In this scenario the water economy grows significantly however there may be some negative impact on ecosystem services.
MATLABAS	17a	Mothlabatsi/Mamba	I	95	5	0	**Preferred Scenario: ESBC is to be maintained** • No change in economic results and ecosystem services
	17b	Matlabas/Limpopo	II	75	20	5	

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1 INTRODUCTION

1.1 BACKGROUND

Chapter 3 of the National Water Act (NWA, Act 106 of 1998) provides for the protection of water resources through the implementation of Resource Directed Measures (RDM) which includes the Classification of water resources, setting the Reserve and determination of Resource Quality Objectives (RQOs). Classification of water resources aims to ensure that a balance is reached between the need to protect and sustain water resources on one hand and the need to develop and use them on the other.

In 2011, the Department of Water Affairs (DWA) identified the need to undertake the classification of significant water resources in the Crocodile (West)**,** Marico**,** Matlabas and Mokolo catchments in accordance with the Water Resource Classification System (WRCS).

Three water resources Management Classes (MC) are defined:

- ***Class I*** - minimally used and configuration of ecological categories of that water resource minimally altered from its pre-development condition;
- ***Class II*** - moderately used and configuration of ecological categories of that water resource moderately altered from its pre-development condition; and
- ***Class III*** - heavily used and configuration of ecological categories of that water resource significantly altered from its pre-development condition.

The Crocodile West/Marico WMA and Mokolo catchment are highly utilised and regulated catchments and like many other WMAs in South Africa the water resources are becoming more stressed due to an accelerated rate of development and the scarcity of water resources. The Matlabas catchment is a less stressed catchment with some fairly pristine areas. There is an urgency to ensure that water resources in the Crocodile West/Marico WMA and the Mokolo and Matlabas catchments are able to sustain their level of uses and be maintained at their desired states. The determination of the Management Classes (MC) of the significant water resources in River Systems of the four main catchments will ensure that the desired condition of the water resources, and conversely, the degree to which they can be utilised is maintained and adequately managed within the economic, social and ecological goals of the water users and the catchment.

The ultimate goal of the study is the implementation of the WRCS in the Crocodile West/Marico WMA and the Mokolo and Matlabas catchments in order to determine the management classes. The purpose of the MC once set, is to establish clear goals relating to the quantity and quality of the relevant water resource in order to facilitate a balance between protection and use of water resources.

To classify a water resource, the WRCS lays out a set of procedures grouped together in 7 steps that when applied to a specific catchment will result in the determination of a MC. The study process is now in the final stages of the WRCS (steps 5 and 6) shown in Figure 1

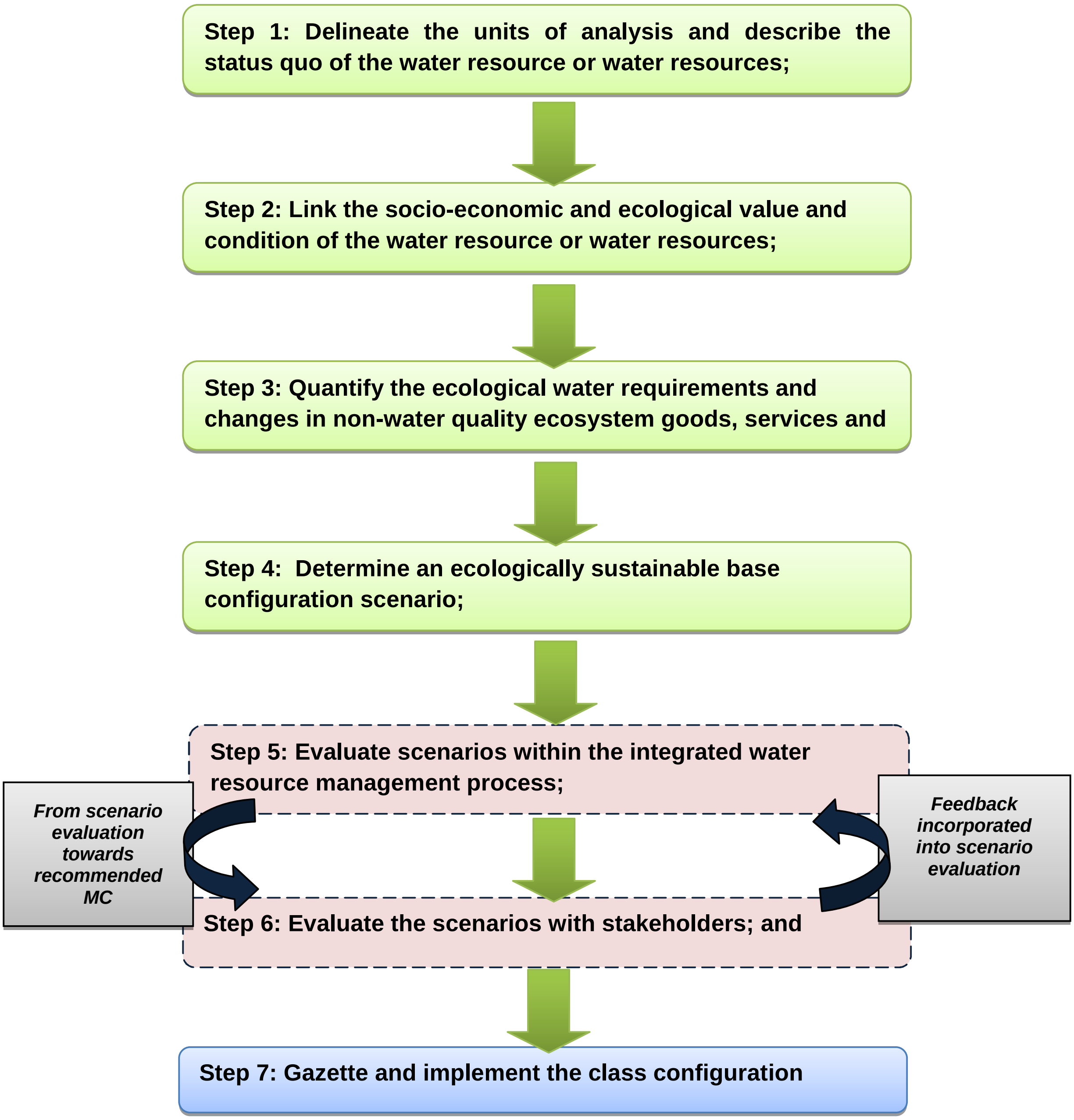


Figure 1: 7 Step WRC Process in the Crocodile (West), Marico, Matlabas and Mokolo catchments

1.2 SPATIAL EXTENT OF STUDY

The spatial extent for the classification study includes tertiary drainage regions A10, A21 to A24, A31, A32, A41, A42 and quaternary drainage region D41A: the Crocodile (West), Marico, Matlabas and Mokolo catchments (Figure 2).The sub-catchments for the study area are set out in Table 1.

Table 1: The sub-catchment areas within the study area

Sub-catchment	Catchment Area (km^2)	Quaternary catchments
Upper Crocodile (A21)	6 336	A21 A – L
Elands (A22)	6 221	A22 A – J
Apies/Pienaars (A23)	7 588	A23 A – L
Lower Crocodile (A24)	9 204	A24 A – J;
Marico (A31 and A 32)	12 030	A32 A – E; A31 A – J
Ngotwane (A10)	1 842	A10 A – C
Upper Molopo (D41))	4 300	D41 A
Matlabas (A41)	6 014	A41A – D
Mokolo (A42))	8 387	A42 A – J

The Mokolo and Matlabas catchments

The Mokolo catchment stretches from the Waterberg Mountains through the upper reaches of the Sand River, and includes the Mokolo Dam and a number of small tributaries that join the main Mokolo River up to its confluence with the Limpopo River, including the Tambotie, Sterkstroom, Poer-se- Loop, and Rietspruit rivers. The catchment covers an area of 8 387 km^2.

The Matlabas catchment is situated in a predominantly flat area of the Limpopo WMA. Matlabas River originates in the Waterberg mountain range and the altitude varies from 1 400 m to approximately 840 m at the confluence with the Limpopo River. The catchment is largely undeveloped with limited water resources and limited water use. The area covers approximately 6 014 km^2.

Crocodile (West) and Marico Catchments

The two major rivers in the Crocodile (West) Marico WMA are the Crocodile (West) River and the Groot Marico River, which form the south-western part of the Limpopo River basin (Drainage Region A), eventually draining into the Indian Ocean in Mozambique. The catchments cover a total area of 47 565 km^2. The area also includes the headwaters of the Molopo River, a tributary of the Orange River which drains westwards to the Atlantic Ocean.

The Pienaars, Apies, Moretele, Hennops, Jukskei, Magalies and Elands rivers are the major tributaries of the Crocodile River which together make up the A20 tertiary drainage catchment, with 39 quaternary catchments. The Crocodile River contributes to the flow of the Limpopo River, which has an international river basin shared with Botswana, Zimbabwe and Mocambique.

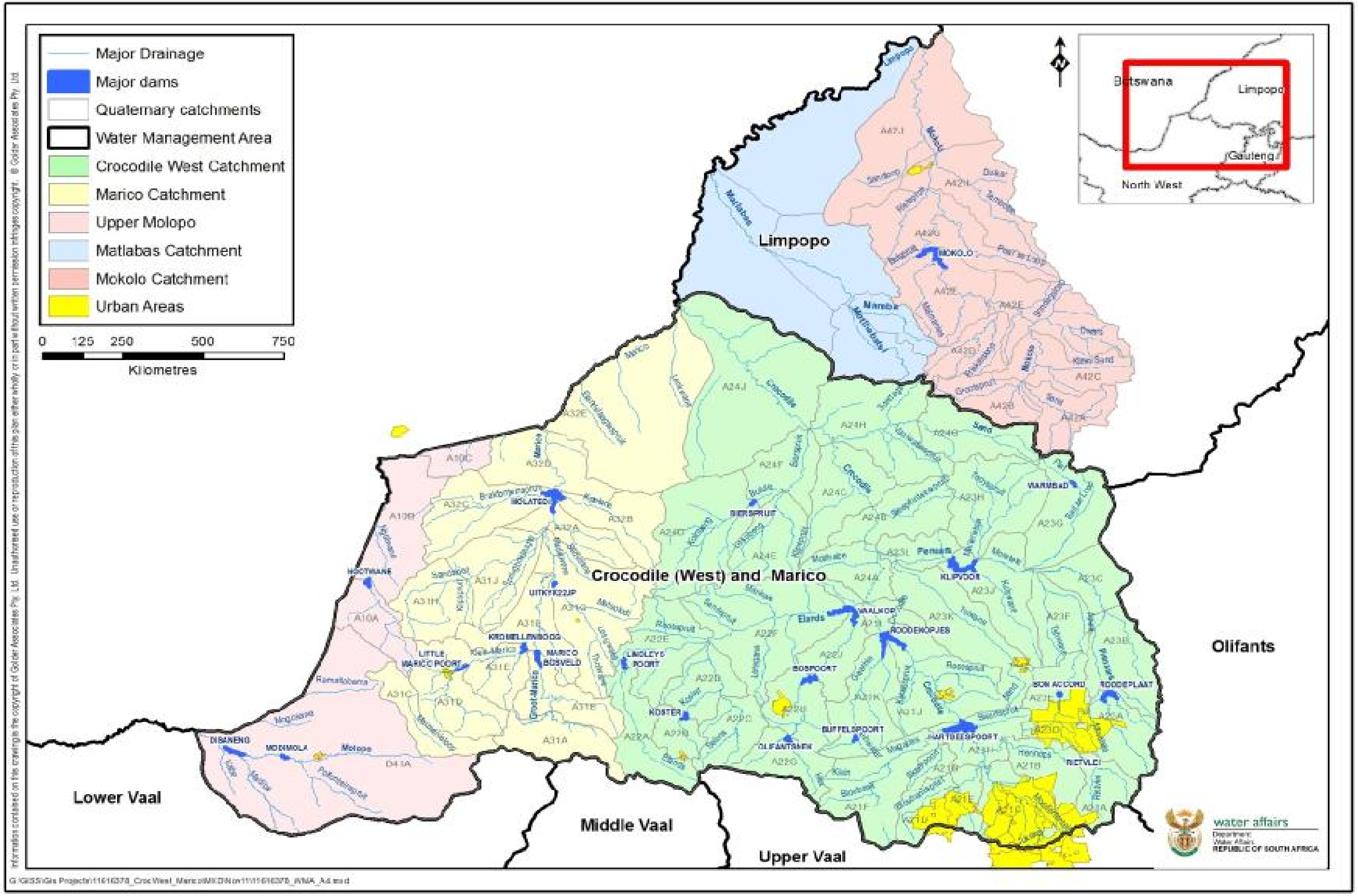


Figure 2: Extent of study area

2 THE STUDY PROCESS

This study is primarily of a technical nature, however is guided by stakeholder participation and engagement. The WRCS has been applied taking account of the local conditions, socio-economic imperatives and dynamics within the Crocodile West/Marico WMA and Mokolo and Matlabas catchments.

The components addressed through the study process (Figure 3) are:

- The study scope definition and water resource information and data gathering;
- The definition of the integrated units of analysis (IUAs) and significant water resources;
- The status quo assessment of the WMA (assessment of present state water resource quality, identification of water resource issues, determination of the institutional environment and assessment of the socio-economics of the study area);
- The application of the WRCS, i.e. establishing the MC by integration of the economic, social and ecological goals through a suitable analytical decision-making system (trade-offs);
- Stakeholder engagement and consultation processes; and
- Completing the classification templates.

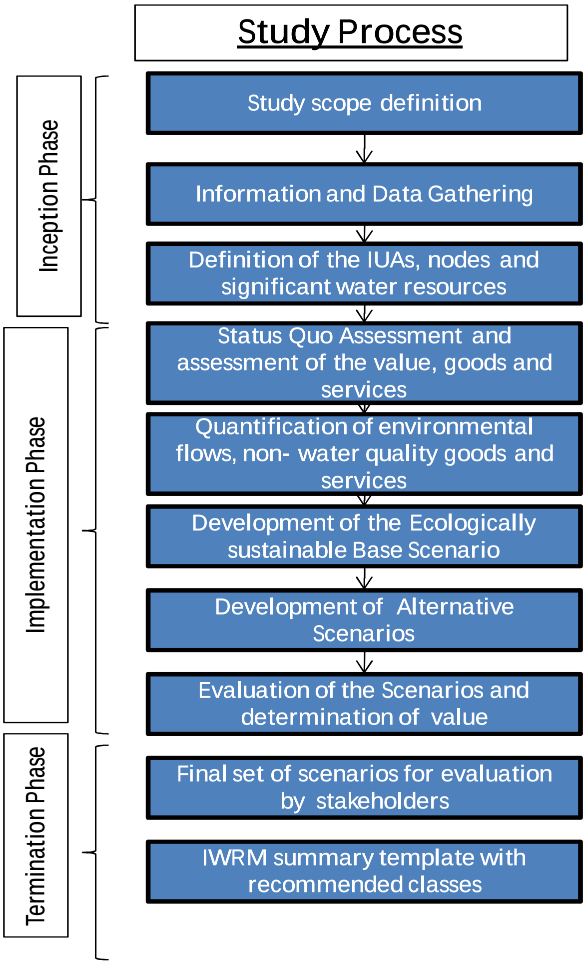


Figure 3: Study process followed for classification of water resources in the Crocodile (West), Marico, Mokolo and Matlabas catchments

In terms of the above process, the approach undertaken by the study team for implementation and application is outlined in Figure 4.

- As part of the inception phase, the IUAs, nodes and significant network of water resources were finalised (July 2012) once confirmed with Project Steering Committee (PSC) members at the second PSC held in February 2012. The feedback obtained was incorporated into IUA delineation.
- The status quo assessment of the WMA, valuation of water resources, and ecological water requirements (EWR) quantification and related flows at each node was completed for the Crocodile West and Marico catchments by November 2012. However, the EWR data for the Matlabas catchment was only finalised in April 2013. The updated Present Ecological State (PES) and Ecological Importance and Sensitivity (EIS) of the water resources was obtained from the recently completed DWA study (DWA, 2012).
- A base scenario with a set of the EWRs based on the present ecological state (PES) at each EWR site was then established. The ecological categories used as the base scenario was based on the 2007 Reserve determination studies conducted for the Crocodile West/Marico and the 2010 Reserve determination for the Mokolo catchment. The water resources yield model (WRYM) for the Crocodile West, Marico, Mokolo and Matlabas catchments were setup and run for the ESBC scenario to evaluate the changes in yield that would result with the EWRs for the PES ecological category.This formed the ecologically sustainable base configuration scenario (ESBC).
- The base scenario was then proposed to the PSC in May 2013. This scenario with the proposed ecological categories per IUA was accepted by the PSC members. At the meeting a further three alternate catchment scenarios were proposed for assessment except for the Matlabas catchment where only one additional scenario was proposed. It was proposed that the scenarios be assessed using the Water Resources Planning Model (WRPM) for the Crocodile West and Mokolo catchments and not the Water Resources Yield Model (WRYM) as the WRPM was being used in the Reconciliation Strategy development. However, the WRYM would still be used for the Marico and Matlabas catchments.
- The alternate scenarios were subsequently taken forward through the modelling processes and the ecological consequences and economic implications of each were assessed. The ecological assessment of responses to various flow scenarios were based on the approach developed by Kleynhans for application in the Habitat Flow Stressor Response Model. The scenarios were evaluated to determine if they are sustainable, economically viable and meet the requirements of the users in the catchment. The evaluation of the scenario results were reported to the PMC at a meeting in July 2013.
- The final set of scenarios was evaluated by consultation with the PSC during August 2013 after which final runs of the scenarios took place based on recommendations from the PSC members. Broader stakeholders will be consulted at two public meetings during October 2013.
- The outcome of this process has resulted in the recommendation of scenarios and proposed MCs for each of the twenty IUAs in the Crocodile West/Marico WMA and Mokolo and Matlabas catchments. These scenarios and associated MCs have been based on what is practical and achievable; while at the same time ensuring the water resources of the WMA are not degraded.

- The classification component of the Integrated Water Resources Management (IWRM) summary template with recommended scenarios, proposed classes and supporting information will be completed by October 2013.
- The recommended scenarios and proposed MCs will be submitted to the Minister for consideration. The final proposed MCs together with the established Resource Quality Objectives (RQOs) for the Crocodile West/Marico WMA and Mokolo and Matlabas catchments will be gazetted together when both processes have been completed. The gazetting process includes a 60 day public comment period.

The above was conducted in terms of the prescribed steps of the WRCS as outlined in the DWA guidelines (DWA, 2007) as best suited to circumstances and conditions that prevailed.

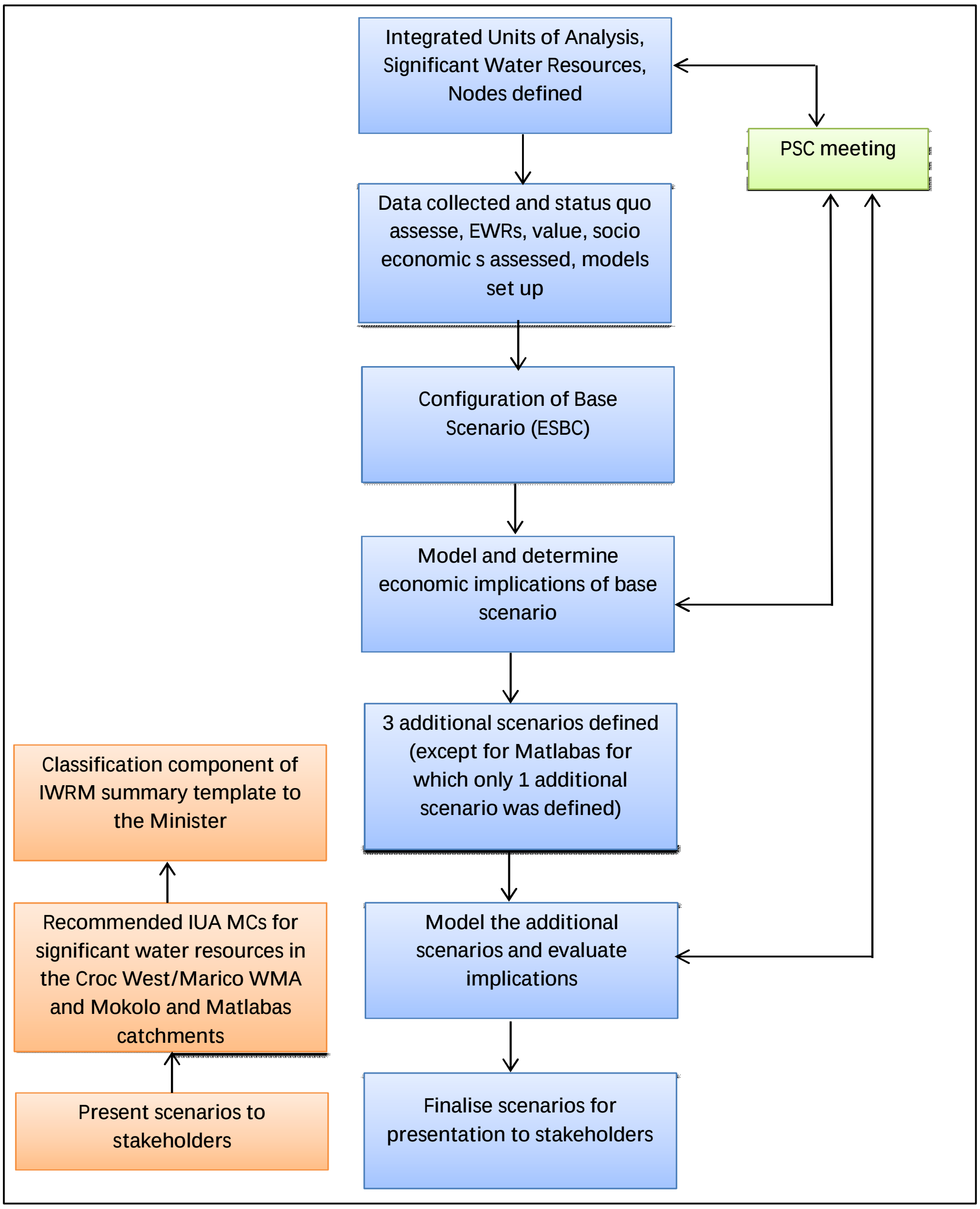


Figure 4: Approach undertaken in terms of implementation of WRC study process

3 THE EVALUATION OF SCENARIOS WITHIN THE INTEGRATED WATER RESOURCE MANAGEMENT PROCESS (STEP 5 FINALISATION)

An integral component of the water resource classification process is the scenario configuration and evaluation. This is an iterative process that assesses the resulting yields of alternate ecological protection categories; conservation targets and future use and development to determine what is most feasible for the catchment being studied, to support the recommended management class options.

This task has been undertaken in compliance with the requirements of the study terms of reference that specifies that the classification process is required to build from existing and current initiatives within the framework of the integrated water resource management processes in the study catchments. The study process is now in the final stages of the WRC process where the scenario evaluation has been finalised and recommended scenarios are proposed.

3.1 OBJECTIVES OF STEP 5 OF THE WRCS

The objective of step 5 of the WRCS is to evaluate scenarios configured as part of Step 4. This was completed in June 2013. Scenario evaluation was incorporated within the integrated water resource management process so that a subset of catchment scenarios can be recommended towards proposed MCs.

The following activities have been undertaken as part of finalisation of Step 5 of the WRCS process:

- Inclusion of the additional three scenarios (except for Matlabas which has only one additional scenario) proposed;
- Water Resources Planning and Water Resource Yield Model analysis and adjustment;
- Reporting of ecological consequences and IUA- level ecological condition;
- Assessment of water quality implications;
- Description of the macro-economic implications;
- Evaluation of the overall scenario implications for the WMAs, and
- Selection of a subset of recommended scenarios.

The process followed is that described in the WRCS Guidelines, Volumes 1, 2, 3 and 4 (Overview and the 7-step classification procedure; Ecological, hydrological and water quality guidelines for the 7-step classification procedure; Socio-economic guidelines for the 7-step classification procedure, and Decision analysis (including the stakeholder engagement process for 7–step Classification Procedure) (DWA, 2007a, 2007b, 2007c and 2007d).

3.2 PURPOSE OF THE REPORT

The purpose of this report is to provide the details of the final assessment and the results of the scenario analysis and evaluation of all scenarios for the Crocodile West/Marico WMA and the Mokolo and Matlabas catchments. This is related to the following:

- Description of the catchment scenarios assessed as part of the scenario analysis;
- Presentation of the yield analysis per scenario (results of the water balance per IUA per scenario);
- Presentation of the results of the socio-economic assessment and evaluation;
- Description of water quality implications and ecological consequences;
- Summary of the scenario analysis (proposed implications per scenario);
- The recommended scenarios and proposed MCs for consideration by the Minister.

4 SUPPORTING INPUTS TO SCENARIO EVALUATION

In terms of the components of the study process the following outputs have been defined/ determined to date or used as key input as support to the evaluation of scenarios:

- Visioning exercise for purposes of the Classification Process;
- Water resource information and data gathering assessment;
- Determination of the integrated units of analysis;
- Socio-economic: Evaluation and the decision-analysis framework and method summary;
- Ecological Water Requirements quantification;
- Present Ecological Status (external to classification process – used as input)(DWA, 2012);
- Ecological Base Scenario Configuration determination; and
- Alternate Catchment Configuration Scenarios definition.

The key elements of the above inputs are briefly described in the sub sections to follow. The individual study reports are available on request from the study public participation office or on the DWA website at http://www.dwa.gov.za/rdm/WRCS.

4.1 VISIONING EXERCISE FOR THE PURPOSES OF THE CLASSIFICATION PROCESS

Visioning is a process of articulating society's aspirations for the future. In the case of water resoures classification, the 'basket' of benefits to be derived from aquatic ecosystem services and the costs associated with their use. Van Wyk *et al*., 2006a state that is widely acknowledged that a fundamental objective of integrated water resource management (IWRM) is to ensure that resource-based costs and benefits are appropriately distributed in society.

In this respect as part of the classification of Crocodile (West), Marico, Matlabas and Mokolo catchments a visioning exercise was undertaken at the second PSC meeting held on the 12th September 2012. The visioning exercise will help to translate stakeholder issues and concerns into a vision for the area in which stakeholders live, work or have interests. The vision will ultimately be translated into management objectives that will drive operational management. In other words, it will help link management actions to the vision and ensure that societal values and management objectives are linked and realised.

It is important to note that a vision is always situation- or context-specific. This means that a shared understanding of the condition of the water resources and of society within a chosen area is needed. The Crocodile (West), Marico, Matlabas and Mokolo catchments are large and diverse areas in terms of ecology, and the economic and social activities that characterise them, and for this reason the units of integrated analysis (IUA) were used for the visioning exercise.

Overall the proposed future MC per IUA by the different stakeholders was similar, however there are a few cases where the proposed classes were different.

- **IUA 1:** Class III: i*t was noted that if small improvements in quality and specifically flow volume can be made the D category (currently ranges between a C and E) can cater for development and basic ecological functionality. Some form of rehab before the water leaves the major problem areas will assist;*
- **IUA 2:** one respondent suggested a Class I while another a Class III: *there is nothing much else left "ecologically" in Gauteng*;
- **IU 4:** I (Upper)/II (Lower)/III proposed: *there are differences with some rivers and tributaries in an A/B PES and other parts an E PES. It is difficult to motivate for this IUA due to these differences*;
- **IU 5:** I (Upper)/II (Lower): *strong action must be taken if the Class deteriorates;*
- **IUA 11a:** one respondent suggested a Class I while another Class III: *in respect of the proposed Class I the comment is that this IUA is part of National Conservation Priority (NFEPA). Provides drinking water for the Tswasa scheme that exports water to Botswana via IUA 11b;*
- **IUA 11b:** one respondent suggested a Class I while another Class II*: in respect of the proposed Class I the comment is that this IUA provides the Tswasa drinking water scheme;* and
- **IUA 15:** II; *it was noted that while the current category is a C PES, Sterkstroom is an exception (A/B)*.

Table 2: Proposed management classes from stakeholders

IUA	Present State	Proposed Future Management Class					
		City of Tshwane	Roux	WESSA	Anglo American	Marico Conservation Catchment	GDARD
1	C/D/E	III					
2	B/C	I	I	III			
3	C/D	III	III				
4	C/D	III	I- Upper; II Lower		III		
5	C	II	I- Upper; II Lower				
6	B/C	I	I				
7	B	I	I			I	
8	-		I				
9	-		I - upper reaches; II below Mafikeng				
10	B/D	II	I - upper ; II - lower				
11a	C/D	III	I				III

IUA	Present State	Proposed Future Management Class					
		City of Tshwane	Roux	WESSA	Anglo American	Marico Conservation Catchment	GDARD
11b	C	II	I				
12	D	III			III		
13	C/D	III					
14	C/D	III					
15	C	II					
16	B/C	I					
17a	C	II					
17b	C	II			II		
17c	C/D	III					

While the above response represents only some of the stakeholder groups in the study area, it provided direction in terms of a framework for the desired state for water resources in the catchments being studied. This framework was used as the basis for defining catchment scenarios within the constraints of the integrated water resources complexities in the Crocodile West/Marico WMA and Mokolo and Matlabas catchments.

4.2 WATER RESOURCE INFORMATION AND DATA GATHERING

Numerous studies have been and are currently being undertaken on the Crocodile West, Marico and Mokolo river systems. The Matlabas River System however has not been studied much so that it was difficult to find data for the Matlabas system. Task 2 of this study focussed on gathering data and collecting information from a wide variety of sources such as the Department of Water Affairs, other government departments, the Water Research Commission, provincial departments, Statistics South Africa, research and academic organisations and other study groups.

An assessment and review of all the existing information and data was undertaken and summaries of the available information were compiled and the information availability was assessed. The above was used to identify any gaps and outstanding information. Specific recommendations were made in relation to the collection of additional data and/or the extrapolation of existing data. For parallel studies ongoing liaison was established with other study teams and was maintained to ensure the transfer of information. More detailed information is available in the following reports:

- Information Analysis Report: Crocodile (West) Marico WMA, RDM/WMA1,3/00/CON/CLA/0112A; and
- Information Analysis Report: Mokolo and Matlabas catchments, RDM/WMA1,3/00/CON/CLA/0112B**.**

4.3 INTEGRATED UNITS OF ANALYSIS

The process followed in terms of IUA delineation is that described in the WRCS Guidelines, Volumes 1 and 2 (Overview and the 7-step classification procedure; and Ecological, hydrological and water quality guidelines for the 7-step classification procedure) (DWA, February 2007).

Delineation of units of analysis is required as it would not be appropriate to set the same MC for all water resources in such an extensive area. The delineation of a WMA/catchment into IUAs for the purpose of determining the MC for significant rivers is done primarily according to a number of socio-economic criteria and drainage region (catchment area) boundaries. IUAs are therefore a combination of socio-economic zones and watershed boundaries (DWA, 2007). Ecological information also plays a role in the delineation.

The following was considered for delineation of IUAs within the Crocodile (West), Marico, Matlabas and Mokolo catchments:

- Socio-economic zones (SEZs);
- Catchment area boundaries (drainage regions and water resource systems);
- Similar land use characteristics/land based activities;
- Eco-regions and geomorphology;
- Ecological information;
- Present status of water resources; and
- Stakeholder input.

Twenty IUA's were identified as shown in Figure 5.

Biophysical and Managements Nodes

Biophysical nodes are established to serve as points that account for interactions between ecosystems and management nodes (allocation). Nodes are established to serve as modelling points for the classification process in a catchment. The establishment of biophysical and management nodes are guided by a number of considerations. The key considerations are:

- Significant water resources;
- Biophysical and eco-regional characteristics;
- Location of Ecological Water Requirement (EWR) sites and ecological information;
- Ecological Importance and Sensitivity (EIS) categories of water resources;
- Present Ecological State (PES);
- Broad-scale hydrological and geomorphological characters;
- Water infrastructure; and
- Water management, planning and allocation information.

Based on the above considerations, proposed biophysical and allocation nodes were established in each of the IUAs delineated for the Crocodile (West) Marico WMA and the Mokolo and Matlabas catchments. The initial nodes proposed were confirmed and finalised at the conclusion of Step 3 of the Classification Process (Table 3 and Figure 5). Further details are available in the Integrated Units of Analysis Delineation Report, RDM/WMA1,3/00/CON/CLA/0212.

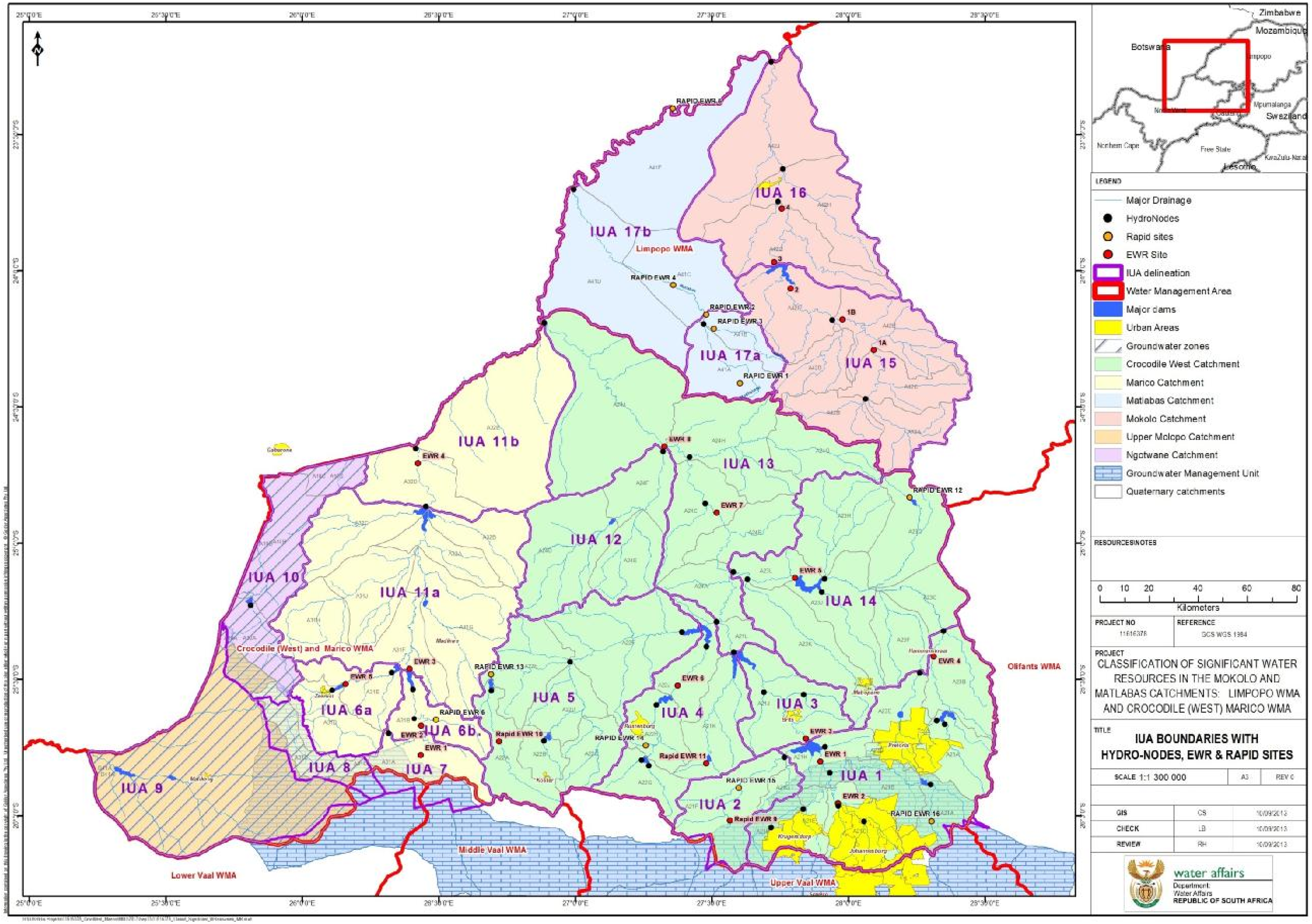


Figure 5: Integrated Units of Analysis, hydro nodes and EWR sites within the Crocodile West/Marico WMA and Mokolo and Matlabas catchments

Table 3: Hydro nodes for the Crocodile West/Marico WMA and Mokolo and Matlabas catchments (per IUA) and extrapolation sites used

IUA	No	Quaternary catchment	Nodes	EWR sites used for extrapolation
1	HN1	A21A	Rietspruit (source) to outlet of Rietvlei Dam	CROC_EWR 16
	HN2	A21B	Sesmylspruit and tributaries to confluence with Hennops	CROC_EWR 16
	HN3 HN4 HN5	A21C	Modderfonteinspruit to confluence with Jukskei Klein Jukskei at confluence with Jukskei Jukskei River at CROC_ EWR2	CROC_EWR 16 CROC_EWR 16 CROC_EWR 2
	HN6	A21D	Bloubankspruit and tributaries (outlet of quaternary/confluence with Crocodile)	Use updated PES with DRM
	HN7 HN8 HN9 HN10	A21A, B, H A21H A21E, H A21H, J	Hennops to confluence with Crocodile Swartspruit to Hartbeespoort Dam Crocodile (source) to CROC_EWR1 Crocodile at Hartbeespoort Dam at CROC_EWR3, outlet of IUA1	CROC_EWR 2 Use updated PES with DRM CROC_EWR 1 CROC_EWR 3
	HN11	A23A	Pienaars (source) and including Morelettaspruit and Edendalespruit to outlet of Roodeplaat Dam	Use updated PES with DRM
	HN12 HN13	A23B A23B	Pienaars from Roodeplaat Dam to outlet of quaternary catchment (outlet of IUA1, CROC_EWR4) Boekenhoutspruit to confluence with Pienaars	CROC_EWR 4 Use updated PES with DRM
	HN14 HN15	A23D A23D, E	Skinnerspruit (source) to confluence with Apies Apies (source) to Bon Accord Dam, below the dam at outlet of IUA1	Use updated PES with DRM Use updated PES with DRM
2	HN16	A21F	Magalies below Maloney's Eye at CROC_EWR9	CROC_EWR 9
	HN17 HN18	A21G, F	Magalies (CROC_EWR15) Skeerpoort at outlet of IUA2	CROC_EWR15 CROC_EWR15
3	HN19 HN20	A21J	Rosespruit at confluence with Crocodile Crocodile from Hartbeespoort Dam to upstream Roodekopjes Dam, outlet of IUA3	Use updated PES with DRM CROC_EWR 3
4	HN21 HN22	A21K	Sterkstroom (source) to Buffelspoort Dam (CROC_EWR11) Sterkstroom from Buffelskloof Dam to Roodekopjes Dam, outlet of IUA4	CROC_EWR 11 Use updated PES with DRM
	HN23	A22G	Hex (source) to Olifantsnek Dam	CROC_EWR 11
	HN24 HN25	A22H	Waterkloofspruit (CROC_EWR14) to confluence with Hex Hex from Olifantsnek Dam to Bospoort Dam	CROC_EWR 14 Use updated PES with DRM
	HN26 HN27	A22J	Hex from Bospoort Dam to Vaalkop Dam (CROC_EWR6) Elands from Vaalkop Dam to confluence with Crocodile, outlet of IUA4	CROC_EWR 6 Use updated PES with DRM
5	HN28 HN29	A22A	Elands (source) to Swartruggens Dam (CROC_EWR10) Elands from Swartruggens Dam to Lindleypoort Dam	CROC_EWR 10 CROC_EWR 10

IUA	No	Quaternary catchment	Nodes	EWR sites used for extrapolation
	HN30	A22B	Koster (source) to Koster Dam	CROC_EWR 10
	HN31	A22C, A22D	Selons to confluence with Elands	CROC_EWR 13
	HN32	A22E, A22F	Elands from Lindleypoort Dam (CROC_EWR13) to Vaalkop Dam, outlet of IUA5	CROC_EWR 13
6b	HN33 HN34 HN63	A31B	Polkadraaispruit to confluence with Marico (MAR_EWR6) Marico from MAR_EWR2 to N4 road at town Marico from N4 road to Marico-Bosveld Dam, outlet of IUA6b	MAR_EWR 6 MAR_EWR 2 MAR_EWR 2
6a	HN64 HN35 HN65 HN36	A31D A31D A31E A31E	Malmaniesloop to confluence with Klein Marico Klein Marico and tributaries upstream of Zeerust Klein Marico from Zeerust to Klein Maricopoort Dam Klein Mario from Klein Maricopoort Dam to Kromellemboog Dam (MAR_EWR5), outlet of IUA6a	Updated PES with DRM/ MAR_EWR1 MAR_EWR 5 MAR_EWR 5 MAR_EWR 5
7	HN37 HN38	A31A A31A	Kaaloog-se-Loop (MAR_EWR1) to concluence with Groot Marico Vanstraatenvlei and tributaries at confluence with Kaaloog-se-Loop, outlet of IUA7	MAR_EWR 1 MAR_EWR 1
8	-	A31C	Groundwater	-
9	HN66 HN67 HN39	D41A	Molopo at outlet of wetland Molopo at Modimola Molopo at outlet of IUA9	MAR_EFR M8 Use updated PES with DRM Use updated PES with DRM
10	HN68 -	A10A A10A, B, C	Ngotwane from Dinokana to Ngotwane Dam Ngotwane from Dinokana to outlet of IUA10	Use updated PES with DRM Groundwater
11a	HN40	A31F, G, A32A	Marico from Marico Bosveld and Kromelmboog Dam to Molatedi Dam (MAR_EWR3), outlet of IUA11a	MAR_EWR 3
11b	HN41	A32D, E	Marico from Molatedi Dam to confluence with Crocodile (MAR_EWR4), outlet of IUA11b	MAR_EWR 4
12	HN42	A24D, E, F	Bierspruit to confluence with Crocodile River, outlet of IUA12	Use updated PES with DRM
13	HN43	A24G, A24H	Sand to confluence with Crocodile	Use updated PES with DRM
	HN44	A21L, A24A-C, A24H	Crocodile from Roodekopjes Dam (CROC_EWR7) to proposed Mokolo transfer (CROC_EWR8)	CROC_EWR 7 CROC_EWR 8
	HN45	A24J	Crocodile from CROC_EWR8 to confluence with Limpopo, outlet of IUA13	CROC_EWR 8
14	HN46	A23G	Platspruit (source, CROC_EWR12) to confluence with Pienaars	CROC_EWR 12
	-	A23C, A23F	Wetland at Pienaars& Apies confluence and inflow to Klipvoor Dam	-

IUA	No	Quaternary catchment	Nodes	EWR sites used for extrapolation
	HN47	A23H	Karee/Rietspruit to confluence with Pienaars	CROC_EWR 12
	HN48	A23J A23J, A23L	Moretele (Pienaars) to confluence with Crocodile (CROC_EWR5), outlet of IUA14	CROC_EWR 5
	HN49	A23K	Tolwane to confluence with Moretele	Use updated PES with DRM
15	HN50	A42A	Sand (source) to confluence with Grootspruit	MOK_EWR 1a
	HN51	A42B	Grootspruit (source) to confluence with Sand	MOK_EWR 1a
	HN52	A42C	Mokolo to confluence with Dwars (MOK_EWR1a)	MOK_EWR 1a
	HN53	A42D, A42E	Mokolo to confluence with Sterkstroom (MOK_EWR1b)	MOK_EWR 1b
	HN54	A42D	Sterkstroom (source) to confluence with Mokolo, including Dwars	MOK_EWR10
	HN55	A42F	Mokolo from Sterkstroom to Mokolo Dam (MOK_EWR2), outlet of IUA15	MOK_EWR 2
16	HN56 HN57	A42G	Rietspruit (source) to Mokolo confluence Mokolo below dam (MOK_EWR3) to Rietspruit confluence (MOK_EWR4)	Use updated PES with DRMMOK_EWR 3, MOK_EWR 4
	HN58	A42H, A42J	Mokolo from MOK_EWR4 to confluence with Limpopo, outlet of IUA16.	MOK_EWR 4 and wetland requirements
17a	HN59	A41A	Mothlabatsi to confluence with Mamba	MAT_EWR 1
	HN60	A41B	Mamba to confluence with Mothlabatsi, outlet of IUA17a	MAT_EWR 3
17b	HN61	A41C	Matlabas from Mamba confluence to MAT_EWR2	MAT_EWR 2
	HN62	A41C, D	Matlabas from MAT_EWR2 to confluence with Limpopo, outlet of IUA17b	MAT_EWR 4

4.4 SOCIO-ECONOMIC EVALUATION AND DECISION ANALYSIS FRAMEWORK

The economic rationale for delineation of Integrated Unit of Analysis (IUAs), and available economic data describing the communities and economies of the Crocodile (West) Marico Water Management Area (WMA) and Matlabas and Mokolo catchments, was summarised per IUA. Initially this was undertaken on the existing 2001 Census data however the results were updated in April 2013 when the 2011 Census data became available.

Further analyses on the state of aquatic ecosystem services in the study area was undertaken, and a preliminary baseline value for determining the relationships between economic value, social well-being and ecosystem characteristics was determined.

One of the objectives of the Integrated Units of Analysis Delineation Report, RDM/WMA1,3/00/CON/CLA/0212, was a proposed decision-analysis framework for the analyses of scenarios in the latter steps of this project, thus linking the socio-economic and ecological value and condition of the relevant water resources.

The water resources of the study area are natural assets that produce raw water and other aquatic ecosystem services. The raw water is used as an input in economic production, whilst households often directly use the other aquatic ecosystem services. Various economic sectors produce a variety of goods and services, many of them consumed as intermediate goods and services, but ultimately consumed by households. Households provide labour to the economic production process. Finally, the economic production process also produces a variety of effluents, which end up back in the aquatic environment as pollutants.

Total economic production of goods and services, measured as Value Added (VAD)[1], was approximately R550 billion in 2011. In contrast, the value of aquatic ecosystem services in that year was estimated at only R1, 983 million, thus contributing less than 1% of the value added to the economy of the study area. However, this aquatic ecosystems valuation excludes a number of important transactions relating to water resources. Firstly, two key ecosystem services were inadequately captured in the analyses: water regulating services and health services. Secondly, the damaging effects of emissions in the form of water pollutants and sedimentation emitted into aquatic ecosystems (i.e. water resources) are key environmental externalities and have thus far not been addressed. Another externality not dealt with is the conservation cost of aquatic ecosystem stewardship function. It is also important to note that these figures are estimations at present and will be updated in subsequent phases of the project.

In order to internalise the environmental costs and benefits into the production economy (and thus link the socio-economic and ecological value and condition of the relevant water resources), the relevant transactions can be modelled using four economic modelling techniques schematically shown in Figure 6. These techniques, together, form the decision-analysis framework:

- Social Accounting Matrixes (SAMs), obtained from the Development Bank of Southern Africa (DBSA), model the transactions between economic production sectors and household consumption.
- Environmental Economic Accounts for Water (Water EEAs) model the transactions between economic production and water resources (and expands the Water sector component of the SAM).
- Environmental and Resource Economics (ERE) modelling, based on the Millennium Ecosystem Assessment framework, models the production of aquatic ecosystem services.
- The effects of water pollutants on water resources and households can be modelled in various ways, however in this case; we will simulate the economic effects of implementing a Waste Discharge Charge System (WDCS).

This decision-analysis framework lends itself to a cost-benefit analysis (CBA) for evaluating scenarios.

[1]Akin to Gross Domestic Product (GDP), and is formally defined as the sum of labour, company profits, taxes paid and interest earned.

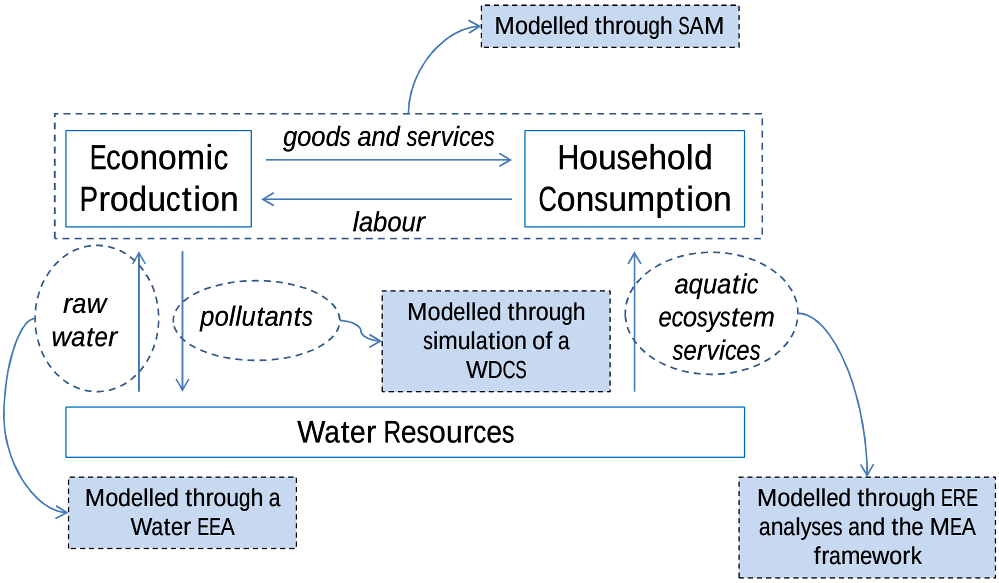


Figure 6: Schematic representation of the economic modelling techniques required to address the transactions of the Crocodile (West), Marico, Matlabas and Mokolo catchments, water economy

4.5 ECOLOGICAL WATER REQUIREMENTS QUANTIFICATION

The classification process requires the quantification of ecological water requirements (EWRs) that have either been determined through previous Reserve studies or through Reserve determination processes that would need to be investigated for the purpose of classification. However, in the case of an existing preliminary Reserve in some instances an extrapolation process would be required, and if necessary, high confidence EWR data collected.

The process followed in terms of quantification of EWRs and EGSA changes is that described in the WRCS Guidelines, Volumes 1 and 2 (Overview and the 7-step classification procedure; and Ecological, hydrological and water quality guidelines for the 7-step classification procedure) (DWA, February 2007a and 2007b).

In terms of the RDM data required as part of the WRCS process the available ecological/EWR information was assessed and the information required for the determination of the catchment configuration scenarios presented. This RDM data included the:

- Final identified nodes (hydro nodes) based on either management or biophysical considerations;
- EWR information available from previous Reserve determination studies;
- Additional rapid Reserve determination studies undertaken to enhance the existing information;
- Extrapolation of existing and new EWR results to all the identified hydro nodes;
- Development of the rule curves, summary tables and modified time series at each hydro node for use in the Water Resources Yield or Planning models during the scenario analysis; and

- EGSAs changes at the established EWR sites and at biophysical nodes to which Reserve data can be extrapolated.

EWR Quantification

A number of Reserve studies were undertaken at various levels of detail. The most significant were the intermediate studies initiated in 2009 and completed in 2012 for the Crocodile West/Marico WMA and during 2009 to 2011 for the Mokolo catchment (**Table 4**). No Reserve study was undertaken in the Matlabas catchment.

Table 4: Information on previous Reserve studies in the catchments of the study area

EWR site	River	Quaternary catchment	PES	EIS	REC	nMAR[(1)] ($10^6 m^3$)	%EWR	Level
CROCODILE WEST								
EWR 1	Crocodile: Upstream of the Hartbeespoort Dam	A21H	*D*	Moderate	D	87.8*	24.07	Intermediate
EWR 2	Jukskei: Heron Bridge School	A21C	*E*	Moderate	D	34.4*	29.19	Intermediate
EWR 3	Crocodile: Downstream of Hartbeespoort Dam in Mount Amanzi	A21J	*C/D*	High	C/D	153.6	25.02	Intermediate
EWR 4	Pienaars: Downstream of Roodeplaat Dam	A23B	*C*	High	C	28.2	20.98	Intermediate
EWR 5	Pienaars/Moretele: Downstream of the Klipvoor Dam in Borakalalo National Park	A23J	*D*	High	C	113.0	11.82	Intermediate
EWR 6	Hex: Upstream of Vaalkop Dam	A22J	*D*	Moderate	D	26.9	14.96	Intermediate
EWR 7	Crocodile: Upstream of the confluence with theBierspruit	A24C	*D*	Moderate	D	463.4	9.14	Intermediate
EWR 8	Crocodile: Downstream of the confluence with the Bierspruit in Ben Alberts Nature Reserve	A24H	*C*	Moderate	C	559.9	14.22	Intermediate
Rapid EWR 9	Magalies: Downstream of Malony's Eye	A21F	*B*	Very high	B	14.7	45.58	Rapid 3
Rapid EWR 10	Elands: Upstream Swartruggens Dam	A22A	*C*	High	B/C	10.1	30.48	Rapid 3
Rapid EWR 11	Sterkstroom: Upstream Buffelspoort Dam	A21K	*C*	High	C	14.0	28.41	Rapid 3
MARICO								
EWR 1	Kaaloog-se-Loop: Below gorge	A31A	*B*	Very high	B	10.539	76.32	Intermediate

EWR site	River	Quaternary catchment	PES	EIS	REC	nMAR(1) (10^6m^3)	%EWR	Level
EWR 2	Groot Marico: Upstream confluence with Sterkstroom	A31B	*B*	Very high	B	42.08	50.26	Intermediate
EWR 3	Groot Marico: Downstream Marico Bosveld Dam	A31F	*C/D*	High	C/D	65.083	23.62	Intermediate
EWR 4	Groot Marico: Downstream Tswasa Weir	A32D	*C*	High	C	153.251	7.96	Intermediate
EWR 5	Klein Marico downstream Klein Maricopoort Dam	A31E	*C*	Moderate	C	29.8	4.67	Rapid 3
EFR M8	Molopo: Wetland	D41A	*C*	-	-	-	-	-
MOKOLO								
EWR 1a	Mokolo: Vaalwater	A42C	*C/D*	High	B/C	84.84	22.6	Intermediate
EWR 1b	Mokolo: Tobacco	A42E	*B/C*	High	B	135.03	17.6	Intermediate
EWR 2	Mokolo: Ka'ingo	A42F	*B/C*	Very high	B	196.2	19.8	Intermediate
EWR 3	Mokolo: Gorge	A42G	*B/C*	Very high	B	214.5	12.5	Intermediate
EWR 4	Mokolo: Malalatau	A42G	*C*	Very high	B	253.3	16.5	Intermediate
EWR 5	Mokolo: Tambotie floodplain	A42G	*D*	-	-	-	-	-

1) nMAR – Natural Mean Annual Runoff is based on the updated hydrology from the DWA 2010and 2011 studies
* EWRs based on present day flows due to increased flows

After assessment of existing data additional Rapid III Reserve determination studies were undertaken in the Crocodile West/Marico WMA to enhance the existing information and to enable the extrapolation of EWRs to all the identified hydro nodes.

Four EWR sites were identified in the Matlabas catchment on which Rapid Reserve studies were undertaken to provide the necessary information for the WRCS.

Table 5 summarises those sites which were selected for additional Rapid Reserves. Rapid III Reserve determination studies were carried out for all the sites except for Matlabas sites 2, 3 and 4 for which limited data was available.

Table 5: Selected EWR sites for additional rapids undertaken

EWR site	Quaternary catchment	River	Level of determination	Latitude	Longitude	Eco-region level 2	MAR ($10^6 m^3$)
CROCODILE WEST							
EWR 12	A23G	Buffelspruit	Rapid III	-24.8304	28.2224	8.01	3.144
EWR 13	A22E	Elands	Rapid III	-25.48108	26.69039	7.03	18.77
EWR 14	A22H	Waterkloofspruit	Rapid III	-25.48108	26.69039	8.05	5.469*
EWR 15	A21F	Magalies	Rapid III	-25.89690	27.59820	7.04	21.89
EWR 16	A21A	Rietvlei	Rapid III	-26.01885	28.30442	11.01	4.788
MARICO							
EWR 6	A31B	Polkadraaispruit	Rapid III	-25.64697	26.48928	7.04	9.866
MATLABAS							
EWR 1	A41A	MatlabasZynKloof	Rapid III	-24.41203	27.60324	7.04	5.23
EWR 2	A41B	Matlabas Haarlem East (A4H004)	Rapid II	-24.160139	27.4797111	1.03	32.80
EWR 3	A41B	Mamba River Bridge	Rapid II	-24.2127	27.50718	1.02	9.54
EWR 4	A41C	MatlabasPhofu	Rapid I	-24.05159	27.35922	1.02	35.58

Initial hydro nodes were selected as part of the IUA report and summarised rationale per IUA provided. After field visits and consideration of the groundwater zones, wetland areas and requirements for the model, the identified hydro nodes have been updated slightly throughout the study area and are reflected in the map, together with the EWR sites (from the previous Reserve studies and additional Rapid sites).

The rules as determined during the initial Reserve studies to obtain the ecological requirements were used for the existing EWR sites and where applicable for estimation and/or extrapolation to other areas. The existing hydraulic profiles were used during a specialist workshop to confirm the flows and determine possible ecological consequences of the various flow scenarios at selected EWR sites during this step of scenario evaluation.

The information generated from the update of the Present Ecological State (PES), Ecological Importance (EI) and Ecological Sensitivity (ES) study (DWA, 2012) was used where applicable.

Quantification of the changes in Ecosystem Goods, Services and Attributes (EGSAs)

Based on the above established EWR sites and identified biophysical nodes to which Reserve data can be extrapolated, the changes in relevant ecosystem aspects as they related to identified EGSAs for the Crocodile (West), Marico, Matlabas and Mokolo catchments were assessed.

The relevant EGSAs for the WMA are listed with the RDM aspects to be considered. The possible ecosystem changes as they relate to the EGSAs and RDM aspects were then described. The EGSAs considered for the Crocodile (West), Marico, Matlabas and Mokolo catchments are listed in

Table 6 and the EGSAs considered for the Crocodile (West), Marico, Matlabas and Mokolo catchments for wetlands are indicated in Table 7 .

Table 6: EGSAs considered for the Crocodile (West), Marico, Matlabas and Mokolo catchments for rivers

Ecosystem Service	Description of Value	Aspects Considered	Output from RDM studies
Domestic water use	Subsistence use of water	Loss of river use: Replacement cost of water shipped via containers	Yield model – changes in yield/supply Water quality – change fitness for use
Grazing	Grazing	Loss of available grazing land: Replacement cost of buying fodder in winter months	Loss of riparian habitat (non-flow) – index of change
Livestock watering	Livestock watering	Replacement cost of boreholes	Drought and maintenance low flows
Harvested products	Sand & clay	Building sand & clay for making bricks/households	Loss of riparian habitat (non-flow) and in-stream habitat
	Fuel wood	Amount harvested/ households	Loss of riparian habitat (non-flow) – index of change
	Raw Materials	Amount harvested/ households	
	Wild foods & medicines	Amount harvested/ households	
	Hunting	Amount harvested/ households	Not provided
	Fishing	Amount harvested/ households	Index of change in abundance (non-flow)
Water regulation		Maintenance of base flows	Yield model (EWR)
Carbon Sequestration	Riparian vegetation has the ability to store carbon	Amount of riparian habitat	Not provided
Tourism	Rafting, adventure tourism	Benefits accrued by tourism operators	Hydraulics/Yield model
Aesthetic value	House prices	Amount of houses near rivers and wetlands	Ecostatus
Education	Peer reviewed journal output	Peer reviewed journal subsidy	Not provided

Table 7: EGSAs considered for the Crocodile (West), Marico, Matlabas and Mokolo catchments for wetlands

Ecosystem Service	Description of Value	Aspects Considered	RDM output
Livestock watering	Livestock watering	Replacement cost of boreholes	Drought and maintenance low flows
Harvested products	Sand & clay	Building sand & clay for making bricks/households	Loss of riparian habitat (non-flow) and in-stream habitat
	Fuel wood	Amount harvested/households	Loss of riparian habitat (non-flow) – index of change
	Raw Materials	Amount harvested/households	
	Wild foods & medicines	Amount harvested/households	
	Hunting	Amount harvested/households	Not provided
	Fishing	Amount harvested/households	Index of change in abundance (non-flow)
Flood attenuation	Ability of wetlands to lessen the impact of flooding	Replacement cost from flood damage	EWR High flows
Groundwater recharge	Ability of wetlands to contribute to groundwater recharge. Utilised through boreholes and wells during dry months	Replacement cost of dam construction	Baseflow contribution
Water purification	Wetlands absorb and breakdown organic and inorganic pollutants	Treatment cost abatement curve	Water Quality – change in fitness for use
Carbon Sequestration	Wetlands seen as a carbon sink	Amount of carbon sequestered by different wetland types	Not provided
Angling	Freshwater angling.	Value of trout industry and other fishing industries	Hydraulics/Yield model
Tourism	Ecotourism value	Tourism market sizing	Not provided

4.6 GROUNDWATER COMPONENT

Classification of the significant groundwater resources in Crocodile (West), Marico, Mokolo and Matlabas catchments has been proposed using groundwater related information obtained from assessments done on groundwater quality, groundwater recharge values (based on information from GRA II, Groundwater Reserve Determinations (Limpopo and Crocodile West & Marico)) and groundwater use information obtained from the August 2008 and recently, the January 2013 WARMS Update.

A stress index based on groundwater recharge and use was calculated for the groundwater component in the IUA's and represents the groundwater quantity specification of the management class. Secondly, the groundwater quality of the IUA's was statistically assessed and specific groundwater quality criteria were applied. In the water quantity classification a "present category (impacted)" is applied to include a factor based on the interpreter's groundwater experience of a specific IUA.

Procedure used to classify the groundwater

The procedure to determine the groundwater classes was done in accordance with the 7-step process used for surface water resources with some slight modifications as described below.

Groundwater management units were established and incorporated into units of analysis (Step 1). The initial boundaries of the units of analysis for these cases were altered to fit the flow regime of a group of groundwater resource units (GRU's). A GRU is regarded as a groundwater body having unique hydrogeological characteristics such as a dolomitic compartment. A group of GRU's represents a groundwater management unit (GMU). The next category of grouping represents a groundwater management area (GMA) and generally coincides with surface catchments such as the quaternary catchments or dolomite compartment boundaries formed by impermeable dykes. A GMA generally includes more than one GMU. The dolomite aquifers (all grouped as groundwater management units) were treated as special cases due to their unique boundary conditions and flow patterns. A GMA based on dolomite compartment boundaries may therefore not coincide with the quaternary catchment as is the case in Crocodile (West) and Marico catchments. The dolomite based GMA's were grouped with other significant non-dolomitic aquifer systems (demarcated by quaternary catchment boundaries) and represents the integrated groundwater units in the IUA. For the non-dolomite aquifer systems, it was decided to group the aquifer systems into the surface water catchment (viz. quaternary catchments) as all the water resources needs to fit into an established geometrical context.

In relation to the groundwater component, linking the socio-economic and ecological value and condition of the water resources (Step 2) refers to the spectrum of groundwater users and their dependence on the water resource. Several categories of significant water users were noted in terms of volume of which: (i) bulk domestic water supplies to communities and villages, (ii) water supply to irrigation schemes, and (iii) mining/industrial applications (e.g. dewatering and use) represents the larger bulk water use components. Schedule 1 (S1) water users represent the remaining component of the water use component of each IUA. Two aquifer systems in terms of the potential are present in the study area and provide substantial volumes of water to sustain the socio-economic values brought about due to their sustainable yields. These are the dolomite aquifer systems and alluvial aquifer systems along the major river systems; the so-called inter-granular alluvial aquifer systems limited to the main river stems: the related dolomite aquifer systems probably represent the most important component of the water resources classification requirement in this regard. The conditions of dolomite aquifer systems are naturally of a good quality and due to their high level of flushing during wet climate cycles (i.e. high recharge rates) they tend to remain in this state. Being the sole water source for many dolomite eyes in the Crocodile (West) and Marico catchments the socio-economic and ecological value will be high compared to the non-dolomite resources in the region. The water supplies from these systems are high in demand and sustainable quality is a concern since they form part of many headwater reaches of the large surface watercourses such as the Marico and Crocodile (West) Rivers. The dolomite aquifer systems have been categorised as significant aquifer systems and their importance was incorporated into the management class classification by empirical interpretation.

In terms of the condition (water quality and quantity) of the remaining non-dolomite groundwater resources in the Crocodile (West), Marico, Matlabas and Mokolo catchments, and especially the Crocodile (West) and Marico catchments, many local aquifers supply water for domestic requirements.

Step 3 relates to quantifying the ecological water requirements and changes in non-water quality ecosystem goods, services and attributes. The headwater regions of the dolomite aquifer systems are particularly important in driving the dolomitic eyes that support and maintain the ecological requirements of surface water systems further downstream. In several cases, for example Grootfontein Eyes at Rooigrond, abstraction from the eye via boreholes has dropped the eye's water table and stopped the decanting resulting in a total collapse of the ecology (running dry) further downstream. If water from the compartment feeding the eye is required for future domestic supplies, special arrangements to keep the eye's flow and ecological flow support intact will need to be exercised.

Steps 4 and 5 relate to the determination of an ecologically sustainable base configuration (ESBC) scenario and evaluation of scenarios within the integrated water resource management (IWRM) process respectively. The groundwater component in terms of areas/sections of surface water drainages where groundwater-surface water interaction occurs were identified and included in the ESBC.

From a groundwater perspective, the most vulnerable aquifer systems in the Crocodile (West), Marico, Matlabas and Mokolo catchments are the southern dolomitic aquifer systems in terms of annual recharge (sustainable yields during low-rainfall seasons) and long-term water quality (highly vulnerable to pollution). Water supplies to the Mahikeng area (Molopo River) are critical and water table depletion in the Grootfontein Eye region has been noted. This has a significant effect on the sustainable yield of the Grootfontein Water Scheme.

In terms of non-dolomitic aquifer systems, the development of coal mines in the lower reaches of the Mokolo and Matlabas Rivers has been addressed as a scenario with possible impacts on the local surface and groundwater resources. The impact(s) however will be localised, but management thereof will be required through dedicated monitoring and auditing.

Defining stress

The concept of stressed water resources is addressed by the NWA, but is not defined. Part 8 of the Act gives some guidance by providing the following qualitative examples of 'water stress':

- Where demands for water are approaching or exceed the available supply.
- Where water quality problems are imminent or already exist.
- Where water resource quality is under threat.

The groundwater stress index reflects water availability versus water used. Groundwater use should include water utilised by current water users, water required to sustain the Reserve as well as for BHN. The Stress Index for an assessment area is defined as follows:

$$SI(\%) = \frac{gwUse}{Recharge} \times 100$$

Where:

gwUse = Current groundwater use

Recharge = Recharge (as a volume)

In calculating the Stress Index, the variability of annual recharge is taken into account in the sense that not more than 65%[1] of average annual recharge can be allocated on a catchment scale).

PRESENT CATEGORY	DESCRIPTION	COMPLIANCE (SPATIAL/TEMPORAL)
I	Minimally used	≤20%
II	Moderately used	20% – 65%
III	Heavily used	> 65%

A guide for quantifying groundwater use is documented below.

ACTIVITY	PERCENTAGE OF RECHARGE
Small scale utilisation: Schedule 1 water uses, viz. stock watering, farm domestic water supply, rural water supply and irrigation for household food supplies;	Use ranges between 5% and 20% of recharge
Medium scale utilisation: Small-scale commercial irrigation, small scale industries, rural water supply, water supply to villages and small towns; and	Use ranges between 20% and 40% of recharge
Large-scale utilisation: Large scale mining/industries, water supply to cities, water supply for large rural communities, medium to large towns, large-scale commercial irrigation.	Use ranges between 40% and 65% of recharge

[1] 65% of the average annual recharge is available for full abstraction; based on values (66%) used for the Harvest Potential (Baron and Seward, 2000) initially as a norm to sustain base flow support, climate and recharge variability.

Baseline class

Defining the point at which a resource is no longer being used in a sustainable manner is generally very difficult. The level of sustainability probably fluctuates through time, and impacts from over-use could manifest themselves sometime after the impact was caused. The change from sustainable use to over-use is gradual, and not necessarily marked by some distinct change. Indicators of quantitative unsustainable groundwater use include:

- Land subsidence or sinkhole formation.
- Long-term declining water levels on a regional level.
- Long-term declining water quality levels.
- Periodic deterioration of water quality (salinity) and quantity (aquifer saturation levels) during periods of drought impacted by large-scale use on small scale users (viz. Schedule 1 and General Authorizations).

A guide for assessing the status of groundwater units based on **observed impacts** resulting from groundwater abstraction is presented below.

PRESENT CATEGORY	GENERIC DESCRIPTION	AFFECTED ENVIRONMENT
Minimally used (I)	The water resource is minimally altered from its pre-development condition	No sign of significant impacts observed
Moderately used (II)	Localised low level impacts, but no negative effects apparent	Temporal, but not long-term significant impact to: – spring flow – river flow – vegetation – land subsidence – sinkhole formation – groundwater quality
Heavily used (III)	The water resource is significantly altered from its pre-development condition	Moderate to significant impacts to: – spring flow – river flow – vegetation – land subsidence – sinkhole formation – groundwater quality

In the Crocodile West Catchment, most of the IUA's are classified as Class II impacted categories with water quality classifications of Class I and Class II. Some of the IUA's includes large dolomite aquifer systems (Class II on quantity, but Class I on quality) which contain significantly large volumes of good quality water. Stress indices of 50% were calculated.

In the Marico Catchment, the impacted groundwater quantity categories are mostly Class I (only two Class II) and the groundwater quality category mostly Class I. This catchment contains large dolomite aquifer systems towards the south with stress indices between 16 and 21%.

The Eastern Kalahari Catchment (Upper Molopo River) contains a large dolomite aquifer system (Bo Molopo Dolomite Aquifer System) which is categorised as a Class III due to significant over-abstractions (Grootfontein Scheme), although the water quality classification is Class I. This catchment is significantly stressed in terms of water quantity (105%) and mitigation needs to be implemented.

In the Mokolo Catchment, the present impacted groundwater categories (stress index) are Class I and Class IIs and the groundwater quality categories are Class II and Class III's, mainly due to the poor groundwater quality (geological formations).

In the Matlabas Catchment, the impacted groundwater categories (stress index) are all Class I's and the groundwater quality categories are Class II and Class III's. The groundwater quality in this catchment is poor due to natural conditions (geological formations) and impacts on the actual use of groundwater (very low stress indexes).

Table 8 sets out the proposed groundwater classification based on the stress index, present category, present category impact and present category quality.

Table 8: proposed groundwater classification categorisation for each IUA in the study area

	IUA (Catchment)	Stress Index (SI)	Present Category (SI)	Present Category (Impact)	Present Category (Quality)	Protocols: [1] Groundwater Compliance Monitoring [2] Ecological Management Requirements	% contribution to achieving the recommended MC
Mokolo Catchment	IUA15 (A42A & B-F)	27%	**II**	**I**	**II**	[1]_ Sustainability of resources in close proximity of rivers with base flow requirements reviewed. [2]_EWR's: 1A, 1B, 2 & 3: 0.8Mm^3, 1Mm^3, 6Mm^3/a and 5.2Mm^3/a. This reserve needs to be managed (DWA, 2011).	10%
		19%	**I**	**I**	**II**		
	IUA16 (A42G & H, J)	1%	**I**	**I**	**III**	[1]_ Required for management of groundwater resources (Groundwater quality is a concern and needs to be monitored prior to developments). [2]_ EWR 4: 11.4Mm^3/a. To be managed due to future impacts of mining activities (DWA, 2011).	20%
		7%	**I**	**II**	**III**		
Matlabas Catchment	IUA 17a (A41A & B)	5%	**I**	**I**	**-**	[1]_Sustainability to be confirmed by recharge frequency monitoring; low ground water use. Assessment of poor ground water quality required (geological?). Sustainability of resources close to drainage systems reviewed. [2]_No EWR. High ecological requirement in drainages (25% of ground water recharge) and should be reserved.	5%
	IUA 17b (A41C & D & E)	11%	**I**	**I**	**III**	[1]_Expansion of ground water quality evaluation (hydrocensus) and monitoring required. Groundwater potential high, baseline monitoring required to support management of groundwater resources in light of developments of the Lephalale Coalfields. [2]_No EWR. Base flow in drainages supported by	20%

	IUA (Catchment)	Stress Index (SI)	Present Category (SI)	Present Category (Impact)	Present Category (Quality)	Protocols: [1] Groundwater Compliance Monitoring [2] Ecological Management Requirements	% contribution to achieving the recommended MC
						local ground water resources; ecological requirement to be specified/ managed.	
Crocodile West Catchment	IUA 1	34%	**II**	**II**	**I**	[1]_Monitoring programmes for dolomite aquifer systems upgraded and reviewed. Localised pollution impacts on these aquifer systems to be investigated (especially impact from industries). [2]_EWR's 1, 2, 4 & R16: 42, 25, 2.8 & 0.2 Mm^3/a.	10%
	IUA 2	49%	**II**	**II**	**I**	[1]_Gwater monitoring programmes operational; needs to be assessed in terms of quality. Deterioration of Maloney's Eye needs to be noted (long-term SO_4 impact noted). [2]_EWR's R9 & R15: 46 &0.8Mm^3/a. Ecological requirement in the area immediately below Maloney's Eye to be reviewed; expecting base flow contribution from aquifer systems.	7%
	IUA 3	46%	**II**	**II**	**I**	[1]_Groundwater level monitoring programmes to be reviewed (quarterly interval). [2]_ EWR 3: 22Mm^3/a.	5%
	IUA 4	35%	**II**	**II**	**I**	[1]_Groundwater quality monitoring programme to be reviewed and upgraded (quarterly interval) due to high level of mining activities. [2]_EWR's 6, R11 & R14: 1.1, 1.2 & 0.4Mm^3/a.	9%
	IUA 5	14%	**I**	**II**	**I**	[1]_ Groundwater quality monitoring programme to be reviewed and upgraded (quarterly interval) due to high level of mining activities. [2]_EWR's R10 & R13: 0.6 & 0.5Mm^3.	5%

	IUA (Catchment)	Stress Index (SI)	Present Category (SI)	Present Category (Impact)	Present Category (Quality)	Protocols: [1] Groundwater Compliance Monitoring [2] Ecological Management Requirements	% contribution to achieving the recommended MC
	IUA 12	14%	I	I	II	[1]_Low impact on Groundwater resources. Groundwater use Groundwater monitoring programmes to be reviewed in terms of local uses. [2]_EWR 8: 52.06Mm^3/a.	20%
	IUA 13	41%	II	II	II	[1]_Groundwater stress index high (42%); Groundwater levels and quality monitoring need to be reviewed. [2]_EWR 7: 31.4Mm^3/a.	25%
	IUA 14	24%	II	II	II	[1]_Groundwater (levels and quality) to be reviewed in future (current status sufficient) [2]_EWR 5 & R12: 2.53 & 0.27Mm^3/a.	15%
Marico Catchment	IUA 6a	5.0%	I	I	I	[1]_Groundwater level and quality monitoring programme to be reviewed. Local mining and irrigation practices may impact the local resources required for domestic supplies. [2]_ EWR 2 & R6: 9.56Mm^3 & 0.14Mm^3/a; water requirements should be managed.	25%
	IUA 6b	16.0%	I	I	I	[1]_Groundwater level and quality monitoring programme to be reviewed. Local mining and irrigation practices may impact the local resources required for domestic supplies. [2]_ EWR 4 & R5: 6.1Mm^3, 0.6Mm^3 & 0.55Mm^3/a; water requirements should be managed.	10%
	IUA 7	5.4%	I	I	I	[1]_Groundwater level monitoring programme to be reviewed due to high impact on Grootpan dolomite aquifer system and long-term, sustainable	35%

	IUA (Catchment)	Stress Index (SI)	Present Category (SI)	Present Category (Impact)	Present Category (Quality)	Protocols: [1] Groundwater Compliance Monitoring [2] Ecological Management Requirements	% contribution to achieving the recommended MC
						management of resource. [2]_ EWR 1, 5.23Mm^3; water requirement should be managed.	
	IUA 8	21%	**I**	**II**	**I**	[1]_Groundwater monitoring programmes need to be reviewed; although moderate groundwater usage (SI-21%)' local resources may have breached the long-term sustainability. Sustainable management of resource required. [2]_No EWR. Significant impact on dolomite eyes supporting ecological requirements. Status of contribution to baseflow to be evaluated.	70%
	IUA 10	1.7%	**I**	**II**	**-**	[1]_Although SI is low (3.4%), supplies to the Dinokana area depends on the lomg-term sustainability of the Dinokana dolomite aquifer system. [2]_ No EWR. Significant impact on dolomite eyes supporting ecological requirements. Status of contribution to baseflow to be evaluated.	70%
	IUA 11a	5%	**I**	**I**	**II**	[1]_Almost natural conditions prevail; local groundwater status should be monitored for new developments. [2]_EWR 3: 6.7Mm^3/a.	20%
	IUA 11b	1.8%	**I**	**I**	**II**	[1]_ Almost natural conditions prevail; local groundwater status should be monitored for new developments. [2]_EWR 4: 6.1Mm^3/a.	20%
Cod	IUA 9- D41A (Dolomite Aqf.)	105%	**III**	**III**	**I**	[1]_Groundwater monitoring programmes for aquifer	-

	IUA (Catchment)	Stress Index (SI)	Present Category (SI)	Present Category (Impact)	Present Category (Quality)	Protocols: [1] Groundwater Compliance Monitoring [2] Ecological Management Requirements	% contribution to achieving the recommended MC
						system need to be reviewed in the light of localized over abstraction, viz. the Grootfontein dolomite aquifer system. [2]_No EWR; Groundwater contribution to the upper Molopo River from the Molopo Eye needs to be sustained/ managed.	
	IUA 9- D41A (Other Aqf.)	1.2%	**I**	**I**	**II**	[1]_Low groundwater use; limited monitoring required. [2]_No EWR: Groundwater contribution to baseflow not existing due to deep water table status (a result of low groundwater recharge status).	-
	IUA 9 (Summary)	72%	**III**	**III**	**II**		70%

4.7 WETLAND ASSESSMENT

A summary of the wetland types found and expected to occur in each IUA is provided in Figure 7. A few patterns emerge at this scale with peatlands associated predominantly with the dolomites which are restricted to IUAs 1, 4, 7, 8 and 9. Larger floodplains occur in IUAs 14 and 16 with floodplain systems also occurring along the Marico and Limpopo Rivers in IUAs 11b and 17b. Pans are common or occur in relatively high numbers, *albeit* of different types, in IUAs 1, 5, 9, 11b, 13 and 17b. IUAs with a high diversity of wetland types include IUA 1, 4, 5 and 15.

Based on the findings of this study, priority or important wetlands occur in a number of the IUA's, but most prominently in IAUs 1, 2, 4, 5, 7, 8, 9 10, 11b, 13, 14, 15, 16 and 17b.

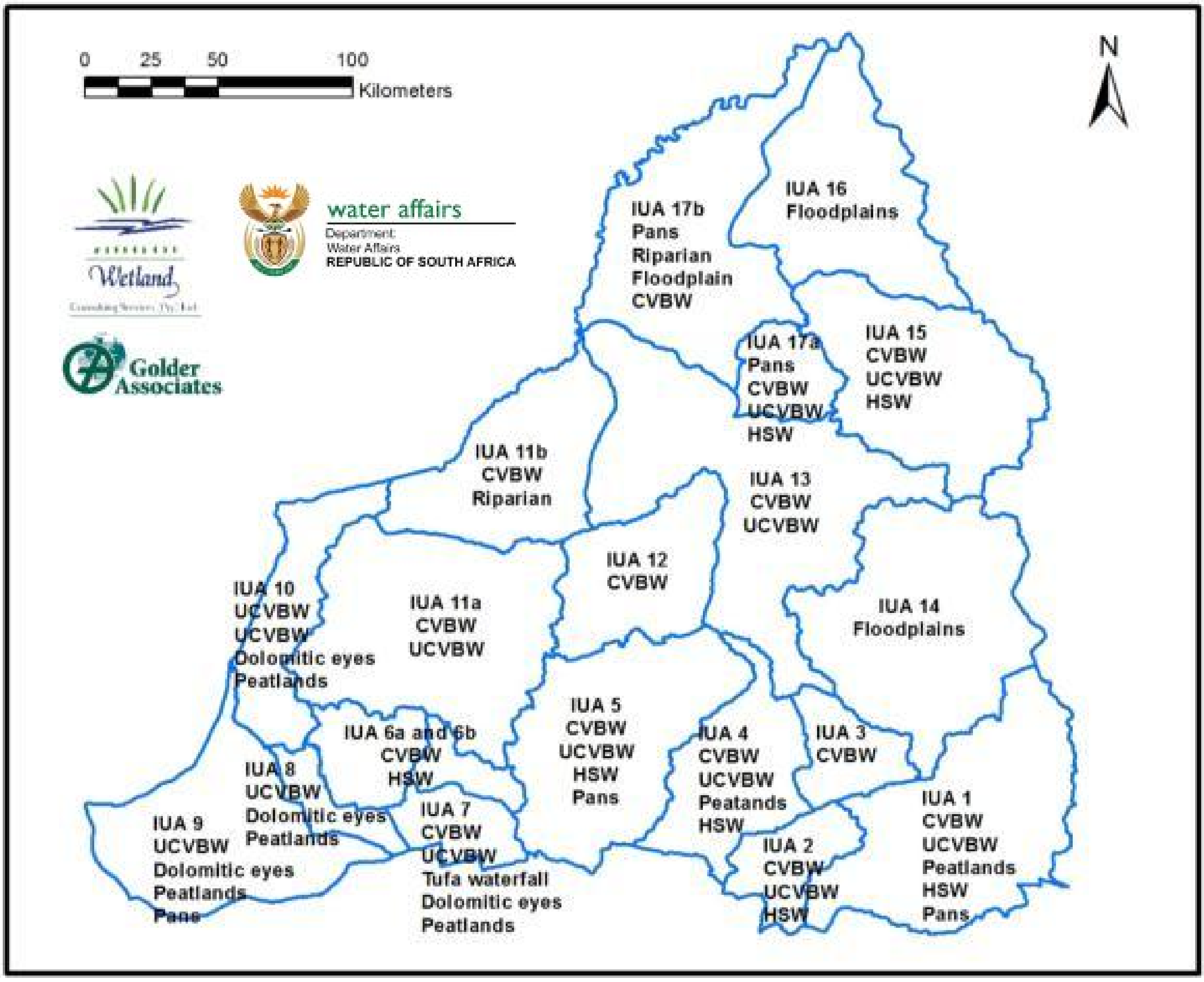


Figure 7: Map showing the main wetland types found and expected to occur in each IUA indicated as: CVBW – Channelled valley bottom wetland; UCVBW – Unchannelled valley bottom wetland; HSW – Hillslope seepage wetland; Pans; Dolomitic eyes; Peatlands.

It should be noted that there are likely to be other wetlands that have not been identified or covered as part of this study due to the level of investigation undertaken, the extent of the study area, the limited nature of field verification, and accuracy and level of detail of the information used to derive the wetland coverage. Some of these could also potentially rank as important and hence priority wetlands could potentially occur in the IUAs not specifically pointed out above.

Inherent in trying to assess the possible effects of different water use scenarios on wetlands is understanding the underlying drivers of the different wetland types that occur. For example, wetlands such as hillslope seepage systems that are maintained by interflow can be expected to respond separately to water use scenarios that may affect the river in the same catchment. Wetlands maintained by regional groundwater such as the dolomitic peatlands in certain of the IUAs, would also less likely be affected by surface water use scenarios, but certainly would be affected by future groundwater use scenarios. Floodplains will be more affected by changes to high flows or floods in most cases, but under certain circumstances elevated base flows too may have an effect through causing channel erosion which reduces the frequency of bank overtopping and hence leaving the floodplain drier for longer. These are some the factors that were considered in trying to understand how the future water use scenarios might affect the priority wetland systems identified (Table 9).

Table 9: Preliminary assessment of the likely changes relative to the desktop PES and preliminary REC that could be expected based on future use scenarios (derived from the Scenario Report) for the identified priority wetlands per IUA

Wetland	Type	PES	EIS	REC (Recommended Ecological Category)	Changes that may be expected based on the recommended scenarios from the Scenarios Report and general recommendations relating to trying to deal with these	% contribution to overall recommended MC
IUA 1						
-	Pans	C/D to E	Very High	Specific to individual pans	Not related to changes in flow in the rivers. Non-flow related impacts such as development within and adjacent to these systems poses a risk to the remaining systems. Flow related impacts will occur as a result of changes in hydrology mostly as a result of urban development, and in some cases agricultural, impacts in the catchments of these systems. Water quality impacts as a result of urban runoff and even intentional decant of industrial and sewage effluent into pans potentially pose a high risk to these systems in the long term. Maintaining water quality is a critical aspect in pans as this determines pan geochemistry which in turn drives the biodiversity aspects. Strict compliance monitoring will be required to ensure that the REC is achieved in the case of individual development assessments and applications.	**10%**
-	Valley bottom wetlands	A/B to D/E	Moderate	Specific to individual systems but should aim for at least the same as the PES or at least one category higher if possible	Increased return flows are likely to result in more water entering the systems. Higher baseflows can thus be expected which together with regular high flows due to an increase in runoff as a result of hardened catchment surfaces will promote erosion and scour of most of the systems. It will be very difficult to achieve the REC for most systems as a general deterioration in wetland condition throughout the urban areas is expected in the long-term.	
-	Hillslope seepage wetlands	C/D to E/F	High	Specific to individual systems	Not related to changes in flow in the rivers. Non-flow related impacts such as development within and adjacent to these systems poses a risk to the remaining systems. Flow related impacts will occur as a result of changes in hydrology mostly as a result of urban development, and in some cases agricultural, impacts in the catchments of these systems. Interruption of interflow and increased surface runoff as a result of the development of the local catchment that feed these systems therefore poses the main flow related threat to the remaining systems in the long-term. It will be very difficult to achieve the REC for most systems as a general deterioration in wetland condition throughout the urban areas is expected in the long-term.	
Rietvlei wetland complex	Peatland	C/D to D/E	High to Very High	Improvement from current PES of individual systems	Main risk to this system is groundwater abstraction. Rehabilitation has been implemented in parts of the system to try to improve the current condition. Waste water return flows from sewage treatment and increased peak flows as the upper catchment is developed could potentially pose a risk to the system in the long-term.	
Colbyn Valley wetland	Peatland	D	High to Very High	C/D	System is stable at present and no deterioration is expected as long as the rehabilitation structures at the key point of the system remain intact.	
IUA 2						

Wetland	Type	PES	EIS	REC (Recommended Ecological Category)	Changes that may be expected based on the recommended scenarios from the Scenarios Report and general recommendations relating to trying to deal with these	% contribution to overall recommended MC
-	Pans	-	High	Specific to individual pans	Not related to changes in flow in the rivers. Non-flow related impacts such as agricultural practices and development within and adjacent to these systems poses a risk to the remaining systems. Water quality impacts as a result of agricultural practices also potentially poses a high risk to these systems in the long term, although these effects are likely to have already occurred as the area is already farmed in most areas where pans occur. Maintaining water quality is a critical aspect in pans as this determines pan geochemistry which in turn drives the biodiversity aspects. Strict compliance monitoring will be required to ensure that the REC is achieved in the case of individual development assessments and applications.	7%
-	Valley bottom wetlands	-	Moderate	Specific to individual systems but should aim for at least the same as the PES or at least one category higher if possible	Increased return flows and the resulting higher base flows expected are likely to promote erosion and scour of most of the systems on the main rivers. Water quality changes may also occur depending on the risk of AMD entering the systems. It will be very difficult to achieve the REC for most systems along the main rivers as a general deterioration in wetland condition is expected in the long-term.	
-	Hillslope seepage wetlands	-	High	Specific to individual systems	Not related to changes in flow in the rivers. Non-flow related impacts such as development within and adjacent to these systems poses a risk to the remaining systems. Flow related impacts will occur as a result of changes in hydrology mostly as a result of urban development, and in some cases agricultural and mining related impacts in the catchments of these systems. Interruption of interflow and increased surface runoff as a result of the development of the local catchment that feed these systems therefore poses the main flow related threat to the remaining systems in the long-term.	
Maloney's eye	Dolomitic eye and peatland	B	Very High	Maintain (B)	Main risk to this system is groundwater abstraction and pollution.	
IUA 4						
Waterval Valley Bottom Mire (peatland)	Unchannelled valley bottom	-	Very High	Maintain	No risks expected as the system is at the head of the catchment within a nature reserve.	**14%**
IUA 5						
-	Pans	-	Very High	Specific to individual pans	Not related to changes in flow in the rivers. Non-flow related impacts such as agricultural practices within and adjacent to these systems poses a risk to the remaining systems. Water quality impacts as a result of agricultural practices also	**20%**

Wetland	Type	PES	EIS	REC (Recommended Ecological Category)	Changes that may be expected based on the recommended scenarios from the Scenarios Report and general recommendations relating to trying to deal with these	% contribution to overall recommended MC
					potentially poses a high risk to these systems in the long term, although these effects are likely to have already occurred as the area is already farmed in most areas where pans occur. Maintaining water quality is a critical aspect in pans as this determines pan geochemistry which in turn drives the biodiversity aspects. The application of buffer zones around the wetlands could be considered if the objective is to improve the current state of the systems.	
-	Valley bottom wetlands	-	Moderate	Specific to individual systems but should aim for at least the same as the PES or at least one category higher if possible	No flow related impacts are expected at this stage based on the Scenarios Report. At least maintain the *status quo.* The application of buffer zones around the wetlands could be considered if the objective is to improve the current state of the systems.	
-	Hillslope seepage wetlands	-	High	Specific to individual systems but should aim for at least the same as the PES or at least one category higher if possible	Not related to changes in flow in the rivers. At least maintain the *status quo.* The application of buffer zones around the wetlands could be considered if the objective is to improve the current state of the systems.	
IUA 7						
-	Valley bottom wetlands	C/D	Moderate to High	Specific to individual systems but should aim for at least the same as the PES or at least one category higher if possible	No flow related impacts are expected at this stage based on the Scenarios Report. At least maintain the *status quo.* The application of buffer zones around the wetlands could be considered if the objective is to improve the current state of the systems.	**30%**
-	Pans	D	High	Specific to individual pans	Not related to changes in flow in the rivers. Non-flow related impacts such as agricultural practices within and adjacent to these systems poses a risk to the remaining systems. Water quality impacts as a result of agricultural practices also potentially poses a high risk to these systems in the long term, although these effects are likely to have already occurred as the area is already farmed in most areas where pans occur. Maintaining water quality is a critical aspect in pans as this determines	

Wetland	Type	PES	EIS	REC (Recommended Ecological Category)	Changes that may be expected based on the recommended scenarios from the Scenarios Report and general recommendations relating to trying to deal with these	% contribution to overall recommended MC
					pan geochemistry which in turn drives the biodiversity aspects. The application of buffer zones around the wetlands could be considered if the objective is to improve the current state of the systems.	
-	Tufa waterfall	B	Very High and very sensitive to water quality changes	Maintain	Main risk to this system is groundwater abstraction and pollution or changes in water quality which could potentially affect the process of tufa formation/deposition. Site specific management measures would also help to ensure the continued protection of this system.	
Marico eye	Valley bottom Peatland	B/C	Very High	Maintain	Main risk to this system is groundwater abstraction and pollution . Site specific management measures would also help to ensure the continued protection of this system.	
IUA 8						
Malmanie Loop	Valley bottom mire or peatland	B to C/D	Very High	Maintain	Main risk to this system is groundwater abstraction and pollution . Future groundwater use will potentially pose a high risk to this system. Any applications for further groundwater use in the area will need to consider the impacts on this system, both from an EIA and WUL perspective, and strict licensing conditions including monitoring of the system should apply. It is recommended that a Wetland Reserve is undertaken for this system. Site specific management measures would also help to ensure the continued protection of this system.	**30%**
IUA 9						
-	Pans	-	High	Specific to individual pans	Not related to changes in flow in the rivers. Non-flow related impacts such as agricultural practices within and adjacent to these systems poses a risk to the remaining systems. Water quality impacts as a result of agricultural practices also potentially poses a high risk to these systems in the long term, although these effects are likely to have already occurred as the area is already farmed in most areas where pans occur. Maintaining water quality is a critical aspect in pans as this determines pan geochemistry which in turn drives the biodiversity aspects. The application of buffer zones around the wetlands could be considered if the objective is to improve the current state of the systems.	**25%**
-	Pans	-	High			
-	Valley bottom wetlands	-	Moderate	Specific to individual systems but should aim for at least the same as the PES or at least one category higher if possible	No flow related impacts are expected at this stage based on the Scenarios Report. At least maintain the *status quo.* The application of buffer zones around the wetlands could be considered if the objective is to improve the current state of the systems.	
-	Valley bottom wetlands	-	Moderate			
Molopo	Unchannelled valley bottom wetlands and peatlands	B to D	Very High	Maintain	Main risk to this system is groundwater abstraction and pollution . Future groundwater use will potentially pose a high risk to this system. Any applications for further groundwater use in the area will need to consider the impacts on this system, both from an EIA and WUL perspective, and strict licensing conditions including monitoring	

Wetland	Type	PES	EIS	REC (Recommended Ecological Category)	Changes that may be expected based on the recommended scenarios from the Scenarios Report and general recommendations relating to trying to deal with these	% contribution to overall recommended MC
					of the system should apply. It is recommended that a Wetland Reserve is undertaken for this system. Site specific management measures would also help to ensure the continued protection of this system.	
Bodibe peatland	Unchannelled valley bottom wetlands	E/F	Very High	System is lost	System is essentially lost and without reinstating the groundwater that drives the system it will not recover and will continue to burn until all the peat is lost.	
IUA 10						
Ngotwana Wetland	Unchannelled valley bottom wetland and spring	B to D/E	High to Very High	Specific to individual systems within the complex but should aim for at least the same as the PES or at least one category higher if possible	No flow related impacts are expected at this stage based on the Scenario Report. At least maintain the *status quo.* As a non-flow related intervention, it is recommended that a rehabilitation plan is developed and implemented for this system in consultation with the local community. The plan should address the erosion at the head of the system and make a provision, not only for structural interventions, but also the development of a grazing management plan for the system and its catchment.	**15%**
Dinokana eye and Wetland	Unchannelled valley bottom, spring and hillslope seepage wetlands	C to D/E	High to Very High	Maintain C and improve D/E	Main risk to this system is groundwater abstraction and pollution. Future groundwater use will potentially pose a high risk to the eye. Any applications for further groundwater use in the area will need to consider the impacts on this system, both from an EIA and WUL perspective, and strict licensing conditions including monitoring of the system should apply. It is recommended that a Wetland Reserve is undertaken for this system. Site specific management measures would also help to ensure the continued protection of this system.	
IUA 11b						
Lower Marico River	Riparian zone and floodplains	B to D	Very High	Specific to individual systems but should aim for at least the same as the PES or at least one category higher if possible	Not clear what the effect of the recommended scenario will be on this system. It is assumed that no flow related impacts will be expected at this stage based on the Scenario Report which would mean at least maintaining the *status quo.* It is however recommended that further studies are undertaken on this system to get a better understanding of the flow related changes that have occurred in the system and what the current trajectory of change is in order to better evaluate the impact of implementing the recommended scenario on the system.	**5%**
Lengope la Kgamanyane River	Floodplain	C	High	Maintain (C)	It is assumed that no flow related impacts will be expected at this stage based on the Scenario Report which would mean at least maintaining the *status quo.* It is however recommended that further studies are undertaken on this system to get a better understanding of the system, its extent and key hydrological drivers and what the current trajectory of change is in order to better evaluate the impact of implementing the recommended scenario on the system.	

Wetland	Type	PES	EIS	REC (Recommended Ecological Category)	Changes that may be expected based on the recommended scenarios from the Scenarios Report and general recommendations relating to trying to deal with these	% contribution to overall recommended MC
Lenkwane River	Floodplain	C	High	Maintain (C)	It is assumed that no flow related impacts will be expected at this stage based on the Scenario Report which would mean at least maintaining the *status quo.* It is however recommended that further studies are undertaken on this system to get a better understanding of the system, its extent and key hydrological drivers and what the current trajectory of change is in order to better evaluate the impact of implementing the recommended scenario on the system.	
-	Pans	B to D	High to Very High	Specific to individual pans	Not related to changes in flow in the rivers. Non-flow related impacts such as agricultural practices within and adjacent to these systems poses a risk to the remaining systems. Water quality impacts as a result of agricultural practices also potentially poses a high risk to these systems in the long term, although these effects are likely to have already occurred as the area is already farmed in most areas where pans occur. Maintaining water quality is a critical aspect in pans as this determines pan geochemistry which in turn drives the biodiversity aspects. The application of buffer zones around the wetlands could be considered if the objective is to improve the current state of the systems,	
IUA 13						
Sections of the Crocodile River	Riparian zone, off-channel wetlands, backwaters and floodplains	B to D	High	Specific to individual systems but should aim for at least the same as the PES or at least one category higher if possible	Increased baseflows are expected which could potentially promote erosion and scour of the channel. This could affect the frequency of overtopping and hence wetting of the off-channel wetlands and floodplain features during high flows. The scenario with respect to high flows required for overtopping are unclear. It may thus be difficult to achieve the REC for most systems as a general deterioration in associated wetland condition could be expected in the long-term.	**7%**
IUA 14						
Moretele River floodplain	Floodplain	D to E	Very High	C/D	Increased return flows will result in more water entering the system. Higher baseflows can thus be expected which together with regular high flows due to an increase in runoff as a result of hardened catchment surfaces will promote erosion and scour in the system. Increased channel incision could affect the frequency of overtopping onto the floodplain during high flows. Management of Roodeplaat Dam under the future water use scenario could further impact on middle-order flood events which are required for maintaining the floodplain system. There are likely to be less of these getting through to the floodplain. This together with increased baseflows is likely to have a significant negative effect on the floodplain system . It will thus be very difficult to achieve the REC or even maintain the current PES for the system as a general deterioration in wetland condition is expected in the long-term.	**20%**
Apies River floodplain	Floodplain	E to F	Very High	D	Increased return flows will result in more water entering the system. Higher baseflows can thus be expected which together with regular high flows due to an increase in runoff as a result of hardened catchment surfaces will promote erosion and scour in the system. Increased channel incision could affect the frequency of overtopping onto	

Wetland	Type	PES	EIS	REC (Recommended Ecological Category)	Changes that may be expected based on the recommended scenarios from the Scenarios Report and general recommendations relating to trying to deal with these	% contribution to overall recommended MC
					the floodplain during high flows. It will thus be very difficult to achieve the REC for the system as a general deterioration in wetland condition is expected in the long-term.	
Tswaing Crator	Depression	-	Very High	-	Not related to changes in flow in the rivers.	
IUA 15						
-	Valley bottom wetlands	A/B to C/D	High	Specific to individual systems but should aim for at least the same as the PES or at least one category higher if possible	No flow related impacts are expected at this stage based on the Scenarios Report. At least maintain the *status quo.* The application of buffer zones around the wetlands could be considered if the objective is to improve the current state of the systems.	**16%**
-	Valley bottom wetlands	A/B to C/D	High			
-	Hillslope seepage wetlands	A/B to C/D	High	Specific to individual systems	Not related to changes in flow in the rivers. Non-flow related impacts such as development within and adjacent to these systems poses a risk to the remaining systems. Flow related impacts will occur as a result of changes in hydrology mostly as a result of urban development, and in some cases agricultural, impacts in the catchments of these systems. Interruption of interflow and increased surface runoff as a result of the development of the local catchment that feed these systems therefore poses the main flow related threat to the remaining systems in the long-term. It will be very difficult to achieve the REC for most systems as a general deterioration in wetland condition throughout the urban areas is expected in the long-term.	
-	Hillslope seepage wetlands	A/B to C/D	High			
IUA 16						
-	Valley bottom wetlands	-	High	Specific to individual systems but should aim for at least the same as the PES or at least one category higher if possible	No flow related impacts are expected at this stage based on the Scenarios Report. At least maintain the *status quo.* The application of buffer zones around the wetlands could be considered if the objective is to improve the current state of the systems,	**20%**

Wetland	Type	PES	EIS	REC (Recommended Ecological Category)	Changes that may be expected based on the recommended scenarios from the Scenarios Report and general recommendations relating to trying to deal with these	% contribution to overall recommended MC
-	Hillslope seepage wetlands	-	High	Specific to individual systems	Not related to changes in flow in the rivers. Non-flow related impacts such as development within and adjacent to these systems poses a risk to the remaining systems. Flow related impacts will occur as a result of changes in hydrology mostly as a result of urban development, and in some cases agricultural, impacts in the catchments of these systems. Interruption of interflow and increased surface runoff as a result of the development of the local catchment that feed these systems therefore poses the main flow related threat to the remaining systems in the long-term. It will be very difficult to achieve the REC for most systems as a general deterioration in wetland condition throughout the urban areas is expected in the long-term.	
Mokolo River and floodplain	Floodplain	C/D to D/E	High	C	No further flow related impacts are expected at this stage based on the Scenarios Report. The floodplain features and associated wetland habitats have already been affected by changes to flow as a result of the upstream dam (DWA, 2010). It is unlikely that flows to the system will improve in the future, which together with non-flow related impacts such as sand mining and other flow related impacts such as abstraction, means it is unlikely that there will be any improvement in the system. A REC of C will thus likely be unachievable. While the aim is to try to maintaining the *status quo* for the associated wetlands, this may even be difficult to achieve under the future water use scenario.	
Tambotie River floodplain	Floodplain	C/D to D/E	High to Very High	C/D	No further flow related impacts are expected at this stage based on the Scenarios Report. The floodplain has already been affected by a reduction in flow which affected the alluvial aquifer in the past resulting in a die-off of large sections of the riparian forest. It is unlikely that flows to the system will improve in the future and as such it is unlikely that there will be any improvement in the system. A REC of C/D will thus likely be unachievable. Maintaining the *status quo*, while not ideal, is all that is likely achievable under the future water use scenario.	
IUA 17b						
Lower Matlabas River	Valley bottom wetland	C	High	B/C	No flow related impacts are expected at this stage based on the Scenarios Report. At least maintain the *status quo.* The application of buffer zones around the wetlands could be considered if the objective is to improve the current state of the systems. Further studies on this system are recommended.	**5%**
Aslaagte	Valley bottom wetland	C	High	B/C	No flow related impacts are expected at this stage based on the Scenarios Report. At least maintain the *status quo.* The application of buffer zones around the wetlands could be considered if the objective is to improve the current state of the systems. Further studies on this system are recommended.	
Limpopo River and associated riparian zone and floodplain features	Riparian zone and floodplains	B to D	Very High	Specific to individual systems but should aim for at least the same as the PES or at least one category higher if	Not clear what the effect of the recommended scenario will be on this system. It is assumed that no flow related impacts will be expected at this stage based on the Scenario Report which would mean at least maintaining the *status quo.* It is however recommended that further studies are undertaken on this system to get a better understanding of the flow related changes that have occurred in the system and what the current trajectory of change is in order to better evaluate the impact of implementing the recommended scenario on the system.	

Wetland	Type	PES	EIS	REC (Recommended Ecological Category)	Changes that may be expected based on the recommended scenarios from the Scenarios Report and general recommendations relating to trying to deal with these	% contribution to overall recommended MC
				possible		
-	Pans	B to D	High to Very High	Specific to individual pans	Not related to changes in flow in the rivers. Non-flow related impacts such as agricultural practices within and adjacent to these systems poses a risk to the remaining systems. Water quality impacts as a result of agricultural practices also potentially poses a high risk to these systems in the long term, although these effects are likely to have already occurred as the area is already farmed in most areas where pans occur. Maintaining water quality is a critical aspect in pans as this determines pan geochemistry which in turn drives the biodiversity aspects. The application of buffer zones around the wetlands could be considered if the objective is to improve the current state of the systems,	

4.8 PRESENT ECOLOGICAL STATE (PES)

The Present Ecological State (PES), Ecological Importance (EI) and Ecological Sensitivity (ES) per hydro-node were provided by the Reserve determination studies and the DWA desktop PES, EI and ES study that was undertaken for the Crocodile (West), Marico, Matlabas and Mokolo catchments during 2012 (DWA, 2012). In situations where the selected hydro-node is an existing EWR site from a previous Reserve study, the PES and EIS information provided was obtained from these studies. The PES, REC (at EWR sites), EI and ES per hydro-node and the consideration for node selection in the Crocodile West/Marico WMA and Mokolo and Matlabas catchments are indicated in Table 10 and PES per node is indicated in Figure 8. The PES assessment was undertaken external to the Crocodile (West), Marico, Matlabas and Mokolo catchments classification process by the DWA, however it has formed a key input in terms of the ecological condition of the water resources in the study area. The supporting information and reports for the PES study may be obtained from the DWA, Chief Directorate Resource Directed Measures.

The river Freshwater Ecosystem Priority Areas (FEPAs) identified through the National Freshwater Ecosystem Priority Areas (NFEPAS) Project of the Water Research Commission (WRC, 2011), were assessed to determine if they were adequately protected through the PES categories for the nodes for these catchments. FEPAs have been identified as those areas that are important for sustaining the integrity and continued functioning of their related ecosystems. The FEPAs identified in the Crocodile (West), Marico, Matlabas and Mokolo catchments are shown in Figure 9 and set out in Table 11 (Crocodile (West)), Table 12 (Marico) and Table 13 (Mokolo and Matlabas).

Table 10: Hydro nodes selected for the Crocodile West/Marico WMA and Mokolo and Matlabas catchments indicating PES and consideration for selection

IUA	No	Quaternary catchment	Hydro node	EI	ES	PES	Node type and considerations	
1	HN1	A21A	Rietspruit (source) to Rietvlei Dam (CROC_EWR16)	Low	Low	C	Management, urban impacts, Rietvlei Dam	Quantity/quality, dolomitic
	HN2	A21B	Sesmylspruit with its' tributaries to confluence with Hennops	Moderate	Moderate	E	Biophysical, urban impacts	Quality
	HN3	A21C	Modderfonteinspruit to confluence with Jukskei	Moderate	Moderate	E	Biophysical, urban, industrial;	Quality
	HN4	A21C	Klein Jukskei at confluence with Jukske	Moderate	Moderate	E	Biophysical. semi urban	Quality
	HN5	A21C	Jukskei River at CROC_ EWR2	Moderate	Moderate	E	Biophysical, WWTW	Quantity/quality
	HN6	A21D	Bloubankspruit and tributaries (outlet of quaternary/confluence with Crocodile)	Moderate	Moderate	D	Biophysical, acid mine drainage, dolomitic, Botanical gardens, Cradle of Humankind	Quality/quantity
	HN7	A21A, B, H	Hennops (source) to confluence with Crocodile	Moderate	Moderate	D	Biophysical, urban, industrial	Quantity/quality
	HN8	A21H	Swartspruit to Hartbeespoort Dam	Moderate	Moderate	D	Semi urban	Quality
	HN9	A21E, H	Crocodile (source) to CROC_EWR1	Moderate	Moderate	D	Biophysical, urban	Quantity/quality
	HN10	A21H, J	Crocodile at Hartbeespoort Dam, outlet of IUA1	High	High	C/D	Hartbeespoort Dam, Management	Quantity/quality
	HN11	A23A	Pienaars(source) and including Moreletaspruit and Edendalespruit to outlet of Roodeplaat Dam	Low	Low	E	Management, urban, industrial; WWTW, canalised, Roodeplaat Dam	Quantity/quality
	HN12	A23B	Pienaars from Roodeplaat Dam to outlet of quaternary catchment (outlet of IUA1) (CROC_EWR4)	High	High	C	Management, sand mining	Quantity/quality
	HN13	A23B	Boekenhoutspruit to confluence with Pienaars	High	High	C	Biophysical	Quantity/quality
	HN14	A23D	Skinnerspruit (source) to confluence with Apies	Low	Low	E	Biophysical, urban, canalised urban river	Quantity/quality,
	HN15	A23D, E	Apies (source) to Bon Accord Dam, below the dam at outlet of IUA1	Low	Low	F	Management, dolomitic at source	Quantity/quality,
2	HN16	A21F	Magalies below Maloney's Eye at CROC_EWR9	Very high	Very high	B	Biophysical, dolomitic at source	Quantity

IUA	No	Quaternary catchment	Hydro node	EI	ES	PES	Node type and considerations	
	HN17 HN18	A21G, F	Magalies (CROC_EWR15) Skeerpoort at outlet of IUA2	Low Low	Low Low	C/D C/D	Management Management	Quantity/quality Quality/quantity
3	HN19 HN20	A21J	Rosespruit at confluence with Crocodile Crocodile from Hartbeespoort Dam to upstream Roodekopjes Dam, outlet of IUA3	High Moderate	High Moderate	C/D D	Biophysical Biophysical	Ecological Ecological
4	HN21 HN22	A21K	Sterkstroom (source) to Buffelspoort Dam (CROC_EWR11) Sterkstroom from Buffelskloof Dam to Roodekopjes Dam, outlet of IUA4	High high	High HIGH	C C	Biophysical Management	Quantity/quality Quantity/quality
	HN23	A22G	Hex (source) to Olifantsnek Dam	Moderate	High	C	Management, Olifantsnek Dam	Quantity/quality
	HN24 HN25	A22H	Waterkloofspruit (CROC_EWR14) to confluence with Hex Hex from Olifantsnek Dam to Bospoort Dam	Low Moderate	Low Moderate	B/C D	Biophysical, wetland, nature reserve Management, urban, mining, Bospoort Dam	Wetland driven Quantity
	HN26 HN27	A22J	Hex from Bospoort Dam to Vaalkop Dam (CROC_EWR6) Elands from Vaalkop Dam to confluence with Crocodile, outlet of IUA4	Moderate Moderate	Moderate Moderate	D D	Biophysical, Bospoort Dam Management, Vaalkop Dam	Quantity/quality Quantity/quality
5	HN28 HN29	A22A	Elands (source) to Swartruggens Dam (CROC_EWR10) Elands from Swartruggens Dam to Lindleypoort Dam	High Moderate	High High	C C	Management Management, Swartruggens Dam, WWTWs	Quantity Quantity/quality, management
	HN30	A22B	Koster (source) to Koster Dam	Moderate	High	C	Biophysical, wetland	Wetland driven
	HN31	A22C, A22D	Selons to confluence with Elands	Moderate	High	C	Biophysical	Quantity/quality
	HN32	A22E, A22F	Elands from Lindleypoort Dam (CROC_EWR13) to Vaalkop Dam, outlet of IUA5	Low	Low	C	Management, Lindleyspoort Dam	Quantity/quality, management
6b	HN33	A31B	Polkadraaispruit to confluence with Marico (MAR_EWR6)	Moderate	Moderate	B/C	Biophysical	Quantity/quality

IUA	No	Quaternary catchment	Hydro node	EI	ES	PES	Node type and considerations	
	HN34 HN63		Marico from MAR_EWR2 to N4 road at town Marico from N4 road to Marico-Bosveld Dam, outlet of IUA6b	Very High Very High	Very High Very High	B B	Biophysical Biophysical	Quantity/quality Quantity/quality
6a	HN64 HN35 HN65 HN36	A31D A31D A31E A31E	Malmaniesloop to confluence with Klein Marico Klein Marico and tributaries upstream of Zeerust Klein Marico from Zeerust to Klein Maricopoort Dam Klein Mario from Klein Maricopoort Dam to Kromellemboog Dam (MAR_EWR5), outlet of IUA6a	High High High Moderate	High High High Moderate	C C C C	Biophysical, groundwater, WWTW, urban Biophysical Management, Klein Maricopoort Dam Management, Kromellemboog Dam	Groundwater node Quantity/quality Quantity/quality Quantity/quality
7	HN37 HN38	A31A A31A	Kaaloog-se-Loop (MAR_EWR1) to concluence with Groot Marico Vanstraatenvlei and tributaries at confluence with Kaaloog-se-Loop, outlet of IUA7	Very High High	Very High High	B B	Biophysical, dolomitic Biophysical, dolomitic	Quantity Quantity
8	-	A31C	Groundwater	-	-	-	Management, groundwater	Groundwater node
9	HN66 HN67 HN39	D41A	Molopo at outlet of wetland Molopo at Modimola Molopo at outlet of IUA9	- Low Low	- Low Low	- E E	Management, groundwater Biophysical Management	Groundwater node Quality Quality
10	HN68 -	A10A A10A, B, C	Ngotwane from Dinokana to Ngotwane Dam Ngotwane from Dinokana to outlet of IUA10	- -	- -	- -	Management, groundwater, Ngotwane Dam Management	Groundwater node
11a	HN40	A31F, G, A32A	Marico from Marico Bosveld and Kromelmboog Dam to Molatedi Dam (MAR_EWR3), outlet of IUA11a	High	High	C/D	Management, Madikwe Nature Reserve, Marico-Bosveld Dam	Quantity
11b	HN41	A32D, E	Marico from Molatedi Dam to confluence with Crocodile (MAR_EWR4), outlet of IUA11b	High	High	C	Management, Molatedi Dam, Twasa weir, international, Madikwe Nature Reserve	Quantity/quality
12	HN42	A24D, E, F	Bierspruit to confluence with	Moderate	Moderate	D	Mining	Seasonal rivers,

IUA	No	Quaternary catchment	Hydro node	EI	ES	PES	Node type and considerations	
			Crocodile River, outlet of IUA12					quantity
13	HN43	A24G, A24H	Sand to confluence with Crocodile	Moderate	Moderate	C	Biophysical	Quantity/quality
	HN44	A21L, A24A-C, A24H	Crocodile from Roodekopjes Dam (CROC_EWR7) to proposed Mokolo transfer (CROC_EWR8)	Moderate	Moderate	D	Management, irrigation, mining, transfer	Quantity/quality,
	HN45	A24J	Crocodile from CROC_EWR8 to confluence with Limpopo, outlet of IUA13	Moderate	Moderate	C	Management for international, groundwater	Quantity/quality
14	HN46	A23G	Platspruit (source, CROC_EWR12) to confluence with Pienaars	Moderate	Moderate	B/C	Biophysical	Quantity
	-	A23C, A23F	Wetland at Pienaars& Apies confluence and inflow to Klipvoor Dam	Moderate	Moderate	C	Biophysical; floodplain	Quantity/wetland
	HN47	A23H	Karee/Rietspruit to confluence with Pienaars	Moderate	Moderate	C	Biophysical	Quantity
	HN48	A23J A23J, A23L	Moretele (Pienaars) to confluence with Crocodile (CROC_EWR5), outlet of IUA14	High	High	D	Management, Klipvoor Dam, Borakalalo Nature Reserve	Quantity/quality
	HN49	A23K	Tolwane to confluence with Moretele	High	High	D	Biophysical	Quantity/quality
15	HN50	A42A	Sand (source) to confluence with Grootspruit	Moderate	Moderate	C	Biophysical	Quantity/quality
	HN51	A42B	Grootspruit (source) to confluence with Sand	Moderate	Moderate	C	Biophysical	Quantity/quality
	HN52	A42C	Mokolo to confluence with Dwars (MOK_EWR1a)	High	High	C/D	Biophysical	Quantity/quality
	HN53	A42D, A42E	Mokolo to confluence with Sterkstroom (MOK_EWR1b)	High	High	B/C	Biophysical	Quantity/quality
	HN54	A42D	Sterkstroom (source) to confluence with Mokolo, including Dwars	High	High	B/C	Biophysical, Ecological	Quantity,
	HN55	A42F	Mokolo from Sterkstroom to Mokolo Dam (MOK_EWR2), outlet of IUA15	Very high	Very high	B/C	Biophysical	Quantity/quality
16	HN56	A42G	Rietspruit (source) to Mokolo confluence	Moderate	Moderate	B/C	Biophysical	Quantity/quality
	HN57		Mokolo below dam (MOK_EWR3) to	Very High	Very High	B/C	Management, Mokolo Dam	Quantity/quality

IUA	No	Quaternary catchment	Hydro node	EI	ES	PES	Node type and considerations	
			Rietspruit confluence (MOK_EWR4)					
	HN58	A42H, A42J	Mokolo from MOK_EWR4 to confluence with Limpopo, outlet of IUA16.	Very High	Very High	C	Biophysical, floodplain	Use wetlands requirements for river
17a	HN59	A41A	Mothlabatsi to confluence with Mamba	Very High	Very High	B	Biophysical, Marekele National Park	Quantity
	HN60	A41B	Mamba to confluence with Mothlabatsi, outlet of IUA17a	Moderate	Moderate	C	Biophysical	Quantity
17b	HN61	A41C	Matlabas from Mamba confluence to MAT_EWR2	High	High	B/C	Biophysical	Quantity/quality
	HN62	A41C, D	Matlabas from MAT_EWR2 to confluence with Limpopo, outlet of IUA17b	Moderate	Moderate	B	Management, international	Quantity/quality

Note: The PES and EIS included in the above table are at the EWR sites as determined during the Reserve studies with the rest of the PES, EI and ES from the desktop assessments undertaken for that specific reach during 2010-2012

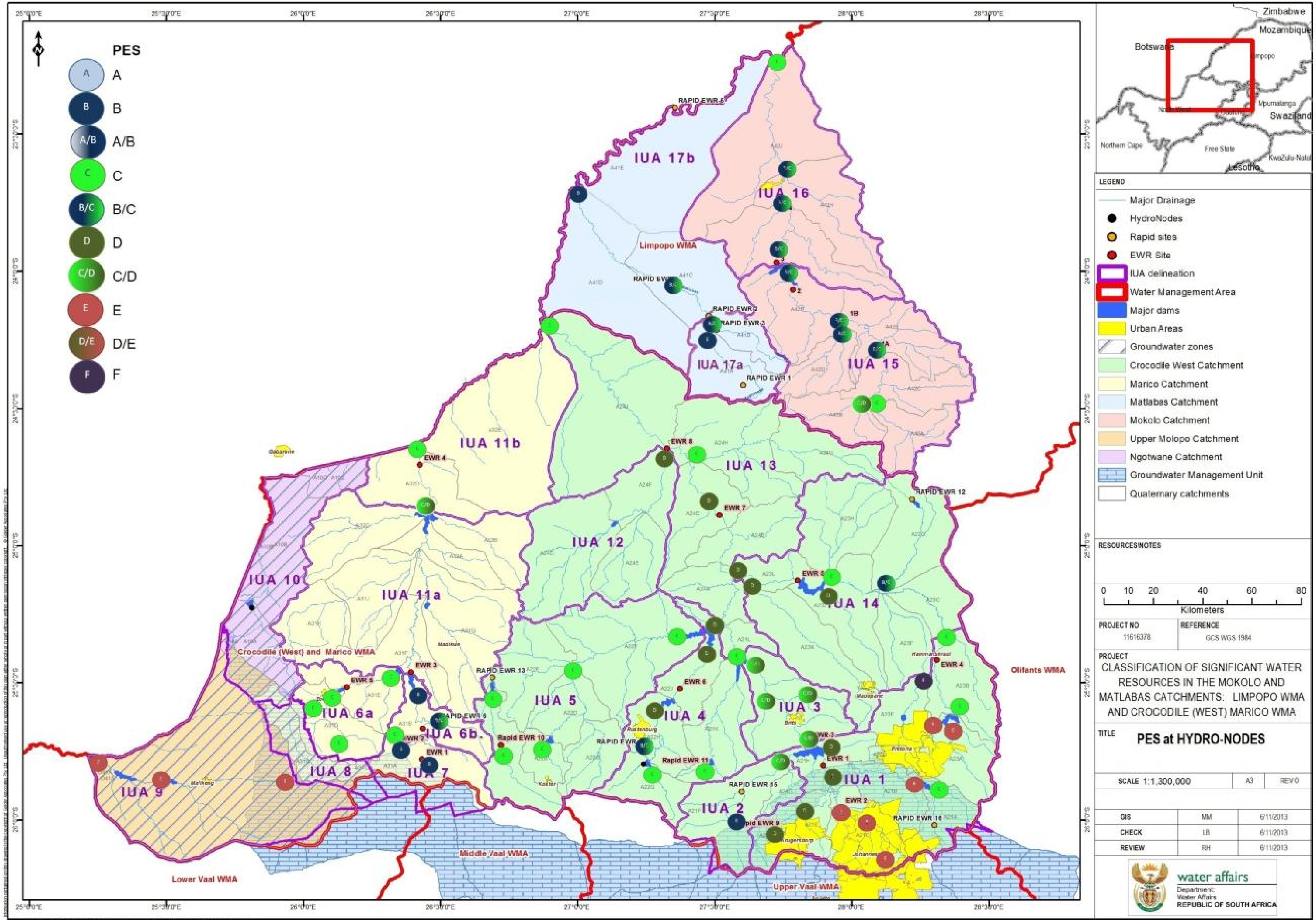


Figure 8: PES per hydro-node for the Crocodile (West), Marico, Mokolo and Matlabas catchments

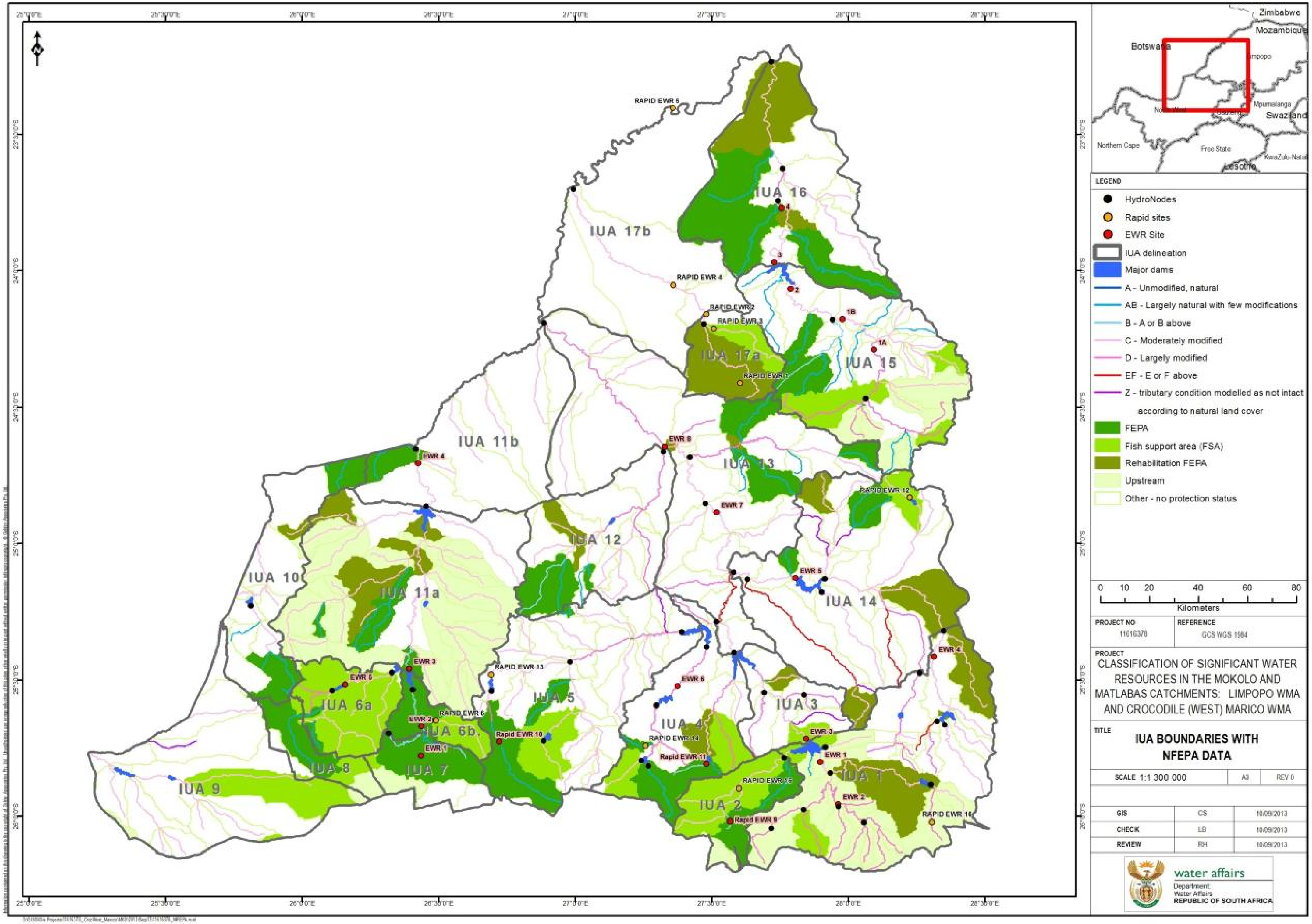


Figure 9: FEPAs identified for the Crocodile (West), Marico, Mokolo and Matlabas catchments

Table 11: NFEPA associated with the IUAs of the Crocodile (West) catchment

IUA	Catchment area	Quaternaries with NFEPAs		% NFEPA supported	Proposed IUA MC	Does the MC give effect to the NFEPAs?
			CROCODILE WEST			
1	Upper Crocodile/ Hennops/ Hartbeespoort	A23B; A23A; A21A; A21C; A21B; A23D; A23E; A21H; A21E; A21D	Upstream management area; Phase 2 FEPA and associated sub-quaternary catchment; Fish support area; Fish sanctuary; wetland FEPA	80%	III	Yes, however the current PES is such that it will not meet the NFEPAs
2	Magalies	A21F; A21G	River FEPA and associated sub-quaternary catchment; Fish support area and associated sub-quaternary catchment	80%	II	Yes
3	Crocodile/ Roodekopjes	A21J	Fish sanctuary; Phase 2 FEPA and associated sub-quaternary catchment;	0%	III	No NFEPAS where nodes located
4	Hex/ Waterkloofspruit/Vaalkop	A22G; A22H; A21K; A22J	River FEPA and associated sub-quaternary catchment; Fish sanctuary	90%	II	Yes
5	Elands/Vaalkop	A22A; A22B; A22C; A22D; A22E; A22F;	River FEPA and associated sub-quaternary catchment; Fish sanctuary;	90%	II	Yes
12	Bierspruit	A24D; A24E; A24F;	River FEPA and associated sub-quaternary catchment; Phase 2 FEPA and associated sub-quaternary catchment;	20%	III	Nor adequately; NFEPA areas have been highlighted as areas requiring a higher level of protection than the MC
13	Lower Crocodile	A24A; A24B; A24C; A24G; A24H; A24J	River FEPA and associated sub-quaternary catchment; Phase 2 FEPA and associated sub-quaternary catchment;	20%	III	No, but NFEPA areas have been highlighted as areas requiring a higher level of protection than the MC
14	Tolwane/Kulwane/Moretele/ Klipvoor	A23K; A23J; A23F; A23C; A23G; A23H; A23L;	River FEPA and associated sub-quaternary catchment; Phase 2 FEPA and associated sub-quaternary catchment; Wetland FEPA;	75%	III	Yes

Table 12: NFEPA associated with the IUAs of the Marico catchment

IUA	Catchment area	Quaternaries with NFEPAs		% of IUA based on hydronodes location	Proposed IUA MC	Does the MC give effect to the NFEPAs?
			MARICO			
6a	Klein Marico/ Kromellemboog	A31D; A31E	River FEPA and associated sub-quaternary catchment; Fish sanctuary: other threatened; River FEPA and associated sub-quaternary catchment;	90%	II	Yes
6b	Groot Marico/Marico Bosveld Dam	A31A; A31B;	River FEPA and associated sub-quaternary catchment; Fish sanctuary; Fish support area and associated sub-quaternary catchment	90%	II	Yes
7	Kaaloog-se-Loop	A31A	River FEPA and associated sub-quaternary catchment; Fish sanctuary; wetland FEPA	90%	I	Yes
8	Malmaniesloop	A31C	Wetland FEPA; River FEPA and associated sub-quaternary catchment	0% as groundwater zone	III*	No
9	Molopo	D41A	Wetland FEPA; River FEPA and associated sub-quaternary catchment	0% as groundwater zone	II*	No
10	Dinokana Eye/Ngotwane Dam	A10A; A10B; A10C	River FEPA and associated sub-quaternary catchment; Phase 2 FEPA and associated sub-quaternary catchment;	0% as groundwater zone	III*	No
11a	Groot Marico/Molatedi Dam	A31H; A31F; A31J; A31G; A32C; A32A; A32B	Upstream management area; Phase 2 FEPA and associated sub-quaternary catchment; River FEPA and associated sub-quaternary catchment;	60%	II	Yes
11b	Groot Marico/seasonal tributaries	A32D; A32B	River FEPA and associated sub-quaternary catchment;	80%	II	Yes

Table 13: NFEPAs associated with the Mokolo and Matlabas catchments

IUA	Catchment area	Quaternaries with NFEPAs		% coverage of IUA based on hydronodes location	Proposed IUA MC	Does the MC give effect to the NFEPAs?
MOKOLO						
15	Upper Mokolo	A42A; A42B; A42D; A42C; A42F; A42E	Upstream; Fish support areas; FEPA;	75%	II	Yes
16	Lower Mokolo	A12G; A42J; A42H	FEPA; Rehabilitation FEPA;	75%	II	Yes
MATLABAS						
17a	Mothlabatsi/ Mamba	A41A; A41B	River FEPA and associated sub-quaternary catchment; Phase 2 FEPA and associated sub-quaternary catchment; Wetland FEPA; Fish support areas;	100%	I	Yes
17b	Matlabas/ Limpopo	A41C; A41D	Wetland cluster	100%	II	Yes

Table 14: Summary of Present Ecological Status of water resources in the Crocodile West/Marico WMA and Mokolo and Matlabas catchments

IUA 1

Rivers: Bloubankspruit, Hennops, Crocodile

Water resources presently in a D category due to urbanization, return flows (increased flows) and poor water quality. However *Barbus Mattozi* is still present in the system. Rietvlei Dam is situated in the upper reaches of the Hennops River.

Rivers: Modderfontein, Sandspruit, Jukskei

Water resources presently in an E category due to urbanization, industrialization, return flows (increased flows) and poor water quality.

Rivers: Apies, Pienaars, Moreletta, Bloubankspruit

The upper parts of the catchment are impacted by urbanization, irrigation in some areas; water treatment works releases and increased flows. Roodeplaat Dam on the Pienaars and Bon Accord Dam on the Apies contribute to changes in the flow regime. The present state of the Pienaars River downstream of Roodeplaat Dam is in a C category and the EIS is high. This reach of the river provides for the colonization of several fish species no longer found in other tributaries and the system is important for fish movement, especially with Roodeplaat Dam upstream and Klipvoor Dam downstream. No EWR site is situated on the Apies River.

EWR sites:

- Intermediate on Crocodile: Upstream of the Hartbeespoort Dam - EWR 1 (A21H)
- Intermediate on Jukskei: Heron Bridge School - EWR 2 (A21C)
- Intermediate on Pienaars: Downstream of Roodeplaat Dam - EWR 4 (A23B)
- Rapid III upstream Rietvlei Dam – EWR16 (A21A)

IUA 2

Rivers: Magalies, Skeerpoort

The present state of the Magalies River is in a B category, especially with Maloney's Eye situated in the upper reaches. The EIS is very high due to the presence of the rare *Barbus motebensis* in the system.
The Magalies River is an important provincial conservation area and has been identified as a sensitive catchment in the Gauteng conservation plan.

The lower reaches of the Magalies and Skeerpoort Rivers are impacted by water abstraction for irrigation.

EWR sites:

- Rapid III on the Magalies: downstream of Malony's Eye - EWR 9 (A21F)
- Rapid III on lower Magalies – EWR 15 (A21F)

IUA 3

Rivers: Crocodile and smaller tributaries (Rosespruit, Kareespruit)

The water resources are in a degraded state (C/D to E category) due to changes in the flow regime as a result of Hartbeespoort Dam just upstream of this IUA and the poor water quality from IUA1. Roodekopjes Dam is situated at the outlet of this IUA.

EWR sites:

- Intermediate on Crocodile: downstream of Hartbeespoort Dam in Mount Amanzi - EWR 3 (A21J)

IUA 4
Rivers: Hex, Waterkloofspruit The water resources of the Hex River have been degraded due to the Olifantsnek, Bospoort and Vaalkop Dams situated on the river. Rustenburg and extensive mining in the middle reaches of the catchment further impacts on the water resources, both quantity and quality. The Waterkloofspruit (mostly wetland) is still in a very good condition and forms part of a conservation area. Vaalkop Dam is situated at the outlet of this IUA. **Rivers: Sterkstroom** The present state of the water resources is in a C category. Some irrigation is present in the upper reaches of the system. Buffelskloof Dam and part of Roodekopjes Dam is situated in the catchment. The EIS is high due to the presence of the vulnerable *Barbus motebensis* and the high abundance of the unique *Amphilius uranoscopus* and *Barbus motebensis* upstream in catchment.
EWR sites: • Intermediate on the Hex: Upstream of Vaalkop Dam - EWR 6 (A22J) • Rapid III on the Sterkstroom: Upstream Buffelspoort Dam - EWR 11 (A21K) • Rapid III on Waterkloofspruit: Lower reaches – EWR14 (A22H)
IUA 5
Rivers: Koster, Selons, Elands and some smaller tributaries in the lower reaches of the IUA The water resources in the upper catchment of the Elands River are in a C category. This deteriorates further downstream with the presence of Swartruggens and Lindleyspoort dams, mining, irrigation and return flows from water treatment works. The presence of the vulnerable *Barbus motebensis* contributes to a high EIS for the upper reaches. This reach also serves a refugia as the downstream catchment and river has been degraded. The unique Pilanesberg area is situated in the middle reaches of the IUA. Vaalkop Dam is situated at the outlet of this IUA.
EWR sites: • Rapid III on the Elands: Upstream Swartruggens Dam - EWR 10 (A22A) • Rapid III on Elands: Downstream Lindleyspoort Dam – EWR 13 (A22E)
IUA 6a
Rivers: Rhenosterfontein, Malmaniesloop, Klein Marico, Karee The water resources are in a C category due to the impacts of Zeerust and the Klein Maricopoort Dam (irrigation) in the upper reaches of the catchment. Kromellenboog Dam, mainly being used for irrigation is situated in the lower Klein Marico River just before the confluence with the Groot Marico.
EWR sites: • Rapid III on Klein Marico: Downstream Klein Maricopoort Dam - EWR 5 (A31E)
IUA 6b
Rivers: Polkadraaispruit, Groot Marico The water resources are in a B category with some impacts due to irrigation and degraded riparian zone and alien invasive plants. The EIS is very high mainly due to the unique Blepharoceridae, locality of aquatic lampyridae as well as a large number of inverts and fish sensitive to water quality changes. The Marico Bosveld Dam is situated at the outlet of this IUA.
EWR sites: • Intermediate Reserve on Groot Marico: Upstream confluence with Sterkstroom - EWR 2 (A31B) • Rapid III on Polkadraaispruit: Upstream of confluence with Marico – EWR 6 (A31B)

IUA 7
Rivers: Kaaloog-se-Loop, Vanstraatenvlei The water resource is in a B category and is situated close to the source of the Marico River. The EIS is very high with the presence of the rare and endangered *B motebensis and B waterburg* and the very high taxon richness of inverts (>45). The area has been identified as a national priority area for protection/conservation due to the dolomitic eyes and associated fauna and flora.
EWR sites: • Intermediate on Kaaloog-se-Loop: Below gorge - EWR 1 (A31A)
IUA 8
Mainly groundwater – Malmanie's Eye
IUA 9
Mainly groundwater – Molopo Eye. Water from the eye is diverted for use and only a small volume is released into the Molopo River.
EWR sites: • Molopo: Wetland - EFR M8 (D41A)
IUA 10
Mainly groundwater – Dinokana Eye. The water from the eye flows to the Ngotwane Dam at the border of Botswana and is mainly used for domestic purposes.
IUA 11a
Rivers: Groot Marico and a number of seasonal streams The presence of Kromellemboog Dam (Klein Marico) and specifically the Marico Bosveld Dam just upstream of this IUA has severely impacted on the flow of the Marico River. Only small volumes of seepage from the dams are available instream. This resulted in a degraded system with a PES of a C/D. The EIS is high due to the species/taxon richness of the system and the presence of a number of inverts sensitive to water quality changes.
EWR sites: • Intermediate on Groot Marico: Downstream Marico Bosveld Dam - EWR 3 (A31F)
IUA 11b
Rivers: Groot Marico and a number of seasonal tributaries. The present state is a C category mainly due to the impact of the Molatedi Dam upstream and the release pattern from the Tswasa Weir for irrigation purposes just upstream of the EWR site. The EIS is high as this reach forms a natural refugia with a number of perennial pools and is adjacent to the Madikwe Provincial Nature Reserve. Water is currently transferred from Molatedi Dam to Botswana.
EWR sites: • Intermediate on Groot Marico: Downstream Tswasa Weir - EWR 4 (A32D)
IUA 12
Rivers: Wilgespruit, Bierspruit and some seasonal tributaries The water resources are degraded due to mining activities, town development and irrigation in the

catchment. The Bierspruit Dam is situated in the upper reaches of the Bierspruit.

EWR sites:

- No EWR site is present in this IUA.

IUA 13

Rivers: Crocodile West and smaller tributaries (Sand)

The water resources are in a C to D category mainly due to irrigation use and return flows. The proposed transfer of water to Lephalale is situated in the middle reaches of the river, downstream of Thabazimbi.

EWR sites:

- Intermediate on Crocodile: upstream of the confluence with the Bierspruit - EWR 7 (A24C)
- Intermediate on Crocodile: in Ben Alberts Nature Reserve - EWR 8 (A24H)

IUA 14

Rivers: Pienaar/Moretele, Plat, Riet, Tolwane, Kutswane, Tshwane

The lower reach of the Pienaars/Moretele River flows through the extensive Moretele Floodplain and the Borakalalo National Park. Klipvoor Dam is situated in this reach.
The present state is in a D category mainly due to the changes in flow as a result of the releases from the dams and water quality impacts from upstream urbanization.
The EIS is high due to the presence of the unique *Barbus Mattozi* and a number of fish species (*Chiloglanis pretoriae, Labeobarbus marequensis, Labeo cylindricus, Labeo molybdinus*) and inverts intolerant to water quality and flow changes.
The downstream reach is important for fish movement, especially with Roodeplaat and Klipvoor Dams upstream and downstream of the site.

EWR sites:

- Intermediate on Pienaars/Moretele: Downstream of Klipvoor Dam in Borakalalo National Park - EWR 5 (A23J)
- Rapid III on Buffelspruit: Before confluence with Plat – EWR12 (A23G)

IUA 15

Rivers: Mokolo, Sand, Klein Sand, Grootspruit and a number of smaller tributaries

The PES is a C/D category mainly due to the abstractions for irrigation purposes and general farming activities.

The EIS is high due to the presence of rare and endangered mammals, reptiles and unique fish species.

Rivers: Frikkie-se-Loop, Sterkstroom, Dwars, Mokolo

The present state is in a B/C category with farming activities the main impact on the water resources.
The EIS is high due to the presence of rare and endangered mammals, reptiles and unique fish species and the taxon and species richness of the system.

Rivers: Taaibosspruit, Mokolo

The present state is in a B/C category with farming activities and abstraction weirs the main impacts on the water resources.
The EIS is very high due to the presence of rare and endangered mammals, reptiles and unique fish and invert species and the taxon and species richness of the system.

EWR sites:

- Intermediate on Mokolo: Vaalwater - EWR 1A (A42C)
- Intermediate on Mokolo: Tobacco – EWR 1B (A42E)
- Intermediate on Mokolo: Ka'ingo - EWR 2 (A42F)

IUA 16
Rivers: Mokolo, Malmanies, Bulspruit The present state is in a B/C category with farming activities and the Mokolo Dam the main impacts on the water resources. The EIS is very high due to the presence of rare and endangered biota and fish species intolerant to water quality changes. **Rivers: Mokolo, Rietpruit** The present state is in a C category with farming activities and the Mokolo Dam the main impacts on the water resources. The EIS is very high due to the presence of rare and endangered biota and fish species intolerant to water quality changes. **Rivers: Mokolo, Tambotie, Sandloop** This reach of the river was assessed as a floodplain. The IHI for the floodplain was determined as a D category due to decreased flows, farming activities and sand mining that changed the groundwater characteristics of the system.
EWR sites: • Intermediate on Mokolo: In gorge below Mokolo Dam - EWR 3 (A42G) • Intermediate on Mokolo: Malalatau - EWR 4 (A42G) • Mokolo: Tambotie Floodplain - EWR 5
IUA 17a
Rivers: Mamba and Motlhabatsi The present state is in a C category with a high EIS. The Matlabas River flows through the Marakele Nature Reserve with a present state on a B.
EWR sites: • Rapid III on Matlabas-Zyn-Kloof – EWR 1 (A41A) • Rapid II on Mamba – EWR 3 (A41B)
IUA 17b
River: Matlabas The present state is in a C category with a high EIS. Grazing and abstraction from small farm dams are the main activities impacting on the water resources.
EWR sites: • Rapid II on Matlabas: At Haarlem Oos after Mamba confluence – EWR 2 (A41C) • Rapid 1 on Matlabas: upstream of confluence with Limpopo – EWR 4 (A41C)

4.9 ECOLOGICAL SUSTAINABLE BASE CONFIGURATION

The process followed in terms of the establishment of the ESBC is that described in the WRCS Guidelines, Volumes 1 and 2 (Overview and the 7-step classification procedure; and Ecological, hydrological and water quality guidelines for the 7-step classification procedure) (DWAF, February 2007a and 2007b).

The ESBC scenario, which would permit the maximum water use scenario, requires that the base condition for each water resource is at minimum established as either a D category or as whichever higher category is required to maintain all downstream nodes in at least a D category. However where the ecological condition requires it, a higher ecological category needs to be set.

The ESBC scenario is established once this base condition is hydrologically and ecologically tested to ensure that it is feasible and can be achieved. In other words the results will reflect whether the catchment water balance would be in surplus or deficit by implementing a D category EWR.

In terms of the Crocodile (West), Marico, Matlabas and Mokolo catchments, the D ecological category (EC) was not selected as the default ESBC. Rather the selected EC per IUA was based on the assessment of the present ecological state (PES) and ecological/conservation importance of water resources within the IUAs. These selected ECs at the outlet of the IUAs are listed in Table 15. The proposed IUA management classes (MCs) associated with this ESBC scenario are also indicated.

Table 15 EC (PES) for the ecological sustainable base configuration (aggregated per IUA)

IUA	Catchment area	Ecological Category (ESBC)
1	Upper Crocodile/Hennops/Hartebeespoort	D
2	Magalies	C
3	Crocodile/Roodekopjes	C/D
4	Hex/Waterkloofspruit/Vaalkop	C
5	Elands/Vaalkop	C
6a	Klein Marico/Kromellemboog	B/C
6b	Groot Marico	B
7	Kaaloog-se-Loop	B
8	Malmaniesloop (groundwater)	-
9	Molopo (groundwater and wetland)	C
10	Dinokana Eye/Ngotwane Dam (groundwater)	-
11a	Groot Marico/Molatedi Dam	C/D
11b	Groot Marico/seasonal tributaries	C
12	Bierspruit	D
13	Lower Crocodile	C/D
14	Tolwane/Kulwane/Moretele/Klipvoor	D
15	Upper Mokolo	B/C
16	Lower Mokolo	B/C
17a	Mothlabatsi/Mamba	B/C
17b	Matlabas/Limpopo	B/C

Having established the ECs required for the sustainable use of the water resources in the WMAs (the EC represented per IUA above), the ESBC scenario (Scenario 1) to be tested in the WRYM included the following parameters (Table 16).

Table 16: Ecological sustainable base configuration criteria

Sub-catchment	Present day water requirements	EWR
Crocodile West	2015: Water Requirements as per Reconciliation Strategy (present day water use)	PES EC Include all flow components (maintenance low and floods/freshets)
Marico, Molopo & Ngotwane	2009: Updated hydrology for the Marico, Ngotwane and Molopo catchments (present day water use)	PES EC Include all flow components (maintenance low and floods/freshets)
Mokolo	2007: Updated hydrology and yield analysis of the Mokolo River catchment(present day water use)	PES EC Include all flow components (maintenance low and floods/freshets)
Matlabas	2004: ISP documents and WR2005 information (present day water use)	PES EC Include all flow components (maintenance low and floods/freshets)

The yield model was set up for the various catchments within the WMAs and tested before the changes were made for the ESBC scenario. The assessment allowed for evaluation of the changes in yield with the inclusion of the EWRs for maintaining the PES ecological category. This allowed the assessment of the water balance (surpluses/deficits). Table 17 sets out the preliminary guidelines for determining the IUA management class with Table 18 showing the ESBC management classes.

Table 17: Preliminary guidelines for determining the IUA class for a scenario

		Percentage (%) nodes in the IUA falling into the indicated groups				
		A or A/B	B or B/C	C or C/D	D	>D
Class I		60	40	20	1	-
Class II			60	30	5	-
Class III	Either			70	20	-
	Or				100	-

Table 18: IUA Classes for Crocodile West/Marico/Mokolo and Matlabas IUAs for ESBC scenario based on percentage representation of indicated EC groups as per Table 8 (main stem river)

	Percentage (%) of nodes in the IUA falling into the indicated EC groups					IUA Class for ESBC Scenario
IUA	> = A/B	>= B	> = C	> = D	< D	
1			20%	33.3%	46.6%	III
2		50%	50%			II
3			100%			III
4		14.2%	42.9%	42.9%		II
5			100%			II
6a			100%			II
6b		66.7%	33.3%			II
7		100%				I
8						III*
9						II*
10						III*
11a			100%			II
11b			100%			II
12				100%		III
13			75%	25%		III
14		25%	25%	50%		III
15		66.7%	33.3%			II
16		66.7%	33.3%			II
17a		100%				I
17b		100%				II
*Relates to groundwater use						

Table 19: IUA Class associated with the ESBC (PES) scenario

IUA	Catchment area	Ecological Category (ESBC)	IUA Management Class associated with scenario
1	Upper Crocodile/Hennops/Hartebeespoort	D	III
2	Magalies	C	II
3	Crocodile/Roodekopjes	C/D	III
4	Hex/Waterkloofspruit/Vaalkop	C	II
5	Elands/Vaalkop	C	II
6a	Klein Marico/Kromellemboog	B/C	II
6b	Groot Marico/Marico Bosveld Dam	B	II
7	Kaaloog-se-Loop	B	I

IUA	Catchment area	Ecological Category (ESBC)	IUA Management Class associated with scenario
8	Malmaniesloop	-	III*
9	Molopo	C	II*
10	Dinokana Eye/Ngotwane Dam	-	III*
11a	Groot Marico/Molatedi Dam	C/D	II
11b	Groot Marico/seasonal tributaries	C	II
12	Bierspruit	D	III
13	Lower Crocodile	C/D	III
14	Tolwane/Kulwane/Moretele/Klipvoor	D	III
15	Upper Mokolo	B/C	II
16	Lower Mokolo	B/C	II
17a	Mothlabatsi/Mamba	B/C	I
17b	Matlabas/Limpopo	B/C	II

*Relates to groundwater use

The details of the ESBC scenario and the results are included in the report entitled: Ecologically Sustainable Base Configuration (ESBC) Scenario Report, RDM/WMA 1,3/00/CON/CLA/0312.

Table 20: Sub-nodes within IUAs requiring a higher level of ecological protection than the IUA ESBC

IUA	No	Quaternary catchment	Hydro node	EI	ES	PES	Overall IUA REC
1	HN1	A21A	Rietspruit (source) to Rietvlei Dam (CROC_EWR16)	Low	Low	C	D
	HN12	A23B	Pienaars from Roodeplaat Dam to outlet of quaternary catchment (outlet of IUA1) (CROC_EWR4)	High	High	C	
	HN13	A23B	Boekenhoutspruit to confluence with Pienaars	High	High	C	
2	HN16	A21F	Magalies below Maloney's Eye at CROC_EWR9	Very high	Very high	B	C
4	HN24	A22H	Waterkloofspruit (CROC_EWR14) to confluence with Hex	Low	Low	B/C	C
13	HN43	A24G, A24H	Sand to confluence with Crocodile	Moderate	Moderate	C	C/D
	HN45	A24J	Crocodile from CROC_EWR8 to confluence with Limpopo, outlet of IUA13	Moderate	Moderate	C	
14	HN46	A23G	Platspruit (source, CROC_EWR12) to confluence with Pienaars	Moderate	Moderate	B/C	D
	-	A23C, A23F	Wetland at Pienaars and Apies confluence and inflow to Klipvoor Dam	Moderate	Moderate	C	
	HN47	A23H	Karee/Rietspruit to confluence with Pienaars	Moderate	Moderate	C	
17a	HN59	A41A	Mothlabatsi to confluence with Mamba	Very High	Very High	B	B/C
17b	HN62	A41C, D	Matlabas from MAT_EWR2 to confluence with Limpopo, outlet of IUA17b	Moderate	Moderate	B	B/C

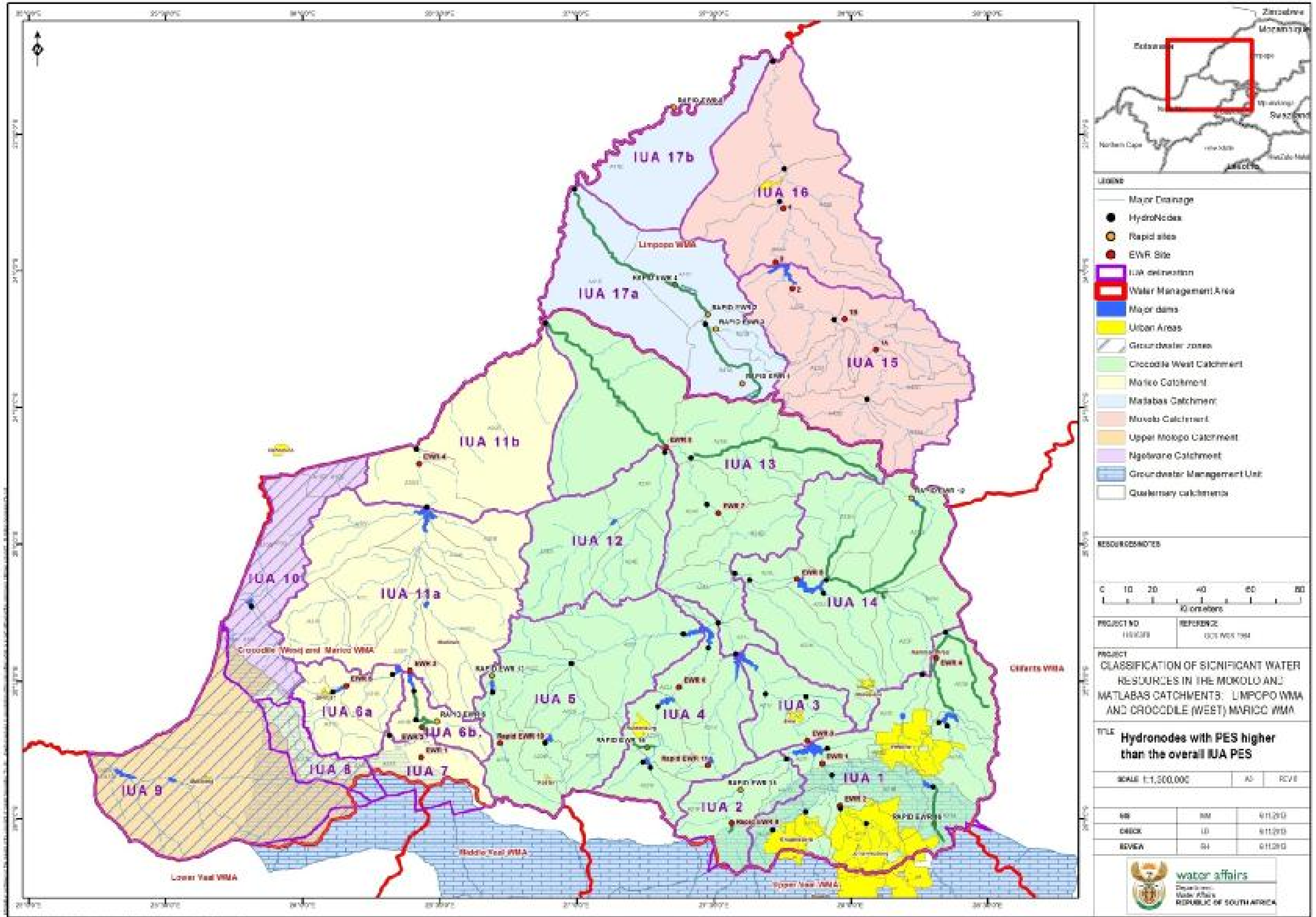


Figure 10: Hydronodes where PES is higher than overall IUA PES

4.10 ALTERNATE CATCHMENT SCENARIOS DEFINITION

Following the establishment of the ESBC, the classification process requires that additional catchment scenarios are configured for the IUAs within the WMA to assess the resulting yields of alternate ecological protection categories; conservation targets and future use and development to determine what is most feasible and achievable in terms of a MC.

At the study Project Steering Committee (PSC) of 16 May 2013 the stakeholders in the WMA confirmed acceptance of the ESBC (PES) scenario and proposed additional catchment scenarios to be evaluated for the Crocodile West/Marico WMA and Mokolo and Matlabas catchments as part of the alternate scenario analysis.

The scenario evaluation results were presented to the PSC at a meeting during August 2013. The results will then be taken to broader public stakeholder consultation during October 2013.

4.11 TOWARDS SCENARIO EVALUATION

The outcomes of the Crocodile West/Marico WMA and Mokolo and Matlabas catchments classification process described in sections 4.1 to 4.10 above, serve as building blocks to scenario analysis and evaluation. Scenario evaluation includes these individual parts, which requires combining these ‘blocks’ in different configurations to obtain results that reflect:

- A water balance (yield required – surplus or deficit in the IUA);
- A specific ecological protection level (a management class);
- An ecological consequence; and
- A socio-economic implication (cost-benefit analysis of the regional economy and social well-being).

Figure 11 illustrates the evaluation process.

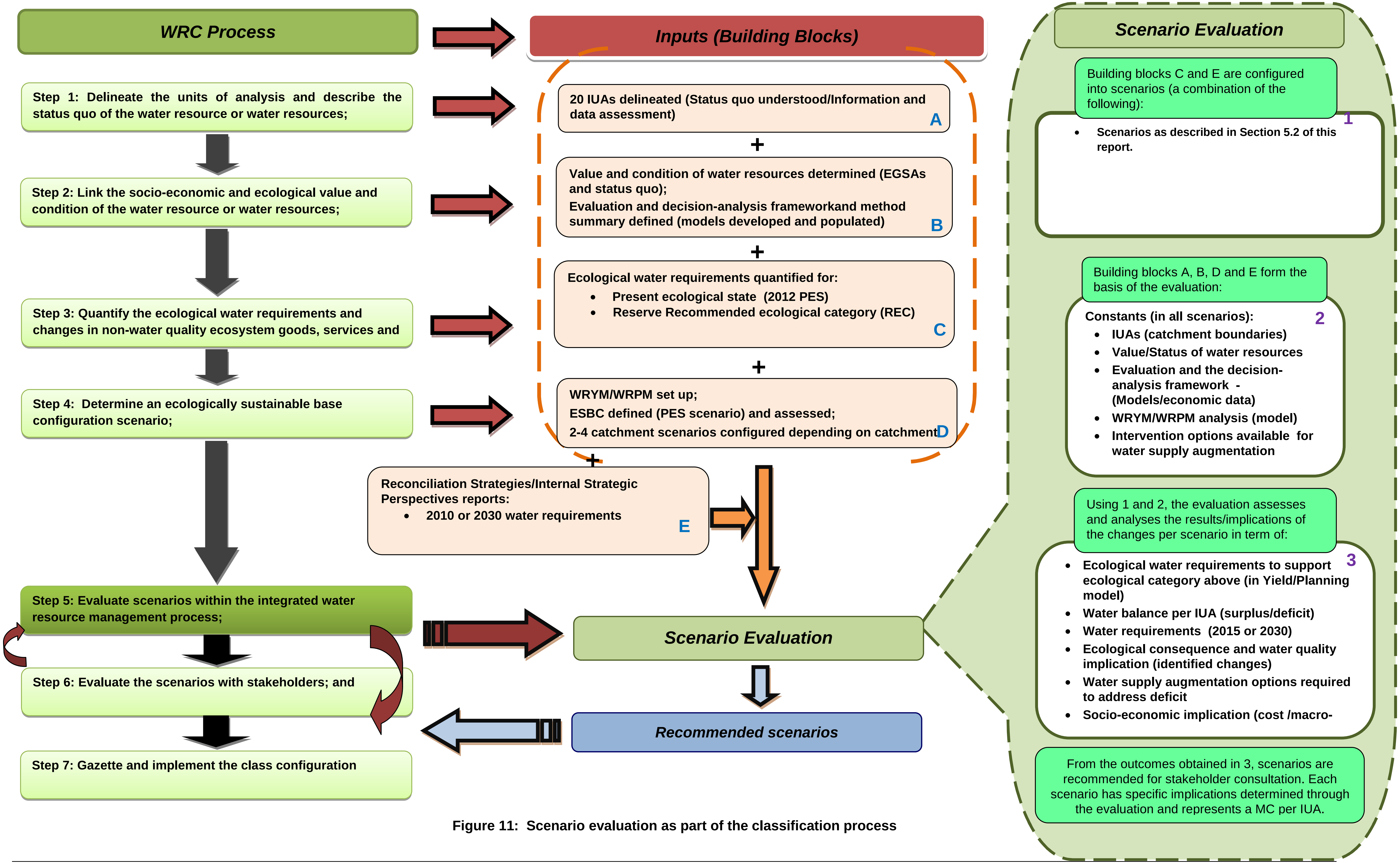


Figure 11: Scenario evaluation as part of the classification process

5 DESCRIPTION OF THE CATCHMENT CONFIGURATION SCENARIOS

A scenario can be defined as “a story of what could happen in the future”, and is used to understand different ways that future events might unfold. Scenarios, in the context of water resource management and planning, are plausible definitions (settings) of factors (variables) that influence the water balance and water quality in a catchment and the system as a whole.

Each scenario represents an alternative future condition, generally reflecting a change to the present condition. Analysis thereof gives the ability to compare the implications of one scenario against another, with the ultimate aim to make a selection of the preferred scenario.

In terms of the classification of water resources, a range of scenarios are established in order to understand what the result would be in terms of system yield by implementing a certain level of ecological protection required to ensure sustainable use of the catchment water resources (consideration of ecological, water quality and quantity needs).

Each scenario defines a certain ecological condition (ecological category of A, B, C or D) for each water resource (and the EWRs required for maintaining that category), and the yield that would result. This involves the linking of the flow and resource condition using the selected ecological category as a starting point, ensuring that the river reaches are maintained in a sustainable condition.

To facilitate the classification decision making process for the Crocodile West/Marico WMA and Mokolo and Matlabas catchments, the catchment scenarios for the different catchments that were evaluated as part of the analysis are described below.

5.1 SCENARIO 1: ESBC SCENARIO (PES SCENARIO)

The ESBC scenario is defined below and for this scenario the following was applied:

- The Present Ecological State (PES) was used as the ecological category (Table 21).
- PES EWR flows were applied.
- Water Requirements per water use sector as detailed in:
  - Crocodile West: Water Requirements as per Reconciliation Strategy, 2015 (present day water use);
  - Marico, Molopo & Ngotwane: Updated hydrology for the Marico, Ngotwane and Molopo catchments, 2009 (present day water use);
  - Mokolo: Updating the hydrology and yield analysis of the Mokolo River catchment, 2007 (present day water use); and
  - Matlabas: ISP documents and WR2005 information, 2004 (present day water use).

Table 21: ECs per IUA for Scenario 1 (PES Scenario – ESBC)

IUA	Catchment area	EWR site	PES	
			Ecological Category at EWR site	Ecological Category (ESBC)
1	Upper Crocodile/Hennops/Hartebeespoort	CROC_1	D	D
		CROC_2	E (D)	
		CROC_4	C	
		CROC_16	C	
2	Magalies	CROC_9	B	C
		CROC_15	C/D	
3	Crocodile/Roodekopjes	CROC_3	C/D	C/D
4	Hex/Waterkloofspruit/Vaalkop	CROC_6	D	C
		CROC_11	C	
		CROC_14	B/C	
5	Elands/Vaalkop	CROC_10	C	C
		CROC_13	C	
6a	Klein Marico/Kromellemboog	MAR_5	C	B/C
6b	Groot Marico, Polkadraaispruit upstream Maricopoort Dam	MAR_6	B/C	B
		MAR_2	B	
7	Kaaloog-se-Loop	MAR_1	B	B
8	Malmaniesloop	Groundwater	-	-
9	Molopo	Wetland	-	C
10	Dinokana Eye/Ngotwane Dam	Groundwater	-	-
11a	Groot Marico below Marico Bosveld Dam	MAR_3	C/D	C/D
11b	Groot Marico/Molatedi Dam/seasonal tributaries	MAR_4	C	C
12	Bierspruit	-	-	D
13	Lower Crocodile	CROC_7	D	C/D
		CROC_8	C	
14	Tolwane/Kulwane/Moretele/Klipvoor	CROC_5	D	D
		CROC_12	B/C	
15	Upper Mokolo	MOK_1a	C/D	B/C
		MOK_1b	B/C	
		MOK_2	B/C	
16	Lower Mokolo	MOK_3	B/C	B/C
		MOK_4	C	
17a	Mothlabatsi/Mamba	MAT_1	B	B
		MAT_3	B/C	
17b	Matlabas	MAT_2	C	B/C
		MAT_4	B	

5.2 ALTERNATE SCENARIOS

A combination of the following scenarios was evaluated, depending on the availability of data at each specific site. The hydrology supplied by the DWA through the various reconciliation and hydrology studies was used and no new hydrology was run. IUAs 8, 9 and 10 (Molopo and Ngotwane catchments) are catchments that rely on groundwater.

In addition to the scenarios set out below, model runs were done for the present day water use without EWR.

It should also be noted that where the PES = REC, only one scenarios has been included.

Molopo

ESBC: Ecological = PES, present water use

Future water use: the upper part of this dolomite aquifer system has been grouped together with the head waters of the Marico Catchment and included into IUA 7. The eastern part of quaternary catchment D41A includes a significant dolomite aquifer system: Grootfontein, Molopo Eye and Itsoseng aquifer systems, supplying water to towns, rural communities and mines. The aquifer system is also highly impacted by irrigation practices in the Grootfontein sub-compartment.

Flow from the Molopo Eye is diverted between an ecological supporting yield and water discharged into a pipe line supplying water to Mahikeng. The hydrostatic elevation of the Grootfontein Eye has been lowered significantly due to multiple borehole abstraction from the eye and lies currently at a level of 30 to 38m below ground elevation. Water supply shortages for Mahikeng occurred occasionally during 2010-2011 due to several borehole pump failures and a depleted aquifer saturation situation at Grootfontein because of over-abstraction. The water balance status in this portion of the Grootfontein Dolomite Aquifer System is a concern and will probably deteriorate in future if the historical annual average recharge rate is not met from now on.

Ngotwane

ESBC: Ecological = PES, present water use

Future water use: according to the ISP (DWA 2011a) the aquifers in these areas are underutilised. A potential exists to further develop the groundwater resources to supply surrounding villages. Following a conservative approach future utilization should not exceed 0.2 million m^3/a in addition to the current estimated use.

Klein Marico

ESBC: Ecological = PES, present water use

Present water use no EWR

Future water use according to the ISP (DWA 2011b) Zeerust currently gets all its' water from groundwater. The area appears to be sufficiently supplied with water against benchmark water requirements. However, a lack of reliable groundwater data makes it difficult to make accurate assessments in relation to future water use and availability.

Groot Marico

ESBC: Ecological = PES, present water use

Present water use, no EWR

1) PES, future water use – additional RDP housing; capacity of new WWTW: 500 kl/d; no return flows;

2) C category at MAR_EWR3, present water use,

3) C category at MAR_EWR3: future water use,

4) D category at MAR_EWR3: present water use;

5) PES without floods and freshets and present water use

Crocodile West

ESBC: Ecological = PES, present water use

Present water, no EWR

1) PES, future water use (mining – Rustenburg area, transfer of water to Mokolo – MCWAP)

Water quality – nutrients, AMD

Mokolo

ESBC: Ecological = PES, present water use

Present water use, no EWR

1) REC, present water use

Possible return flows downstream Lephalale.

Matlabas

ESBC: Ecological = PES, present water use

1) REC, present water use

6 SCENARIO EVALUATION

Determining the class of a water resource in terms of the process, involves taking into account the social, economic and ecological landscape in a catchment in order to assess the costs and benefits associated with utilisation versus protection of a water resource. As such, classification is not carried out in isolation, but is integrated within the overall planning for water resource protection, development and use and the broader goals of the IUA and WMA.

The basis for determining the MC is the determination of the ecological sustainable level of protection that is required for water resources and integrating this with the economic and social goals. It is therefore important that an appropriate ecological protection base condition is established for the water resources; and from this determine what is feasible by understanding the economic and social implications of attaining this ecological protection level. Once this sustainable ecological protection level is understood, various levels of ecological protection and degrees of water use/growth (possible scenarios) can be assessed in terms of the overall implications to the WMA or specific catchments.

The Crocodile West/Marico WMA and Mokolo and Matlabas catchments Classification study has progressed to the point of establishment and evaluation of the ESBC (PES) scenario and configuration of the alternate catchment scenarios. The following sections describe and present the results of the evaluation of these alternate scenarios.

6.1 WATER BALANCE PER SCENARIO

6.1.1 THE APPROACH FOLLOWED

Background and setup

The Water Resources Planning Model (WRPM) that was used as part of the development of the Reconciliation Strategies for the Crocodile West and Mokolo catchments was obtained and used for analysis per scenario. The WRYM from the Planning study for the Marico catchment was obtained and used to evaluate the scenarios. The WRYM used in the Matlabas had to be set up and run from scratch.

The following are the specific considerations that were included in the setup for the scenarios:

Crocodile West Catchment

The following were considered as part of the scenarios evaluations:

- Present day or future water use for irrigation, mining, domestic, rural and afforestation as provided in the water requirements and water resources report that forms part of the reconciliation strategy;
- Future water use (mining – Rustenburg area, transfer of water to Mokolo – MCWAP; and
- Water quality – nutrients (eutrophication), Acid Mine Drainage

The following dams were included:

- Hartbeespoort Dam;
- Roodekopjes Dam;
- Lindleyspoort Dam;
- Bospoort Dam;
- Vaalkop Dam;
- Klipvoor Dam;
- Roodeplaat Dam;

Marico Catchment

The following were considered as part of the scenarios evaluations:

- Present day or future water use for irrigation, mining, domestic, rural and afforestation as provided in the water requirements and water resources report that forms part of the reconciliation strategy;

- Reductions in outflow of dolomitic eyes in Upper Marico and Malmanies (upper Klein Marico);
- Reductions in groundwater (outflow from dolomitic eyes in Ngotwane and Molopo catchments);
- Water quality – especially relating to the urban areas of Mafikeng, Zeerust, Swartruggens and the town of Dinokana, WWTW discharge from these areas and metals contamination;
- Water requirements for wetland (less diverted for domestic use);
- Potential reduction in water from Maloney's Eye;
- Alien vegetation clearing;
- Future water use (incl emerging farmers);
- Proposed WWTW in Groot Marico; and
- Proposed prospecting for mining.

The following dams were included:

- Klein Maricopoort Dam;
- Kromelmboog Dam;
- Marico Bosveld Dam; and
- Molatedi Dam.

Matlabas Catchment

The following were considered as part of the scenarios evaluations:

- Present day water use for irrigation, mining, domestic, rural and afforestation as provided in the ISP and WR2005 reports; and
- Scouring of river – Mokolo transfer pipeline crossing.

Mokolo Catchment

The following were considered as part of the scenarios evaluations:

- Present day or future water use for irrigation, mining, domestic, rural and afforestation as provided in the water requirements and water resources report that forms part of the reconciliation strategy; and
- Groundwater abstraction;
- Transfer of water to Mokolo – MCWAP;
- Raising of Mokolo Dam not considered;
- Water quality – Acid mine drainage, WWTW (Lephalale); and
- Development of Waterberg area.

The following dams were included:

- Mokolo Dam.

System schematic – major nodes/points

Detailed schematic diagrams were obtained from the study teams responsible for the development of the various reconciliation strategies and these were used as the basis for changing, checking and evaluation of the scenarios. The following major nodes were included as part of the setup per IUA:

- All major dams as well as combined farm dams and irrigation areas; and
- Ecological requirements for all the EWR sites for the PES and REC ecological categories.

The detailed system diagrams are available as part of the Reconciliation Strategy Studies being undertaken by the DWA.

Planning model runs

The WRPM was run for the Crocodile West and Mokolo catchments with present day (2013 for Crocodile West and 2010 for Mokolo) or future growth (2030) water requirements and with the EWR requirements for PES and REC ecological category.

The WRYM was run for the Marico catchment with present day (2009) or future growth (2030) water requirements and with the EWR requirements for PES and REC ecological category.

The WRYM was setup and run for the Matlabas catchment with present day use (WR2005) and no future water use requirements and with the EWR requirements for PES and REC ecological category.

This allowed for the determination of the resulting water balance for the Crocodile West, Marico and Mokolo and Matlabas catchments with the implementation of the alternate scenarios. The results of the water balances were then used as input to the economic analyses to determine the macro-economic consequences of each scenario.

6.1.2 WATER SUPPLY SYSTEM RECONCILIATION STRATEGY/HYDROLOGY REPORTS/ISP

The various reconciliation strategies, hydrology reports and Internal Strategic Perspectives (ISP) identified a series of interventions to achieve a balance in the various catchments between water availability and water requirements. The identified measures lean towards management interventions rather than development interventions.

6.1.2.1 Crocodile West Catchment

The following options were identified in the Reconciliation Strategy:

- Effluent reuse: direct reuse before discharging;
- New dam downstream of confluence with Moretele;
- Abstraction of water from Hartbeespoort Dam for treatment to industrial standard for mines and industries;
- Madibeng Town and the communities around the dam should best be served with potable water directly from the Rand Water system;

- The feasibility of routing effluent discharges from the local communities to a location downstream of the dam should also be investigated;
- Rustenburg mines currently use potable water from Rand Water; if water is used from the river this would free up Rand Water water; and
- Transfer of water to Lephalale area: the pumping of raw water from the Vaal River or Vaal Dam up to the divide, where it can be released for gravity flow to Hartbeespoort Dam and then to the new possible dam at Boschkop. Given the constant effluent returns already providing for base flows in several tributaries, the addition of raw water to such streams should not result in significant additional losses. Tight abstraction control will need to be exercised; diversion of effluent from waste water treatment plants in the Vaal River catchment but close to the divide with the Crocodile catchment, to be diverted towards the Crocodile River;

6.1.2.2 Marico Catchment

The following options were identified in the Updated hydrology (2009 report):

Marico

- Effluent reuse: direct reuse before discharging;
- Groundwater use;
- International obligations (TSWASA);
- Marico biosphere; and
- Irrigation: trading of water

Upper Molopo

- Direct effluent reuse: direct reuse before discharging
- Groundwater use; and
- Irrigation: trading of water.

Upper Ngotwane

- Effluent reuse: direct reuse before discharging
- Groundwater use; and
- Irrigation: trading of water.

6.1.2.3 Matlabas Catchment

The following options were identified in the ISP document and from WR2005 information

- Groundwater use; and
- Future mining in Steenbokpan.

6.1.2.4 Mokolo Catchment

The following options were identified in the document "Updating the hydrology and yield analysis of the Mokolo River" (2007 report):

- Improvements to the irrigation distribution systems;
- The raising of the Mokolo Dam; irrigation water could be re-allocated (through purchase) to the developments in Lephalale – this was not included here as it is no longer an option being considered;

- Such irrigation areas could be located either upstream or downstream of the proposed dam at Boschkop, or be in the Mokolo River catchment; and
- Debottlenecking of the existing Exxaro pipeline.

6.1.3 RESULTS OF THE YIELD ANALYSIS PER SCENARIO

The assessment of the scenarios included running of the WRPM and WRYM using the required EWRs per scenario and water requirements (as per the Reconciliation strategies, hydrology reports and ISPs) to test whether these EWRs for all nodes can be met. The WRPM and WRYM for the catchments in the study were run with the scenarios as described above.

The assessment allows for evaluation of the availability of water in the catchment with the EWRs required for maintaining the different ecological categories per scenario. This allows for the determination of the water balance (surpluses/deficits) per IUA.

6.1.3.1 The PES (ESBC) Scenario - Scenario 1

The yield analysis results with the ESBC scenario indicate varying degrees of water surpluses and deficits. The results of the simulation for the ESBC are listed in **Table 22**.

Table 22: Impact of EWR (PES) at major dams

Major Dam	Catchment	Yield without EWR (million m^3/a)	Yield with EWR (million m^3/a)
Klein Maricopoort	A31D	5.38	3.98
Kromelmboog	A31E	2.61	2.44
Marico Bosveld	A31B	21.54	9.19
Molatedi	A32C	11.37	11.9
Mokolo	A42F	38.7	3.48 – dependent on operating rules
Hartbeespoort	A21H	237.9	231.0
Roodekopjes	A21L	59.0	55.0
Lindleyspoort	A22E	3.4	2.7
Bospoort	A22H	1.3	0.9
Vaalkop	A22J	6.5	3.4
Roodeplaat	A23A	37.5	35.0
Klipvoor	A23J	24.5	28.0

* All other water user requirements (irrigation, domestic, industrial, mining, power generation and forestry) within the catchments were included for both yield with and without EWR.

This configuration of ecological categories ensures that a sustainable level of ecosystem functioning is maintained in the Crocodile (West), Marico, Matlabas and Mokolo catchments.

The modelling of the various catchments including the EWRs (Present State) resulted in most of the cases a reduction of yield in the major dams. The following can be concluded:

Crocodile West catchment: The modelling of the EWRs in the Crocodile West catchment resulted in a slight decrease of yield with the largest decrease in the Elands River catchment at Vaalkop Dam with a reduction from 6.5 x 10^6m^3 to 3.4 x 10^6m^3. The yield from Klipvoor Dam increased mainly due to EWR releases.

Marico catchment: The most severe change in yield was in the Marico Bosveld Dam with a reduction in yield from 21.5 x 10^6m^3 to 9.2 x 10^6m^3. The slight increase in yield in Molatedi Dam is due to the releases for EWR from the upstream dams.

6.1.3.2 Alternate Scenarios per EWR site

The assessment of the ecological consequences were based on the resulting ecological categories for the fish and macroinvertebrates at the various EWR sites using the FFHA and IFHA models as developed by Dr Kleynhans form the DWA. As the IFHA (macroinvertebrates) model is still under development and due to the absence of indicator macroinvertebrate species at a number of the EWR sites, the results of the FFHA (fish) model should be used as a final indication of the ecological consequences.

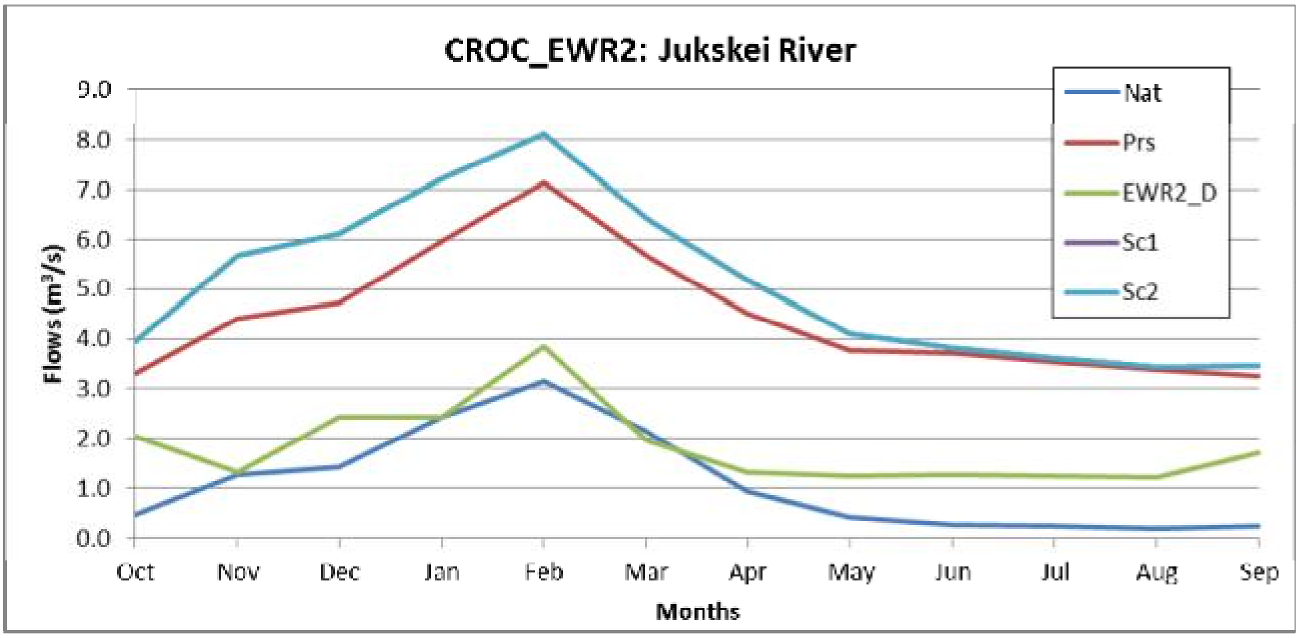
CROC_EWR 2: Jukskei River

The following scenarios were evaluated:

- Nat: Natural flows
- Prs: Present day flows
- Sc1: Present day water use (2010), PES
- Sc2: Future water use (2030), PES

Table 23: CROC_EWR 2

Optimum base flows - May (wet for Feb) and Aug (dry)						
	February			August		
	Average	Percentile	%	Average	Percentile	%
Nat	3.155	2.182	30	0.192	0.826	0.1
Prs	7.150	5.182	40	3.374	4.493	0.1
EWR2_D	3.839	4.473	40	1.222	1.436	0.1
Sc1	8.062	6.779	40	3.440	4.943	0.1
Sc2	8.980	7.704	40	4.236	5.849	0.1



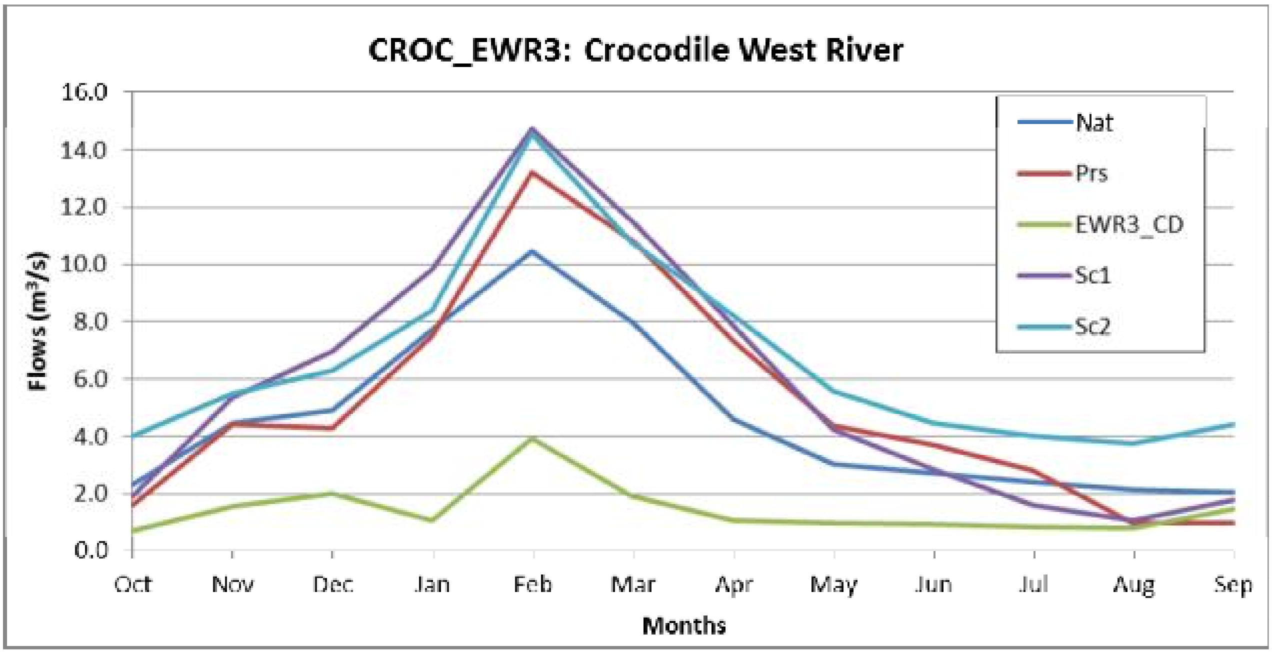
CROC_EWR 3: at Hartbeespoort Dam (IUA outlet)

The following scenarios were evaluated:

- Nat: Natural flows
- Prs: Present day flows
- Sc1: Present day water use (2010), PES
- Sc2: Future water use (2030), PES

Table 24: CROC_EWR 3

Optimun base flows - May (wet for Feb) and Aug (dry)						
	February			August		
	Average	Percentile	%	Average	Percentile	%
Nat	10.439	7.357	30	2.154	4.421	0.1
Prs	13.228	11.080	30	0.967	5.066	0.1
EWR3_CD	3.941	5.228	30	0.810	0.915	0.1
Sc1	14.720	12.657	30	1.131	6.075	0.1
Sc2	14.424	9.745	30	3.792	7.536	0.1



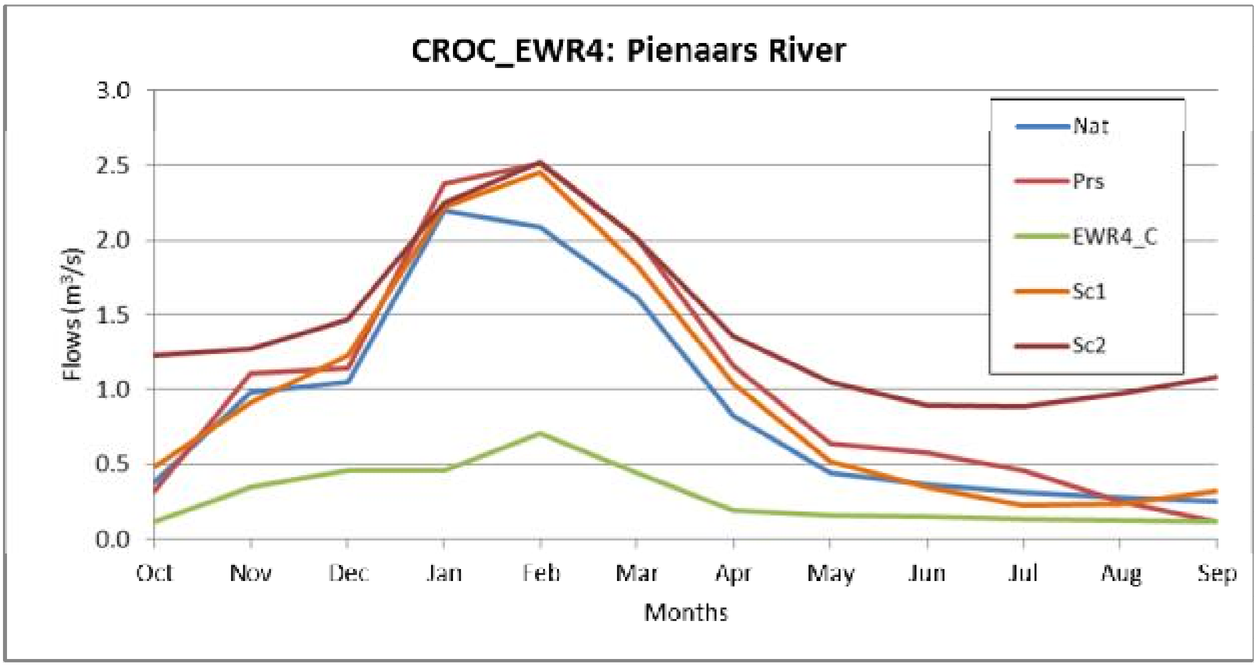
CROC_EWR 4: Pienaars to outlet of IUA1

The following scenarios were evaluated:

- Nat Natural flows
- Prs Present day flows
- Sc1 Present day water use, PES
- Sc2 Future water use, PES

Table 25: CROC_EWR 4

Optimun base flows - May (wet for Jan) and Sep (dry)							
	January			September			
	Average	Percentile	%	Average	Percentile	%	
Nat	2.203	2.466	20	0.255	0.540	0.1	
Prs	2.381	3.142	20	0.115	0.834	0.1	
EWR4_C	0.458	0.631	20	0.115	0.140	0.1	
Sc1	2.205	2.393	20	0.328	0.930	0.1	
Sc2	2.241	1.414	20	1.085	1.145	0.1	



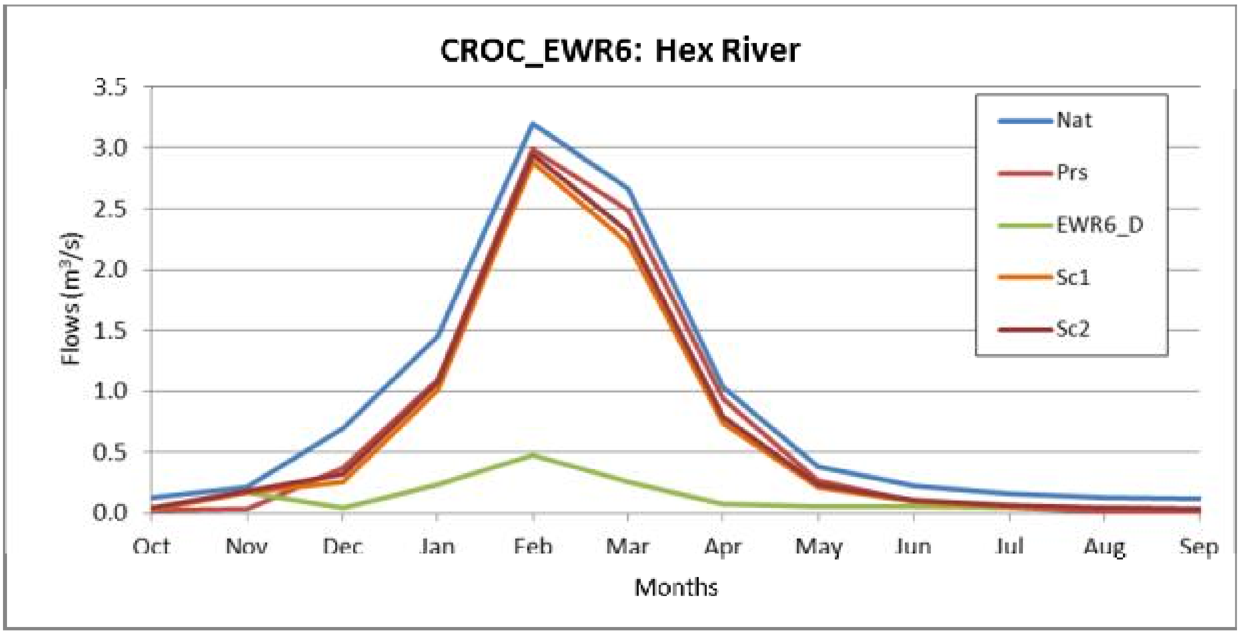
CROC_EWR 6: Hex River from Bospoort Dam to Vaalkop

The following scenarios were evaluated:

- Nat Natural flows
- Prs Present day flows
- Sc1 Present day water use, PES
- Sc2 Future water use, PES

Table 26: CROC_EWR 6

Optimun base flows - June (wet for Feb) and Sep (dry)						
	February			September		
	Average	Percentile	%	Average	Percentile	%
Nat	3.200	2.304	15	0.112	0.410	1
Prs	2.991	1.979	15	0.015	0.306	1
EWR6_D	0.474	1.060	15	0.033	0.047	1
Sc1	2.888	1.351	15	0.036	0.083	1
Sc2	2.951	1.459	15	0.037	0.096	1



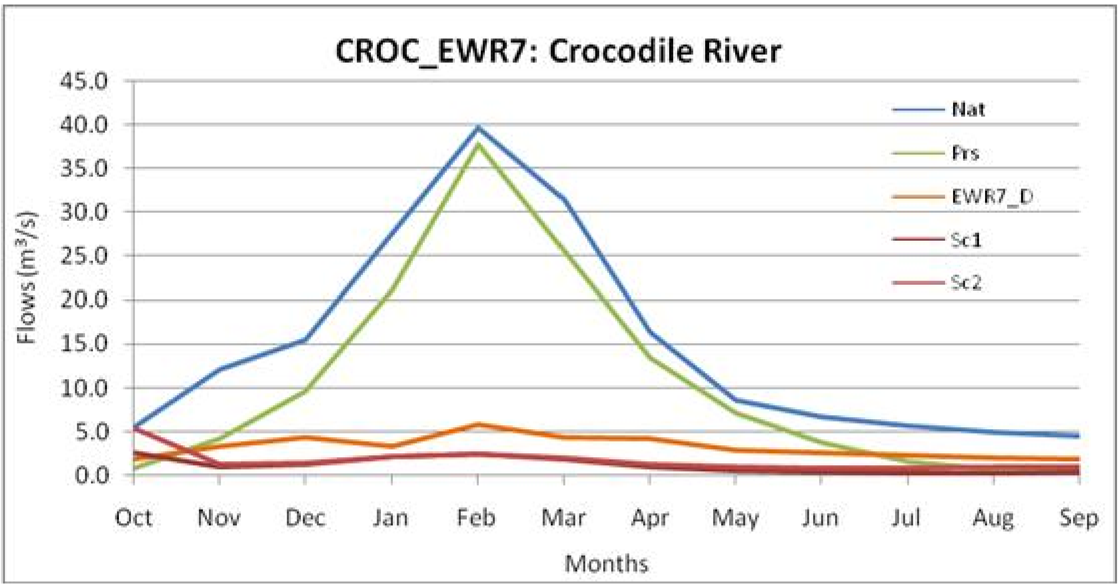
CROC_EWR 7: Crocodile from Roodekopjes Dam

The following scenarios were evaluated:

- Nat Natural flows
- Prs Present day flows
- Sc1 Present day water use, PES
- Sc2 Future water use, PES

Table 27: CROC_EWR 7

Optimun base flows - June (wet for Feb) and Sep (dry)						
	February			September		
	Average	Percentile	%	Average	Percentile	%
Nat	39.650	12.918	40	11.425	9.059	5
Prs	37.801	11.997	40	0.909	0.884	5
EWR7_D	3.858	4.454	40	1.091	1.282	5
Sc1	37.028	10.090	40	2.572	3.111	5
Sc2	36.314	7.887	40	5.404	6.021	5

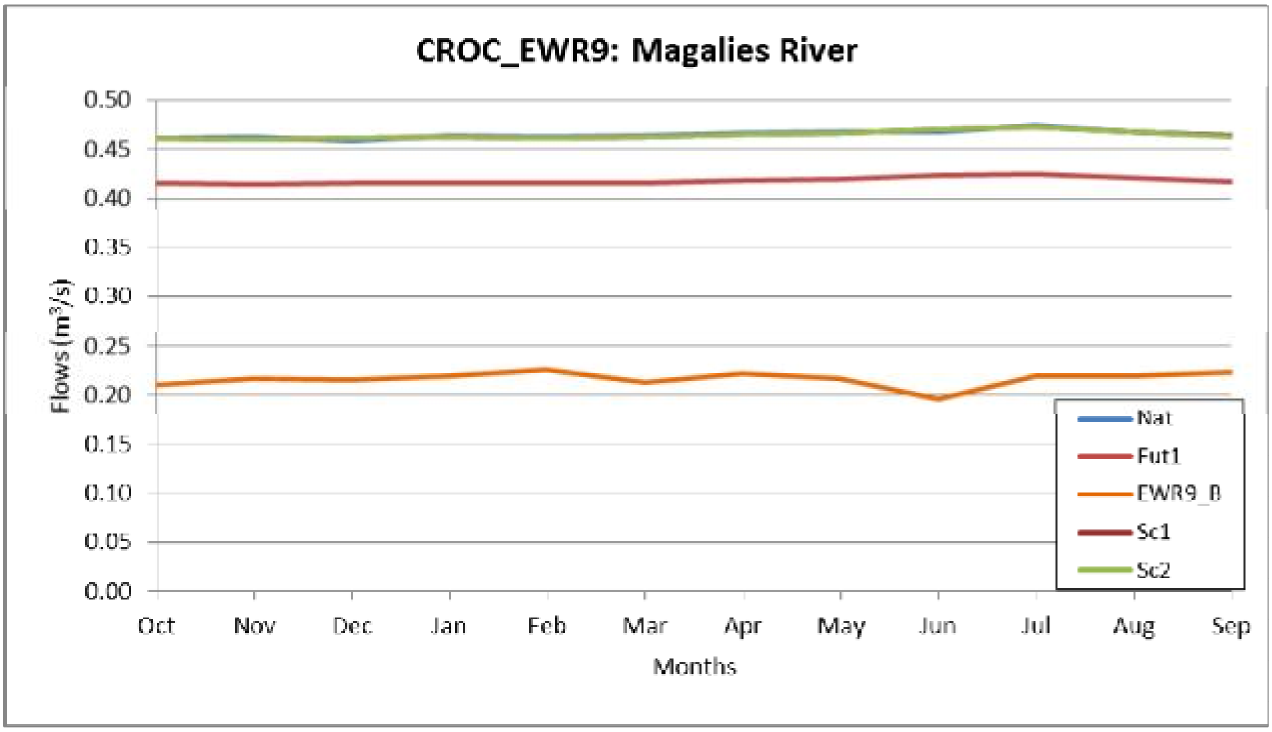


CROC_EWR 9: Magalies below Maloney's Eye

- Nat Natural flows (used observed flows as reference for EWR)
- Fut Sc1 - 10% (dolomitic outflow reduced by 10%)
- Sc1 Present day water use, PES
- Sc2 Future water use, PES

Table 28: CROC _EWR 9

Optimun base flows - Feb (wet) and Sep (dry)						
	February			September		
	Average	Percentile	%	Average	Percentile	%
Nat	0.463	1.021	0.1	0.463	0.750	5
Fut1	0.415	0.919	0.1	0.417	0.676	5
Fut2	0.369	0.817	0.1	0.371	0.601	5
EWR9_B	0.225	0.232	0.1	0.224	0.228	5
Sc1	0.462	1.021	0.1	0.463	0.751	5
Sc2	0.461	1.021	0.1	0.463	0.751	5

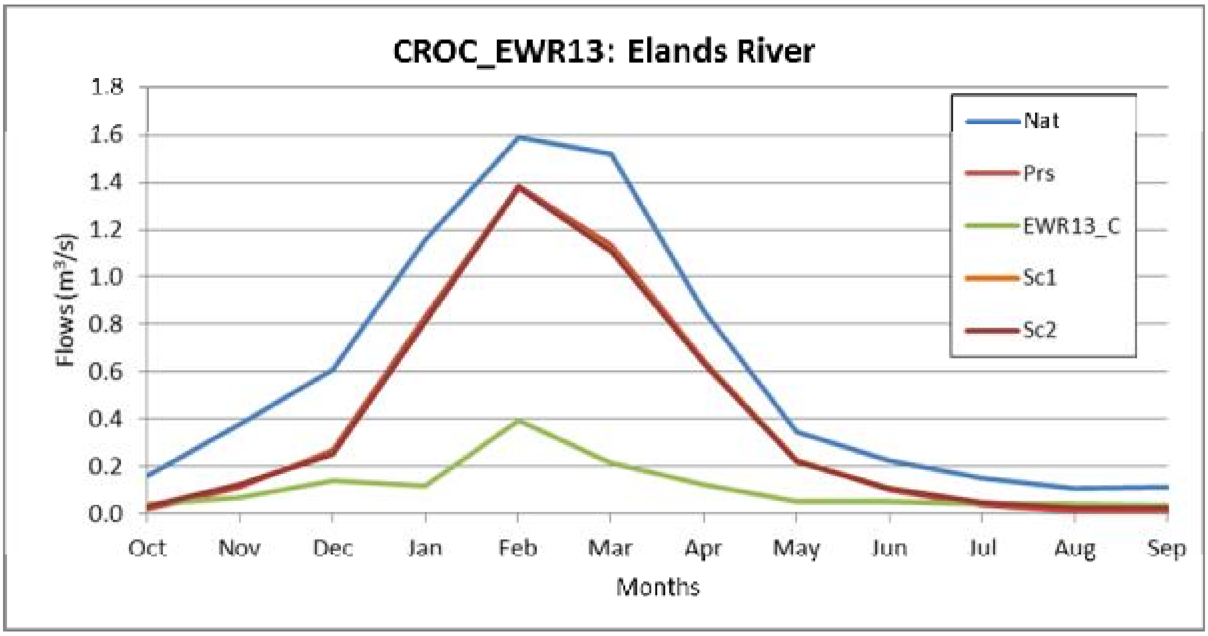


CROC EWR_13: Elands River from Lindleyspoort Dam

- Nat Natural flows
- Prs Present day flows without EWR
- Sc1 Present day water use (same as Sc1), PES
- Sc2 Future water use, PES

Table 29: CROC_EWR 13

Optimun base flows - Jun (wet for Feb) and Aug (dry)						
	February			August		
	Average	Percentile	%	Average	Percentile	%
Nat	1.156	0.719	30	0.105	0.409	1
Prs	1.384	0.405	30	0.009	0.195	1
EWR13_C	0.395	0.607	30	0.038	0.069	1
Sc1	1.380	0.345	30	0.022	0.195	1
Sc2	1.376	0.344	30	0.022	0.188	1

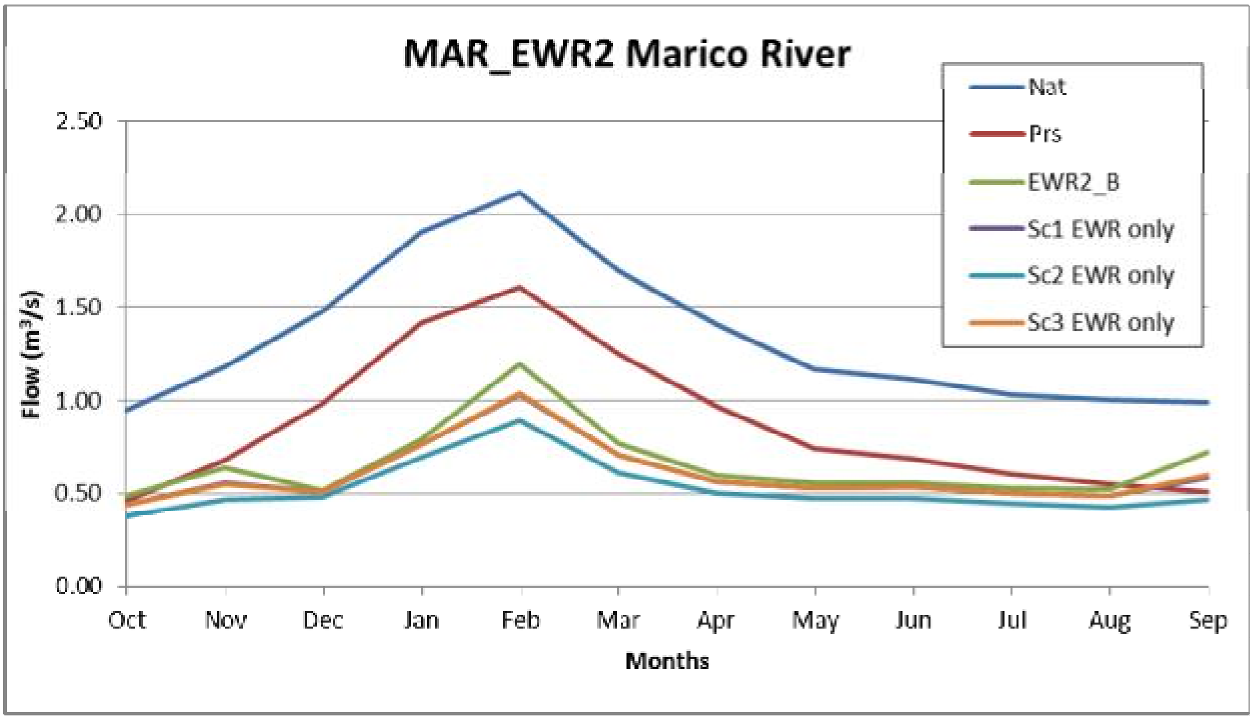


MAR_ EWR 2: Marico River

- Nat Natural flows
- Prs Present day flows
- Sc1 Present day water use, PES - use only EWR proportion for assessment
- Sc2 Future water use (25% Reduction in dolomitic outflows from natural), PES - use only EWR proportion for assessment

Table 30: MAR_EWR 2

Optimun base flows - May (wet for Feb) and Aug (dry)						
	February			August		
	Average	Percentile	%	Average	Percentile	%
Nat	2.115	2.330	20	0.991	1.573	0.1
Prs	1.600	1.818	20	0.808	1.087	0.1
EWR2_B	1.200	1.456	20	0.725	0.762	0.1
Sc1, EWR only	1.033	1.470	20	0.584	0.761	0.1
Sc2, EWR only	0.893	1.463	20	0.469	0.761	0.1
Sc3, EWR only	1.036	1.470	20	0.599	0.761	0.1

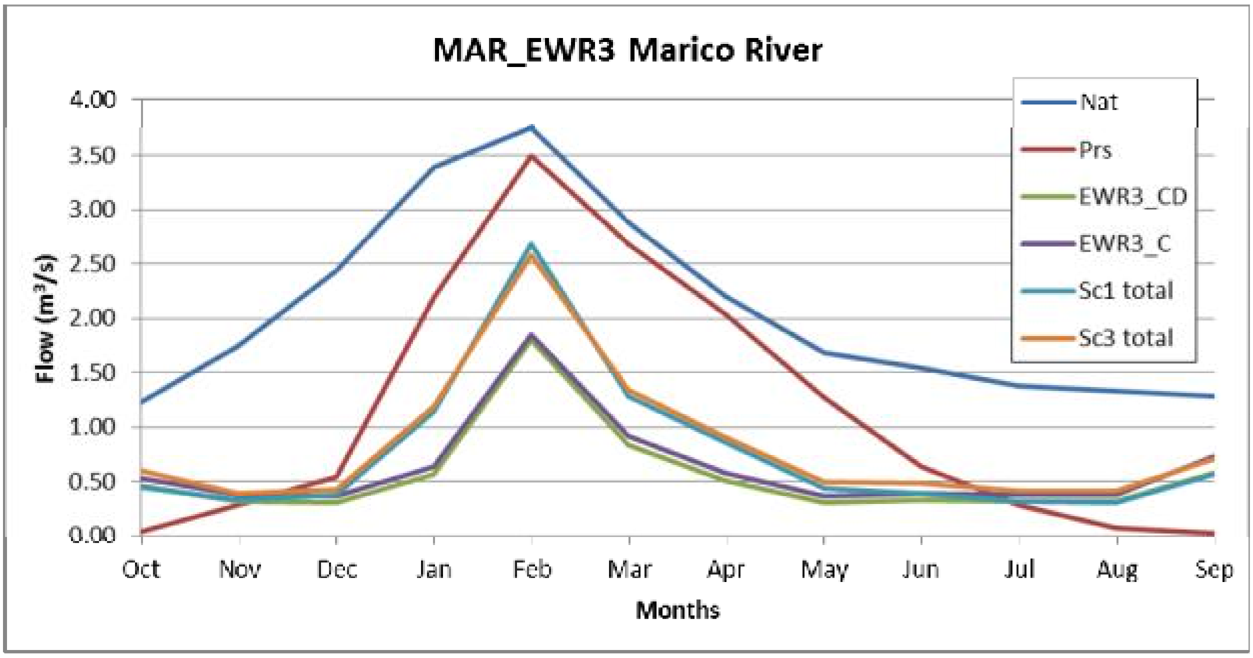


MAR_EWR 3

- Nat Natural flows
- Prs Present day flows
- Sc1 Present day water use, PES
- Sc3 Present day water use, REC

Table 31: MAR_EWR 3

Optimun base flows - June (wet for Feb) and Sep (dry)						
	February			September		
	Average	Percentile	%	Average	Percentile	%
Nat	3.747	4.252	20	1.286	1.915	1
Prs	3.496	2.442	20	0.022	0.180	1
EWR3_CD	1.796	2.477	20	0.576	0.647	1
EWR3_C	1.847	2.633	20	0.733	0.833	1
Sc1 total	2.666	2.483	20	0.566	0.646	1
Sc3 total	2.510	2.617	20	0.652	0.831	1



The following demand curves (Figure 12,Figure 13,Figure 14,Figure 15,Figure 16, Figure 17 and Figure 18) for the Marico Dam for the various scenarios show the problems related to water supply from the dam.

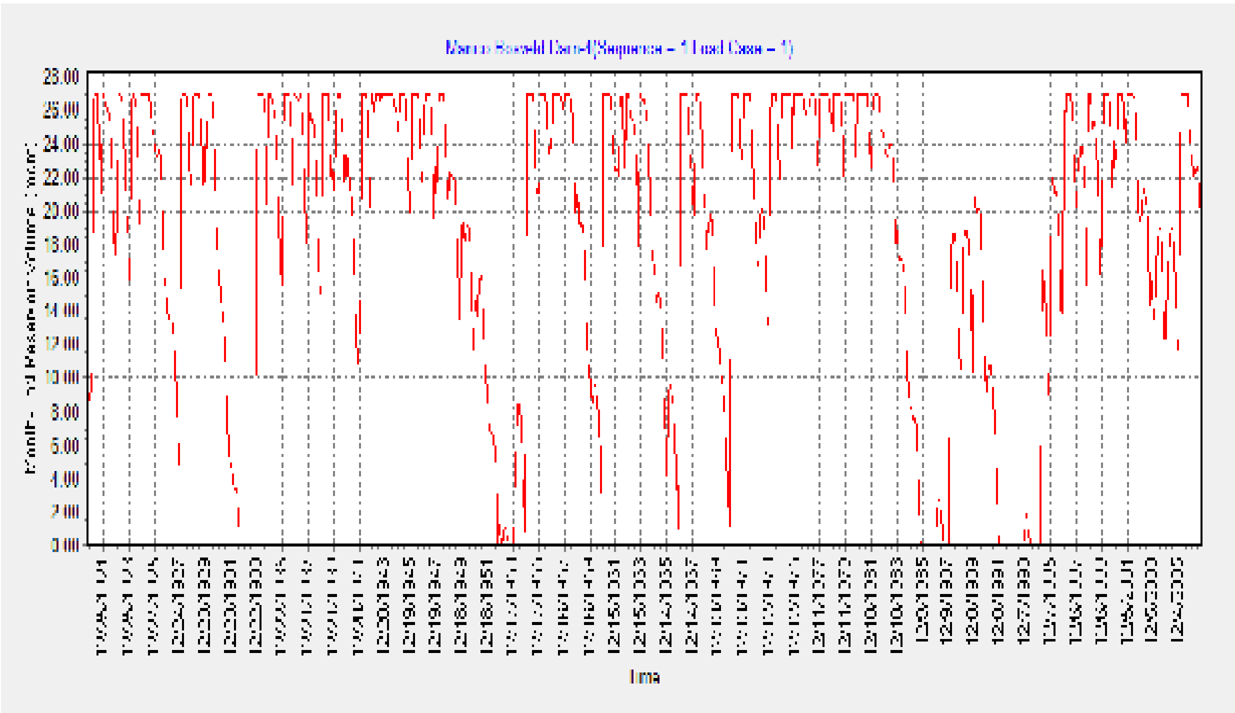


Figure 12: Present day flows without EWR

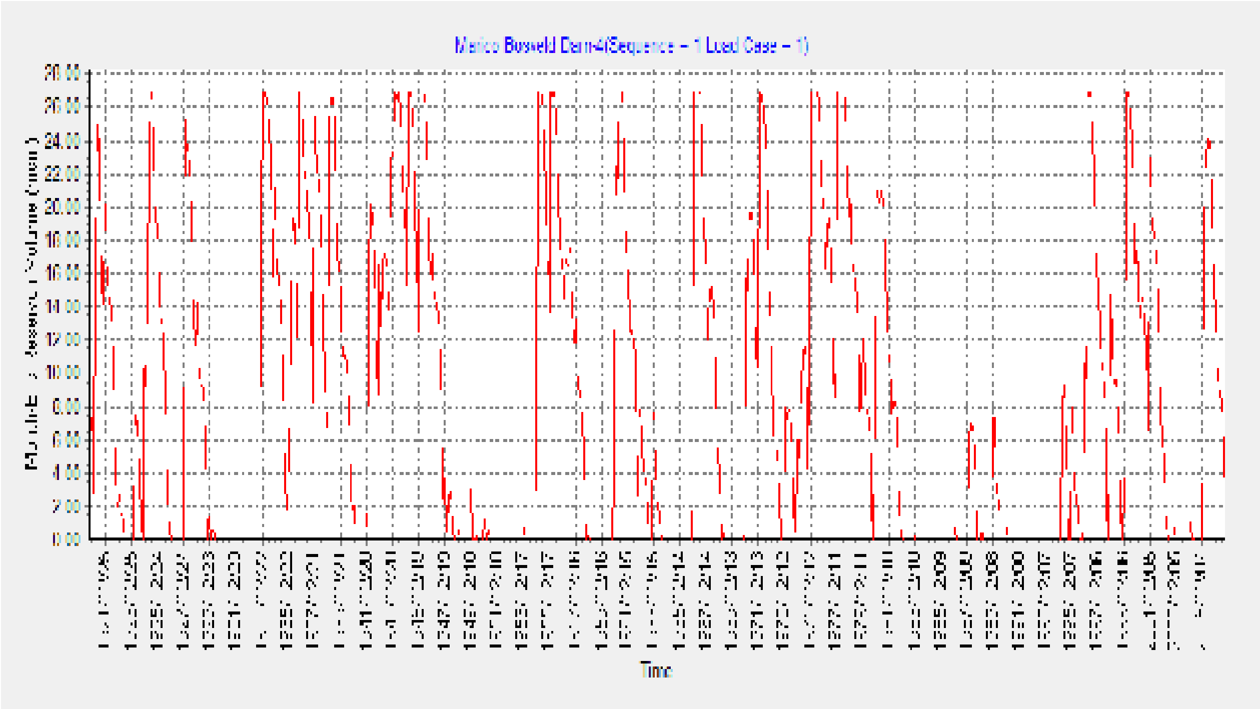


Figure 13: Present day water use, PES

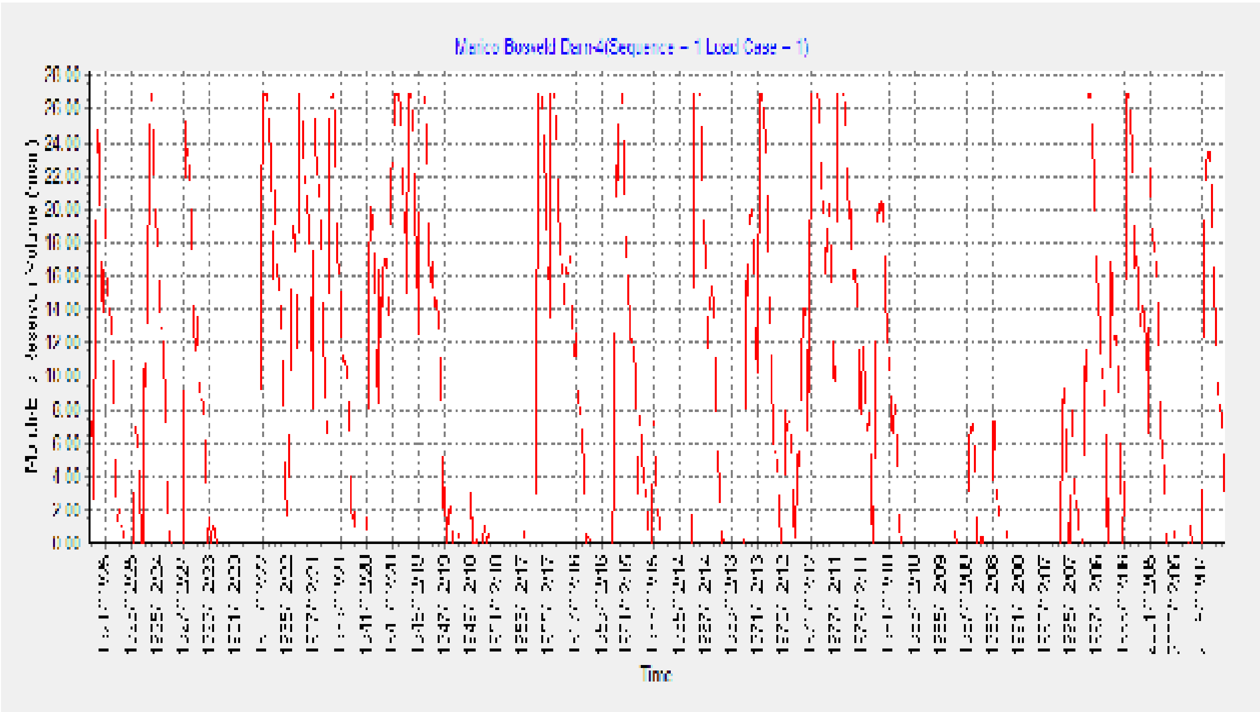


Figure 14: Future water use (500kl/day WWTW), PES

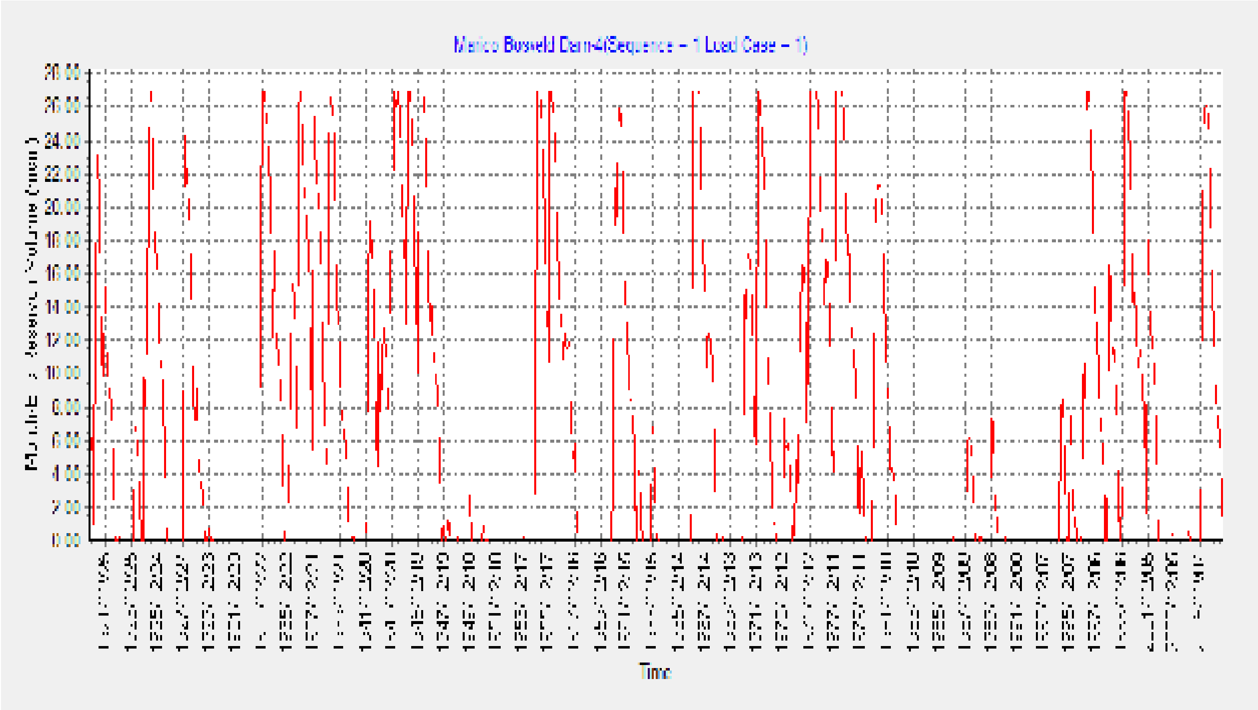


Figure 15: Present day water use, C category at EWR3, B category at EWR6

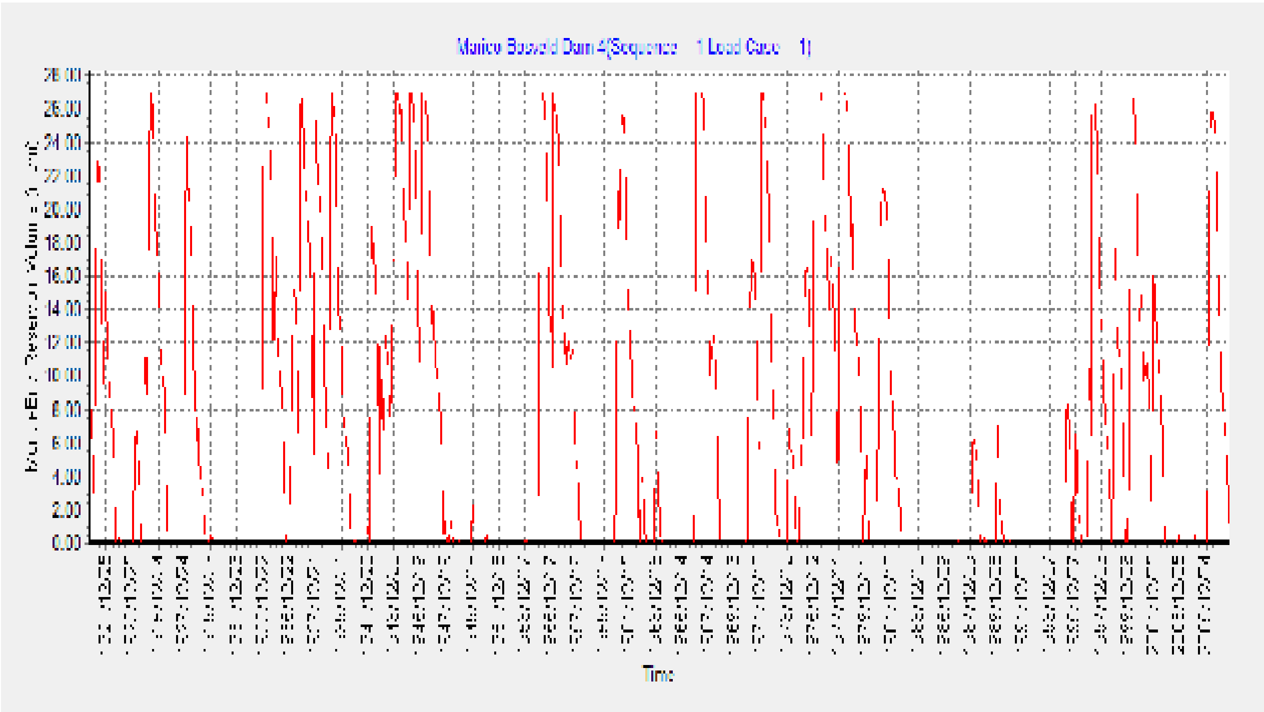


Figure 16: Future water use (500kl/day WWTW), C category at EWR3, B category at EWR6

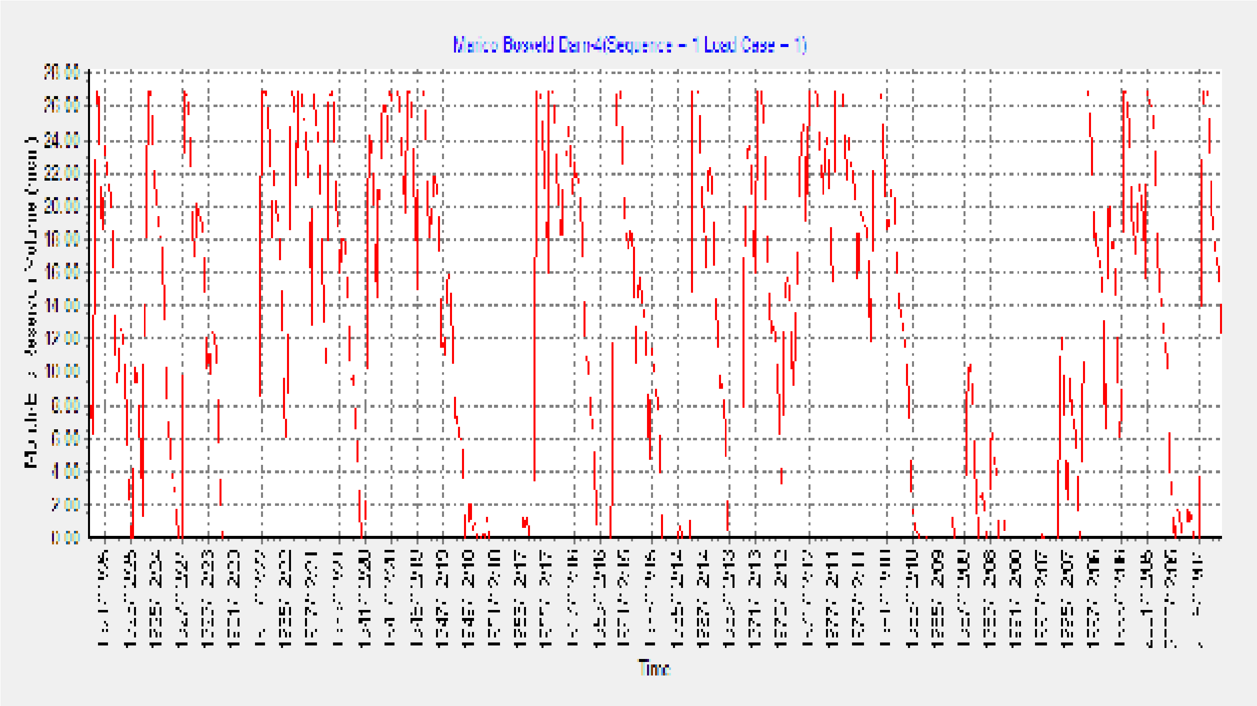


Figure 17: Present day water use, D category at EWR3, PES

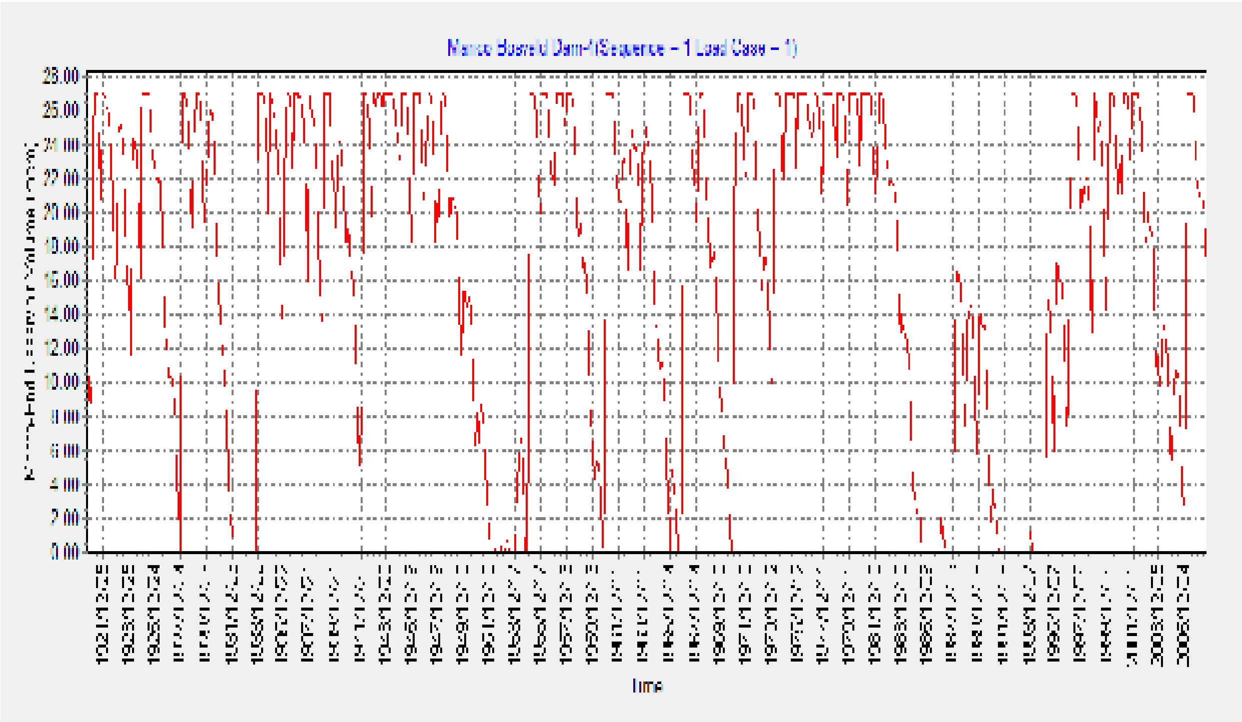


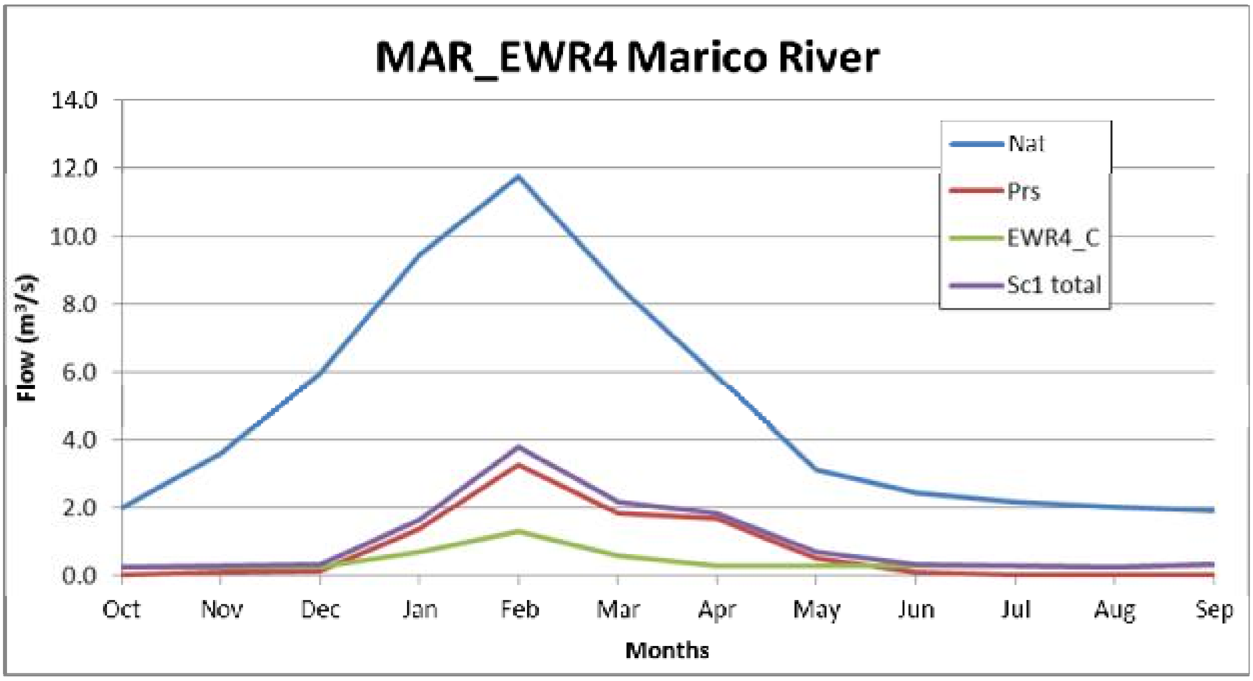
Figure 18: Present day water use, PES without floods/freshets at EWR3

MAR_EWR 4: Marico from Molatedi Dam to confluence with Crocodile

- Nat Natural flows
- Prs Present day flows
- Sc1 Present day water use, PES

Table 32: MAR_EWR 4

Optimun base flows - July (wet for Feb) and Sep (dry)						
	February			September		
	Average	Percentile	%	Average	Percentile	%
Nat	11.746	5.382	40	1.922	4.571	1
Prs	3.273	0.110	40	0.013	0.065	1
EWR4_C	1.311	1.530	40	0.335	0.365	1
Sc1	3.794	1.532	40	0.334	0.364	1



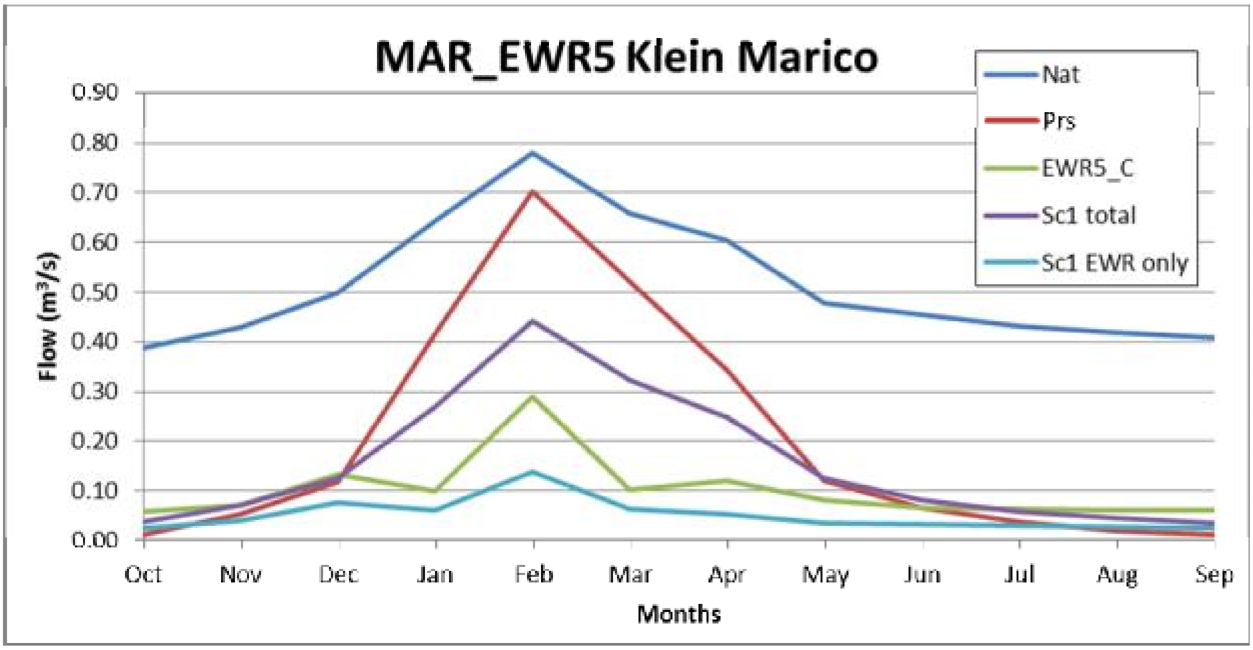
MAR_EWR 5: Klein Marico

- Nat Natural flows
- Prs Present day flows
- Sc1 Present day water use, PES
- Sc2 Future water use (10% Reduction in dolomitic outflows from present), PES

Table 33: MAR_EWR 5

Optimun base flows - May (wet for Feb) and Sep (dry)						
	February			September		
	Average	Percentile	%	Average	Percentile	%

Nat	0.780	2.243	5	0.408	1.359	0.1
Prs	0.701	4.396	5	0.011	0.380	0.1
EWR5_C	0.277	0.476	5	0.025	0.026	0.1
Sc1 total	0.442	2.303	5	0.028	0.402	0.1
Sc1 EWR only	0.140	0.476	5	0.016	0.026	0.1

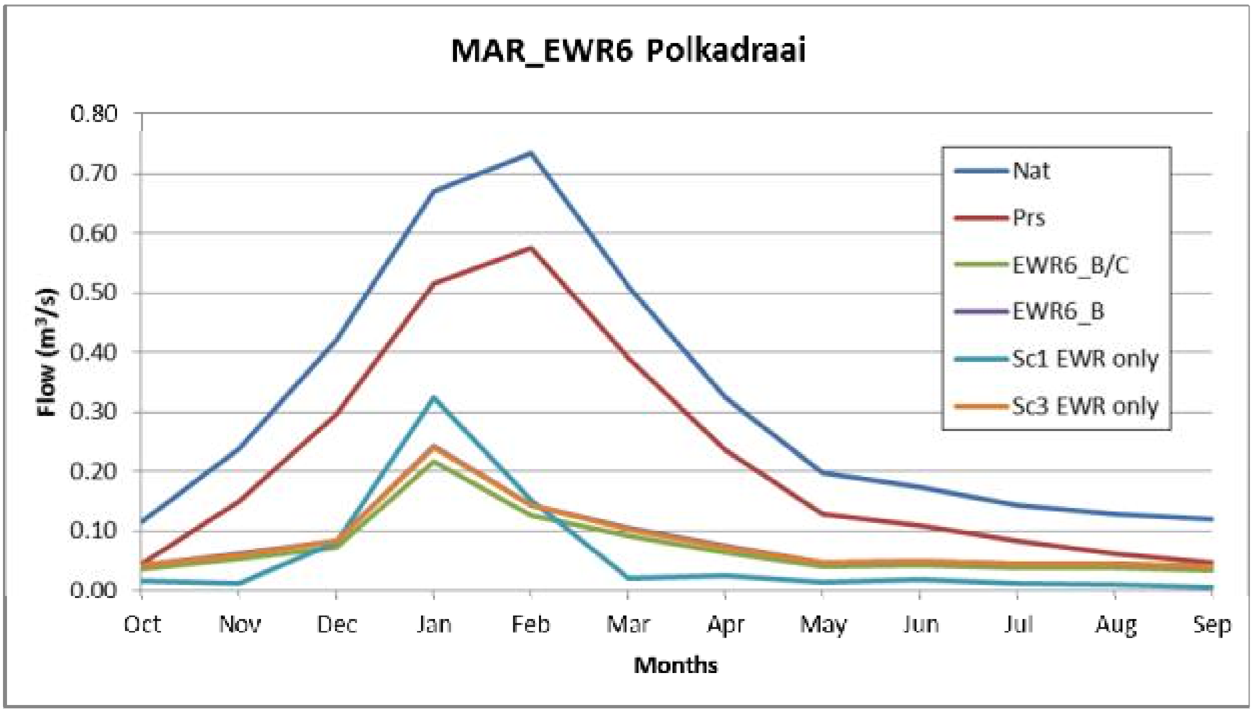


MAR_EWR 6: Polkadraaispruit

- Nat Natural flows
- Prs Present day flows
- Sc1 Present day water use, PES - use EWR channel only
- Sc3 Present day water use, REC - can't supply total

Table 34: MAR_EWR 6

Optimun base flows - Jun (wet for Feb) and Sep (dry)						
	February			September		
	Average	Percentile	%	Average	Percentile	%
Nat	0.734	0.376	30	0.120	0.289	0.1
Prs	0.576	0.283	30	0.047	0.200	0.1
EWR6_B/C	0.126	0.195	30	0.035	0.079	0.1
EWR6_B	0.144	0.223	30	0.041	0.093	0.1
Sc1, EWR only	0.151	0.195	30	0.006	0.078	0.1
Sc3, EWR only	0.143	0.225	30	0.040	0.091	0.1

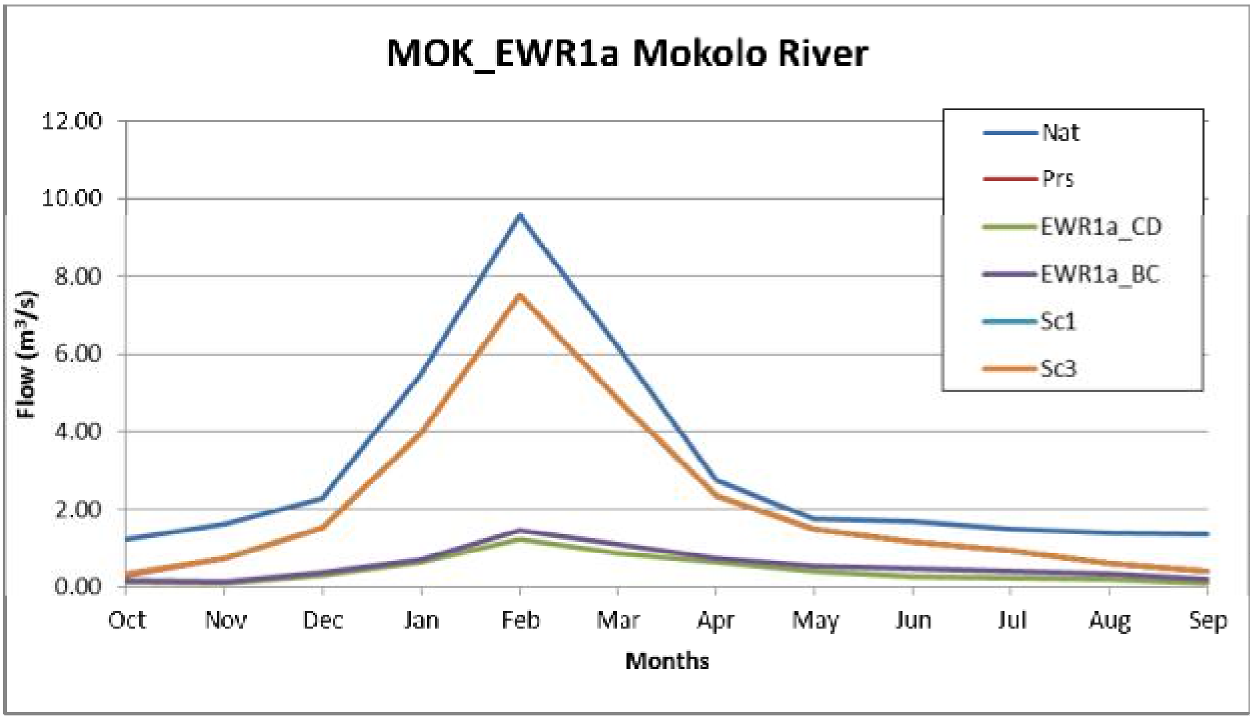


MOK_EWR 1a: Mokolo River

- Nat Natural flows
- Prs Present day flows
- Sc1 Present day water use, PES
- Sc3 Present day water use, REC

Table 35: MOK_EWR 1a

Optimun base flows - Jun (wet for Feb) and Sep (dry)						
	February			September		
	Average	Percentile	%	Average	Percentile	%
Nat	9.560	11.797	20	1.236	2.174	1
Prs	7.532	6.940	20	0.309	2.228	1
EWR1a_C/D	1.229	1.952	20	0.124	0.192	1
EWR1a_B/C	1.460	2.430	20	0.156	0.247	1
Sc1	7.532	6.940	20	0.325	2.228	1
Sc3	7.532	6.940	20	0.333	2.228	1

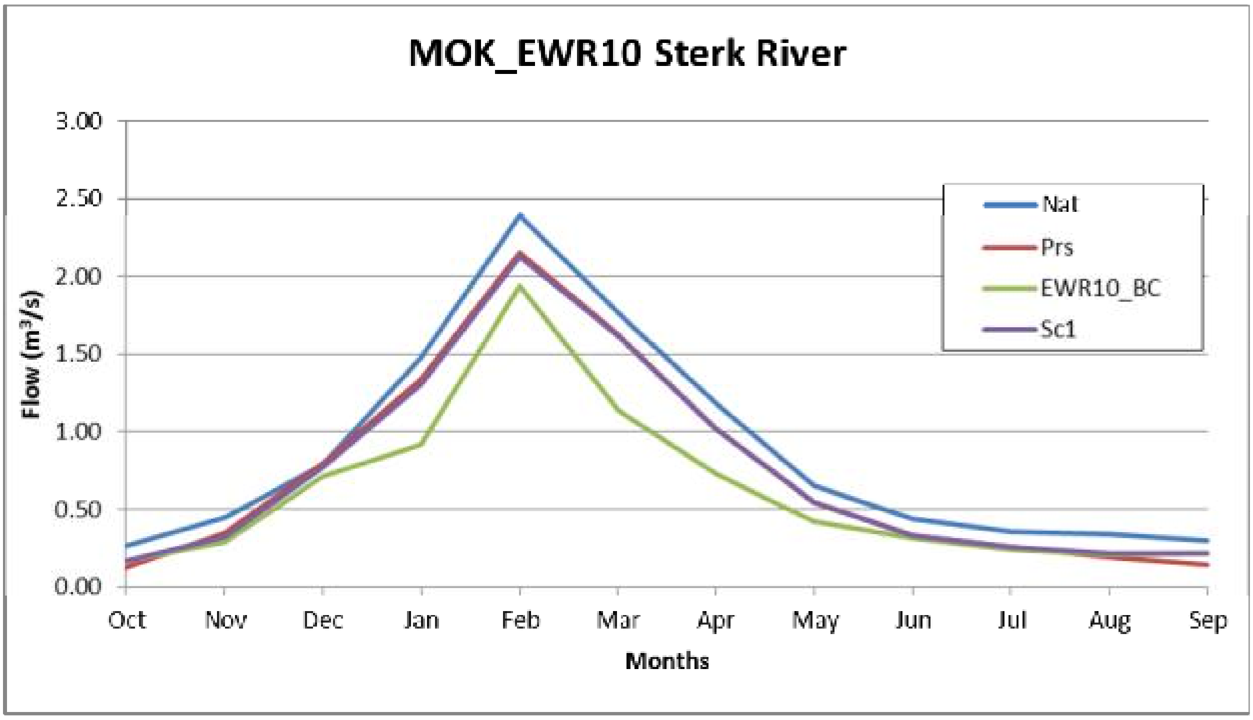


MOK_EWR 10: Sterk River

- Nat Natural flows
- Prs Present day flows
- Sc1 Present day water use, PES

Table 36: MOK_EWR 10

Optimun base flows - Jun (wet for Feb) and Sep (dry)						
	February			September		
	Average	Percentile	%	Average	Percentile	%
Nat	2.395	5.089	15	0.264	0.672	1
Prs	2.150	4.557	15	0.127	0.758	1
EWR10_B/C	1.937	4.557	15	0.167	0.679	1
Sc1	2.130	4.557	15	0.167	0.679	1

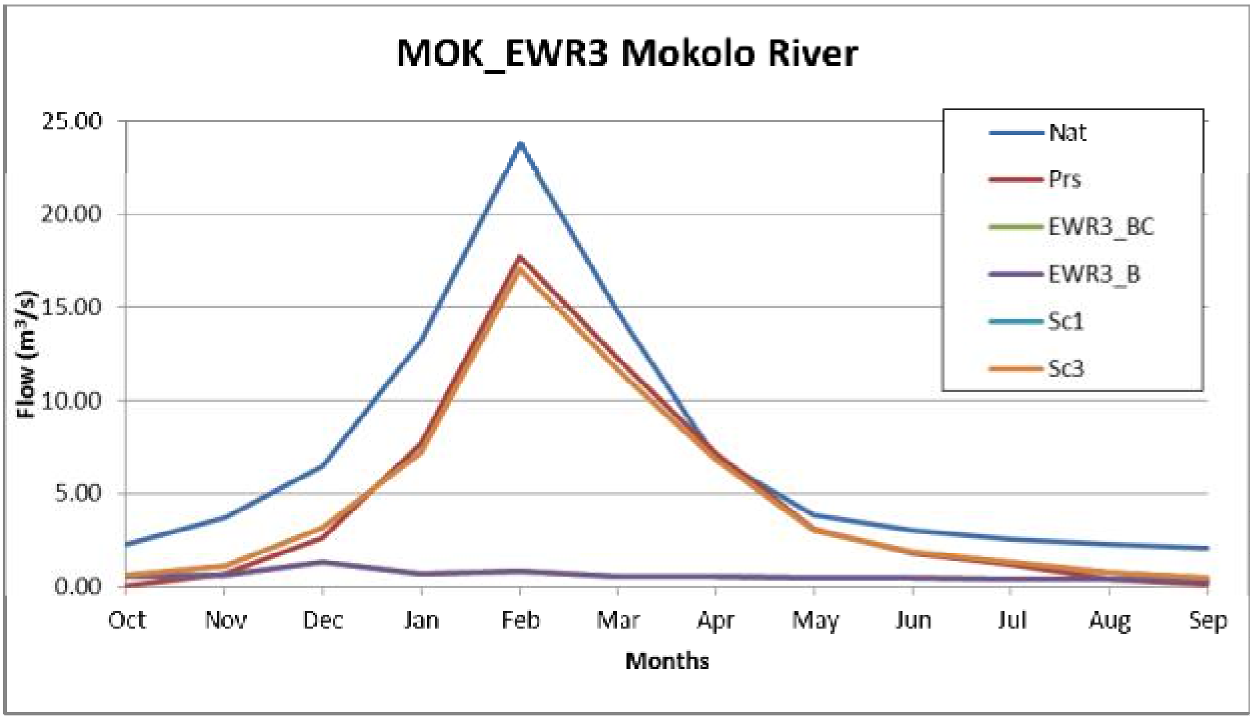


MOK_EWR 3: Mokolo River

- Nat Natural flows
- Prs Present day flows
- Sc1 Present day water use, PES
- Sc3 Present day water use, REC

Table 37: MOK_EWR 3

Optimun base flows - Jun (wet for Feb) and Sep (dry)						
	February			September		
	Average	Percentile	%	Average	Percentile	%
Nat	23.785	30.342	20	2.081	3.924	1
Prs	17.771	31.403	20	0.116	2.274	1
EWR3_B/C	0.835	1.036	20	0.402	0.503	1
EWR3_B	0.835	1.036	20	0.372	0.503	1
Sc1	17.054	24.533	20	0.489	2.274	1
Sc3	17.086	25.191	20	0.459	2.274	1

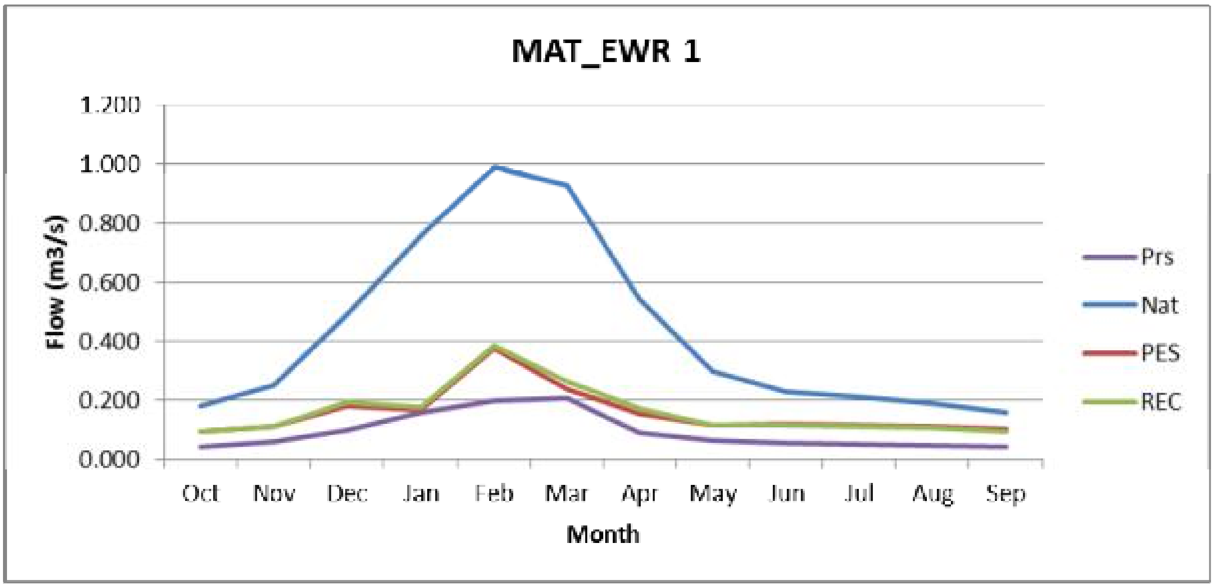


MAT_EWR 1: Motlhabatsi River

- Nat Natural flows
- Prs Present day flows
- Sc1 Present day water use, PES
- Sc2: Present day water use, REC

Table 38: MAT_EWR 1

Optimum base flows - Jun (wet for Feb) and Sep (dry)						
	February			September		
	Average	Percentile	%	Average	Percentile	%
Nat	0.99	0.88	10	0.16	0.073	1
Prs	0.199		10	0.043		1
EWR1_B_PES	0.378	0.96	10	0.101	0.137	1
EWR 1_A_REC	0.386	1.267	10	0.093	0.168	1

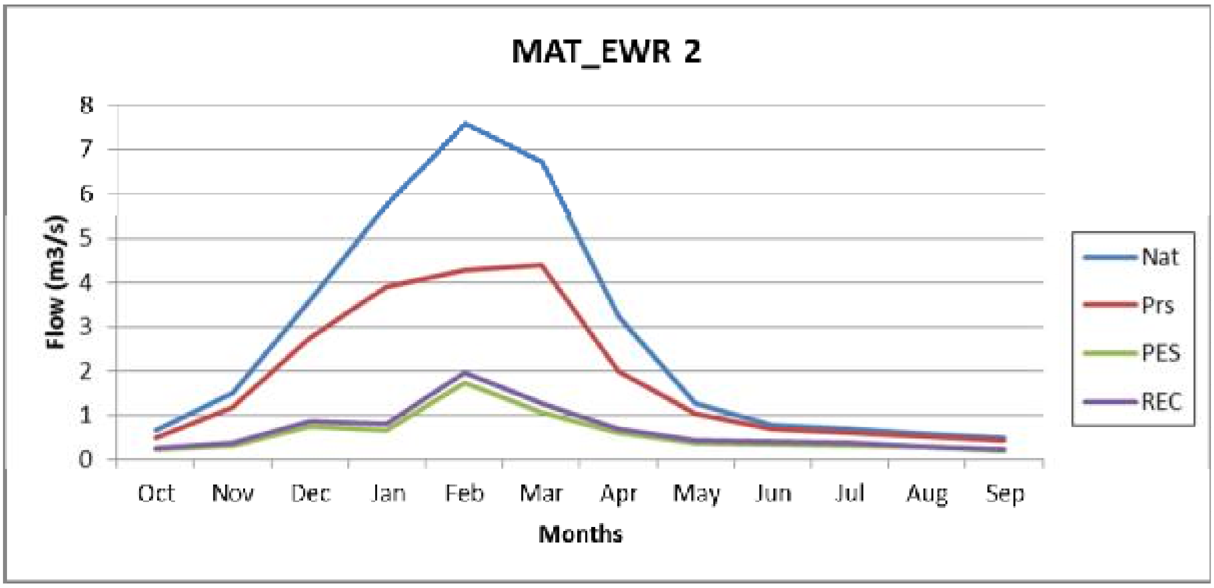


MAT_EWR 2: Matlabas River

- Nat Natural flows
- Prs Present day flows
- Sc1 Present day water use, PES
- Sc2: Present day water use, REC

Table 39: MAT_EWR 2

Optimun base flows - Jun (wet for Feb) and Sep (dry)						
	February			September		
	Average	Percentile	%	Average	Percentile	%
Nat	7.59		10	0.47		1
Prs	4.275		10	0.414		1
EWR2_B_PES	1.721		10	0.193		1
EWR2_A_REC	1.963		10	0.231		1



6.2 ECOLOGICAL CONSEQUENCES

The purpose of this section is to provide the ecological consequences of catchment scenarios, *i.e.* the impact on the Ecological Category of the Ecological Water Requirement (EWR) sites where applicable. The purpose of this is to provide information regarding the implications of the flow scenario and corresponding Ecological Category (EC) on the ecology, by predicting the biota responses to each scenario.

6.2.1 Assessment of ecological consequences

Specific high confidence EWR sites where hydraulic information was available were identified to undertake detail assessment of the ecological consequences. Existing hydraulic cross-sections from the Intermediate Reserve determination studies for the Crocodile West/Marico (DWA, 2009) and Mokolo (DWA, 2008) were used to assess the ecological consequences with higher confidence. Cross-sections were obtained from the hydraulic specialist and re-worked to be interpreted by the ecologists.

Priority EWR sites were assessed. These included EWRs 2, 3, 4, 6, 7, 9 and 13 in the Crocodile West catchment; EWRs 2, 3, 6, 5 and 4 in the Marico catchment; EWRs 1 and 2 in the Matlabas catchment; and EWRs 1a, 3 and 10 in the Mokolo catchment (Table 40 and Figure 19).

The aim was to at least have one EWR site per IUA where detailed ecological consequences were determined. IUAs 7, 8, 9 and 10 were not included as they are all groundwater nodes. The results of the assessments are included in Appendix A.

The other EWR sites from the Reserve determination study and the additional rapid studies were analysed using flow duration curves (FDC) for the identified optimum flow months (high and low optimum flows). These curves were used to determine if the EWRs were met during the specific months. The sites that were analysed using FDCs are listed in Table 42.

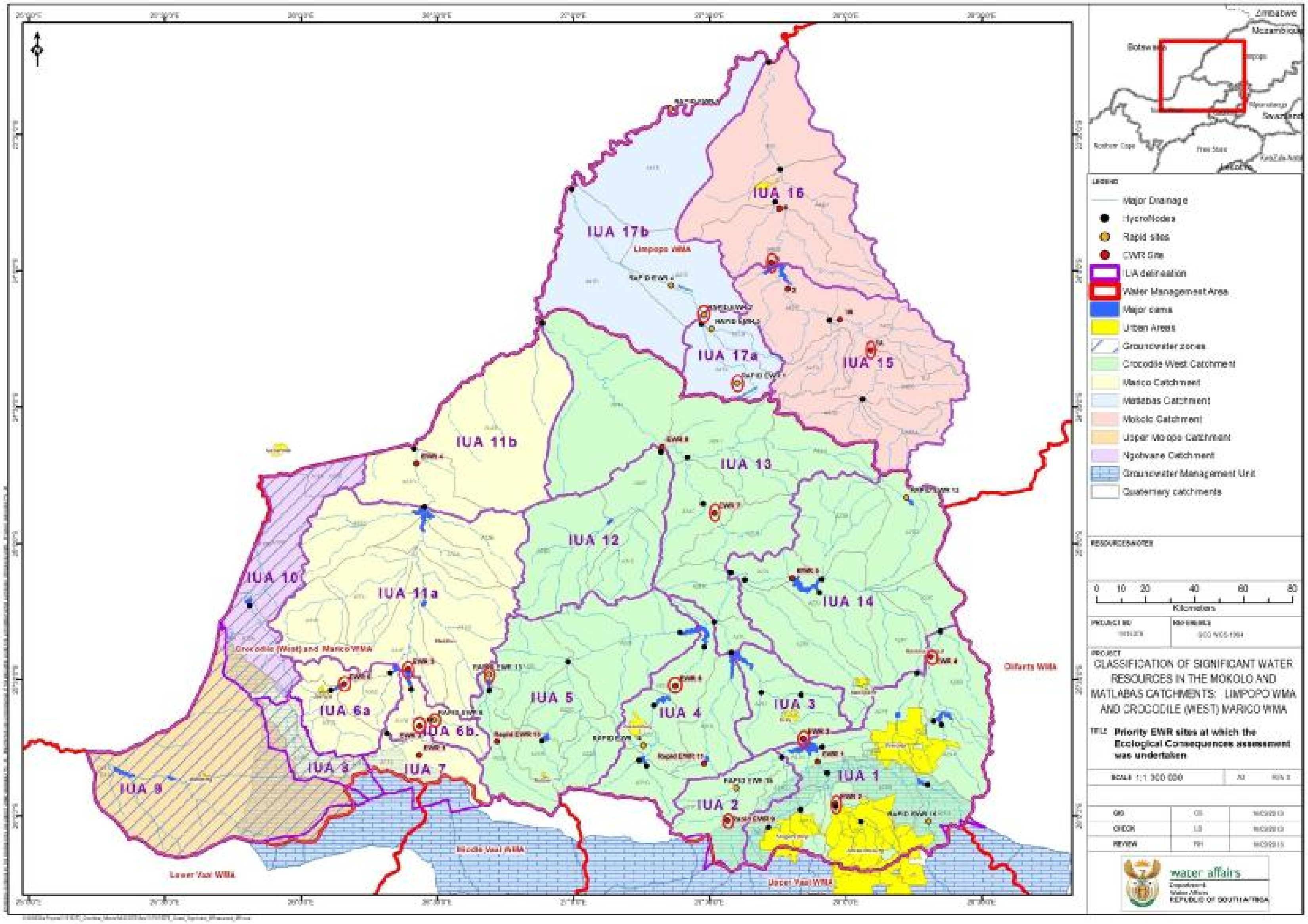


Figure 19: Priority EWR sites at which the ecological consequences assessment was undertaken

The following EWR sites were assessed with the FFHA and IFHA models using the optimum wet and dry season base flows.

Table 40: EWR sites with detail ecological consequences assessment

IUA	Delineation	EWR used for detail assessment	Notes
1	Upper Crocodile/ Hennops/Hartebeespoort	CROC_EWR2	CROC_EWR1, Crocodile upstream Hartbeespoort Dam CROC_EWR2, Jukskei at Heron Bridge School CROC_EWR4, Pienaars downstream of Roodeplaat Dam CROC_16, Rietspruit upstream Rietvlei Dam
2	Magalies	CROC_EWR9	CROC_EWR9, Magalies downstream Malonney's Eye CROC_EWR15, Magalies upstream Skeerpoort confluence
3	Crocodile/Roodekopjes	CROC_EWR3	CROC_EWR3, Crocodile downstream Hartbeespoort Dam
4	Hex/Waterkloofspruit/ Vaalkop	CROC_EWR6	CROC_EWR6, Hex upstream Vaalkop Dam CROC_EWR11, Sterkstrrom upstream Buffelspoort Dam CROC_EWR14, Waterkloofspruit downstream Rustenburg Nature Reserve
5	Elands/Vaalkop	CROC_EWR13	CROC_EWR10, Elands upstream Swartruggens Dam CROC_EWR13, Elands downstream Lindley'spoort Dam
6a	Klein Marico/Kromellemboog	MAR_EWR5	MAR_EWR5, Klein Marico downstream Klein Maricopoort Dam
6b	Groot Marico/Marico Bosveld Dam	MAR_EWR2 MAR_EWR6	MAR_EWR2, Groot Marico upstream confluence with Polkadraaispruit MAR_EWR6, Polkadraaispruit upstream confluence with Groot Marico
7	Kaaloog-se-Loop	Mainly groundwater	MAR_EWR1, Kaaloog-se-Loop below gorge
8	Malmaniesloop	Mainly groundwater	No EWR site
9	Molopo	Mainly groundwater	No EWR site
10	Dinokana Eye/Ngotwane Dam	Mainly groundwater	No EWR site
11a	Groot Marico/Molatedi Dam	MAR_EWR3	MAR_EWR3, Groot Marico downstream Marico Bosveld Dam
11b	Groot Marico/seasonal tributaries	MAR_EWR4	MAR_EWR4, Groot Marico downstream Tswasa Weir
12	Bierspruit	-	No EWR site

IUA	Delineation	EWR used for detail assessment	Notes
13	Lower Crocodile	CROC_EWR7	CROC_EWR7, Crocodile upstream Bierspruit confluence CROC_EWR8, Crocodile in Ben Alberts Nature Reserve
14	Tolwane/Kulwane/ Moretele/Klipvoor	-	CROC_EWR5, Pienaars downstream Klipvoor Dam CROC_EWR12, Buffels before confluence with Plat
15	Upper Mokolo	MOK_EWR1a MOK_EWR10	MOK_EWR1a, Mokolo at Vaalwater MOK_EWR1b, Mokolo at Tobacco MOK_EWR2, Mokolo at Ka'ingo MOK_EWR10, Sterkstroom
16	Lower Mokolo	MOK_EWR3	MOK_EWR3, Mokolo below Mokolo Dam MOK_EWR4, Mokolo at Malalatau
17a	Mothlabatsi/Mamba	MAT_EWR1	MAT_EWR1, Matlabas Zyn Kloof MAT_EWR3, Mamba upstream Matlabas confluence
17b	Matlabas/Limpopo	MAT_EWR2	MAT_EWR2, Matlabas at Haarlem MAT_EWR4, Matlabas at Phofu

The other EWR sites from the intermediate Reserve determination studies and the additional rapid studies were analysed using flow duration curves (FDC) for the identified optimum flow months (high and low flow months). These curves were used to determine if the EWRs were met during the specific months. Those sites where the EWRs could not be met for the months analysed are highlighted.

Table 41: EWR sites analysed with Flow Duration Curves

IUA	Delineation	EWR used	Notes
1	Upper Crocodile/ Hennops/Hartebeespoort	CROC_EWR1 CROC_EWR4 CROC_EWR16	CROC_EWR1, Crocodile upstream Hartbeespoort Dam CROC_EWR2, Jukskei at Heron Bridge School CROC_EWR4, Pienaars downstream of Roodeplaat Dam CROC_16, Rietspruit upstream Rietvlei Dam
2	Magalies	CROC_EWR15	CROC_EWR9, Magalies downstream Malonney's Eye CROC_EWR15, Magalies upstream Skeerpoort confluence
3	Crocodile/Roodekopjes	-	CROC_EWR3, Crocodile downstream Hartbeespoort Dam
4	Hex/Waterkloofspruit/Vaalkop	CROC_EWR11 CROC_EWR14	CROC_EWR6, Hex upstream Vaalkop Dam CROC_EWR11, Sterkstrrom upstream Buffelspoort Dam

IUA	Delineation	EWR used	Notes
			CROC_EWR14, Waterkloofspruit downstream Rustenburg Nature Reserve
5	Elands/Vaalkop	CROC_EWR10	CROC_EWR10, Elands upstream Swartruggens Dam CROC_EWR13, Elands downstream Lindley'spoort Dam
6a	Klein Marico/Kromellemboog	-	MAR_EWR5, Klein Marico downstream Klein Maricopoort Dam
6b	Groot Marico/Marico Bosveld Dam	-	MAR_EWR2, Groot Marico upstream confluence with Polkadraaispruit MAR_EWR6, Polkadraaispruit upstream confluence with Groot Marico
7	Kaaloog-se-Loop	MAR_EWR1	MAR_EWR1, Kaaloog-se-Loop below gorge
8	Malmaniesloop	Mainly groundwater	No EWR site
9	Molopo	Mainly groundwater	No EWR site
10	Dinokana Eye/Ngotwane Dam	Mainly groundwater	No EWR site
11a	Groot Marico/Molatedi Dam	-	MAR_EWR3, Groot Marico downstream Marico Bosveld Dam
11b	Groot Marico/seasonal tributaries	-	MAR_EWR4, Groot Marico downstream Tswasa Weir
12	Bierspruit	-	No EWR site
13	Lower Crocodile	CROC_EWR8	CROC_EWR7, Crocodile upstream Bierspruit confluence CROC_EWR8, Crocodile in Ben Alberts Nature Reserve
14	Tolwane/Kulwane/Moretele/Klipvoor	CROC_EWR5 CROC_EWR12	CROC_EWR5, Pienaars downstream Klipvoor Dam CROC_EWR12, Buffels before confluence with Plat
15	Upper Mokolo	MOK_EWR1b MOK_EWR2	MOK_EWR1a, Mokolo at Vaalwater MOK_EWR1b, Mokolo at Tobacco MOK_EWR2, Mokolo at Ka'ingo MOK_EWR10, Sterkstroom
16	Lower Mokolo	MOK_EWR4	MOK_EWR3, Mokolo below Mokolo Dam MOK_EWR4, Mokolo at Malalatau
17a	Mothlabatsi/Mamba	MAT_EWR3	MAT_EWR1, Matlabas Zyn Kloof MAT_EWR3, Mamba upstream Matlabas confluence
17b	Matlabas/Limpopo	MAT_EWR4	MAT_EWR2, Matlabas at Haarlem MAT_EWR4, Matlabas at Phofu

Table 42: Summary of FDC results

IUA	Site	River	Quat	PES	Comments
1	CROC_EWR1	Crocodile	A21H	D	EWR based on present day flows - increased flows due to WWTW discharges EWR met for Sep and Feb for all scenarios, too much flows for scenarios Prs, ESBC and Sc1
	CROC_EWR4	Pienaars	A23B	C	EWR met partially in Jan for Sc1 but for none of the scenarios in Sep
	CROC_EWR16	Rietspruit	A21A	C	Increased flows due to WWTW discharges EWR met for Sep and Feb for all scenarios, too much flows for scenarios Prs, ESBC and Sc1
2	CROC_EWR15	Magalies	A21F	C/D	Increased flows EWR met for Sep and Feb for all scenarios, too much flows for scenarios Prs, ESBC and Sc1
3	-				Detail assessment at CROC_EWR3
4	CROC_EWR11	Sterkstroom	A21K	C	EWR met partially in Sep for Sc1 Rest of scenarios met for both Mar and Sep
	CROC_EWR14	Waterkloof-spruit	A22H	B/C	EWR met in Mar and Oct for all scenarios
5	CROC_EWR10	Elands	A22A	C	EWR met in Mar for all scenarios EWR only partially met in Sep for scenarios Prs, ESBC and Sc1
6a	-				Detail assessment at MAR_EWR5
6b	-				Detail assessments at MAR_EWR2 and MAR_EWR6
7	MAR_EWR1	Kaaloog-se-Loop	A31A	B	EWR could be met in Sep and Feb for all scenarios, mainly groundwater
8	-				Mainly groundwater
9	-				Mainly groundwater
10					Mainly groundwater
11a	-				Detail assessments at MAR_EWR3
11b	-				Detail assessments at MAR_EWR4
12	-				No EWR site
13	CROC_EWR8	Crocodile	A24H	C	EWR could be met in Sep and Feb for all scenarios EWR site will be inundated with transfer scheme to Lephalale
14	CROC_EWR5	Pienaars/ Moretele	A23J	D	EWR could be met in Sep and Jan for all scenarios
	CROC_EWR12	Buffels	A23G	B/C	EWR met in Feb for all scenarios EWR only partially met in Sep for scenarios Prs, ESBC and Sc1
15	MOK_EWR1b	Mokolo	A42F		EWR site not good for assessment, rather use MOK_EWR2

IUA	Site	River	Quat	PES	Comments
	MOK_EWR 2	Mokolo	A42F		Detail assessments at MOK_EWR 10
16	MOK_EWR 4	Mokolo	A42G		Detail assessments at MOK_EWR 3
17a	MAT_EWR3	Mamba	A41B	B/C	EWR could be met for PES=B/C and REC=B/C, no scenarios
17b	MAT_EWR4	Matlabas	A41C	B	EWR could be met for PES=B and REC=B, no scenarios

6.2.2 Results of the ecological consequences assessment

The Fish Frequency Habitat Assessment (FFHA) and Invertebrate Frequency Habitat Assessment (IFHA) models were used by the ecologists to interpret the results of the various scenarios. The ecological consequences provided by the ecologists based on the models were based on flow only and quality and marginal vegetation were not included. Thus, only the instream ecological category is determined by these models.

Optimum base flows based on the natural hydrology at the EWR sites are used by the models. For CROC_EWR the optimum base flows were based on the present day flows due to the increased flows. These optimum flows exclude floods and freshets and represent the minimum stress in the rivers for fish and macroinvertebrates during the wet and dry season. The months identified to represent the optimum flows for use in the FFHA and IFHA models were varying depending on the site.

The ecological assessment of responses to various flow scenarios were based on the approach developed by Kleynhans for application in the Habitat Flow Stressor Response Model. The flow patterns for the various scenarios were presented to ecological experts at a workshop during the week of 24-28 June 2013. The consequences of the shortages in meeting the full EWR requirements on the fish and invertebrates were discussed. The changes in the optimum flows were in some of the scenarios so small that the models were not sensitive enough to show any changes in ecological categories. Thus, only selected scenarios (Table 43) were assessed by the ecologists.

Table 43: Details of EWR sites assessed showing optimum base flows

EWR site	PES	REC	Natural MAR ($10^6 m^3$)	Optimum flows (m^3/s)	
				Wet	Dry
CROCODILE WEST					
EWR 2	E	D	34.4*	(Feb) 3.155 (2.18%tile)	(Aug) 0.192 (0.1%tile)
EWR 3	C/D	C/D	153.6	(Feb) 10.439 (7.3%tile)	(Aug) 2.154 (0.1%tile)

EWR site	PES	REC	Natural MAR ($10^6 m^3$)	Optimum flows (m^3/s)	
				Wet	Dry
EWR 4	C	C	28.2	(Jan) 2.203 (2.5%tile)	(Sept) 0.255 (0.1%tile)
EWR 6	D	D	26.9	(Feb) 3.2 (2.3%tile)	(Sept) 0.112 (1%tile)
EWR 7	D	D	463.4	(Feb) 39.65 (12.9%tile)	(Sept) 11.4 (9.1%tile)
EWR 9	B	B	14.7	(Feb) 0.463 (1%tile)	(Sept) 0.463 (5%tile)
EWR 13	C	C	18.77	(Feb) 1.156 (0.7%tile)	(Aug) 0.105 (1%tile)
MARICO CATCHMENT					
EWR 2	B	B	42.08	(Feb) 2.115 (2.3%tile)	(Aug) 0.991 (0.1%tile)
EWR 3	C/D	C/D	65.083	(Feb) 3.747 (4.3%tile)	(Sept) 1.286 (1%tile)
EWR 4	C	C	153.251	(Feb) 11.75 (5.4%tile)	(Sept) 1.922 (1%tile)
EWR 5	C	C	29.8	(Feb) 0.78 (2.2%tile)	(Sept) 0.408 (0.1%tile)
EWR 6	B/C	B	9.866	(Feb) 0.734 (0.38%tile)	(Sept) 0.12 (0.1%tile)
MOKOLO CATCHMENT					
EWR 1a	C/D	B	84.84	(Feb) 9.56 (11.8%tile)	(Sept) 1.236 (2.2%tile)
EWR 3	B/C	B	214.5	(Feb) 23.79 (30%tile)	(Sept) 2.08 (1%tile)
EWR 10	B/C	B/C		(Feb) 2.395 (5.1%tile)	(Sept) 0.26 (0.67%tile)
MATLABAS CATCHMENT					
EWR 1	B	A	4.13	(Feb) 0.99 (10%tile)	(Sept) 0.023 (1%tile)
EWR 2	C	B/C	30.38	(Feb) 7.59 (10%tile)	(Sept) 0.023 (1%tile)

It should be noted that although both the FFHA and IFHA models were used to determine the ecological consequences, only the FFHA results should be used for final interpretation. This is due to the continuous development of the IFHA. The detailed results are presented in Appendices A and B and are summarised in Table 44, Table 45, Table 46 and Table 47.

Table 44: Ecological Consequences for the Crocodile West catchment

IUA	Water Resource	EWR sites	Nat: Natural flows			Prs: Present day flows			Sc1: Present day water use (2015), PES			Sc2: Future water use (2030), PES		
			EC at EWR site (PES)	**Ecological Con-sequence of flows**	**Recommendation**	**EC at EWR site (PES)**	**Ecological Con-sequence of flows**	**Recommendation**	**EC at EWR site (PES)**	**Ecological Con-sequence of flows**	**Recommendation**	**EC at EWR site (PES)**	**Ecological Con-sequence of flows**	**Recommendation**
1	Jukskei	CROC_EWR 2 (A21C)	E	A	√	E	B	√	E	B	√	E	B	√
	Pienaars	CROC_EWR 4 (A23B)	C	C/D	x	C	B/C	√	C	A	√	C	A	√
2	Upper Magalies	CROC_EWR 9 (A21F)	B	-	√	B	B	√	B	A	√	B	A	√
3	Crocodile	CROC_EWR 3 (A21J)	C/D	B	√	C/D	C	√	C/D	B/C	√	C/D	A	√
4	Hex	CROC_EWR 6 (A22J)	D	D	X	D	C	√	D	C	√	D	C	√
5	Elands	CROC_EWR 13 (A22E)	C	na	X	C	C	√	C	E	X	C	E	X
13	Crocodile	CROC_EWR 7 (A24C)	D	na	X	D	D	X	D	B/C	√	D	A	√

Table 45: Ecological Consequences for the Marico catchment

IUA	Water Resource	EWR sites	Natural flows			Present day flows without EWR			Present day water use (same as Sc1), PES			Future water use, PES		
			EC at EWR site (PES)	Ecological Con-sequence of flows	Recommendation	EC at EWR site (PES)	Ecological Con-sequence of flows	Recommendation	EC at EWR site (PES)	Ecological Con-sequence of flows	Recommendation	EC at EWR site (PES)	Ecological Con-sequence of flows	Recommendation
6a	Klein Marico	MAR_EWR 5 (A31E)	C	F	X	C	C/D	√	C	E	X	C	E	x
6b	Groot Marico	MAR_EWR 2 (A31B)	B	B	√	B	A	√	B	A	√	B	B	√
	Polkadraais pruit	MAR_EWR 6 (A31B)	B/C	D	X	B/C	D	x	B/C	D	X	B/C	D	X
11a	Groot Marico	MAR_EWR 3 (A31F)	C/D	F	X	C/D	B/C	√	C/D	B	√	C/D	B/C	√
11b	Groot Marico	MAR_EWR 4 (A32D)	C	F	X	C	C	√	C	C	√	C	-	x

Table 46: Ecological Consequences for the Mokolo catchment

IUA	Water Resource	EWR sites	Natural flows			Present day flows			Present day water use, PES			Future water use, PES		
			EC at EWR site (PES)	Ecological Con-sequence of flows	Recommendation	EC at EWR site (PES)	Ecological Con-sequence of flows	Recommendation	EC at EWR site (PES)	Ecological Con-sequence of flows	Recommendation	EC at EWR site (PES)	Ecological Con-sequence of flows	Recommendation
15	Mokolo	MOK_EWR 1A (A42C)	C/D	E	X	C/D	(B/C) F (C/D) D	X	C/D	E	X	C/D	E	X
	Sterkstroom	MOK_EWR 10 (A42D)	B/C	B	√	B/C	B	√	B/C	B	√	B/C	na	X
16	Mokolo:	MOK_EWR 3 (A42G)	B/C	F	X	B/C	D	√	B/C	D	x	B/C	D	x

Table 47: Ecological Consequences for the Matlabas catchment

IUA	Water Resource	EWR sites	Present day water use, PES			REC, present water use		
			EC at EWR site (PES)	Ecological Con-sequence of flows	Recommendation	EC at EWR site (PES)	Ecological Con-sequence of flows	Recommendation
7a	Matlabas Zyn Kloof	MAT_ EWR 1 (A41A)	B	A	√	B	A	√
17b	Matlabas	MAT_EWR 2 (A41C)	C	A	√	C	A	√

6.3 WATER QUALITY IMPLICATIONS

As part of the scenario evaluation, the classification process requires that water quality is assessed at two levels:

- The present-day water quality requirements for all water users (fitness for use); and
- The water quality implications of different scenarios for different users.

6.3.1 PRESENT DAY WATER QUALITY ASSESSMENT

6.3.1.1 Background

A water quality present day assessment was undertaken for the Crocodile West/Marico WMA and the Matlabas and Mokolo catchments based on the routine monitoring conducted by the DWA in recent years. This was a high level qualitative assessment of current in stream water quality making use of the available data.

The primary source of data for the water quality analysis was the Directorate: Resource Quality Services of the DWA. Historical data for water quality monitoring points in the Crocodile West/Marico WMA and the Matlabas and Mokolo catchments was obtained from the national monitoring network (Water Management System). The water quality monitoring data at these sites have different time scales, different sampling frequencies, variation in the water quality variables monitored and different laboratories and analytical methods used. In addition many of the tributary catchment's points monitoring data records are poor so that there were gaps in the available data.

The present day water quality status at these points for the period 2006 to 2013 was assessed (where available) by determining the compliance of the current water quality state to the resource water quality objectives derived from the South African Water quality guidelines

(SAWQGs) in terms of 'fitness for use'. The water quality data was analysed statistically and compared to the RWQOs and SAWGs to determine the compliance of water quality variables of concern in the different parts of the catchment. This assessment provided an indication of the overview water quality status of the Crocodile West/Marico WMA and the Matlabas and Mokolo catchments. The table of results is included as Appendix C to this report.

6.3.1.2 Water quality status in summary

The water quality of the Upper Crocodile River is impacted by urbanisation and large volumes of wastewater discharges (sewage works and industrial). Water quality in the rivers is relatively poor with high levels of nutrients and total dissolved solids concentrations (Figure 21, Figure 22 and Figure 23).

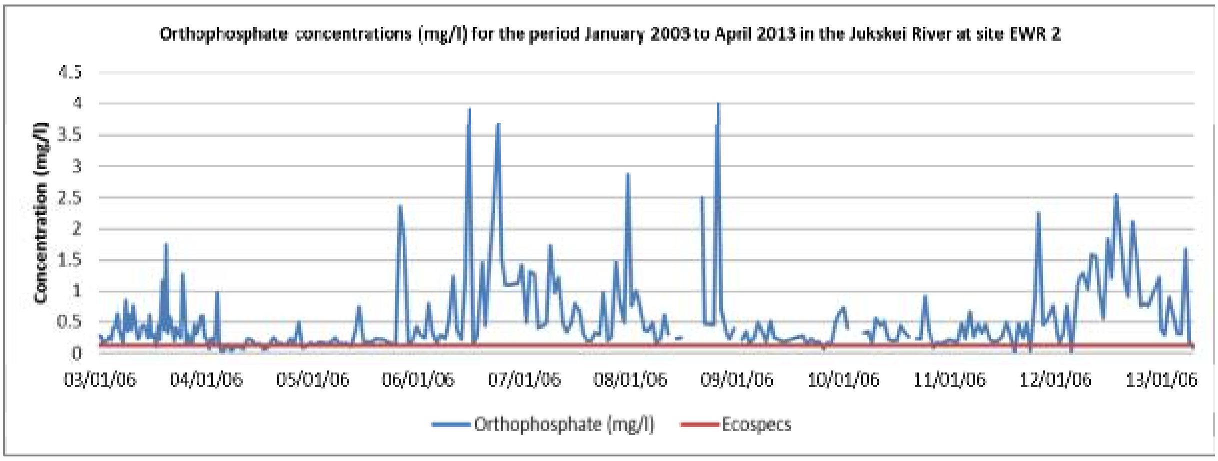


Figure 20: Orthophosphate concentrations in the Jukskei River (IUA 1) at CROC_EWR 2

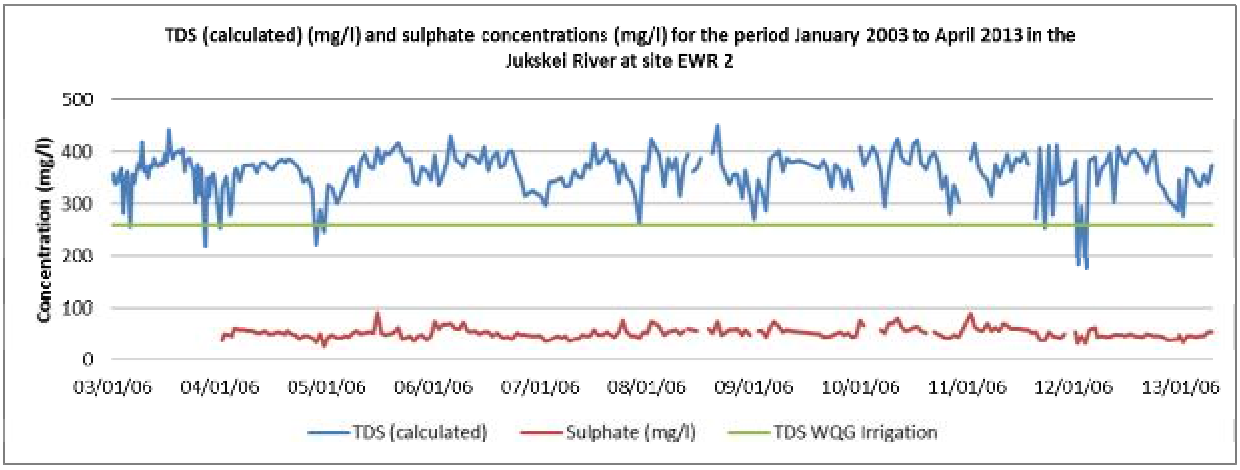


Figure 21: TDS and sulphate concentrations in the Jukskei River (IUA 1) at CROC_EWR 2

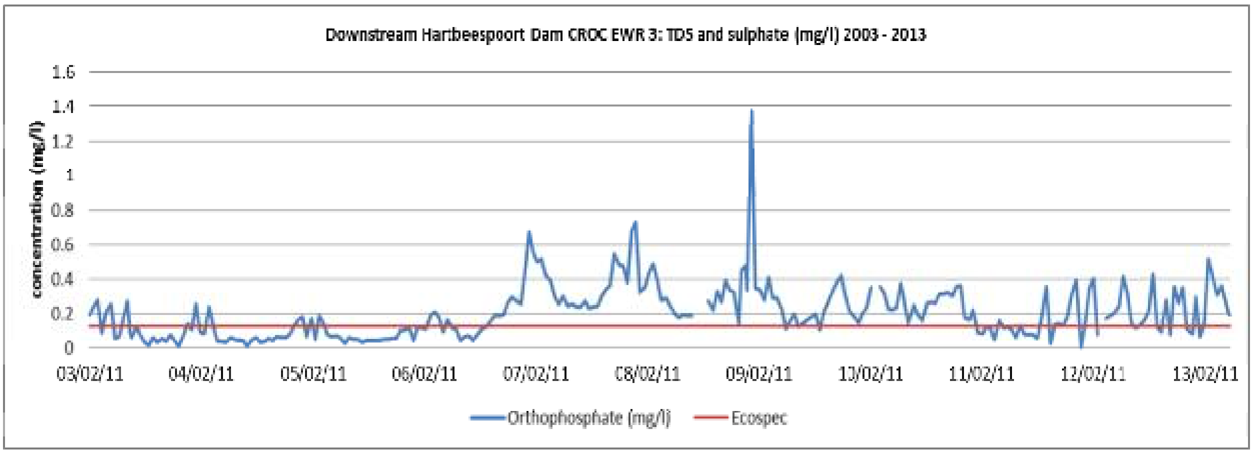


Figure 22: Orthophosphate concentrations in the Crocodile River (IUA 1) at CROC_EWR 3

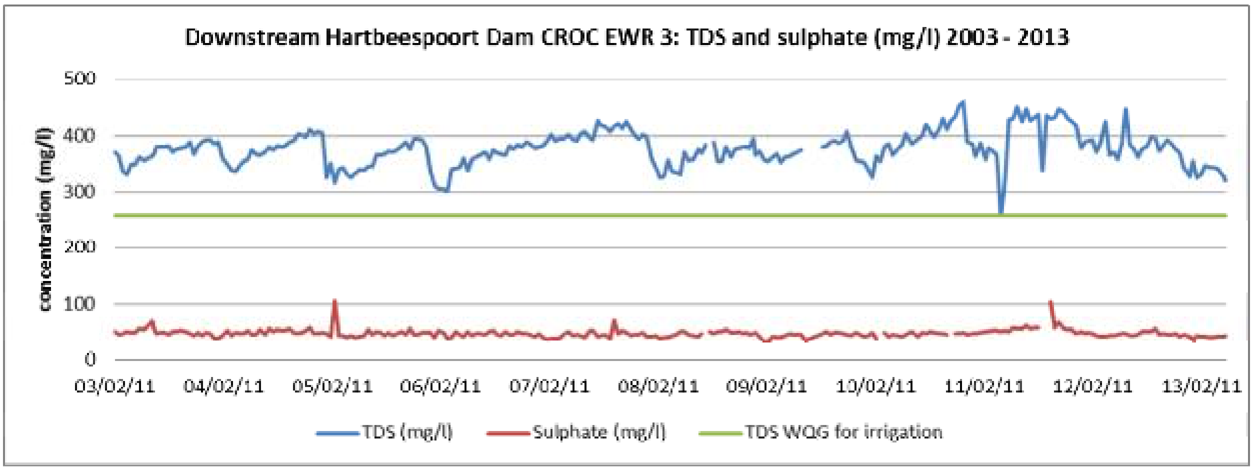


Figure 23: TDS and sulphate concentrations in the Crocodile River (IUA 1) at CROC_EWR 3

The water quality of the Magalies River is relatively good with localised impacts from land based activities (Figure 24 and Figure 25). The impoundments in the system impact on the water quality in the rivers.

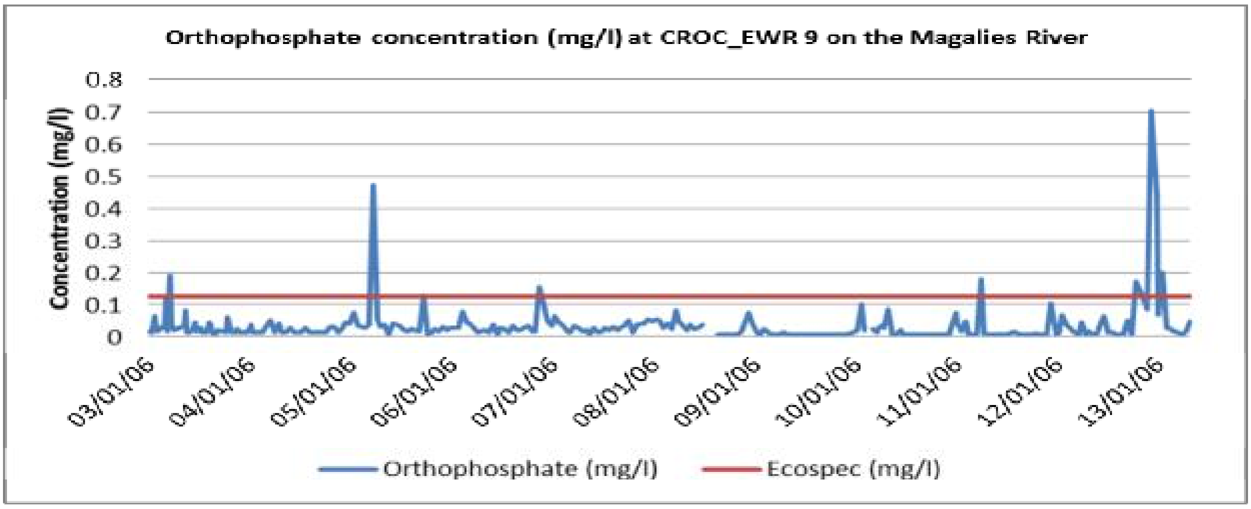


Figure 24: Orthophosphate concentrations in the Magalies River (IUA2) at CROC_EWR 9

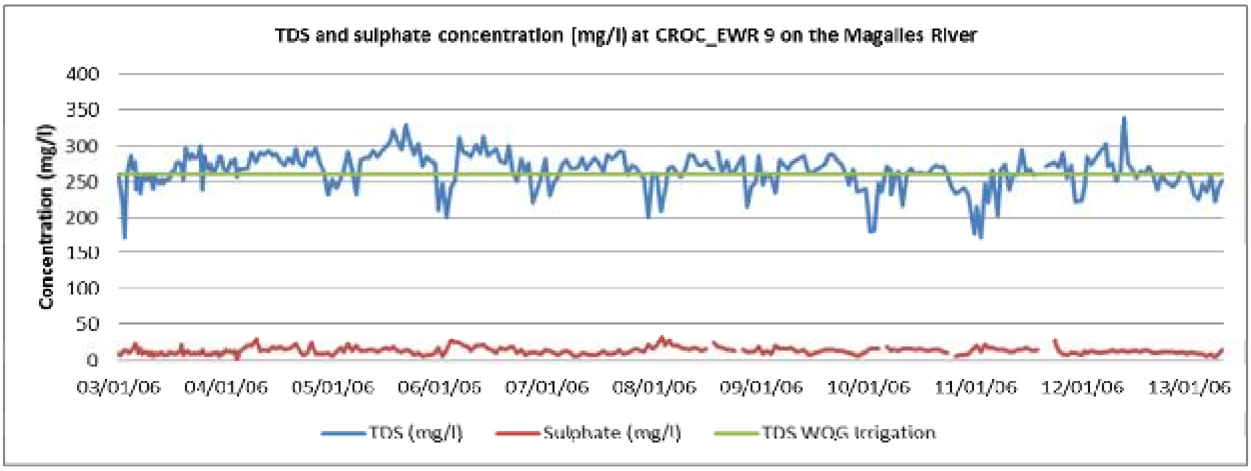


Figure 25: TDS and sulphate concentrations in the Magalies River (IUA 2) at CROC_EWR 9

Water quality of the Elands River catchment is good in the upper reaches. However the middle and lower reaches are of a fair quality with mining activities in the catchment impacting on the river. Water quality has also deteriorated as a result of erosion and high sediment loads (Figure 26 and Figure 27).

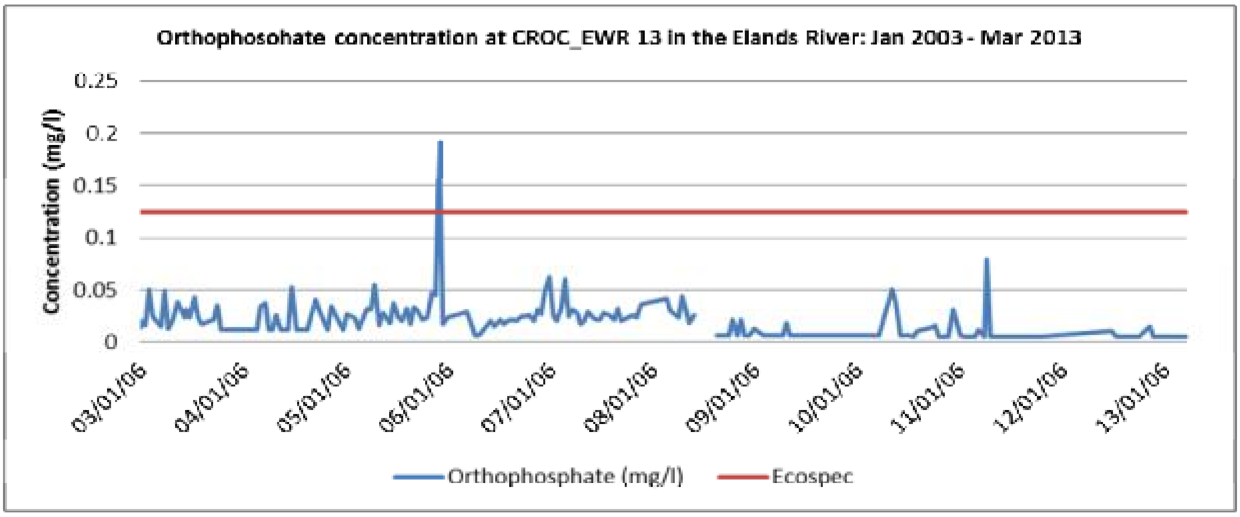


Figure 26: Orthophosphate concentrations in the Elands River (IUA 5) at CROC_EWR 13

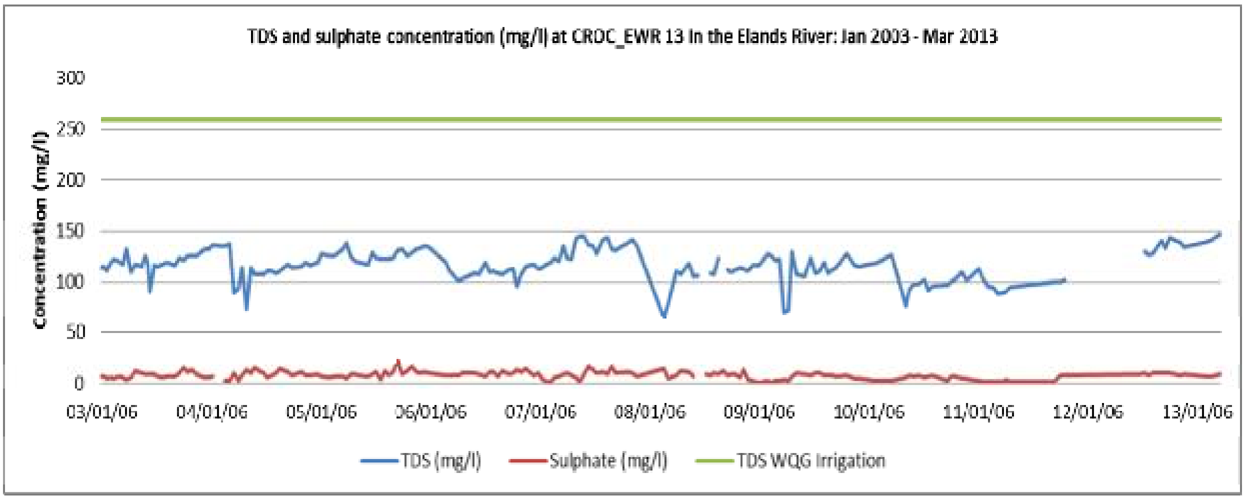


Figure 27: TDS and sulphate concentrations in the Elands River (IUA 5) at CROC_EWR 13

The Hex River shows elevated concentrations of salts and nutrients (Figure 28 and Figure 29). There are impacts from agricultural (intensive irrigation) activities in the catchment.

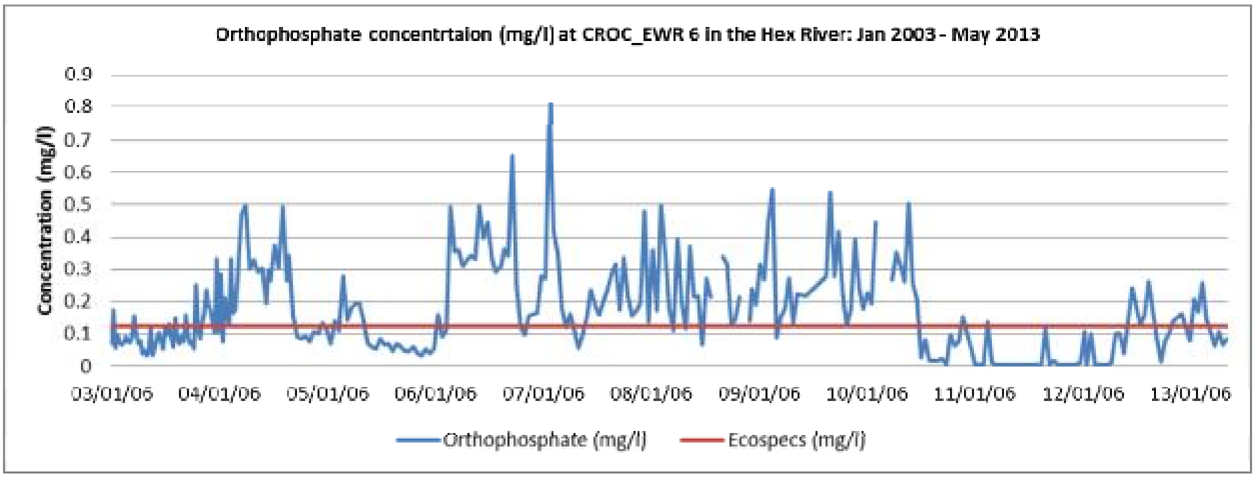


Figure 28: Orthophosphate concentrations in the Hex River (IUA 4) at CROC_EWR 6

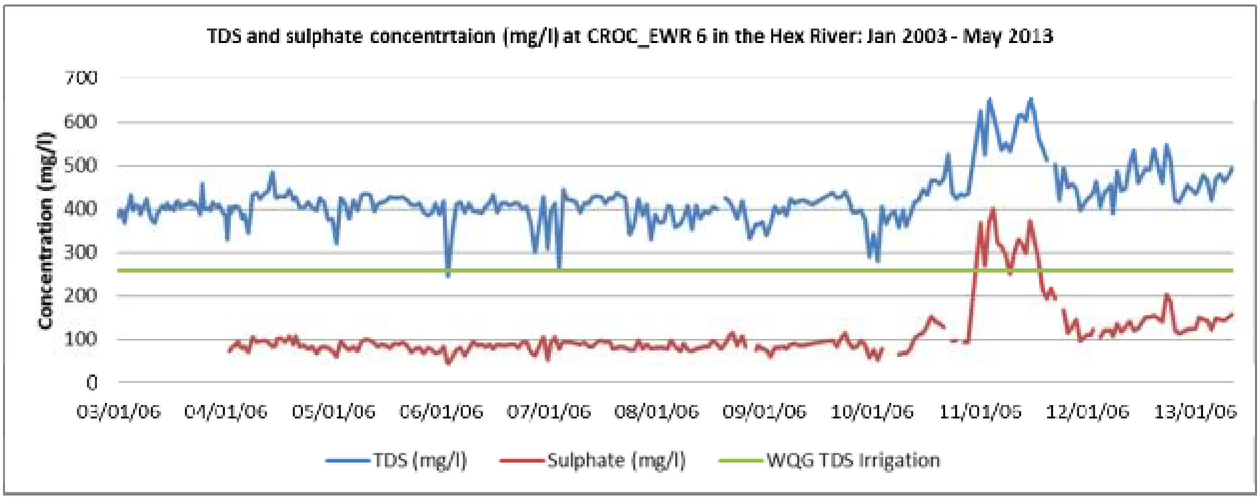


Figure 29: TDS concentrations in the Hex River (IUA 4) at CROC_EWR 6

The water quality of the Apies/Pienaars catchment is of poor quality with certain areas being impacted by nutrients and salinization (Figure 30 and Figure 31). There are thirteen point source discharges into the system from industries and domestic wastewater treatment works. The water quality of the upper catchments is deteriorating even further in certain areas. pH is high but salts are stable. Sources of pollution are mainly from urban return flows, sewage works and land based activities.

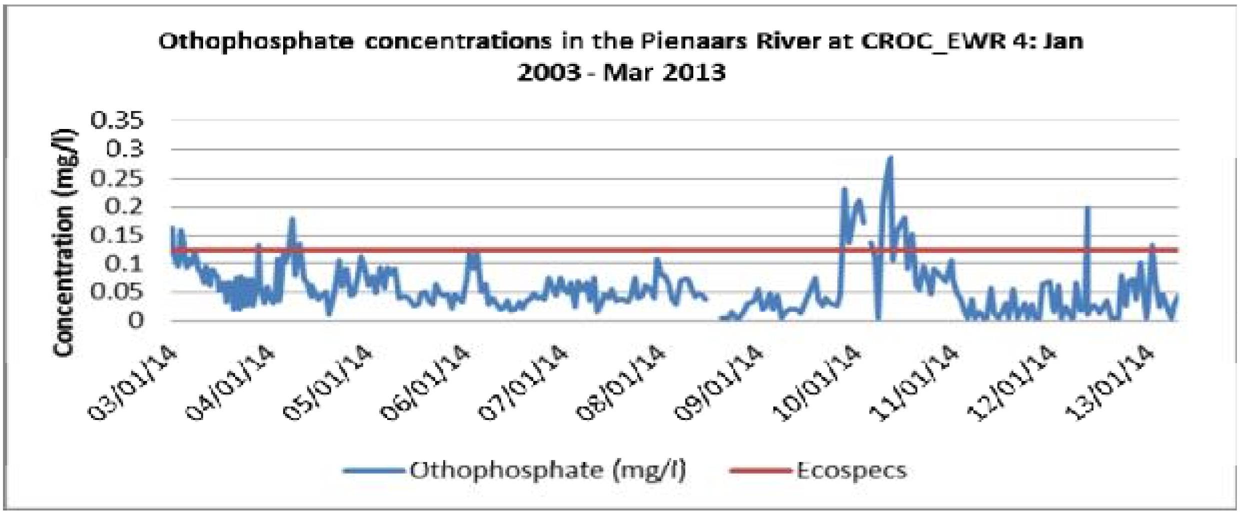


Figure 30: Orthophosphate concentrations in the Pienaars River (IUA 1) at CROC_EWR 4

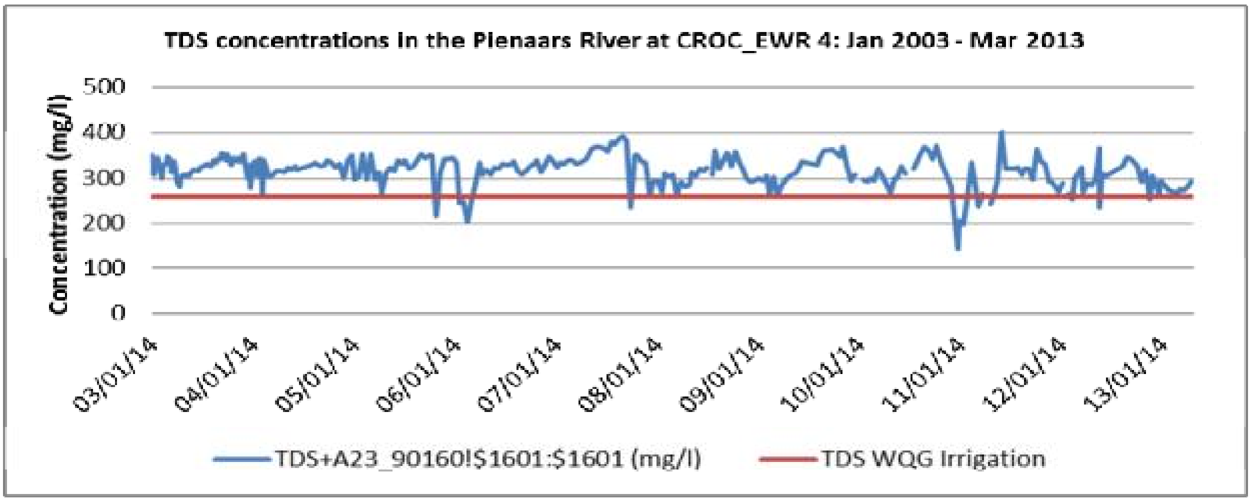


Figure 31: TDS concentrations in the Pienaars River (IUA 1) at CROC_EWR 4

The Lower Crocodile River is deteriorating in terms of water quality. Salts and nutrients are high. There are also increased levels of toxicants in the middle reaches of the river. Urbanisation, industrial diffuse sources and high agricultural return flows are the major impacting activities (Figure 32 and Figure 33).

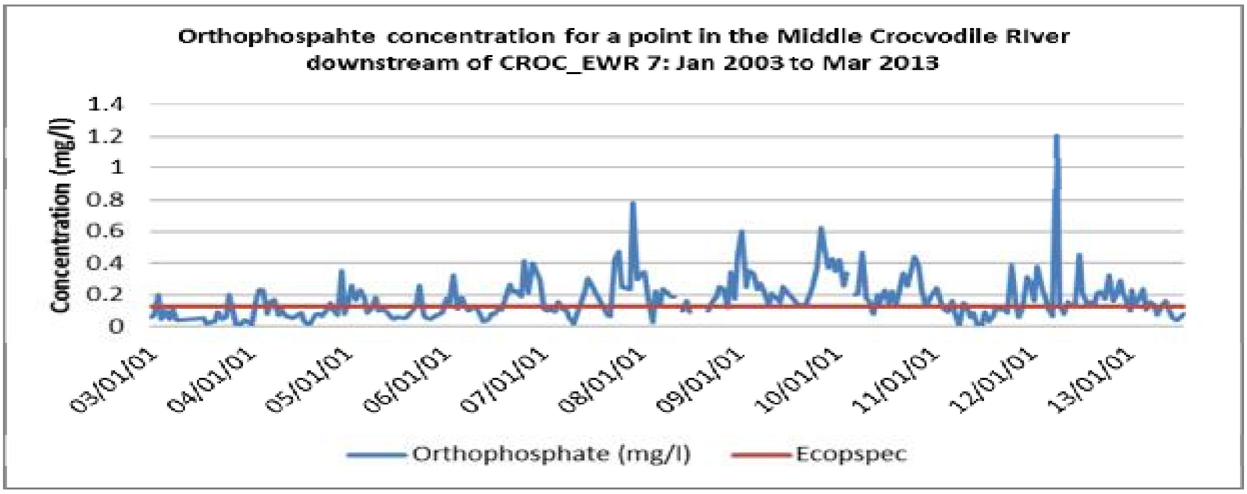


Figure 32: Orthophosphate concentrations in the Crocodile River (IUA 13) downstream CROC_EWR 7

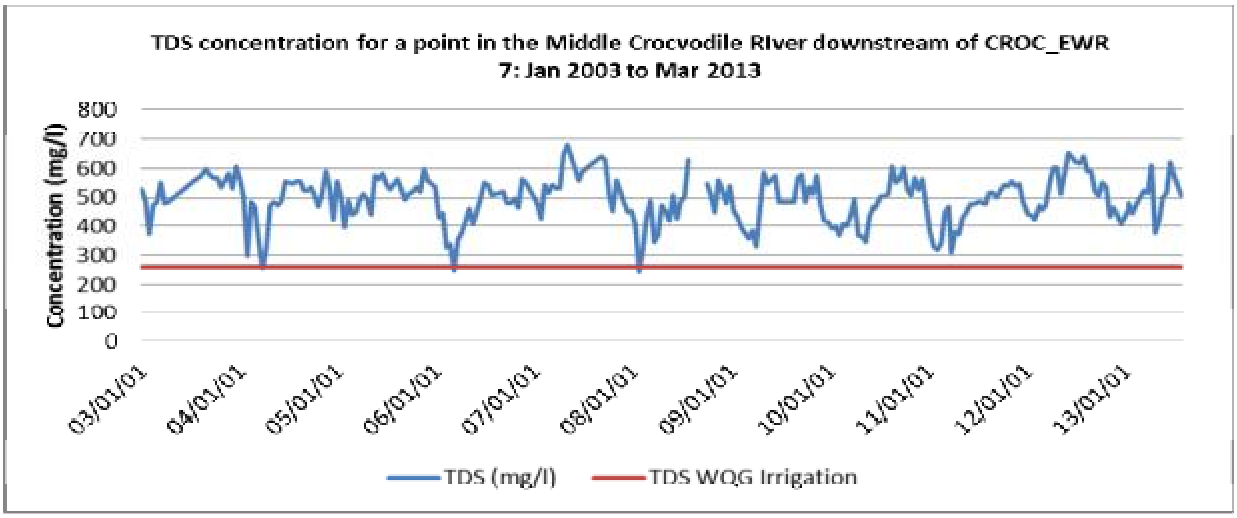


Figure 33: TDS concentrations in the Crocodile River (IUA 13) downstream CROC_EWR 7

The water quality of the Upper Marico River is relatively good with localised impacts from land based activities. There are however only limited water quality data for the period 2004 to 2008 with an average 189 mg/l TDS and an average 0.023 mg/l orthophosphate recorded in IUA 6b, within the water quality requirements for irrigation and the Eco Specs for orthophosphate. The tributaries are impacted to some extent by slate mining activities and agricultural impacts. Turbidity and erosion are the main water quality issues.

Water quality of the Klein Marico River catchment is good in the upper reaches. However the middle and lower reaches are of a fair water quality with urbanisation and the dams in the catchment impacting on the quality (Figure 34 and Figure 35). Water quality has also deteriorated as a result of erosion and sedimentation. The Klein Marico River shows elevated concentrations of nutrients from urbanisation as evidenced from phosphate spikes downstream of the town of Zeerust. There are also impacts from agricultural activities in the catchment.

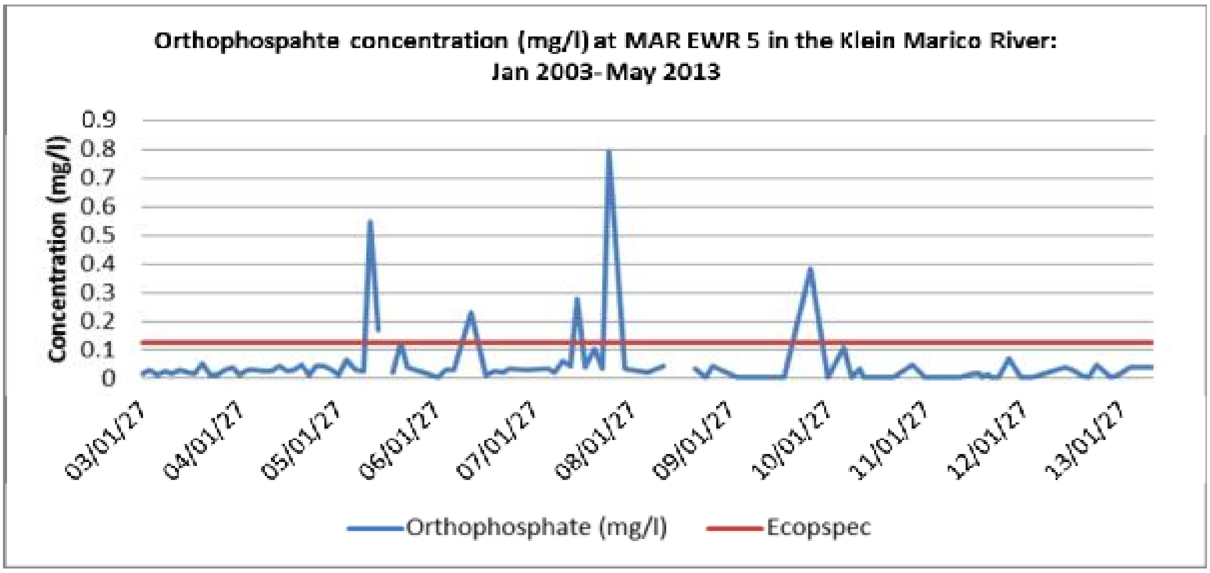


Figure 34: Orthophosphate concentrations in the Klein Marico River (IUA 6a) at MAR_EWR 5

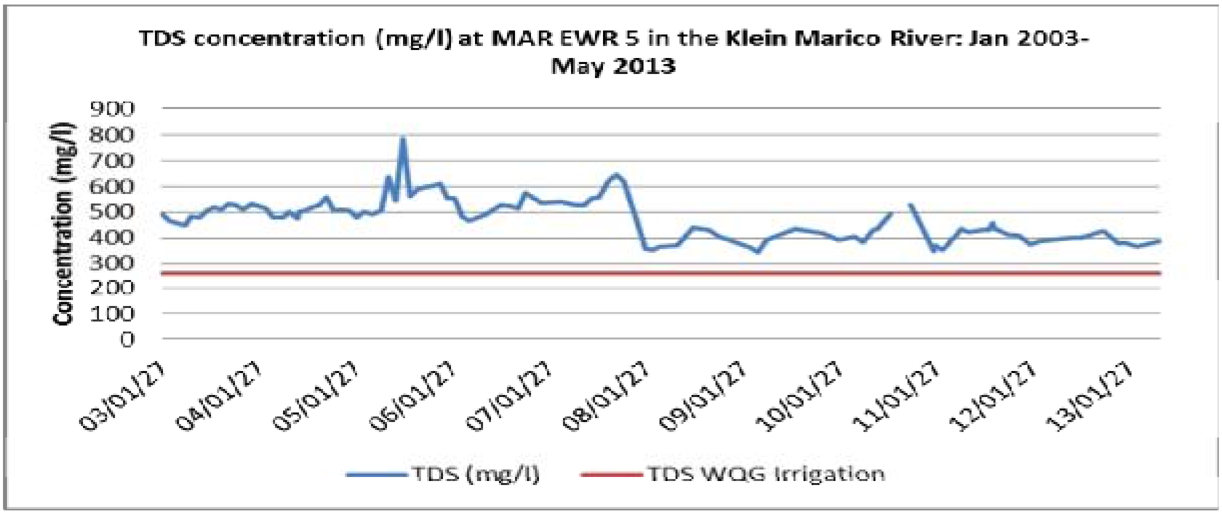


Figure 35: TDS concentrations in the Klein Marico River (IUA 6a) at MAR_EWR 5

The Marico Bosveld dam also impacts on the water quality in the river (Figure 36 and Figure 37) however the water quality is still good.

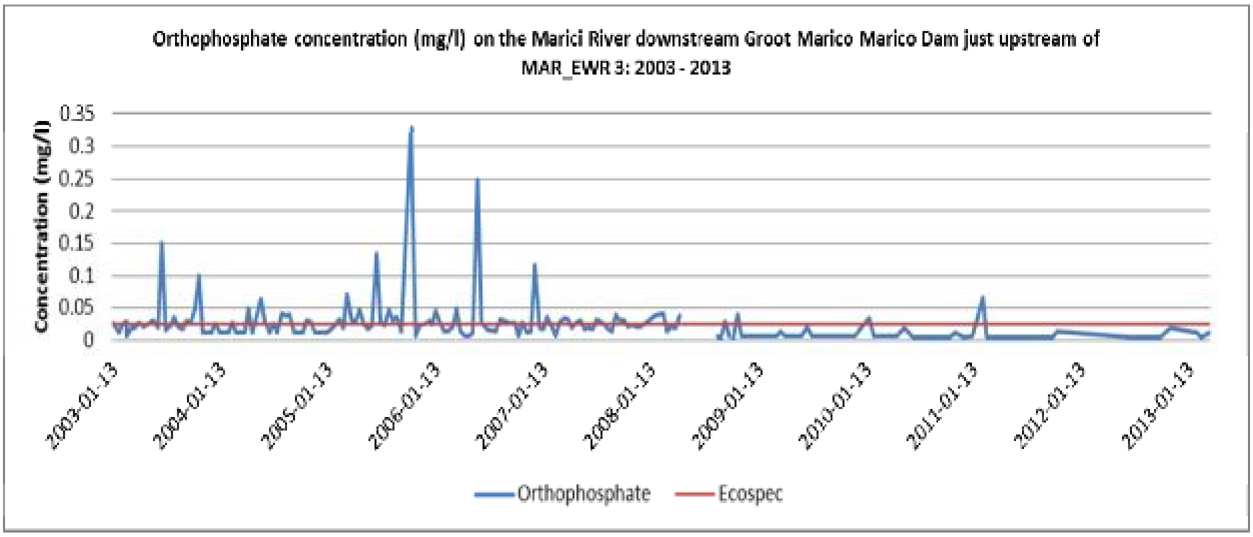


Figure 36: Orthophosphate concentrations in the Marico River (IUA 11a) just upstream of MAR_EWR 3

Figure 37: TDS concentrations in the Marico River (IUA 11a) just upstream of MAR_EWR 3

The water quality of the middle and lower Marico River is of fair to poor quality with certain areas being impacted by nutrients, erosion and salinization. The impoundments' impact on the water quality of the river relate to flows as these are largely managed by demand for irrigation. The Lower Marico River (Figure 38 and Figure 39) is deteriorating in terms of water quality. Nutrients are high because of the impacts of high agricultural return flows.

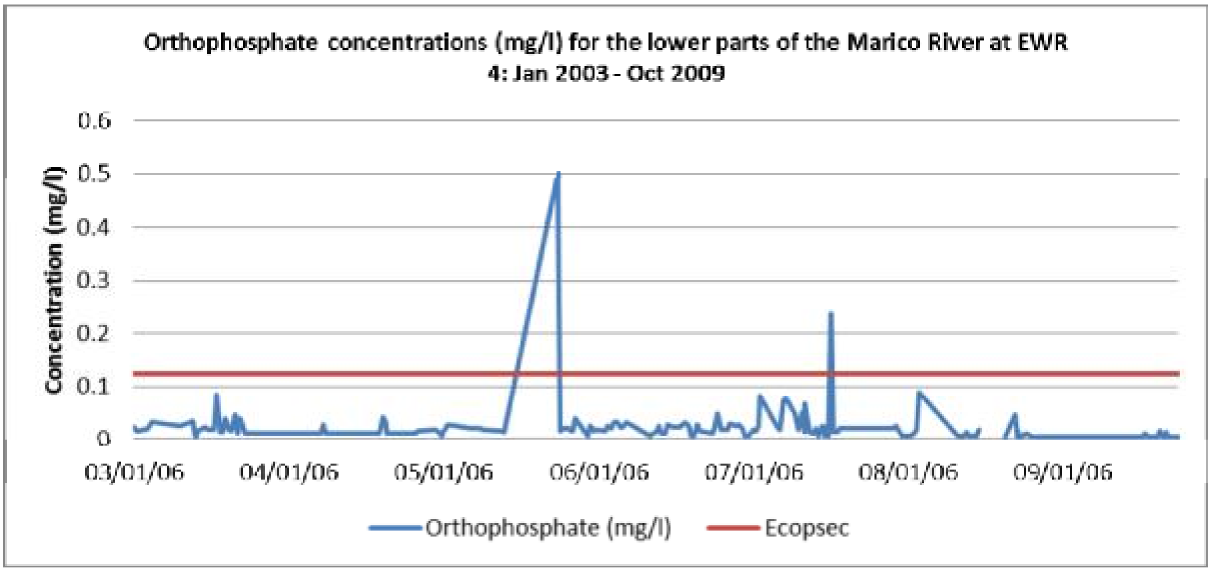


Figure 38: Orthophosphate concentrations in the lower parts of the Marico River (IUA 11b) at MAR_EWR 4

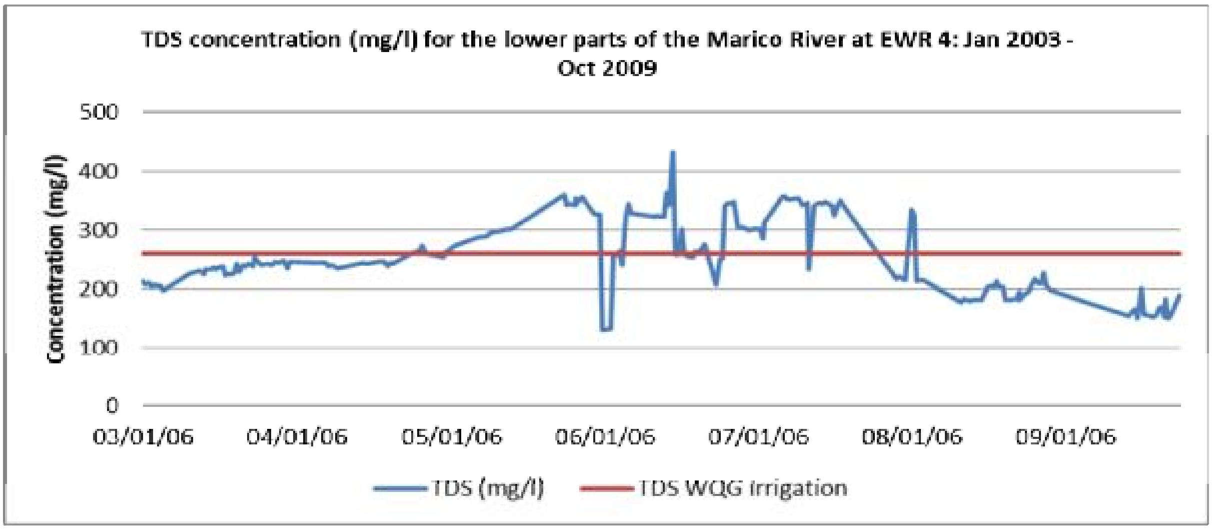


Figure 39: Orthophosphate concentrations in the lower parts of the Marico River (IUA 11b) at MAR_EWR 4

The current surface water quality of the Mokolo River is generally good upstream of the Mokolo Dam (Figure 40). Nutrient impacts are likely from agriculture return flows in the area.

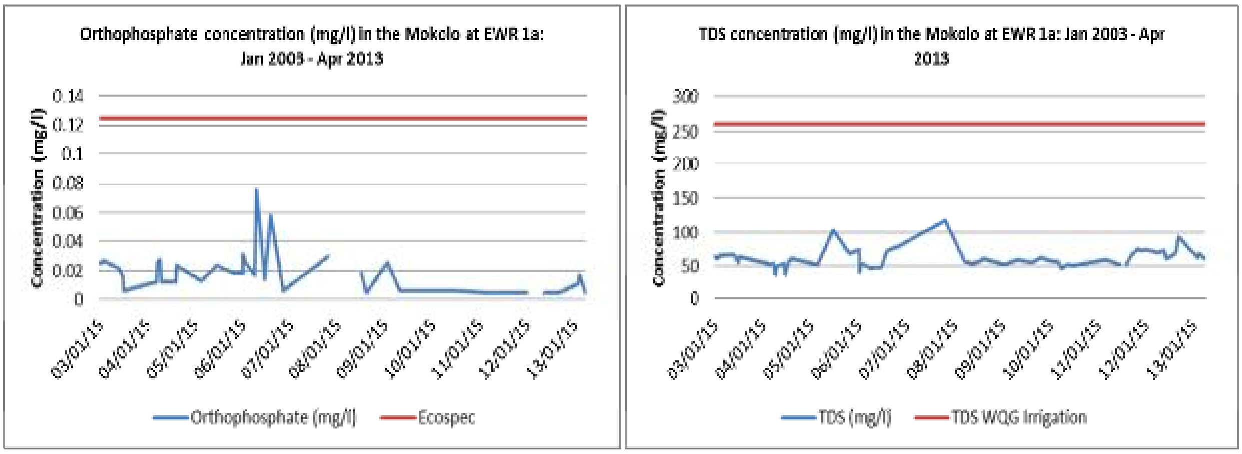


Figure 40: Water quality (Orthophosphate and TDS concentrations) in the Mokolo River (IUA 15) at MOK_EWR 1a

The water quality data downstream of the Mokolo Dam at MOK_EWR 3 indicates limited data after 1996 for samples taken during 2006, 2009, 2010 and two samples during 2013. The average data however shows a good water quality with a TDS concentration of 52.5 mg/l and orthophosphate of 0.016 mg/l.

There is only one water quality monitoring point in the Matlabas catchment. It is located at Haarlem East, downstream of the confluence with the Mamba River. The water quality at this point in the catchment is still very good (Figure 41). The only current impacts in the catchment are from the Marakele National Park and the game farms along the river. Flows in the catchment are variable.

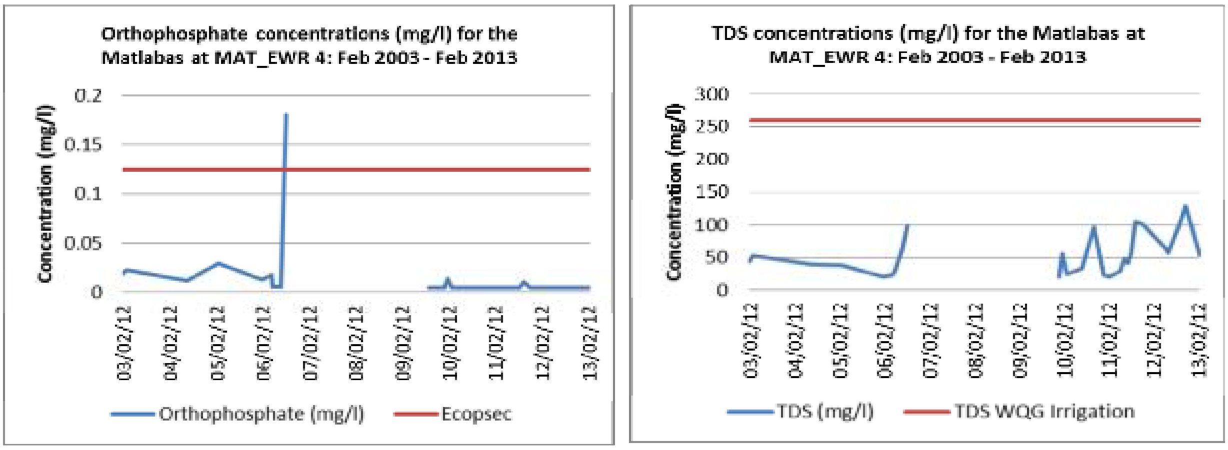


Figure 41: Water quality (Orthophosphate and TDS concentrations) in the Matlabas River (IUA 17b) at MAT_EWR 4

6.3.2 THE WATER QUALITY IMPLICATIONS OF THE DIFFERENT CATCHMENT SCENARIOS

This component of the WRCS process requires assessing the change a scenario would have on water quality and specifically the implications on the fitness for use for the water users.

Concentrations of chemical constituents and values of physical variables are frequently dependent on flow. Consequently, changes in the flow regime (scenarios) can cause shifts in water quality. Since efficient functioning of aquatic ecosystems is dependent, not only on an appropriate hydrological regime, but also on water of a suitable quality, there is a need to assess what this implication could be.

The following approach was followed for assessing the water quality changes related to the scenarios:

- The water quality related changes and impacts were assessed for total dissolved solids, sulphate (where applicable and orthophosphate, related to nutrient concerns;
- The water quality REC associated with the scenarios for the EWR sites were determined from the Intermediate and Rapid Reserve determinations undertaken in the 4 major catchments and the DWA guideline ‘Methods for determining the Water Quality Component of the Reserve (DWAF, 2008);
- The current water quality status at the EWR sites was obtained from the data for the water quality variables assessed; and
- The WRPM was run to assess certain scenarios around the Acid Mine Drainage concerns. The results of the model are included as Appendix D. In summary the results for the AMD scenarios show significant increases in salinity load and concentration levels in river stretches immediate downstream of the possible decant/return flow points. These impacts however, decrease with distance downstream with the confluence of tributaries of the Crocodile River. The net impact of the different scenarios shows about a 15 % increase in salinity into Hartbeespoort Dam for scenarios which neutralize the AMD to 2 776 mg/L and only about a 4 to 5% increase in salinity into Hartbeespoort Dam for the scenario with longer term neutralized AMD of 1 000 mg/L. As there is currently no specific blending rule or other similar water quality related operating rule in the Crocodile (West) River catchment, these potential impacts related to the long term solution options are not quantifiable from a water quantity impact. The acceptability of these impacts will need to be confirmed using the resource quality objective guidelines. Further to this, more information on the dolomites is needed to increase the confidence in the results for the scenarios that return AMD above the dolomites, particularly over the short term.

The water quality eco-classification per EWR site as determined through the various Reserve studies and expected changes due to the scenarios is reflected in Table 48.

Table 48: Crocodile West/Marico WMA and Mokolo, Matlabas catchments EWR sites indicating PES, REC and Water Quality EC as well as expected water quality changes

	IUA	EWR site	Quat	River	PES	EIS	REC	WQ	Changes in water quality expected for recommended scenarios
CROCODILE WEST	1	EWR 1	A21H	Crocodile: Upstream of the Hartbeespoort Dam	D	Mod	D	D	It is not expected that water quality will deteriorate further, rather that with management options relating to improved operation in WWTW (based on the implementation of the Green Drop) as well as the AMD project implementation (see Appendix D for specific AMD scenarios) the water quality can be improved to a C/D category. Water use license conditions should also be reviewed to implement more stringent discharge standards regarding nutrients, in particular phosphorus. A study on the implementation of the waste discharge charge system in relation to phosphate is currently being undertaken in the Upper Crocodile catchment.
		EWR 2	A21C	Jukskei: Heron Bridge School	E	Mod	D	D	
		EWR 4	A23B	Pienaars: Downstream of Roodeplaat Dam	C	High	C	B/C	It is possible that the water quality may deteriorate at this point due to potential lower levels in the dams to support the MCWAP transfer project.
		EWR 16	A21A	Rietvlei upstream Rietvlei Dam	C	Low	C	D	It is not expected that water quality will deteriorate further, however it will be difficult to improve it from a D. Improved storm water management within the industrial and urban areas could help.
	2	EWR 9	A21F	Magalies: Downstream of Malony's Eye	B	V High	B	B	No changes expected.
		EWR 15	A21F	Lower Magalies before confluence with Skeerpoort	C/D	Low	C/D	C	

	IUA	EWR site	Quat	River	PES	EIS	REC	WQ	Changes in water quality expected for recommended scenarios
	3	EWR 3	A21J	Crocodile: Downstream of Hartbeespoort Dam in Mount Amanzi	C/D	High	C/D	D	Water quality is not expected to deteriorate and may improve if the water entering the dam improves as described for IUA 1, however if the dam levels is maintained at lower levels because of the MCWAP transfer some water quality impacts may be seen
	4	EWR 6	A22J	Hex: Upstream of Vaalkop Dam	D	Mod	D	C/D	No changes expected.
	4	EWR 11	A21K	Sterkstroom: Upstream Buffelspoort Dam	C	High	C	C	
	4	EWR 14	A22H	Waterkloofspruit downstream Rustenburg Nature Reserve	B/C	Low	B/C	B	
	5	EWR 10	A22A	Elands: Upstream Swartruggens Dam	C	High	B/C	C	No changes expected.
	5	EWR 13	A22E	Elands downstream Lindleyspoort Dam	C	Low	C	C	
	14	EWR 5	A23J	Pienaars/Moretele: Downstream of the Klipvoor Dam in Borakalalo National Park	D	High	C	C/D	No changes expected.
	14	EWR 12	A23G	Buffelspruit before confluence with Plat	B/C	Mod	B/C	B	
	13	EWR 7	A24C	Crocodile: Upstream of the confluence with the Bierspruit	D	Mod	D	D	No changes expected. An improvement is difficult at this point due to the low flows.
	13	EWR 8	A24H	Crocodile downstream the confluence with Bierspruit in Ben Alberts Nature Reserve	C	Mod	C	C	No changes expected.
MARICO	7	EWR 1	A31A	Kaaloog-se-Loop: Below gorge	B	V High	B	A/B	No changes expected.
MARICO	7	EWR 2	A31B	Groot Marico: Upstream confluence with Sterkstroom	B	V High	B	B	No changes expected.
MARICO	11a	EWR 3	A31F	Groot Marico: Downstream Marico Bosveld Dam	C/D	High	C/D	B/C	No changes expected.
MARICO	11b	EWR 4	A32D	Groot Marico: Downstream Tswasa Weir	C	High	C	B	No changes expected.
MARICO	6a	EWR 5	A31E	Klein Marico Downstream Klein Maricopoort Dam	C	Mod	C	C	Increased development may impact on the Klein Marico, however improved management of WWTW and sewer surcharges can maintain the category as a C.

	IUA	EWR site	Quat	River	PES	EIS	REC	WQ	Changes in water quality expected for recommended scenarios
	6b	EWR 6	A31B	Polkadraaispruit before confluence with Marico	B/C	Mod	B	C	No changes expected.
MOKOLO	15	EWR 1a	A42C	Mokolo at Vaalwater	C/D	High	B	B	No changes expected
		EWR 1b	A42E	Mokolo at Tobacco	B/C	High	B	B	
		EWR 2	A42F	Mokolo at Ka'ingo	B/C	V High	B	B	
	16	EWR 3	A42G	Mokolo below Mokolo Dam in the Gorge	B/C	V High	B	B	Flows in the catchment are variable, with reductions in low and moderate flows, and unseasonal releases from Mokolo Dam having an impact on water quality. Increased urbanisation, mining and power stations development may have an impact on the category B and stringent conditions must be included in all IWULs to ensure water quality is maintained as a category B.
		EWR 4	A42G	Mokolo: Malalatau	C	V High	B	B	
MATLABAS	17a	EWR 1	A41A	MatlabasZynKloof	B	V High	A	B	No changes expected. Increased TDS because of scouring of the transfer pipeline (MCWAP) where it crosses the Matlabas is possible. Strict measures must be put in place to maintain the category B.
		EWR 2	A41C	Matlabas at Haarlem East (A4H004)	C	High	B/C	B	
		EWR 3	A41B	Mamba River Bridge	B/C	Mod	B/C	B	
	17b	EWR 4	A41C	Matlabas at Phofu	B	Mod	B	B	

It is important to understand that water quality category that is reflected is from an eco-classification perspective and not a fitness for use perspective (not RWQO or guideline).

The resource water quality objectives (limit or range) for the water resources of the Crocodile West Marico and Mokolo and Matlabas catchments will be set as part of the establishment of Resource Quality Objectives (RQO) process, which will ensure that the water quality requirements as per the Ecological Reserve are met as well as those of the water users. This will in many instances result in stricter water quality objectives, as user requirements are more stringent than the ecological component.

This RQO study has recently been initiated by the DWA, and will build on the outcome of this WRCS process. The ecological protection levels emanating from the selected scenario *i.e*. the MC established will guide the establishment of the in-stream resource water quality objectives.

6.3.3 ECONOMIC ASSESSMENT PER SCENARIO

6.3.3.1 Macro-Economic Analyses

Water resource management scenarios need to be evaluated in terms of their implications on the broader economy at a regional scale. The WRCS Guidelines proposes the use of a Social Accounting Matrix (SAM) (such as that developed by the Development Bank of Southern Africa (DBSA)) to model the macro-economic and social implications of different scenarios.

A SAM is a matrix that summarises the linkages that exist between the different role players in the economy *i.e.* business sectors, households and government. Thus, a SAM reflects all of the inter-sectoral transactions in an economy and the activities of households. A household is a very important economic definition, as it is the basic unit where significant decisions regarding important economic variables such as expenditure and saving are taken. A SAM combines households into meaningful groups, and thus enables analysis of different household groups, and its dependence on the rest of the economy. A SAM thus enables modelling of changes in economic activity on economic growth (*i.e*. the impact on GDP); job creation (i.e. the impact on labour requirements); impact on capital formation; and income distribution (i.e. the impact on low-income, poor households and the total income households).

A SAM enables the simulation of changes in sector turnover (please see the table below for a definition of sectors covered by a SAM) to estimate macro-economic impacts using economic multipliers. Economic models fundamentally incorporate a number of “multipliers” that form the nucleus of the modelling system. A multiplier specifies the nature and extent of the impact of a change in a specific economic quantity (e.g. agriculture) on another economic quantity or quantities (e.g. food manufacturing or employment). Multipliers consist of direct, indirect and induced multipliers. The direct multiplier measures an economic effect occurring in a specific sector, whilst the indirect multiplier measures those effects occurring in the different economic sectors that link backwards and forwards to this sector. The induced effect measures the additional economic activity generated by the spending of additional salaries and profits generated. Sectoral multipliers are calculated using information contained in the Sectoral SAMs and data obtained from the Reserve Bank of South Africa and Stats SA.

The DBSA has published SAMs for each of the nine Provinces of South Africa. The catchments in the study area located in the Gauteng, North West and Limpopo and Provinces and thus the SAMs for these three provinces are being used in the decision framework.

6.3.3.2 Analyses of Water Yield Effects

The economic transactions associated with water supply and use in the economy is officially captured in a format, which is referred to as Environmental Economic Accounts for Water. The United Nations sets out guidelines the System of Environmental Economic Accounting for Water (SEEAW). Statistics South Africa has developed various Water EEAs for South Africa. These accounts are compatible with SAMs.

Water EEAs, also referred to here as Water Hybrid Accounts, provide an accounting framework that enables the integration of specialised physical resource sector data with other information on the economics of water supply and use in a structure that is consistent with the way data on economic activities are organised in the System of National Accounts (SNA). In addition to facilitating integration and sharing of a more comprehensive knowledge base, the Natural Resource Accounting (NRA) framework provides the basis for evaluating the consistency between the objectives and priorities of water resource management and broader goals of economic development planning and policy at national and local scales.

In Water EEAs, physical accounts present the physical flow of water resources (measured by volume), and monetary accounts convert the volumetric flow of water to economic values.

The physical accounts provide information on the volumetric supply and use of water. The monetary accounts provide a basket of measures that describe the economic and welfare impacts of water supply and use.

6.3.3.3 Analyses of Aquatic Ecosystem Services

Ecosystem Services Accounts have been constructed for the Crocodile West Marico WMA and Mokolo and Matlabas catchments based on the Millennium Ecosystems Assessment (MEA) Framework. As in the case of Water Hybrid Accounts, Ecosystem Services Accounts provide an accounting framework that enables the integration of ecosystem service values with other information on the economics of water supply and can be integrated into a structure that is consistent with the System of National Accounts (SNA).

Production of aquatic ecosystem services is highly dependent upon the flow of water through rivers and wetlands. Thus reduction in flow is a hazard that puts aquatic ecosystem services at risk. This results through the desiccation of wetlands and riparian zones.

6.3.3.4 Modelling of Scenarios

The overall analysis framework for the scenario evaluation thus consists of four analytical components:

- Sectoral and SAM analyses;
- Ecosystem services analyses based on the MEA Framework;
- Water quality analyses using a water quality load model; and
- Water yield analyses using a Hybrid Water Account.

The analysis starts with the development of a set of plausible water resource management scenarios for all the IUAs. The risks to every economic sector, aquatic ecosystems and households are estimated, whereafter these risks are quantified through the Water SEEA, the WDCS simulation, the ERE analysis and finally the sectoral and SAM analyses.

Such analyses will enable cost-benefit assessment comparison of the different scenarios.

These various aspects are being run.

6.3.4 ANALYSIS OF SCENARIOS

Prime Africa Consultants developed an integrated environmental-economic model, as set out in the project methodology, and simulated the scenarios set out below. The salient features of each scenario in the various catchments are described in Table 49.

Table 49: Summary of scenarios per catchment, key aspects and preferred scenarios fort the socio-economic assessment

Scenarios	*Key findings*	*Preferred Scenario*
Crocodile West		
The ESBC Scenario (Ecological category = PES, combined with the present water use pattern) 1) (Ecological category = REC, future water use)	Future water use and river flows in the Crocodile West are driven by: • Future urban expansion in Gauteng, leading to significantly increased return flows; • Additional future mining activities in the Rustenburg area, primarily related to platinum mining; • Future water use requirements around Lephalale, which would necessitate water transfer from the Crocodile directly to Lephalale. • There is enough water from the available supply sources to meet the future demand. • The Recommended (REC) ecological category for the Crocodile-West River is achievable. • From 2018, dam-related aquatic ecosystem services at the Hartbeespoort Dam, Roodeplaat Dam and Rietvlei Dam may be negatively affected due to dam drawdowns during the dry winter season. • The costs of water supply may be affected through measures implemented through DWA's AMD (Acid Mine Drainage) and WDCS (Waste Discharge Charge System) initiatives.	1) Ecological category = REC + future water use as per the Crocodile-West Reconciliation Strategy.
Marico		
Klein Marico: ESBC: Ecological = PES, present water use Present water use no EWR 1) Future water use according to the ISP	• The only EWR site in the Klein Marico is EWR 5. At this site both the REC and PES ecological categories are the same. Thus the ESBC is maintained and is already in the REC ecological category.	Ecological category = REC + present water use.

Scenarios	***Key findings***	***Preferred Scenario***
(DWA 2011b) Zeerust currently gets all its' water from groundwater. The area appears to be sufficiently supplied with water against benchmark water requirements. However, a lack of reliable groundwater data makes it difficult to make accurate assessments in relation to future water use and availability.	• No large scale additional future use is envisaged and additional future water uses are to be achieved through water demand management and well planned and managed groundwater supply schemes. • Municipal waste water treatment works (WWTW) in the Klein Marico River would need to adhere to effluent standards set by the RQO process that follows this project.	
Groot Marico: ESBC: Ecological = PES, present water use Present water use, no EWR 1) PES, future water use – additional RDP housing; capacity of new WWTW: 500 kl/d; no return flows; 2) C category at MAR_EWR3, present water use, 3) C category at MAR_EWR3: future water use, 4) D category at MAR_EWR3: present water use; 5) PES without floods and freshets and present water use.	• No additional significant future water supply is possible in the Groot Marico. The key water source here is the dolomitic outflow, and this supply is current used at a maximum rate, both in the Groot Marico and towards the south towards Lichtenburg. Alien invasive plant removal programmes will have limited impact on water supply. There is therefore also no additional water available for resource poor farmers. • The WRCS scenarios possible in the Groot Marico is therefore limited to Scenarios 1 and 3 where we maintain present water use while implementing either a PES ecological category in Scenario 2 or a REC ecological category in Scenario 3. • Both Scenarios 2 and 3 are of particular interest at EWR site 3, directly downstream of the Marico Bosveld Dam; • Municipal waste water treatment works (WWTW) in the Klein Marico River would need to adhere to effluent standards set by the RQO process that follows this project.	The preferred scenario is a modified version of Scenario 2. The hydrological modelling conducted elsewhere in this study showed that it is not possible to implement either a PES ecological category or a REC ecological category at EWR site 3 without a significant trade-off with existing water users, principally irrigation agriculture.
Molopo: ESBC: Ecological = PES, present water use. Consideration was given to : 1) Reductions in groundwater (outflow from dolomitic eye), PES, present water use 2) Reductions in groundwater (outflow from dolomitic eye), REC, present water use	• No additional future water use possible. • Water quality – Mafikeng, WWTW, metals; • Water requirements for wetland (less diverted for domestic use)	The baseline scenario, which is The ESBC, is to be maintained.

Scenarios	*Key findings*	*Preferred Scenario*
3) Reductions in groundwater (outflow from dolomitic eye), PES, future water use		
Ngotwane: ESBC: Ecological = PES, present water use. Consideration was given to: 1) Reductions in groundwater (outflow from dolomitic eye), PES, present water use 2) Reductions in groundwater (outflow from dolomitic eye), REC, present water use 3) Reductions in groundwater (outflow from dolomitic eye), PES, future water use	• No additional future water use possible; • Water quality – Dinokana town, WWTW	The baseline scenario, which is the ESBC, is to be maintained. The economic results and ecosystem services impacts remain as set out in the Tables above for IUAs 10 and 11b.
Matlabas		
ESBC: Ecological = PES, present water use 1) REC, present water use	• No additional future water use possible.; • Scouring of river – Mokolo transfer pipeline crossing	The baseline scenario, which is the ESBC, is to be maintained.
Mokolo		
Several scenarios were identified for the Mokolo. These included: ESBC: Ecological = PES, present water use 1) PES, future water use (groundwater abstraction, transfer of water to Mokolo – MCWAP) 2) REC, present water use The Lephalale area is forecast to experience a very significant growth in coal mining, power generation and industrial economic activity. The water required for this expansion is significant. These water requirements are to be met through a water	• Large development and growth is expected in future around Lephalale. • This will not directly affect the Mokolo River. • Extensive coal mining IUA 16 could affect aquifers and could lead to AMD in future. • The aesthetic appeal of IUA 16 may be negatively affected.	The preferred scenario is a modified version of Scenario 1. Scenario 1 envisages future economic development and growth while maintaining the PES ecological category which is equivalent to a Class II. The future economic profile of the area however make it unlikely to expect that a Class II may be maintained, especially with a view to the

Scenarios	*Key findings*	*Preferred Scenario*
transfer from the Crocodile West River, directly to the Lephalale. Thus the transfer would not affect the Mokolo River. In addition, there is no EWR site downstream of Lephalale and therefore the effects of any return flows from increased urban demands were not assessed.		extensive coal mining activities that are expected to take place.

6.3.4.1 Crocodile West

Water supply and demand and the economy of the Crocodile (West) catchment

Additional future water demand is driven primarily by the factors mentioned in the section above. The principal additional water demand is expected to come from domestic use, for which a 31% increase (or 211 million m^3) in water demand is expected by 2030 (or 1.6% per year growth in water demand). Growth in the mining sector demand is expected to be 11% by 2013 (or 10 million m^3).

There is enough water from the available supply sources to meet the demand. Water supply, as set out in the Reconciliation Strategy for the Crocodile-West River (DWA 2012), does not constrain the future growth and development of the economy, with the exception of agriculture. There are numerous reasons for this. Firstly, the future urban expansion of the Gauteng region is expected to produce increased volumes of urban runoff via municipal waste water treatment works (WWTW). Effluent from these works will flow into the Crocodile River and its tributaries and contribute to the yield of the system. Secondly, there exist a number of large dams in the Crocodile-West River for which the operating rules can be optimised to increase the yield of the system. These dams principally include the Hartbeespoort Dam, Roodeplaat Dam and Rietvlei Dam, which contain surplus water. Thirdly, there exists a future option for additional water transfers into the Crocodile West River, from the Vaal River. This option was however not investigated in this study.

The exception is agriculture and irrigation agriculture in particular. The DWA Reconciliation Strategy maintains a constant supply of irrigation water for agriculture, thus, although no reduced supply to agriculture is foreseen, and thus no reduction in agricultural activity results from water supply constraints, there are no additional future supplies of water available for agriculture (DWA 2012). The Recommended (REC) ecological category for the Crocodile-West catchment is achievable. As a result, no trade-offs are required between water users and neither are any negative long term impacts on growth of the water economy expected.

Potential negative impacts in the Crocodile-West catchment arising from the scenarios

Two potential negative economic impacts are of concern.

Firstly, at some time in the future, most likely from 2018 onwards, the augmentation of the water supply system through using the surplus water stored in dams is likely to start reducing dam water levels in especially the Hartbeespoort, Roodeplaat and Rietvlei dams during the dry winter seasons. Figure 42, Figure 43 and Figure 44 provide profiles of expected patterns of dam water level drawdown in these dams. These dams have various aquatic ecosystem services associated with it which may or may not be affected. These services include recreation and tourism; and aesthetic services. These negative effects are mitigated to some extent by the fact that dam drawdown would likely be limited to the cold winter months when dam-related recreation activities are generally low.

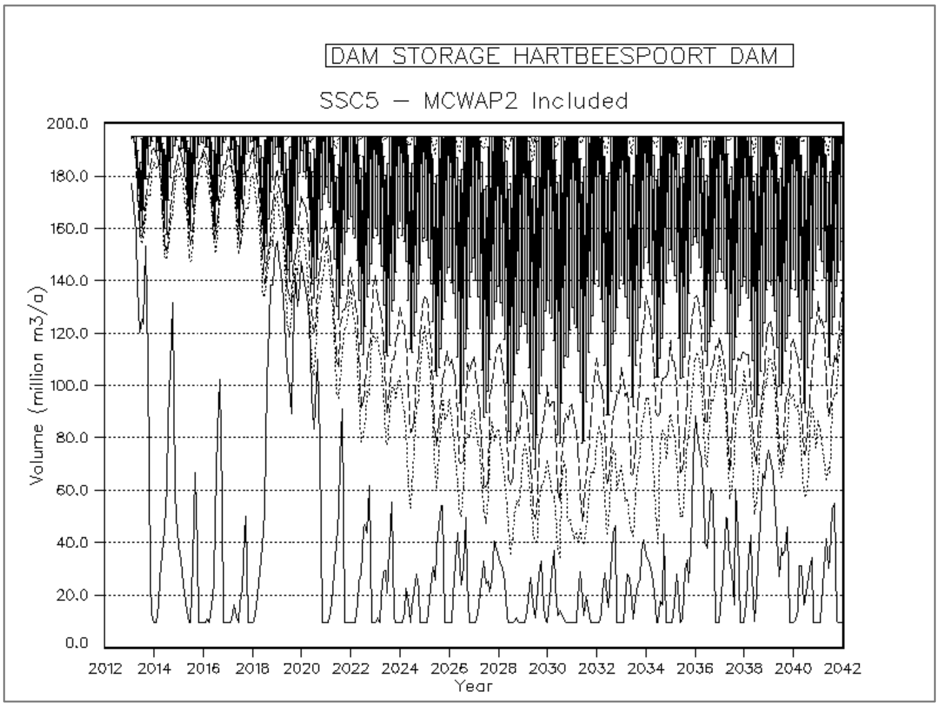


Figure 42: Dam draw-down levels in the Hartbeespoort Dam *(Source: DWA Update on the Crocodile-West Reconciliation Strategy, June 2013)*

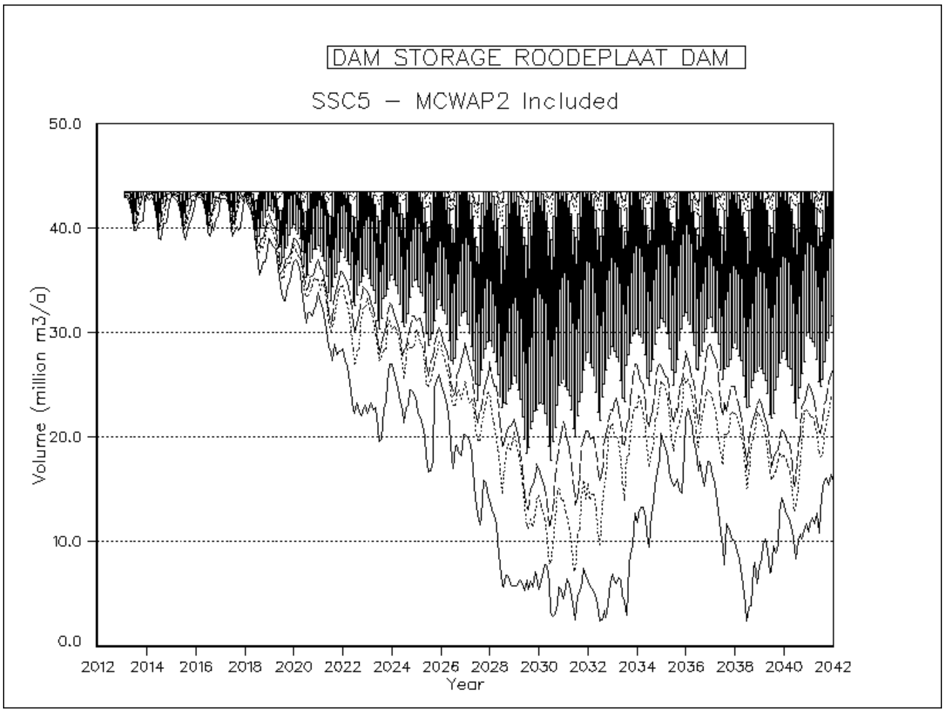


Figure 43: Dam draw-down levels in the Roodeplaat Dam *(Source: DWA Update on the Crocodile-West Reconciliation Strategy, June 2013)*

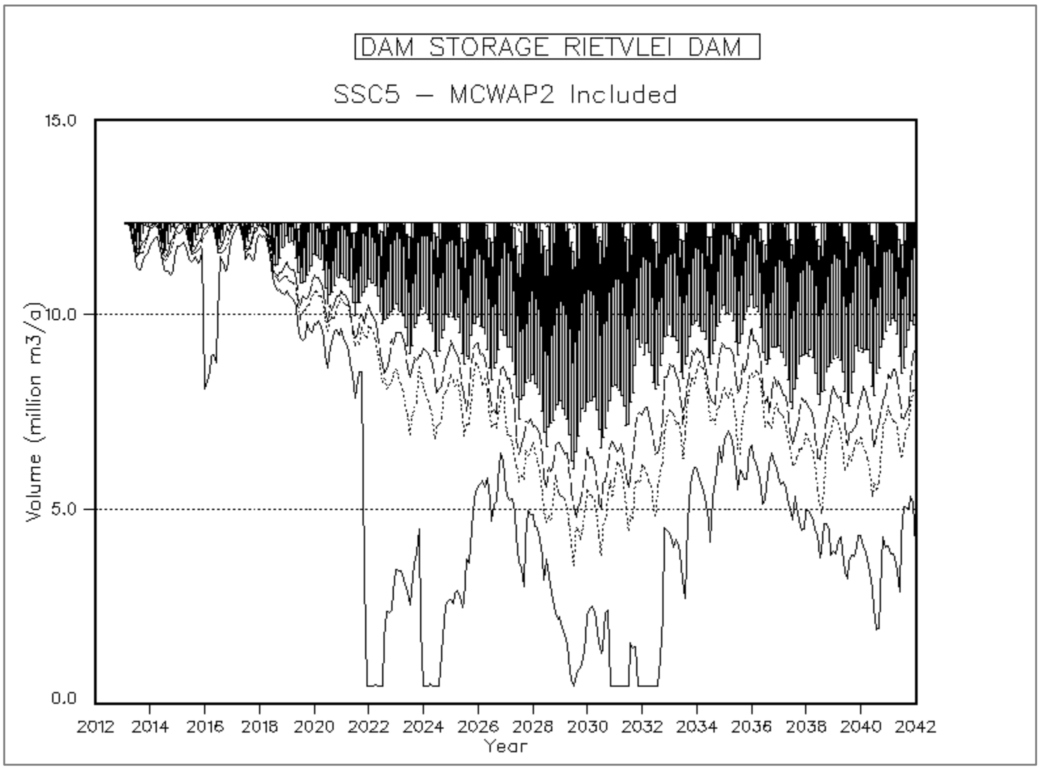


Figure 44: Dam draw-down levels in the Rietvlei Dam *(Source: DWA Update on the Crocodile-West Reconciliation Strategy, June 2013)*

Secondly, there are potential future costs associated with the treatment of AMD and nutrient loads in the Crocodile West River. These costs would result from DWA's AMD treatment initiatives and DWA's WDCS (Waste Discharge Charge System) initiatives.

Two sub-scenarios currently exist from AMD treatment. In the first, AMD is to be neutralised to 2776mg/L resulting in 15% salinity increase in the Hartbeespoort Dam. This would correspond to 50 000tons/a salinity load and 50mg/L TDS concentration increase in the long term. In second scenario, AMD is to be neutralised to 100mg/L resulting in 4 – 5% increase in salinity levels in the dam and significant reduction in impacts. Either of these scenarios is independent of the EWR scenarios evaluated in this report. The Resource Quality Objectives (RQOs) to be set as following this study would have to be considered in the selection of AMD treatment scenarios.

The preliminary findings for the implementation of the WDCS in the Hartbeespoort Dam catchment include an interim phosphorous concentration of 0,085mg/L in the dam and a final phosphorous concentration of 0,055mg/L in the dam, corresponding to a phosphorous load reduction of 81% from 348,000kg/a to 68,000kg/a. As in the case of the AMD treatment, this scenario is independent of the EWR scenarios evaluated in this report). The Resource Quality Objectives (RQOs) to be set as following this study would have to be considered in the selection of WDCS scenarios.

Table 50 sets out a summary of economic impacts of the Crocodile-West Scenarios, expressed in R'million with all results expressed in 2012 prices. The results show the combined impact of the scenarios on the full study area. The preferred scenario is Scenario 3 (Column 8). In this scenario the economy grows and there is no net loss of river and wetland ecosystem services.

Table 50: Summary of economic impacts of the Crocodile-West Scenarios, expressed in R'million

	1	2	3	4	5	6	7	8*
	Zone	Description	Sector	CWMMM 2012	CWMMM 2012 - Adjusted for AqES	CWMMM 2012 - Adjusted for AqES - WUL Dependent	ESBC	Crocodile-West Scenario 3: REC, future water use in 2030
A	Study area	Sectoral Output	Agriculture	31,045	31,549	1,146	31,549	41,728
B	Study area	Sectoral Output	Mining	225,690	225,867	173,541	225,867	260,257
C	Study area	Sectoral Output	Manufacturing	1,388,374	1,393,040	98,420	1,393,040	1,807,810
D	Study area	Sectoral Output	Utilities	45,446	47,460	25,430	47,460	59,549
E	Study area	Sectoral Output	Other commerce	816,374	823,684	124,507	823,684	1,050,731
F	Study area	Value Added	All sectors	661,139	665,181	134,635	665,181	845,691
G	Study area	Value Added	All sectors	43.2%	100.61%		100.61%	127.14%
H	Study area	Ecosystem services			5,468		5,468	5,468
I	Gauteng	Value Added contribution	All sectors	584,687	588,085	62,694	588,085	756,127
J	North-West	Value Added contribution	All sectors	74,459	74,838	70,438	74,838	87,128
K	Limpopo	Value Added contribution	All sectors	1,993	2,258	1,503	2,258	2,436

*preferred scenario

Table 51 sets out the analysis of the effect on GDP for the scenarios evaluated against the baseline for the Crocodile (West) catchment. Scenario 3 shows positive GDP growth and thereby supports job creation. Table 52 shows the results of the analysis of ecosystem services effects. This analysis shows no net loss in ecosystem services.

Table 51: Analysis of the effect on GDP for the scenarios evaluated against the baseline

GDP/IUA	Crocodile-West GDP Baseline - Adjusted for Aquatic ecosystem services (2012)	Crocodile-West GDP ESBC - Adjusted for Aquatic ecosystem services (2012)	Crocodile-West GDP Scenario 3 - Adjusted for Aquatic ecosystem services (2030)
IUA 1	553,146	570,320	725,087
IUA 2	2,167	2,235	2,841
IUA 3	12,123	12,499	15,891
IUA 4	26,195	27,009	34,338
IUA 5	7,985	8,233	10,467
IUA 12	3,554	3,664	4,659
IUA 13	3,583	3,694	4,697
IUA 14	36,397	37,527	47,710

Table 52: Analysis of ecosystem services effects

GDP/IUA	Crocodile-West Ecosystem Services Baseline - (2012)	Crocodile-West Ecosystem Services ESBC - (2012)	Crocodile-West Ecosystem Services Scenario 3 - (2030)
IUA 1	722	722	722
IUA 2	47	47	47
IUA 3	318	318	318
IUA 4	645	645	645
IUA 5	107	107	107
IUA 12	112	112	112
IUA 13	262	262	262
IUA 14	324	324	324

6.3.4.2 Klein and Groot Marico

Table 53 sets out the summary of economic impacts of the Klein Marico scenarios, expressed in R'million. All results are expressed in 2012 prices. The results show the combined impact of the scenarios on the full study area. The preferred scenario is Scenario 2 (Column 8) for the Klein Marico and modified Scenario 2 for the Groot Marico. In this scenario the water economy stays stable and there is no net loss of river and wetland ecosystem services. Table 54 sets out the results of the analysis of ecosystem services effects for the full study area. This analysis shows no net loss in ecosystem services.

Table 53: Summary of economic impacts of the Klein and Groot Marico Scenarios, expressed in R'million

	1	2	3	4	5	6	7	8*	9**
	Zone	Description	Sector	CWMMM 2012	CWMMM 2012 - Adjusted for AqES	CWMMM 2012 - Adjusted for AqES - WUL Dependent	ESBC	Scenario 2: REC, present water use	Modified Scenario 2: REC, present water use
A	Study area	Sectoral Output	Agriculture	31,045	31,549	1,146	31,549	31,798	31,798
B	Study area	Sectoral Output	Mining	225,690	225,867	173,541	225,867	227,270	227,270
C	Study area	Sectoral Output	Manufacturing	1,388,374	1,393,040	98,420	1,393,040	1,392,416	1,392,416
D	Study area	Sectoral Output	Utilities	45,446	47,460	25,430	47,460	47,833	47,833
E	Study area	Sectoral Output	Other commerce	816,374	823,684	124,507	823,684	822,494	822,494
F	Study area	Value Added	All sectors	661,139	665,181	134,635	665,181	665,200	665,200
G	Study area	Value Added	All sectors	43.2%	100.61%		100.61%	100.61%	100.61%
H	Study area	Ecosystem services			5,468		5,468	5,809	5,809
I	Gauteng	Value Added contribution	All sectors	584,687	588,085	62,694	588,085	587,248	587,248
J	North-West	Value Added contribution	All sectors	74,459	74,838	70,438	74,838	75,109	75,109
K	Limpopo	Value Added contribution	All sectors	1,993	2,258	1,503	2,258	2,843	2,843

*preferred scenario – Klein Marico; **preferred scenario – Groot Marico

Table 54: Analysis of the effect on GDP for the scenarios evaluated against the baseline for the study area

GDP/IUA	GDP Baseline - Adjusted for Aquatic ecosystem services (2012)	GDP ESBC - Adjusted for Aquatic ecosystem services (2012)	Klein Marico GDP Scenario 3 - Adjusted for Aquatic ecosystem services (2030)	Groot Marico GDP Scenario 3 - Adjusted for Aquatic ecosystem services (2030)
IUA 6a – Klein Marico	856	856	856	856
IUA 6b – Groot Marico	367	367	367	367
IUA 7- Groot Marico	145	145	145	145
IUA 8 – Klein Marico	110	110	110	110
IUA 9 - Ngotwane	10,944	10,944	10,944	10,944
IUA 10 - Molopo	897	897	897	897
IUA 11a - Groot Marico	1,844	1,844	1,844	1,844
IUA 11b - Groot Marico	612	612	612	612

Table 55: Analysis of ecosystem services effects for the full study area. This analysis shows no net loss in ecosystem services

GDP/IUA	Klein Marico Ecosystem Services Baseline - (2012)	Klein Marico Ecosystem Services ESBC - (2012)	Klein Marico Ecosystem Services Scenario 2 - (2030)	Groot Marico Ecosystem Services Scenario 2 - (2030)
IUA 6a – Klein Marico	457	457	457	457
IUA 6b – Groot Marico	546	546	546	546
IUA 7 - Groot Marico	335	335	335	335
IUA 8 – Klein Marico	285	285	285	285
IUA 9 - Ngotwane	23	23	23	23
IUA 10 - Molopo	180	180	180	180
IUA 11a - Groot Marico	270	270	270	270
IUA 11b - Groot Marico	61	61	61	61

6.3.4.3 Mokolo

Water supply and demand and the economy of the Mokolo River

The DWA reconciliation strategy for the Crocodile-West River includes an analysis of the water requirement projections for Lephalale. These include:

- Two additional coal-fired power stations after Medupi in Waterberg area;
- Coal mining for power generation as well as export to Mpumalanga;
- More comprehensive attention to coal mining for other purposes; and
- Detailed analyses of urban and rural water requirements.

The water requirements associated with these activities are to be supplied via transfer directly to Lephalale (Figure 45).

Although the transfer would thus not affect the Mokolo River directly, there are some indirect risks to ecosystem services in the form of risk associated with coal mining effects in terms of changes in streamflow as a result of dewatering, future AMD and risks to aesthetic effects.

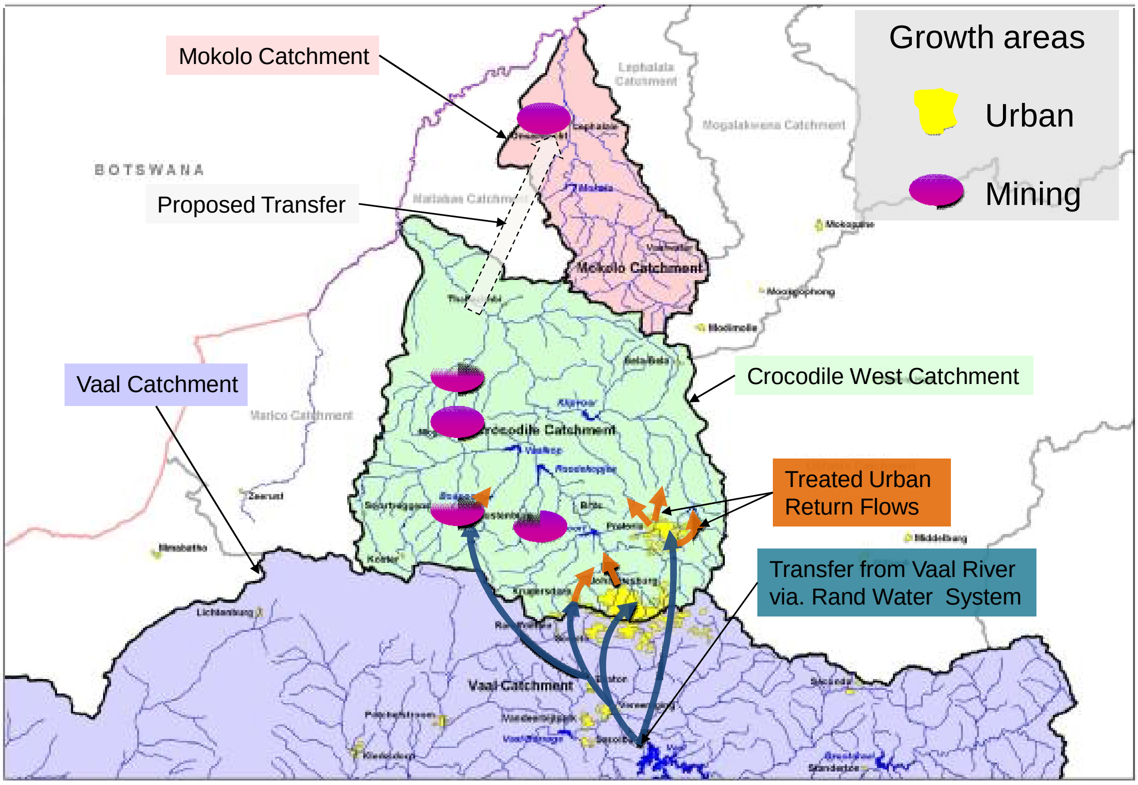


Figure 45: Schematic presentation of the planned transfer from the Crocodile-West River to Lephalale (Source: Crocodile (West) Reconciliation study presentation)

Table 56 sets out a summary of economic impacts of the Mokolo Scenarios, expressed in R'million. All results are expressed in 2012 prices. The results show the combined impact of the scenarios on the full study area. The preferred scenario is Scenario 1 (Column 8). In this scenario the water economy grows significantly (see cells K8, L8 and M8) however there may be some negative impact on ecosystem services.

Table 56: Summary of economic impacts of the Mokolo Scenarios, expressed in R'million

	1	2	3	4	5	6	7	8*
	Zone	Description	Sector	CWMMM 2012	CWMMM 2012 - Adjusted for AqES	CWMMM 2012 - Adjusted for AqES - WUL Dependent	ESBC	Scenario 1: Mokolo - PES, future water use
A	G-NW-L	Sectoral Output	Agriculture	31,045	31,549	1,146	31,549	31,941
B	G-NW-L	Sectoral Output	Mining	225,690	225,867	173,541	225,867	231,168
C	G-NW-L	Sectoral Output	Manufacturing	1,388,374	1,393,040	98,420	1,393,040	1,394,212
D	G-NW-L	Sectoral Output	Utilities	45,446	47,460	25,430	47,460	57,065
E	G-NW-L	Sectoral Output	Other commerce	816,374	823,684	124,507	823,684	827,239
F	G-NW-L	Value Added	All sectors	661,139	665,181	134,635	665,181	672,018
G	G-NW-L	Value Added	All sectors	43.2%	100.61%		100.61%	101.03%
H	G-NW-L	Ecosystem services			5,468		5,468	5,468
I	Gauteng	Value Added	All sectors	584,687	588,085	62,694	588,085	587,121
J	North-West	Value Added	All sectors	74,459	74,838	70,438	74,838	75,079
K	Limpopo	Sectoral Output	Mining	1,852	1,910	1,877	1,910	6,337
L	Limpopo	Sectoral Output	Manufacturing	1,568	1,706	735	1,706	4,118
M	Limpopo	Sectoral Output	Utilities	208	767	717	767	10,201
N	Limpopo	Sectoral Output	Other commerce	3,092	3,360	1,418	3,360	9,235
O	Limpopo	Value Added	All sectors	1,993	2,258	1,503	2,258	9,818

*preferred scenario

Table 57 sets out the results of the analysis of the effect on GDP for the scenarios evaluated against the baseline. Scenario 2 shows strong water economy GDP growth especially in IUA 16. Table 58 shows the results of the analysis of ecosystem services effects. Although this analysis currently shows no net loss in ecosystem services there are possible future risks to ecosystem services resulting from coal mining impacts.

Table 57: Analysis of the effect on GDP for the scenarios evaluated against the baseline

GDP/IUA	GDP Baseline - Adjusted for Aquatic ecosystem services (2012)	GDP ESBC - Adjusted for Aquatic ecosystem services (2012)	Mokolo GDP Scenario 1 - Adjusted for Aquatic ecosystem services (2030)
IUA 15	686	686	686
IUA 16	3,180	3,180	9,888

Table 58: Analysis of ecosystem services effects

GDP/IUA	Mokolo Ecosystem Services Baseline - (2012)	Mokolo Ecosystem Services ESBC - (2012)	Mokolo Ecosystem Services Scenario 1 - (2030)
IUA 15	234	234	234
IUA 16	54	54	54

6.3.4.4 Matlabas

The baseline scenario, which is the ESBC, is to be maintained. The economic results and ecosystem services impacts therefore remain as set out in Table 59 and Table 60 for IUAs 17a and 17b.

Table 59: Analysis of the effect on GDP for the scenarios evaluated against the baseline

GDP/IUA	GDP Baseline - Adjusted for Aquatic ecosystem services (2012)	GDP ESBC - Adjusted for Aquatic ecosystem services (2012)
IUA 17a	176	176
IUA 17b	213	213

Table 60: Analysis of ecosystem services effects

GDP/IUA	Matlabas Ecosystem Services Baseline - (2012)	Matlabas Ecosystem Services ESBC - (2012)
IUA 17a	58	58
IUA 17b	427	427

7 CONCLUSIONS AND RECOMMENDATIONS

The recommended scenarios and proposed MCs will be submitted to the Minister for consideration. The final proposed MCs together with the established Resource Quality Objectives (RQOs) for the Crocodile West/Marico WMA and Mokolo and Matlabas catchments will be gazetted together when both processes have been completed. The gazetting process includes a 60 day public comment period.

Based on the scenario evaluation and consultation with the stakeholders, it was recommended that the go forward options are the following scenarios:

- Crocodile West catchment: scenarios which supply the PES ecological category, which in the context of the Crocodile West catchment is equal to the REC ecological category, and meet the future growth in water requirements (2030) in the WMA;
- Marico catchment: the scenario in the Klein Marico is the REC with present water use (2030); the scenario in the Groot Marico is the REC with present water use (2015);
- Mokolo catchment: PES with future water use (2030); and
- Matlabas, Molopo and Ngotwane: the ESBC is to be maintained.

Table 61: Implications for implementing the proposed scenario in the Crocodile (West) catchment

<table>
<tr><th>IUA</th><th>Catchment area</th><th>Recommended Management Class</th><th>% contribution to achieve the MC</th><th>Implications of implementation</th></tr>
<tr><td>1</td><td>Upper Crocodile/Hennops/ Hartebeespoort</td><td>III</td><td>Surface water: 75
Groundwater: 15
Wetlands: 10</td><td rowspan="8">Preferred Scenario: Ecological category = REC + future water use as per the Crocodile-West Reconciliation Strategy
Future Water Requirements driven by:
• Future urban expansion in Gauteng, leading to significantly increased return flows;
• Additional future mining activities in the Rustenburg area, primarily related to platinum mining; and
• Future water use requirements around Lephalale, which would necessitate a water transfer from the Crocodile directly to Lephalale (MCWAP)
• Water supply, does not constrain the future growth and development of the economy, with the exception of agriculture.
• The Recommended (REC) ecological category for the Crocodile West catchment is achievable.
• From 2018 onwards, the augmentation of the water supply system through using the surplus water stored in dams would start reducing dam water levels in especially the Hartbeespoort Dam, Roodeplaat Dam and Rietvlei Dam during the dry winter seasons.
• There are potential future costs associated with the treatment of AMD and nutrient loads in the Crocodile West River.
• With this scenario the economy grows and there is no net loss of river and wetland ecosystem services.</td></tr>
<tr><td>2</td><td>Magalies</td><td>II</td><td>Surface water: 60
Groundwater: 33
Wetlands: 7</td></tr>
<tr><td>3</td><td>Crocodile/ Roodekopjes</td><td>III</td><td>Surface water: 95
Groundwater: 5
Wetlands: 0</td></tr>
<tr><td>4</td><td>Hex/Waterkloofspruit/ Vaalkop</td><td>II</td><td>Surface water: 77
Groundwater: 9
Wetlands:14</td></tr>
<tr><td>5</td><td>Elands/Vaalkop</td><td>II</td><td>Surface water: 75
Groundwater: 5
Wetlands 20</td></tr>
<tr><td>12</td><td>Bierspruit</td><td>III</td><td>Surface water: 80
Groundwater: 20
Wetlands: 0</td></tr>
<tr><td>13</td><td>Lower Crocodile</td><td>III</td><td>Surface water: 68
Groundwater: 25
Wetlands: 7</td></tr>
<tr><td>14</td><td>Tolwane/Kulwane/ Moretele/Klipvoor</td><td>III</td><td>Surface water: 65
Groundwater: 15
Wetlands: 20</td></tr>
</table>

Table 62: Implications for implementing the proposed scenario in the Marico catchment

IUA	Catchment area	Recommended Management Class	% contribution to achieve the MC	Implications of implementation
6a	Klein Marico/ Kromellemboog	II	Surface water: 75 Groundwater: 25 Wetlands: 0	**Preferred Scenario: Ecological category = REC + present water use** Future water use and river flows are driven by: • Possible future urban expansion in towns, leading to marginal increased demands for domestic water • No large scale additional future use is envisaged and additional future water uses are to be achieved through water demand management and well planned and managed groundwater supply schemes. • In this scenario the water economy stays stable and there is no net loss of river and wetland ecosystem services.
6b	Groot Marico/Marico Bosveld Dam	II	Surface water: 90 Groundwater: 10 Wetlands: 0	**Preferred Scenario: PES, AIP clearing, present water use (incl emerging farmers)** • No additional significant future water supply is possible in the Groot Marico; • The key water source here is the dolomitic outflow, and this supply is current used at a maximum rate, both in the Groot Marico and towards the south towards Lichtenburg; and • In this scenario the water economy stays stable and there is no net
11a	Groot Marico/Molatedi Dam	I	Surface water: 35 Groundwater: 35 Wetlands: 30	
11b	Groot Marico/seasonal tributaries	III	Surface water: 0 Groundwater: 70 Wetlands: 30	
7	Kaaloog-se-Loop	II	Surface water: 5 Groundwater: 70 Wetlands: 25	

IUA	Catchment area	Recommended Management Class	% contribution to achieve the MC	Implications of implementation
8	Malmaniesloop	III	Surface water: 15 Groundwater: 70 Wetlands: 15	loss of river and wetland ecosystem services.
9	Molopo	III	Surface water: 80 Groundwater: 20 Wetlands: 0	**Preferred Scenario: ESBC: Ecological = PES, present water use** • Groundwater supply adequate; and • In this scenario the water economy stays stable and there is no net loss of river and wetland ecosystem services.
10	Dinokana Eye/Ngotwane Dam	III	Surface water: 75 Groundwater: 20 Wetlands: 5	

Table 63: Implications for implementing the proposed scenario in the Mokolo and Matlabas catchments

IUA	Catchment area	Recommended Management Class	% contribution to achieve the MC	Implications of implementation
15	Upper Mokolo	II	Surface water: 74 Groundwater: 10 Wetlands: 16	**Preferred Scenario: PES with future water use (2030)** • The Lephalale area is forecast to experience a very significant growth in coal mining, power generation and industrial economic activity; • This will not directly affect the Mokolo River; • The water required for this expansion is significant; • These water requirements are to be met through a water transfer from the Crocodile West River, directly to the Lephalale;
16	Lower Mokolo	II	Surface water: 60 Groundwater: 20 Wetlands: 20	

IUA	Catchment area	Recommended Management Class	% contribution to achieve the MC	Implications of implementation
				• Extensive coal mining IUA 16 could affect aquifers and could lead to AMD in future; • The aesthetic appeal of IUA 16 may be negatively affected; and • In this scenario the water economy grows significantly however there may be some negative impact on ecosystem services.
17a	Mothlabatsi/Mamba	I	Surface water: 95 Groundwater: 5 Wetlands: 0	**Preferred Scenario: ESBC is to be maintained** • No change in economic results and ecosystem services; • Potential impact from MCWAP pipeline crossing
17b	Matlabas/Limpopo	II	Surface water: 75 Groundwater: 20 Wetlands: 5	

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Department of Water Affairs (2011b). Development Of A Reconciliation Strategy For All Towns In The Northern Region Ngaka Modiri Molema District Municipality Ramotshere Moiloa Local Municipality First Order Reconciliation Strategy For Zeerust Water Supply Scheme Zeerust and Ikageleng. Directorate: National Water Resource Planning

APPENDIX A: ECOLOGICAL CONSEQUENCES

FISH FREQUENCY HABITAT ASSESSMENT (FFHA)

CROC_EWR 2: Jukskei River

	Natural	Present	EWR 2_D	Sc 1	Sc 2
Fish dry	Not assessed	A	D	A	A
Fish wet		A	A/B	A	A
Fish integrated			*C*	*A*	*A*

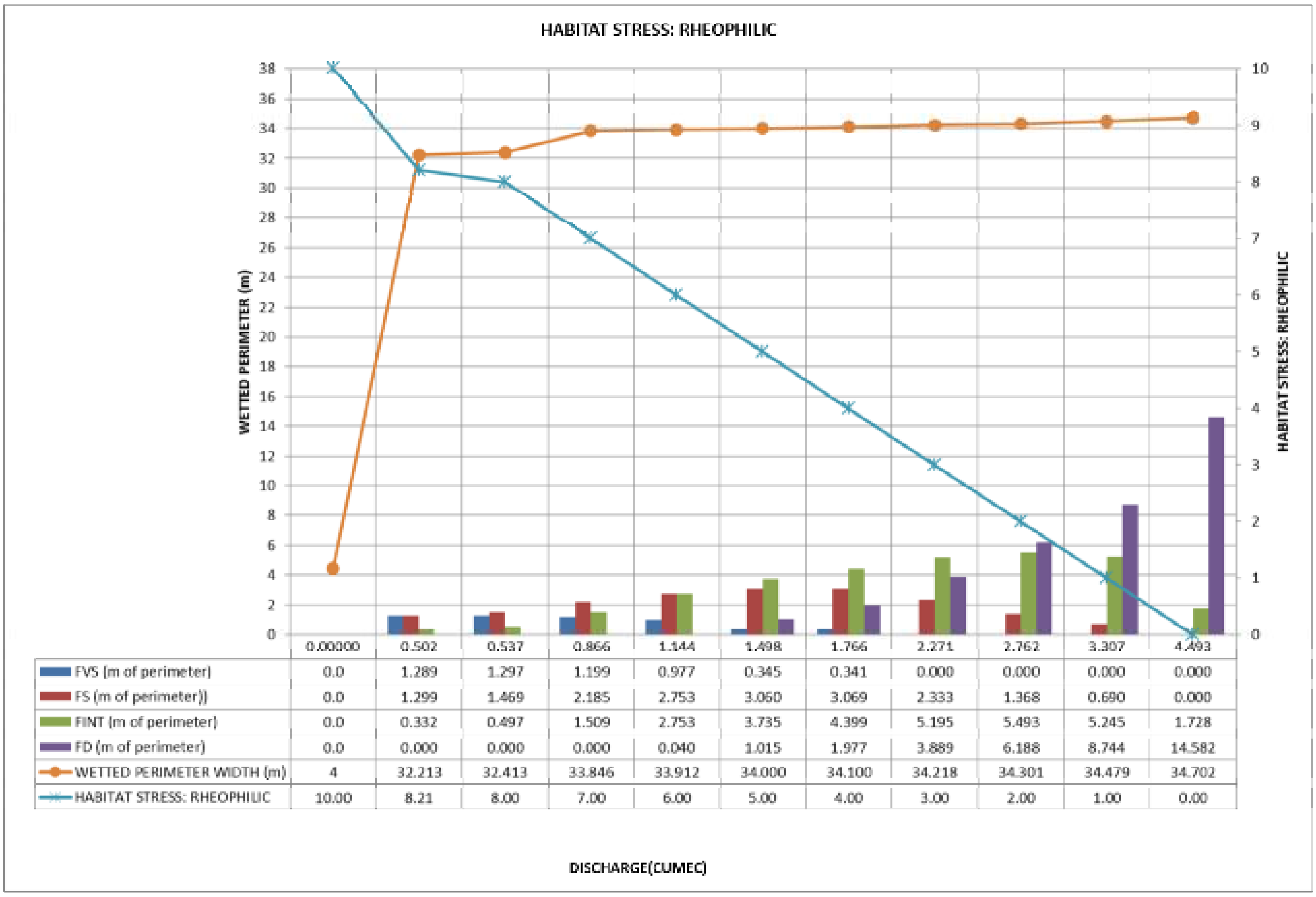
Note: Reference flow used= Present day

Comments:

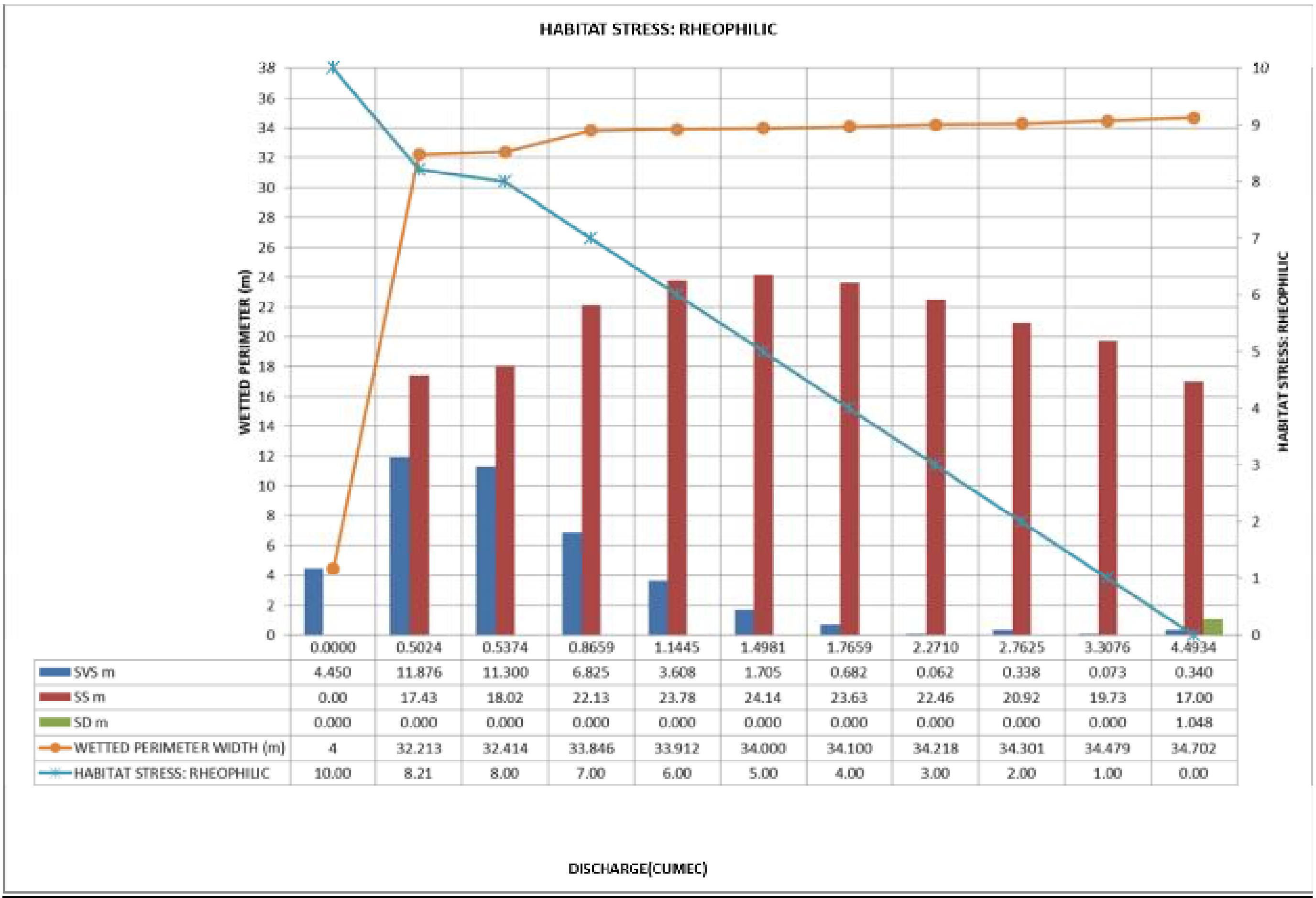
1. Although no rheophilics currently occur in the river, the FHHA was run for this guild as the Velocity-Depth classes under present day flow conditions are dominated by the fast flowing (>0.3 m/s) types.This means that flow requirement assessment was based on habitat (VD classes) available compared to the reference rather than indicator spp or guilds.
2. Flows higher than the reference (i.e. higher than present) were not interpreted as negative (i.e. flows higher than present were interpreted as providing more fast habitat than present and that was interpreted as providing habitat conditions equivalent to “A”)
3. The assessment of flow requirements are only based on cross section through riffles, rapids and runs predominantly with a hard substrate (cobbles, rocks, boulders).

Dry season (August)

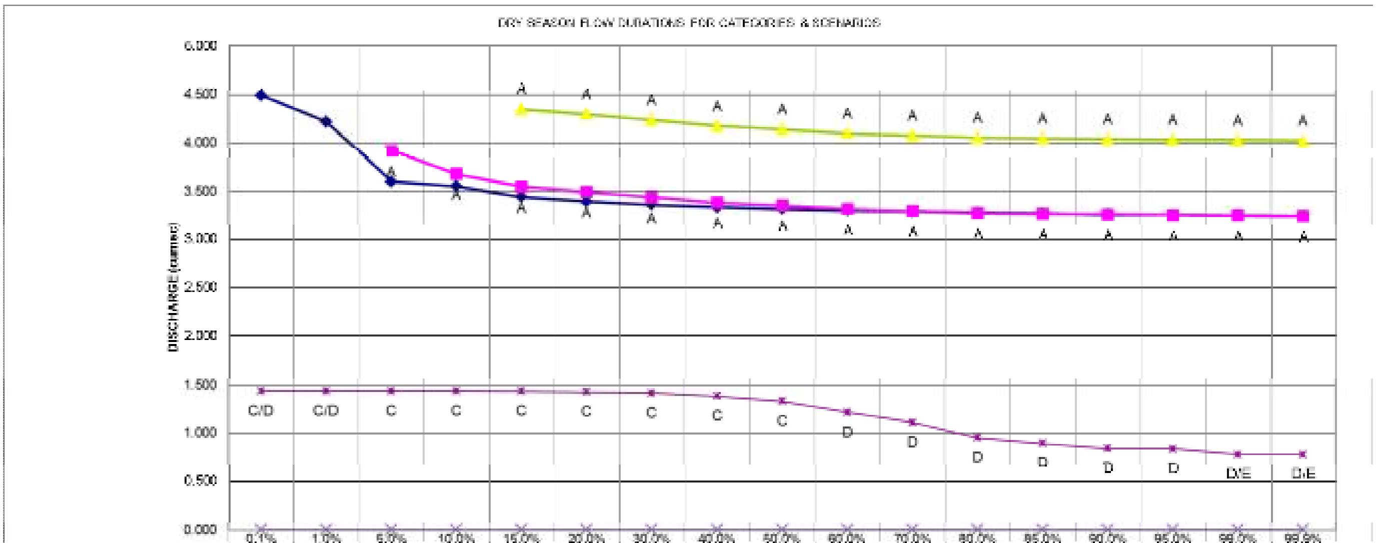
Max natural low flow:= 4.493 cumec.



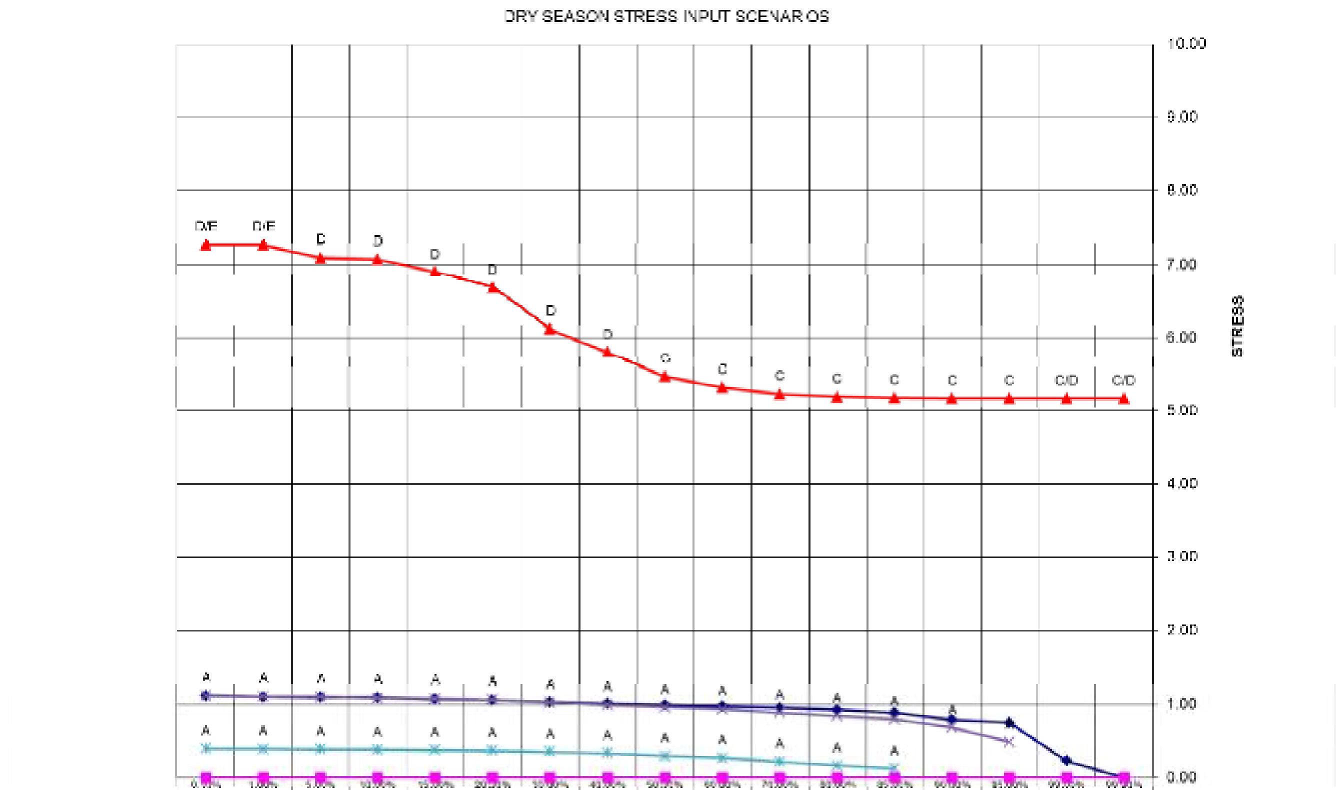
	0.00000	0.502	0.537	0.866	1.144	1.498	1.766	2.271	2.762	3.307	4.493
FVS (m of perimeter)	0.0	1.289	1.297	1.199	0.977	0.345	0.341	0.000	0.000	0.000	0.000
FS (m of perimeter))	0.0	1.299	1.469	2.185	2.753	3.060	3.069	2.333	1.368	0.690	0.000
FINT (m of perimeter)	0.0	0.332	0.497	1.509	2.753	3.735	4.399	5.195	5.493	5.245	1.728
FD (m of perimeter)	0.0	0.000	0.000	0.000	0.040	1.015	1.977	3.889	6.188	8.744	14.582
WETTED PERIMETER WIDTH (m)	4	32.213	32.413	33.846	33.912	34.000	34.100	34.218	34.301	34.479	34.702
HABITAT STRESS: RHEOPHILIC	10.00	8.21	8.00	7.00	6.00	5.00	4.00	3.00	2.00	1.00	0.00



	0.0000	0.5024	0.5374	0.8659	1.1445	1.4981	1.7659	2.2710	2.7625	3.3076	4.4934
SVS m	4.450	11.876	11.300	6.825	3.608	1.705	0.682	0.062	0.338	0.073	0.340
SS m	0.00	17.43	18.02	22.13	23.78	24.14	23.63	22.46	20.92	19.73	17.00
SD m	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.048
WETTED PERIMETER WIDTH (m)	4	32.213	32.414	33.846	33.912	34.000	34.100	34.218	34.301	34.479	34.702
HABITAT STRESS: RHEOPHILIC	10.00	8.21	8.00	7.00	6.00	5.00	4.00	3.00	2.00	1.00	0.00



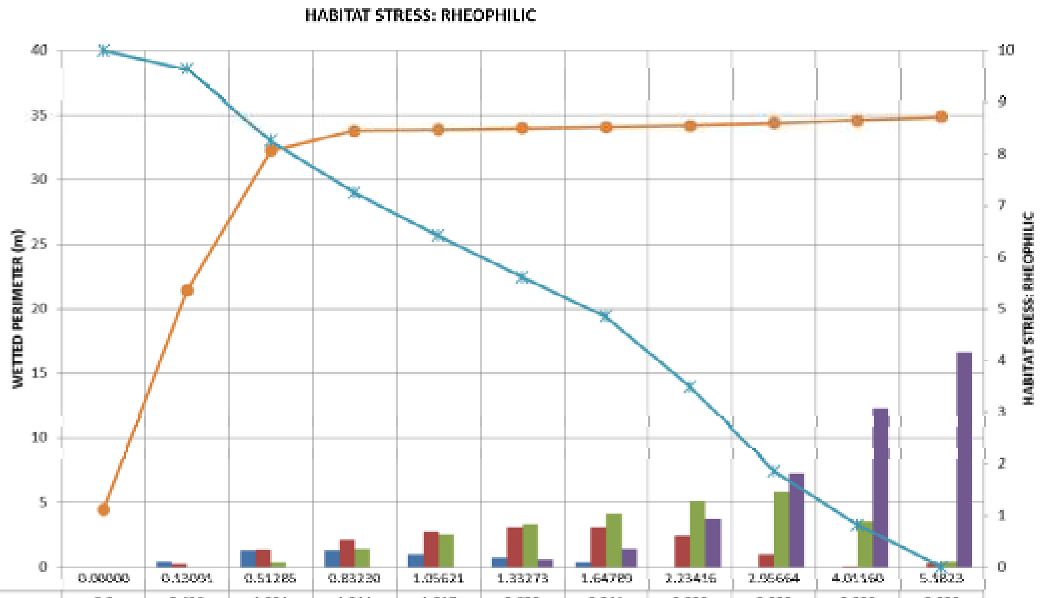
	0.1%	1.0%	5.0%	10.0%	15.0%	20.0%	30.0%	40.0%	50.0%	60.0%	70.0%	80.0%	85.0%	90.0%	95.0%	99.0%	99.9%
REFERENCE FLOWS (present)	4.493	4.221	3.601	3.554	3.441	3.393	3.359	3.336	3.315	3.302	3.288	3.276	3.267	3.257	3.254	3.250	3.242
PRESENT FLOWS	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
HN6 EWR2_D	1.436	1.436	1.436	1.435	1.433	1.427	1.415	1.383	1.330	1.215	1.111	0.954	0.894	0.843	0.837	0.778	0.778
HN6 EWR2 Sc1			3.9160	3.6790	3.5480	3.4940	3.4390	3.3820	3.3530	3.3140	3.2930	3.2730	3.2650	3.2600	3.2520	3.2490	3.2430
HN6 EWR2 Sc2					4.3490	4.2980	4.2380	4.1760	4.1420	4.0990	4.0770	4.0640	4.0460	4.0410	4.0330	4.0280	4.0220



	0.10%	1.00%	5.00%	10.00%	15.00%	20.00%	30.00%	40.00%	50.00%	60.00%	70.00%	80.00%	85.00%	90.00%	95.00%	99.00%	99.90%
NATURAL STRESS (pres)	1.12	1.11	1.10	1.09	1.07	1.06	1.03	1.01	0.99	0.98	0.96	0.93	0.89	0.79	0.75	0.23	0.00
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
HN5 EWR2_D	7.27	7.27	7.09	7.07	6.90	6.68	6.12	5.80	5.48	5.33	5.23	5.20	5.18	5.18	5.18	5.18	5.18
HN5 EWR2 Sc1	1.12	1.11	1.10	1.09	1.08	1.06	1.03	0.99	0.96	0.94	0.89	0.84	0.80	0.69	0.49		
HN5 EWR2 Sc2	0.40	0.39	0.39	0.38	0.38	0.37	0.35	0.33	0.30	0.27	0.22	0.16	0.12				

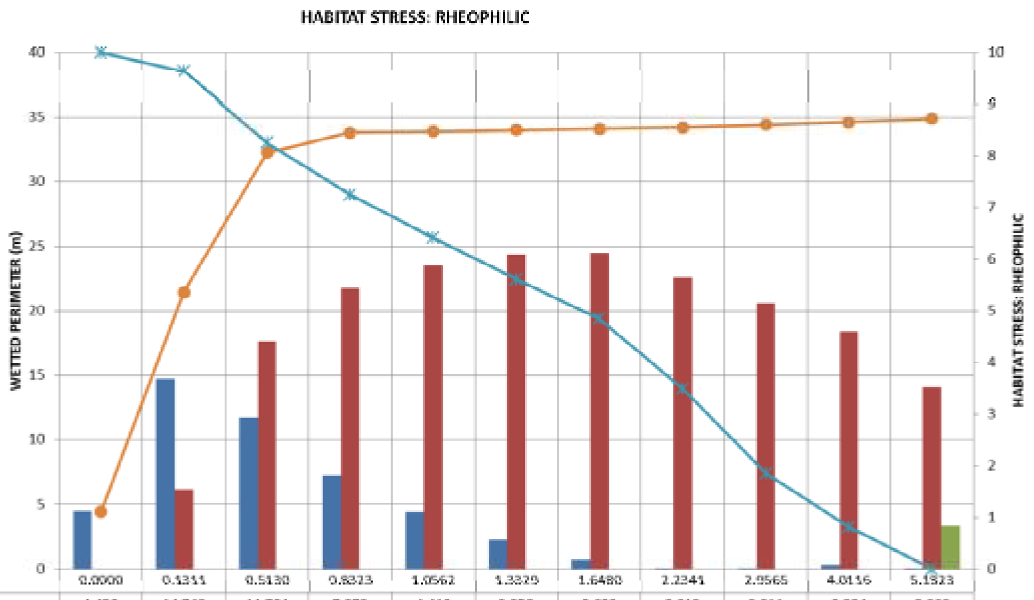
Wet season (February)

Max natural low flow:= 5.1823 cumec



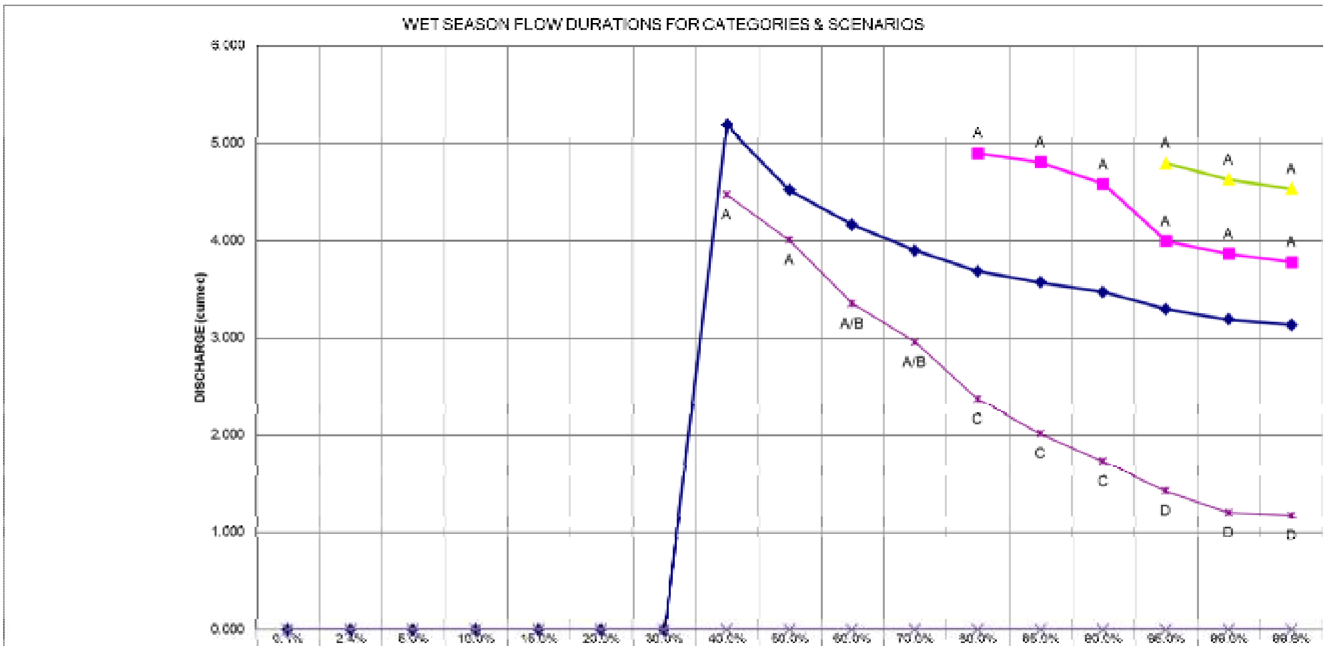
	0.00000	0.13091	0.51285	0.83230	1.05621	1.33273	1.64789	2.23416	2.95664	4.01160	5.1823
FVS (m of perimeter)	0.0	0.429	1.291	1.311	1.017	0.680	0.341	0.000	0.000	0.000	0.000
FS (m of perimeter))	0.0	0.214	1.350	2.070	2.712	3.060	3.069	2.406	1.021	0.042	0.289
FINT (m of perimeter)	0.0	0.000	0.382	1.394	2.485	3.294	4.111	5.130	5.837	3.545	0.409
FD (m of perimeter)	0.0	0.000	0.000	0.000	0.000	0.574	1.402	3.737	7.247	12.329	16.624
WETTED PERIMETER WIDTH (m)	4	21.434	32.273	33.812	33.900	34.000	34.100	34.200	34.400	34.600	34.883
HABITAT STRESS: RHEOPHILIC	10.00	9.63	8.25	7.24	6.41	5.61	4.85	3.49	1.86	0.81	0.00

DISCHARGE(CUMEC)

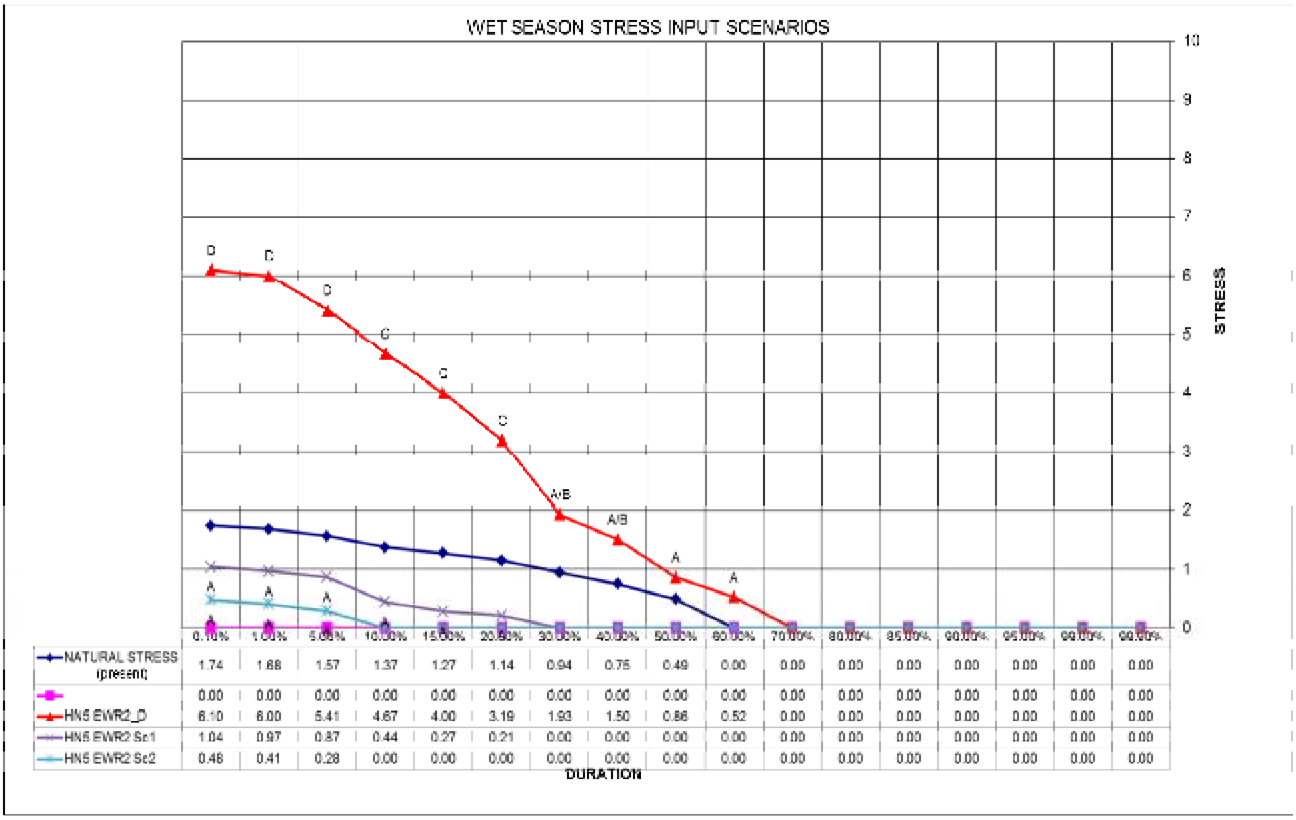


	0.0000	0.1311	0.5130	0.8323	1.0562	1.3329	1.6480	2.2341	2.9565	4.0116	5.1823
SVS m	4.450	14.743	11.701	7.273	4.412	2.250	0.682	0.013	0.011	0.304	0.060
SS m	0.00	6.15	17.61	21.76	23.50	24.37	24.49	22.58	20.62	18.38	14.07
SD m	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	3.369
WETTED PERIMETER WIDTH (m)	4	21.447	32.275	33.812	33.900	34.000	34.100	34.200	34.400	34.600	34.883
HABITAT STRESS: RHEOPHILIC	10.00	9.63	8.25	7.24	6.41	5.61	4.85	3.49	1.86	0.81	0.00

DISCHARGE(CUMEC)



	0.1%	[illegible]	5.0%	10.0%	15.0%	20.0%	30.0%	40.0%	50.0%	60.0%	70.0%	80.0%	85.0%	90.0%	95.0%	98.0%	99.9%
REFERENCE FLOWS (present)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	5.182	4.521	4.165	3.901	3.687	3.571	3.474	3.297	3.189	3.134
PRESENT FLOWS	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
HN5 EWR2_D								4.473	4.007	3.356	2.959	2.370	2.014	1.725	1.425	1.199	1.169
HN5 EWR2 Sc1												4.9000	4.8090	4.5830	4.0000	3.8670	3.7820
HN5 EWR2 Sc2															4.7970	4.6310	4.5350



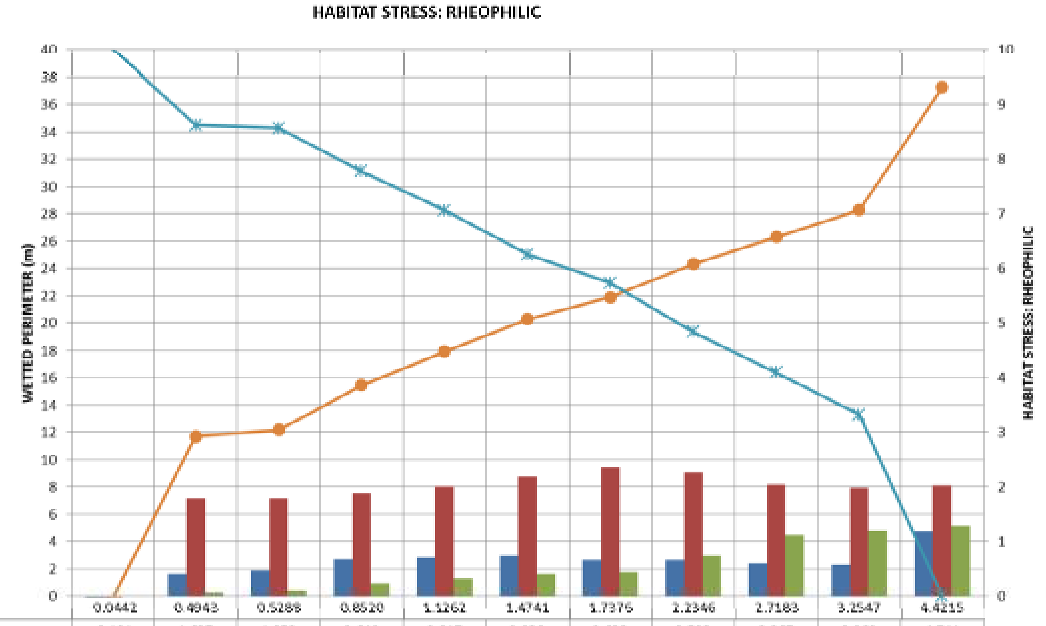
CROC_EWR3: Crocodile below Hartbeespoort Dam

	Natural	Present	EWR 3_C/D	Sc 1	Sc 2
Fish dry	A	D	D	D	A
Fish wet		A	A	A	A
Fish integrated		*A*	*C*	*A*	*A*

Comments:

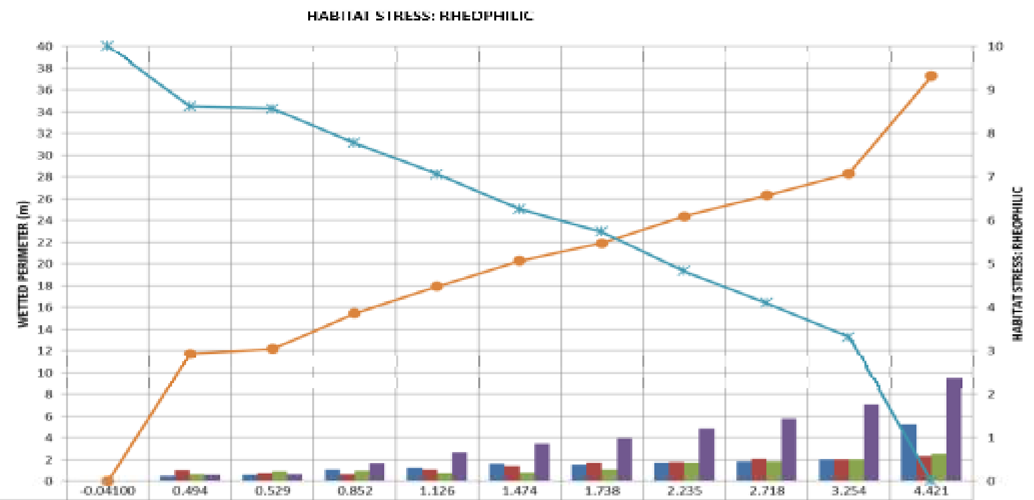
1. Assessment based on requirements of a small rheophilic (Chiloglanis pretoriae)
2. FFHA was run for this guild for all fast flow (>0.3 m/s) types (FVS, FS, FI, FD).
3. This means that flow requirements were relatively “liberal”. Requirement would have been increasingly “conservative” if VD classes were respectively set for >FVS, >FS, >FI or =>FD.

Dry season (August)Max natural low flow:= 4.421 cumec.



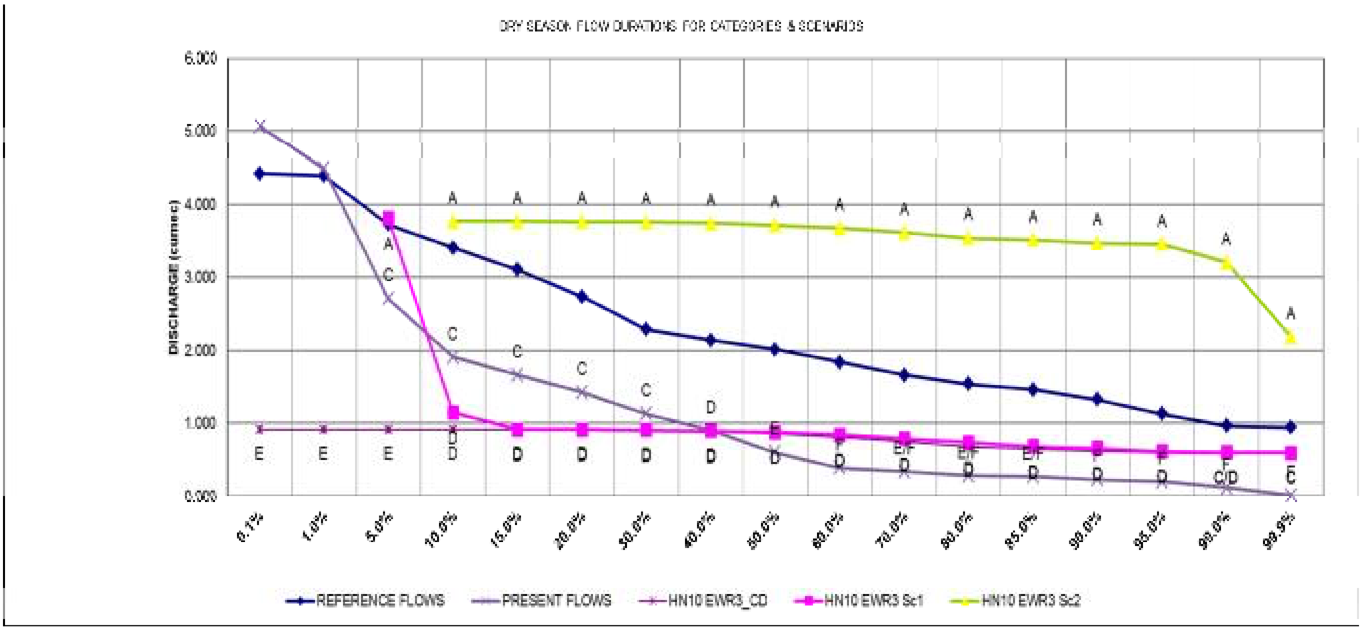
	0.0442	0.4943	0.5288	0.8520	1.1262	1.4741	1.7376	2.2346	2.7183	3.2547	4.4215
SVS m	-0.121	1.637	1.853	2.649	2.817	2.930	2.633	2.593	2.367	2.262	4.741
SS m	-0.03	7.14	7.14	7.56	8.06	8.72	9.41	9.00	8.15	7.92	8.10
SD m	0.000	0.234	0.395	0.926	1.302	1.622	1.751	2.930	4.470	4.808	5.114
WETTED PERIMETER WIDTH (m)	0	11.691	12.151	15.436	17.908	20.276	21.885	24.338	26.294	28.281	37.266
HABITAT STRESS: RHEOPHILIC	10.00	8.62	8.57	7.78	7.06	6.25	5.73	4.83	4.10	3.32	0.00

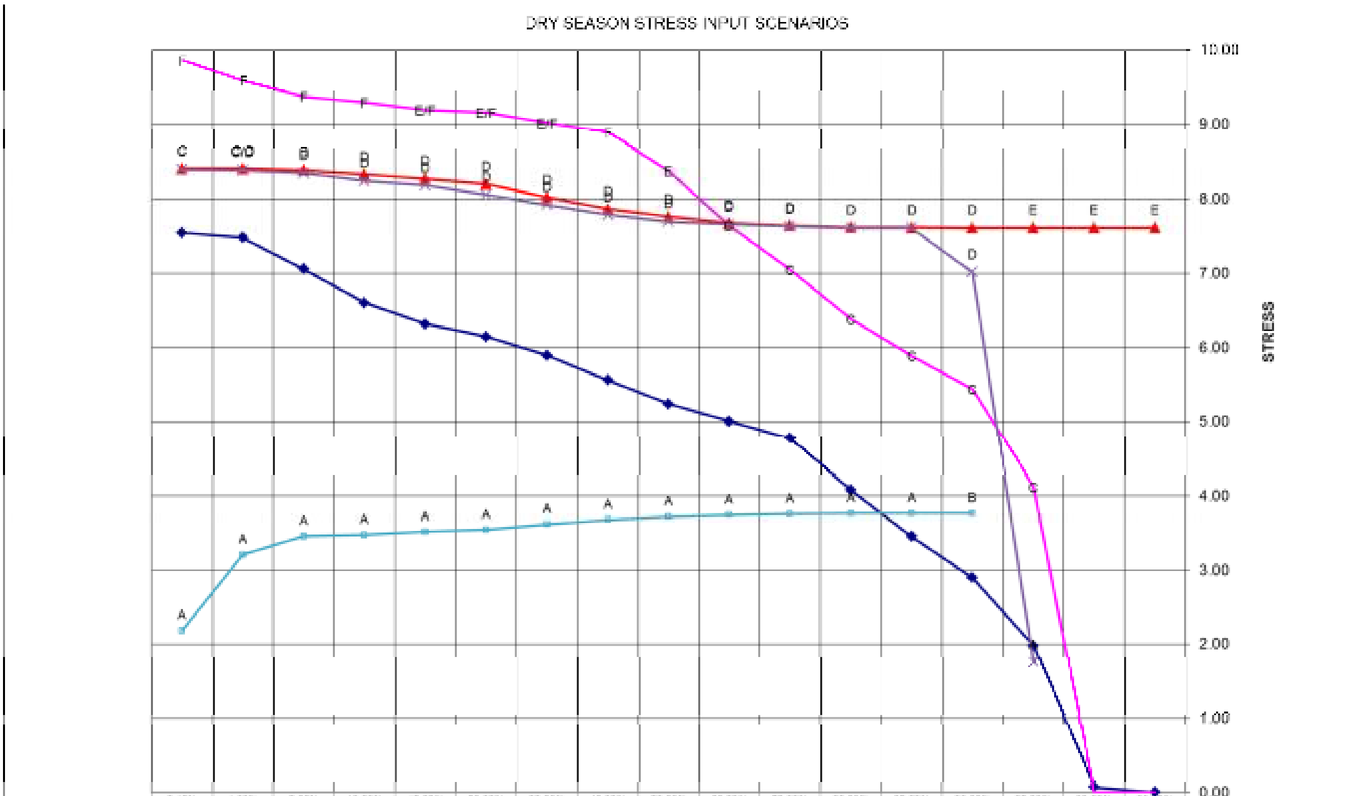
DISCHARGE(CUMEC)



	-0.04100	0.494	0.529	0.852	1.126	1.474	1.738	2.235	2.718	3.254	4.421
FVS (m of perimeter)	0.0	0.468	0.561	1.080	1.253	1.622	1.532	1.704	1.841	1.980	5.218
FS (m of perimeter))	0.0	0.997	0.745	0.617	1.074	1.419	1.751	1.792	2.043	1.986	2.342
FINT (m of perimeter)	0.0	0.640	0.880	0.951	0.716	0.811	1.094	1.704	1.841	1.980	2.503
FD (m of perimeter)	0.0	0.584	0.607	1.673	2.686	3.447	3.933	4.869	5.787	7.067	9.423
WETTED PERIMETER WIDTH (m)	0	11.689	12.149	15.435	17.907	20.276	21.885	24.344	26.306	28.291	37.270
HABITAT STRESS: RHEOPHILIC	10.00	8.62	8.57	7.78	7.06	6.25	5.74	4.83	4.09	3.32	0.00

DISCHARGE(CUMEC)



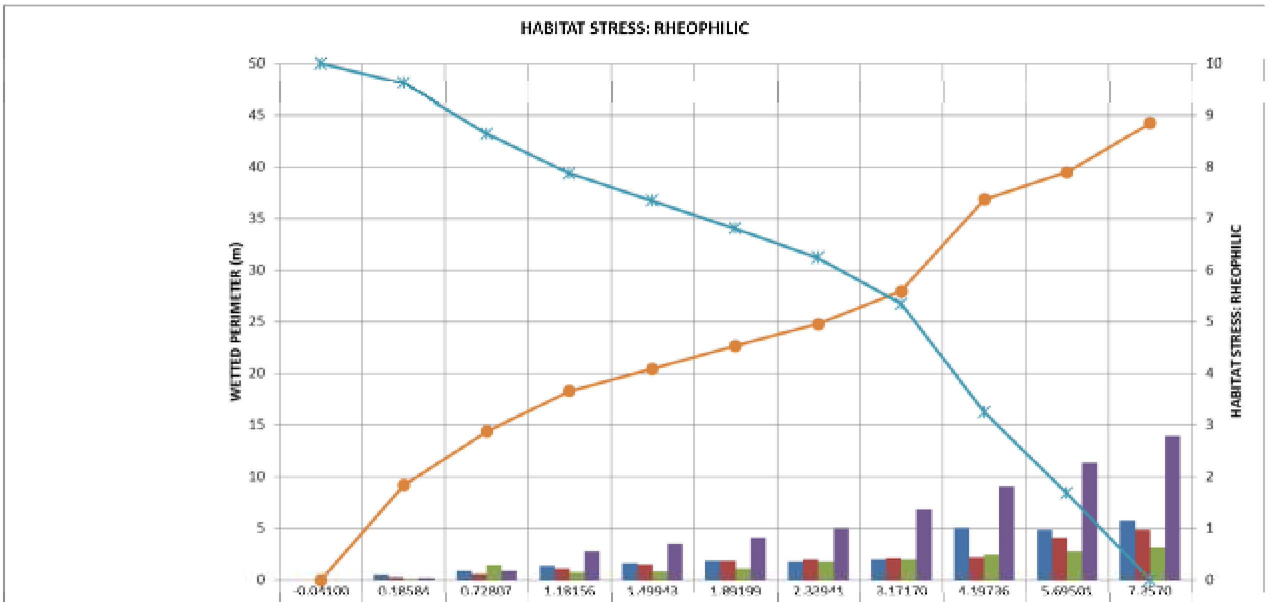


	0.10%	1.00%	5.00%	10.00%	15.00%	20.00%	30.00%	40.00%	50.00%	60.00%	70.00%	80.00%	85.00%	90.00%	95.00%	99.00%	99.90%
NATURAL STRESS	7.54	7.48	7.05	6.60	6.31	6.14	5.89	5.56	5.24	5.00	4.77	4.08	3.45	2.90	1.98	0.07	0.00
PRESENT STRESS	9.86	9.59	9.36	9.30	9.20	9.16	9.02	8.89	8.38	7.64	7.05	6.38	5.89	5.43	4.12	0.00	0.00
HN10 EWR3_CD	8.41	8.41	8.38	8.33	8.27	8.20	8.02	7.86	7.76	7.67	7.64	7.61	7.61	7.61	7.61	7.61	7.61
HN10 EWR3 Sc1	8.40	8.39	8.35	8.24	8.18	8.05	7.92	7.79	7.69	7.66	7.63	7.61	7.61	7.01	1.75		
HN10 EWR3 Sc2	2.19	3.21	3.46	3.47	3.52	3.54	3.62	3.68	3.72	3.74	3.76	3.76	3.77	3.77			

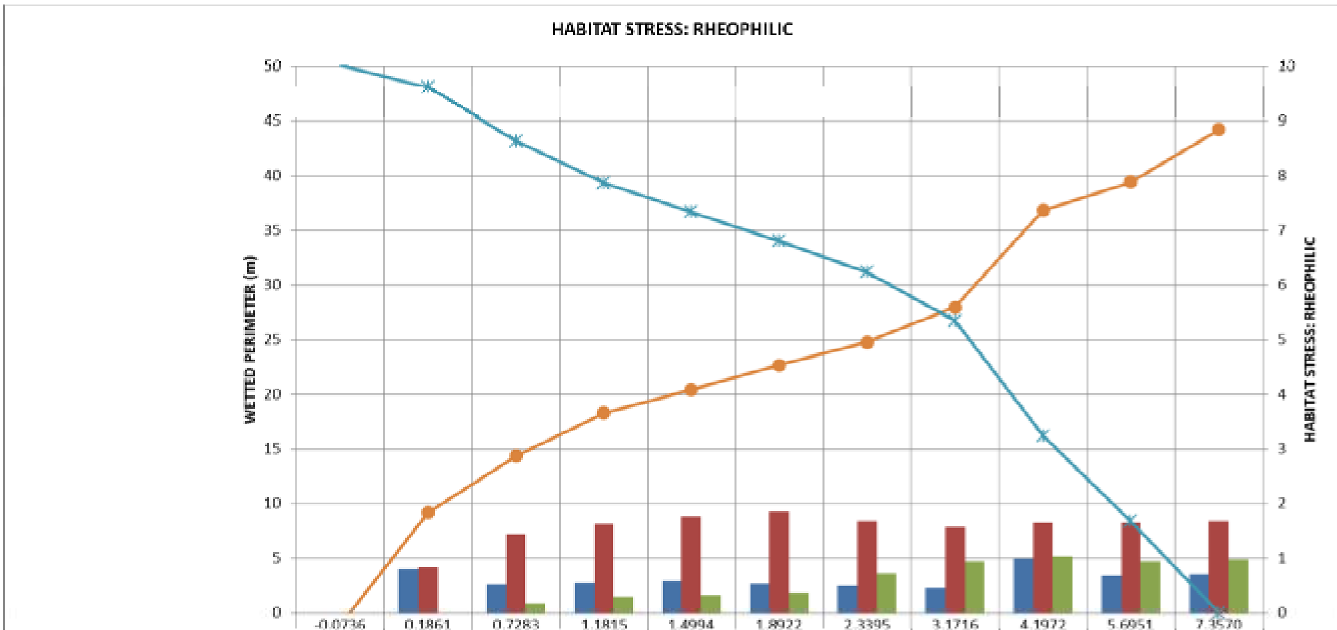
DURATION

Wet season (February)

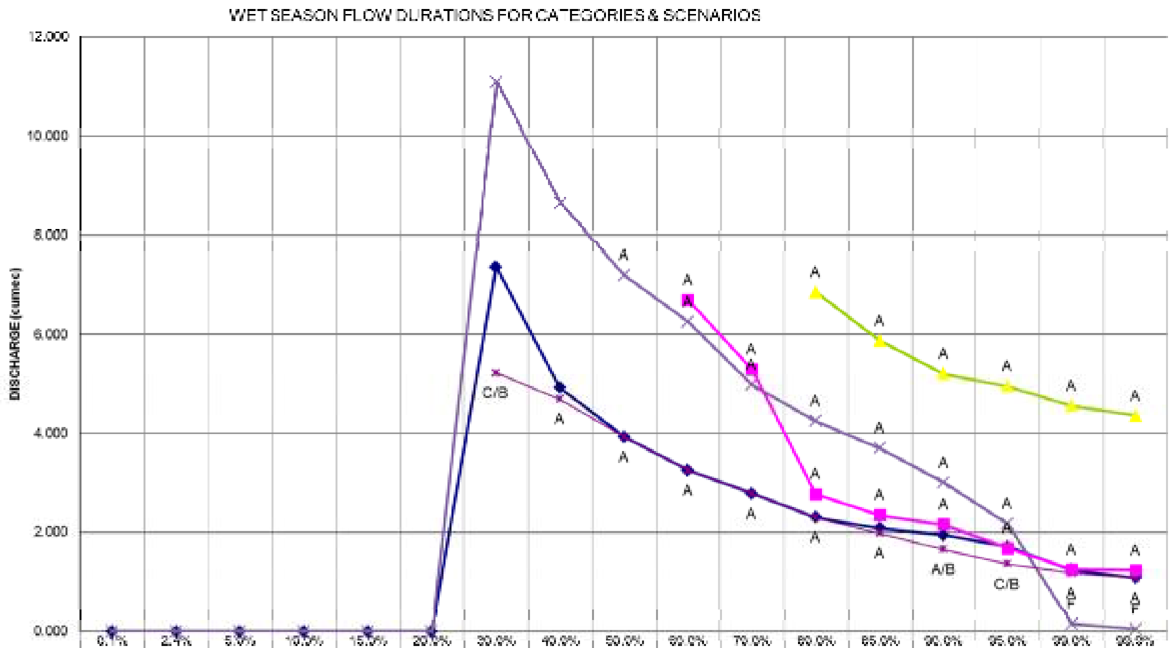
Max natural low flow:= 7.3570 cumec.



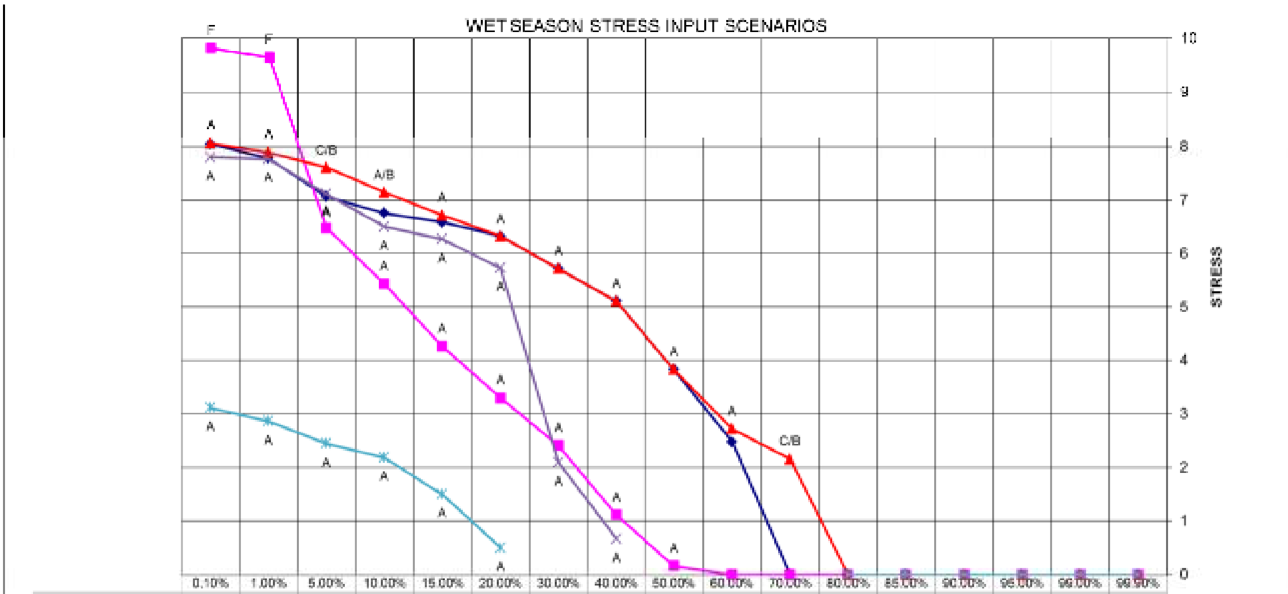
	-0.04100	0.18584	0.72807	1.18156	1.49943	1.89199	2.32941	3.17170	4.39736	5.69501	7.3570
FVS (m of perimeter)	0.0	0.551	0.892	1.316	1.635	1.814	1.735	1.959	5.002	4.863	5.750
FS (m of perimeter))	0.0	0.256	0.575	1.098	1.430	1.814	1.983	2.136	2.211	4.092	4.865
FINT (m of perimeter)	0.0	0.092	1.409	0.732	0.817	1.134	1.735	1.959	2.423	2.763	3.096
FD (m of perimeter)	0.0	0.164	0.892	2.744	3.474	4.083	4.958	6.819	9.055	11.323	13.953
WETTED PERIMETER WIDTH (m)	0	9.179	14.381	18.296	20.434	22.681	24.788	27.984	36.846	39.478	44.229
HABITAT STRESS: RHEOPHILIC	10.00	9.62	8.64	7.87	7.34	6.80	6.24	5.35	3.24	1.67	0.00



	-0.0736	0.1861	0.7283	1.1815	1.4994	1.8922	2.3395	3.1716	4.1972	5.6951	7.3570
SVS m	-1.548	3.980	2.589	2.744	2.888	2.723	2.478	2.239	4.947	3.412	3.538
SS m	-0.18	4.12	7.16	8.16	8.79	9.30	8.41	7.84	8.26	8.29	8.40
SD m	0.000	0.000	0.863	1.464	1.635	1.815	3.647	4.757	5.158	4.737	4.865
WETTED PERIMETER WIDTH (m)	-1	9.181	14.383	18.296	20.433	22.689	24.780	27.984	36.843	39.475	44.227
HABITAT STRESS: RHEOPHILIC	10.02	9.61	8.64	7.87	7.34	6.80	6.24	5.35	3.25	1.67	0.00



	0.1%	2.4%	5.0%	10.0%	15.0%	20.0%	30.0%	40.0%	50.0%	60.0%	70.0%	80.0%	85.0%	90.0%	95.0%	99.0%	99.9%
REFERENCE FLOWS	0.000	0.000	0.000	0.000	0.000	0.000	7.357	4.921	3.927	3.256	2.782	2.304	2.087	1.947	1.705	1.248	1.080
PRESENT FLOWS	0.000	0.000	0.000	0.000	0.000	0.000	11.060	8.639	7.192	6.251	4.985	4.246	3.702	3.004	2.175	0.147	0.048
HN10 EWR3_CD							5.228	4.689	3.927	3.256	2.782	2.304	1.981	1.658	1.360	1.177	1.073
HN10 EWR3 Sc1										6.6934	5.2882	2.7706	2.3480	2.1592	1.6767	1.2539	1.2369
HN10 EWR3 Sc2												6.8590	5.8720	5.2010	4.9540	4.5580	4.3690



	0.10%	1.00%	5.00%	10.00%	15.00%	20.00%	30.00%	40.00%	50.00%	60.00%	70.00%	80.00%	85.00%	90.00%	95.00%	99.00%	99.90%
NATURAL STRESS	8.04	7.78	7.07	6.75	6.58	6.32	5.72	5.11	3.84	2.46	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PRESENT STRESS	9.82	9.65	6.47	5.43	4.26	3.31	2.42	1.11	0.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
HN10 EWR3_CD	8.06	7.89	7.60	7.14	6.71	6.32	5.72	5.11	3.84	2.73	2.16	0.00	0.00	0.00	0.00	0.00	0.00
HN10 EWR3 Sc1	7.79	7.77	7.11	6.49	6.26	5.73	2.10	0.67				0.00	0.00	0.00	0.00	0.00	0.00
HN10 EWR3 Sc2	3.12	2.87	2.45	2.19	1.50	0.50						0.00	0.00	0.00	0.00	0.00	0.00

DURATION

CROC_EWR6: Hex River upstream Vaalkop Dam

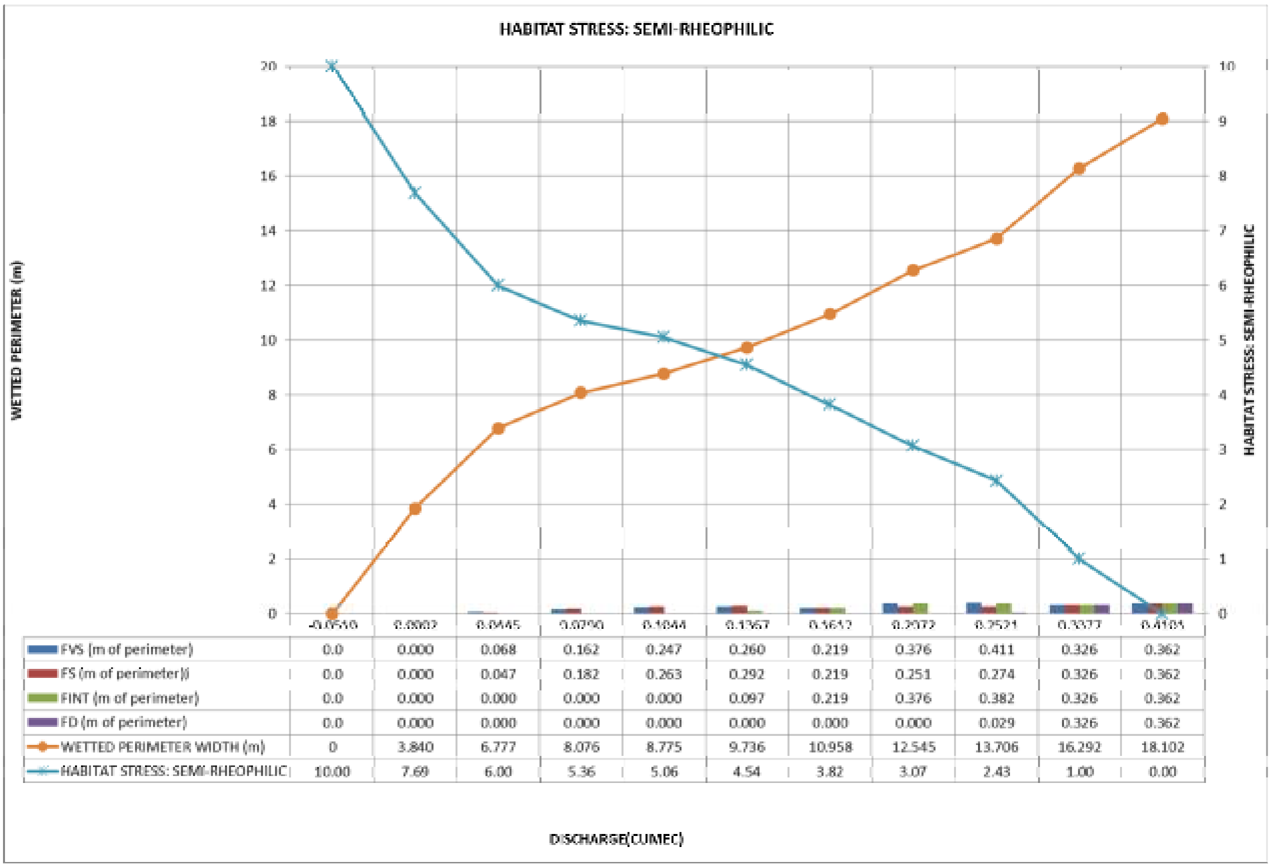
	Natural	Present	EWR 6_D	Sc 1	Sc 2
Fish dry		D	C	C	C
Fish wet		D	B	B	A/B
Fish integrated		*D*	*C*	*C*	*C*

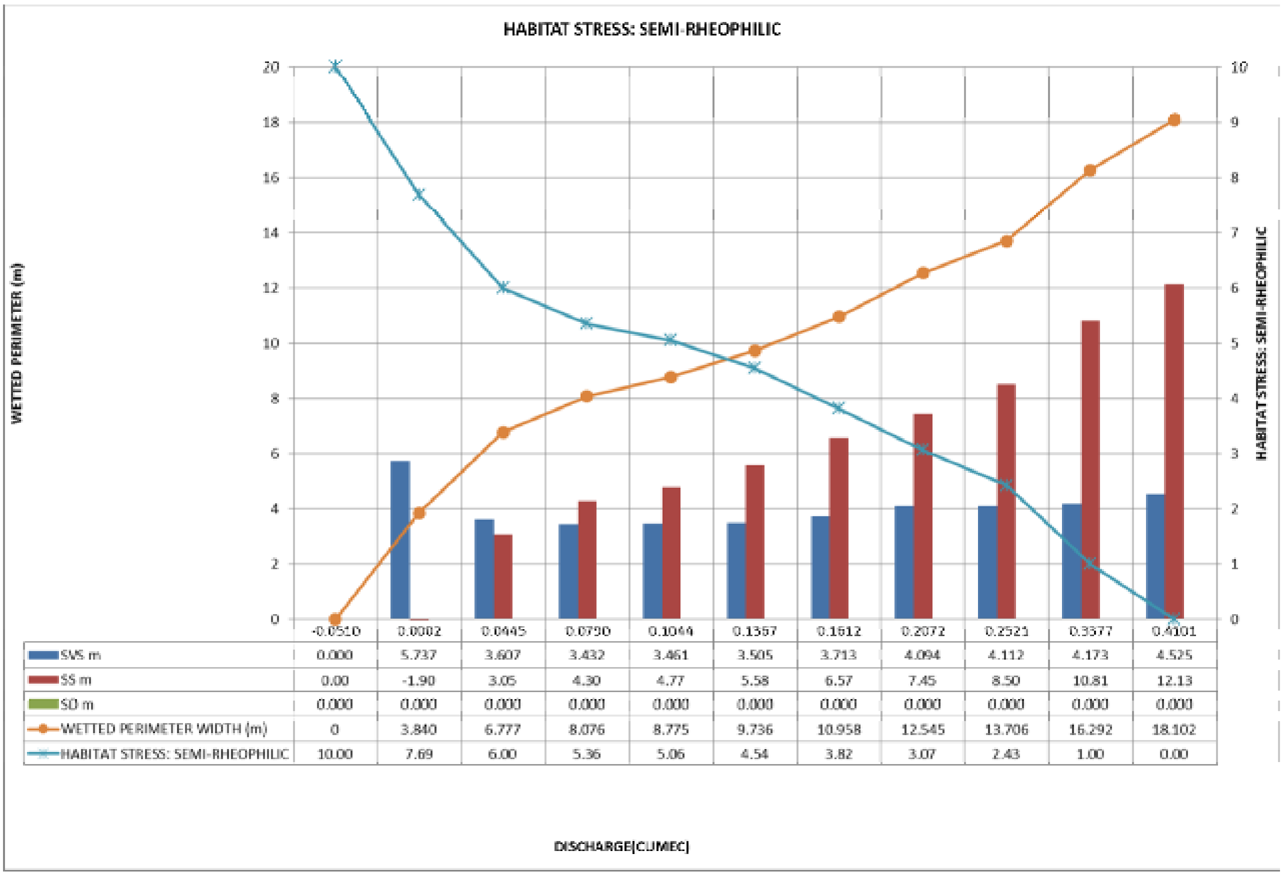
Comments:

1. Assessment based on requirements of a medium sized semi-rheophilic (e.g. Labeobarbus marequensis) that requires fast flows during periods in the wet season for breeding.
2. For the dry season the FFHA was run for this guild using all slow flow classes (SVS, SS, SD) through the cross section. The assumption is that this flow would suffice in maintaining pools and enable movement through shallow sections.
3. For the wet season, flow requirements were set for all fast flows (, FVS, FS, FI, FD). The assumption is that this would provide suitable flows for breeding and connectivity between different habitats.

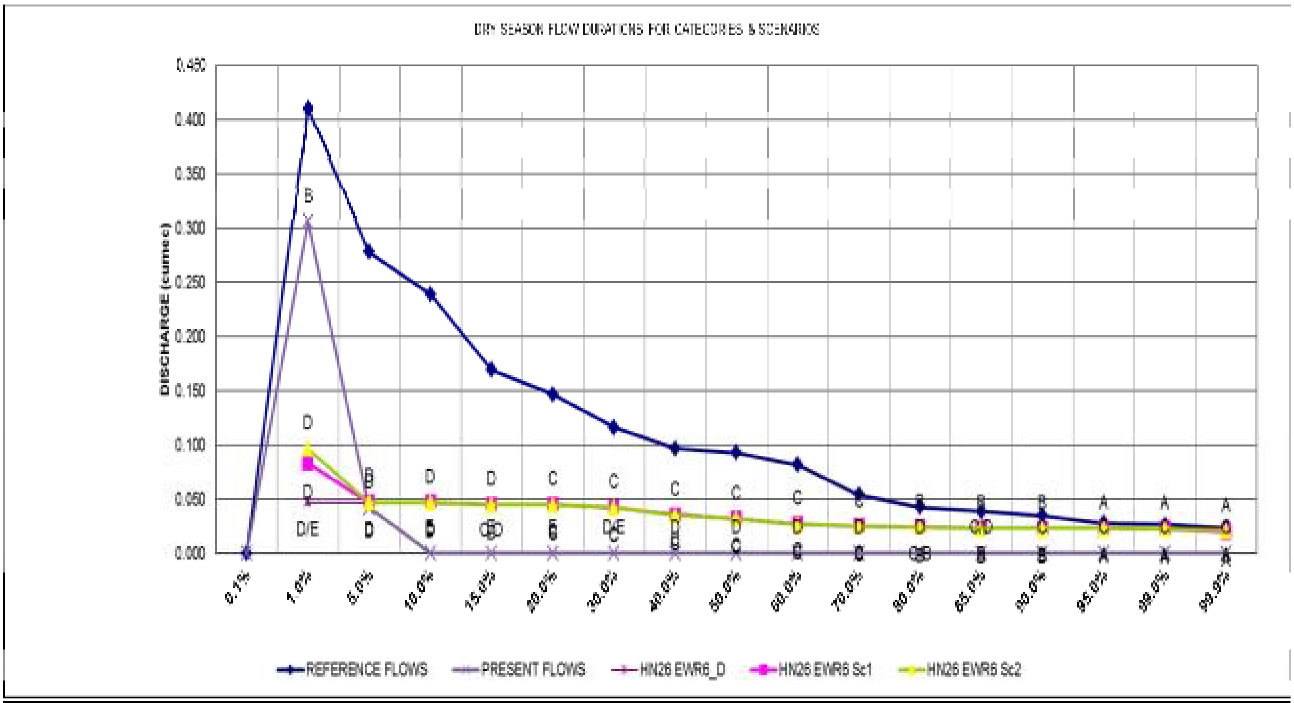
Dry season (September)

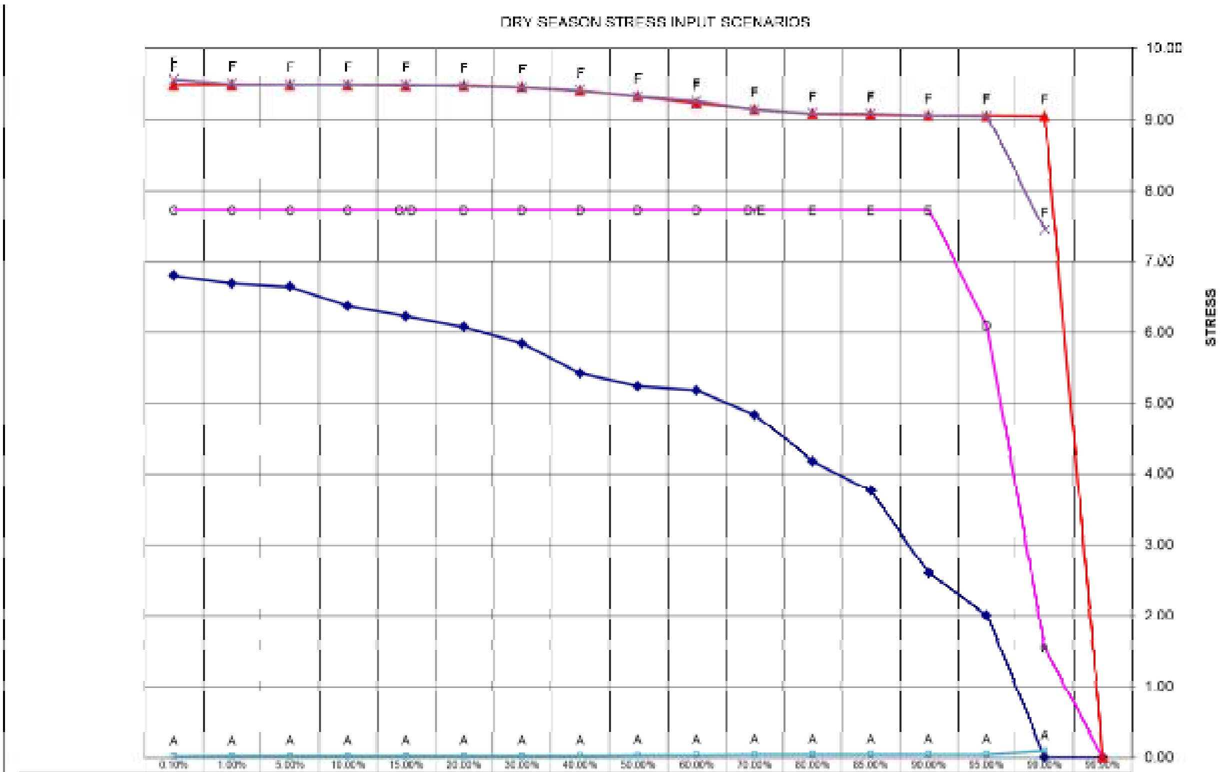
Max natural low flow:= 0. 0.410069 cumec.





	-0.0510	0.0082	0.0445	0.0790	0.1044	0.1367	0.1612	0.2072	0.2521	0.3377	0.4101
SVS m	0.000	5.737	3.607	3.432	3.461	3.505	3.713	4.094	4.112	4.173	4.525
SS m	0.00	-1.90	3.05	4.30	4.77	5.58	6.57	7.45	8.50	10.81	12.13
SD m	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WETTED PERIMETER WIDTH (m)	0	3.840	6.777	8.076	8.775	9.736	10.958	12.545	13.706	16.292	18.102
HABITAT STRESS: SEMI-RHEOPHILIC	10.00	7.69	6.00	5.36	5.06	4.54	3.82	3.07	2.43	1.00	0.00



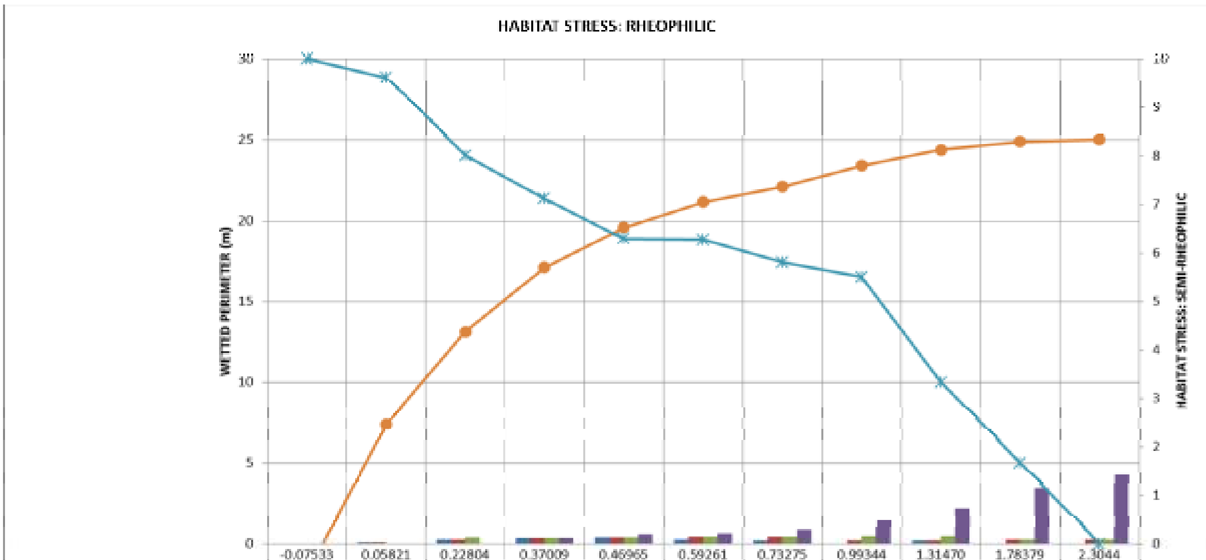


	0.10%	1.00%	5.00%	10.00%	15.00%	20.00%	30.00%	40.00%	50.00%	60.00%	70.00%	80.00%	85.00%	90.00%	95.00%	99.00%	99.90%
NATURAL STRESS	6.80	6.69	6.65	6.32	6.23	6.08	5.85	5.43	5.24	5.18	4.84	4.18	3.78	2.59	2.00	0.00	0.00
PRESENT STRESS	7.74	7.74	7.74	7.74	7.74	7.74	7.74	7.74	7.74	7.74	7.74	7.74	7.74	7.74	6.10	1.55	0.00
HN28 EWR6_D	9.49	9.49	9.49	9.49	9.49	9.49	9.47	9.42	9.34	9.24	9.15	9.09	9.08	9.06	9.06	9.05	0.00
HN28 EWR6 Sc1	9.57	9.51	9.50	9.50	9.50	9.48	9.46	9.42	9.33	9.27	9.14	9.10	9.09	9.06	9.05	7.45	
HN28 EWR6 Sc2	0.08	0.08	0.08	0.08	0.08	0.02	0.01	0.01	0.03	0.04	0.04	0.04	0.05	0.05	0.05	0.18	

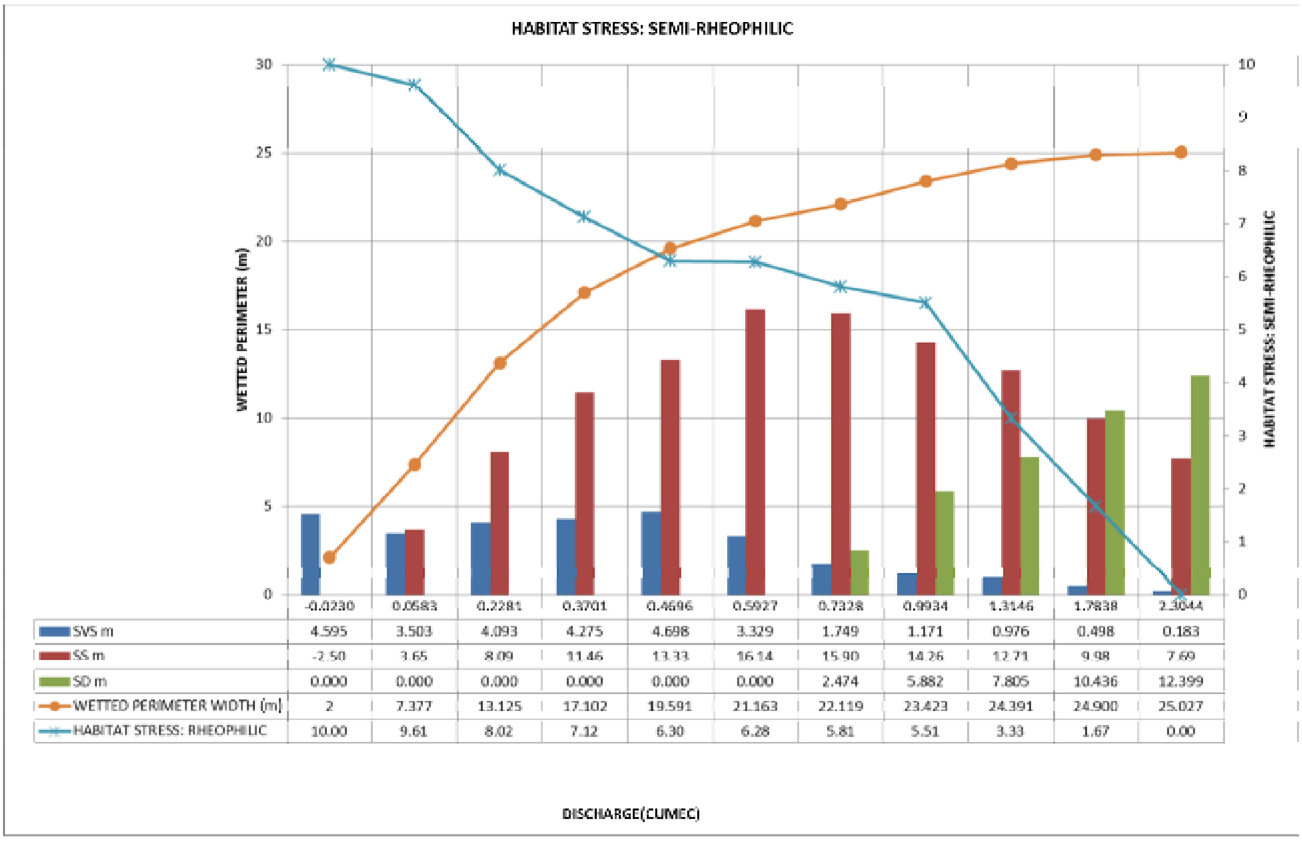
DURATION

<u>Wet season (February)</u>

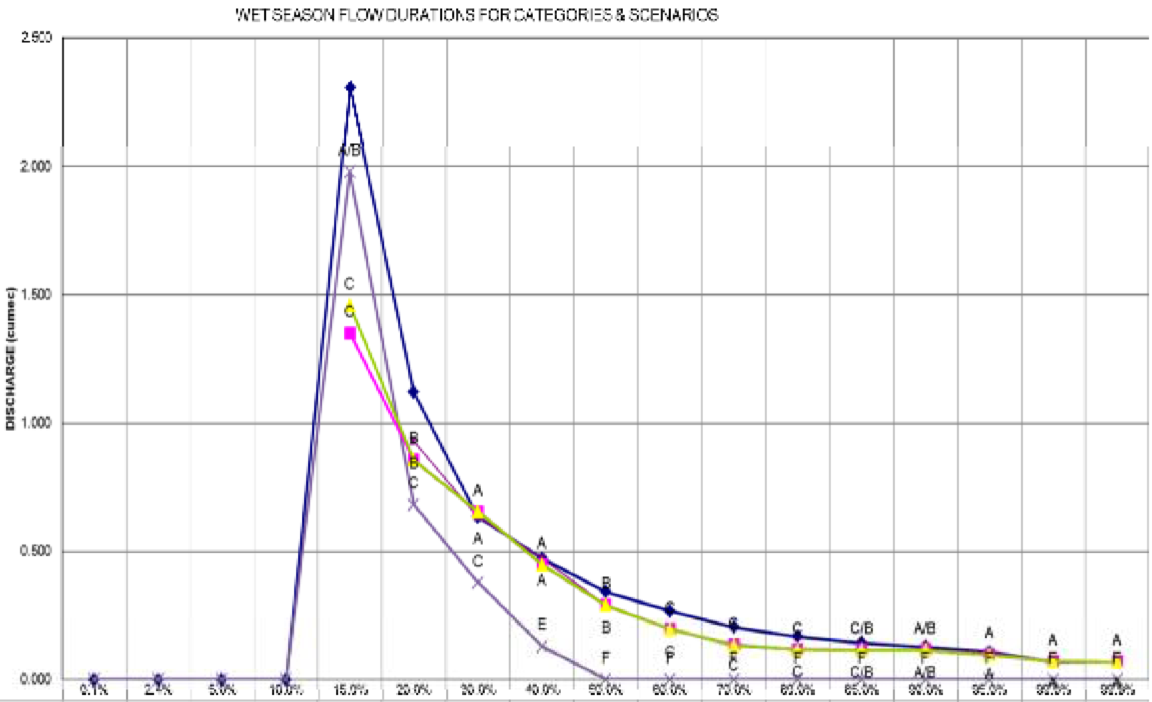
Max natural low flow:= 2.3044 cumec.



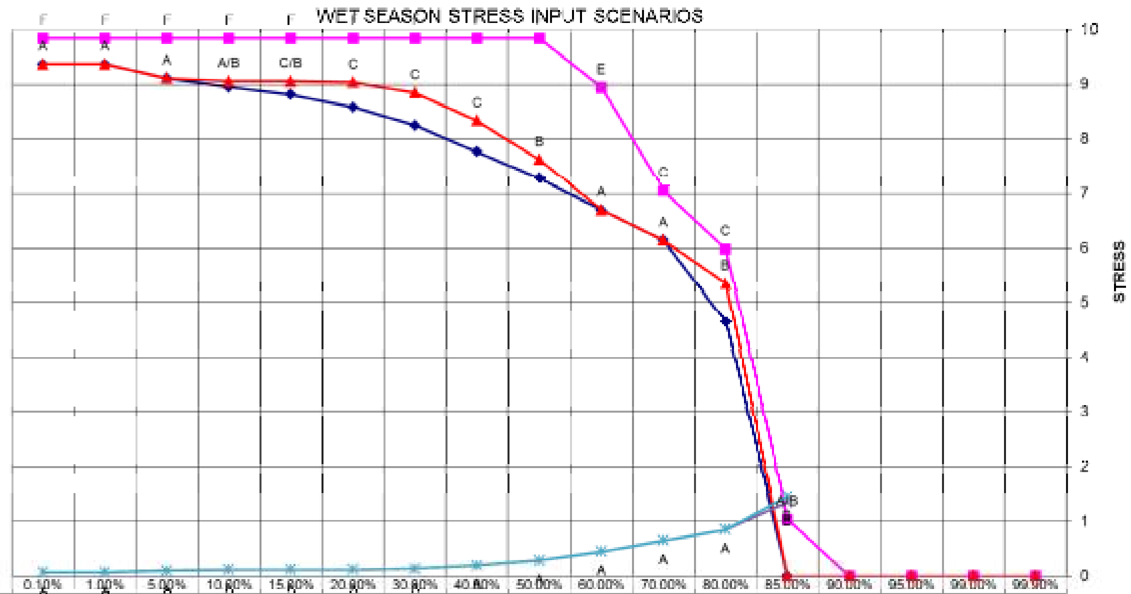
	-0.07533	0.05821	0.22804	0.37009	0.46965	0.59261	0.73275	0.99344	1.31470	1.78379	2.3044
FVS (m of perimeter)	0.0	0.092	0.288	0.342	0.392	0.290	0.221	0.000	0.244	0.000	0.000
FS (m of perimeter))	0.0	0.092	0.262	0.342	0.392	0.423	0.442	0.234	0.244	0.249	0.250
FINT (m of perimeter)	0.0	0.000	0.394	0.342	0.392	0.423	0.442	0.468	0.488	0.249	0.250
FD (m of perimeter)	0.0	0.000	0.000	0.342	0.584	0.635	0.885	1.432	2.195	3.464	4.255
WETTED PERIMETER WIDTH (m)	-2	7.374	13.122	17.102	19.591	21.163	22.118	23.423	24.391	24.900	25.027
HABITAT STRESS: RHEOPHILIC	10.00	9.61	8.01	7.12	6.30	6.28	5.81	5.51	3.33	1.67	0.00



DISCHARGE(CUMEC)	-0.0230	0.0583	0.2281	0.3701	0.4696	0.5927	0.7328	0.9934	1.3146	1.7838	2.3044
SVS m	4.595	3.503	4.093	4.275	4.698	3.329	1.749	1.171	0.976	0.498	0.183
SS m	-2.50	3.65	8.09	11.46	13.33	16.14	15.90	14.26	12.71	9.98	7.69
SD m	0.000	0.000	0.000	0.000	0.000	0.000	2.474	5.882	7.805	10.436	12.399
WETTED PERIMETER WIDTH (m)	2	7.377	13.125	17.102	19.591	21.163	22.119	23.423	24.391	24.900	25.027
HABITAT STRESS: RHEOPHILIC	10.00	9.61	8.02	7.12	6.30	6.28	5.81	5.51	3.33	1.67	0.00



	0.1%	1.0%	5.0%	10.0%	15.0%	20.0%	30.0%	40.0%	50.0%	60.0%	70.0%	80.0%	85.0%	90.0%	95.0%	99.0%	99.9%
REFERENCE FLOWS	0.000	0.000	0.000	0.000	2.304	1.121	0.634	0.472	0.342	0.267	0.204	0.168	0.143	0.128	0.107	0.070	0.070
PRESENT FLOWS	0.000	0.000	0.000	0.000	1.979	0.681	0.377	0.130	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
HN26 EWR6_D						0.929	0.634	0.472	0.289	0.194	0.140	0.117	0.114	0.114	0.107	0.070	0.070
HN26 EWR6 Sc1					1.3513	0.8668	0.6632	0.4472	0.2900	0.1964	0.1342	0.1174	0.1160	0.1152	0.0989	0.0706	0.0692
HN26 EWR6 Sc2					1.4592	0.8668	0.6632	0.4472	0.2900	0.1964	0.1342	0.1174	0.1160	0.1152	0.0989	0.0706	0.0692



	0.10%	1.00%	5.00%	10.00%	15.00%	20.00%	30.00%	40.00%	50.00%	60.00%	70.00%	80.00%	85.00%	90.00%	95.00%	99.00%	99.90%
NATURAL STRESS	9.37	9.37	9.11	8.95	8.81	8.58	8.25	7.76	7.28	6.70	6.15	4.65	0.00	0.00	0.00	0.00	0.00
PRESENT STRESS	9.84	9.84	9.84	9.84	9.84	9.84	9.84	9.84	9.84	8.94	7.05	5.99	1.04	0.00	0.00	0.00	0.00
HN26 EWR6_D	9.37	9.37	9.11	9.06	9.06	9.04	8.85	8.34	7.62	6.70	6.15	5.36	0.00	0.00	0.00	0.00	0.00
HN26 EWR6 Sc1	0.07	0.07	0.10	0.12	0.12	0.12	0.13	0.20	0.29	0.45	0.65	0.86	1.35				
HN26 EWR6 Sc2	0.07	0.07	0.10	0.12	0.12	0.12	0.13	0.20	0.29	0.45	0.65	0.86	1.46				

DURATION

CROC_EWR7: Crocodile: Upstream of the confluence with the Bierspruit FISH

	Natural	**HN26 EWR6_D**	HN44 EWR7 Sc1	**HN44 EWR7 Sc2**
Fish dry		**E/F**	C	A
Fish wet		**D**	C	B
Fish integrated		***E***	*C*	*A*
Recommendation				

SPECIES/GUILD USED for determination: Chiloglanis paratus: rheophilic to semirheophilic. Flow for required velocity-depth set at >= FVS (velocity>= 30cm/s, depth >0.

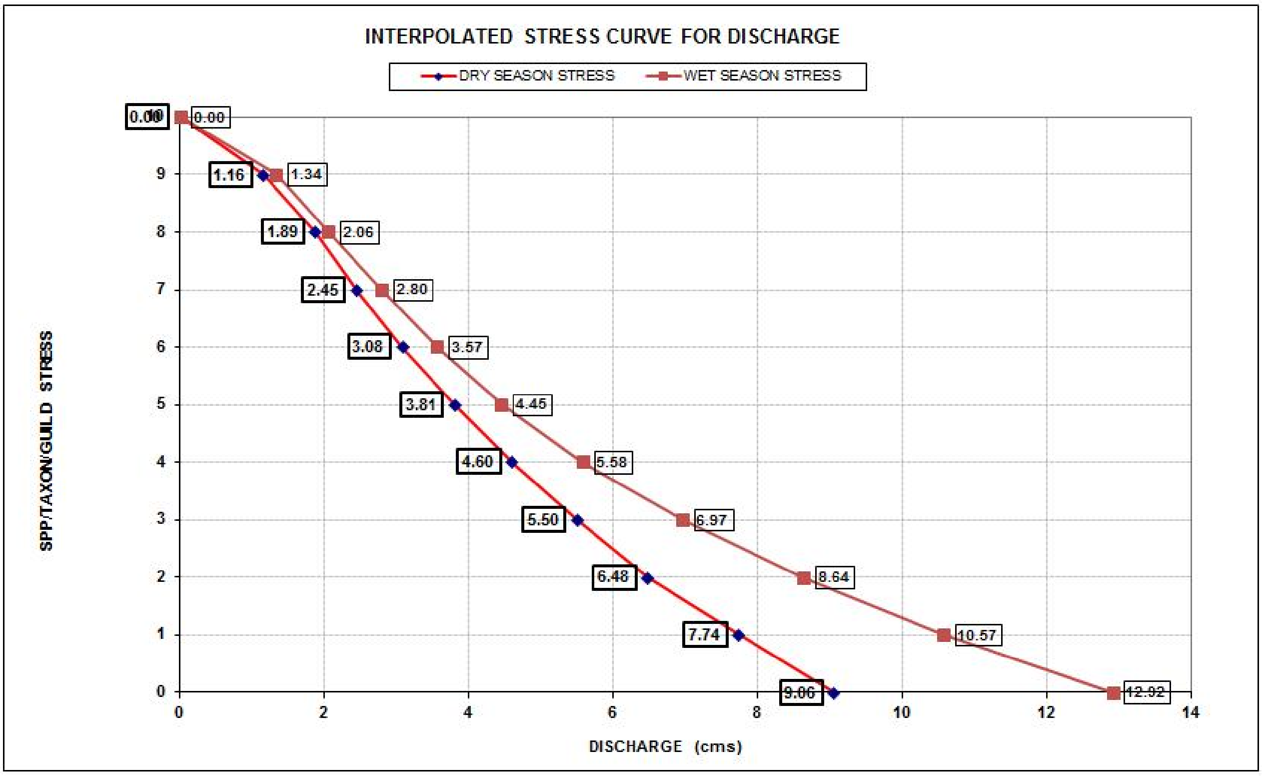
Comments:

1. Assessment based on requirements of a small predominantly rheophilic (Chiloglanis paratus)
2. FFHA was run for this guild for all fast flow (>0.3 m/s) types (FVS, FS, FI, FD).
3. This means that flow requirements were relatively "liberal". Requirement would have been increasingly "conservative" if VD classes were respectively set for >FVS, >FS, >FI or =>FD.
4. The river bed at the site consists of a sandy substrate. The HABLO hydraulic model (which serves as input to the FFHA) was developed for hard substrates (cobble, rocks, etc.). It is therefore uncertain to what degree the results obtained from the FFHA is realistic.
5. The FFHA, EWR workshop suggested category D does not meet this requirement.
6. For the dry season, a D category could be represented by:

	HN44 EWR7_D	**Category**
FLOW DURATION	**Flow (cumec)**	**D**
0.10%		
1.00%		
5.00%	2.300	D/E
10.00%	2.100	D/E
15.00%	1.900	D/E
20.00%	1.900	D
30.00%	1.900	D
40.00%	1.800	D
50.00%	1.800	D
60.00%	1.700	D
70.00%	1.600	D
80.00%	1.600	D
85.00%	1.600	D
90.00%	1.400	D
95.00%	1.300	D
99.00%	1.300	D
99.90%	1.300	C

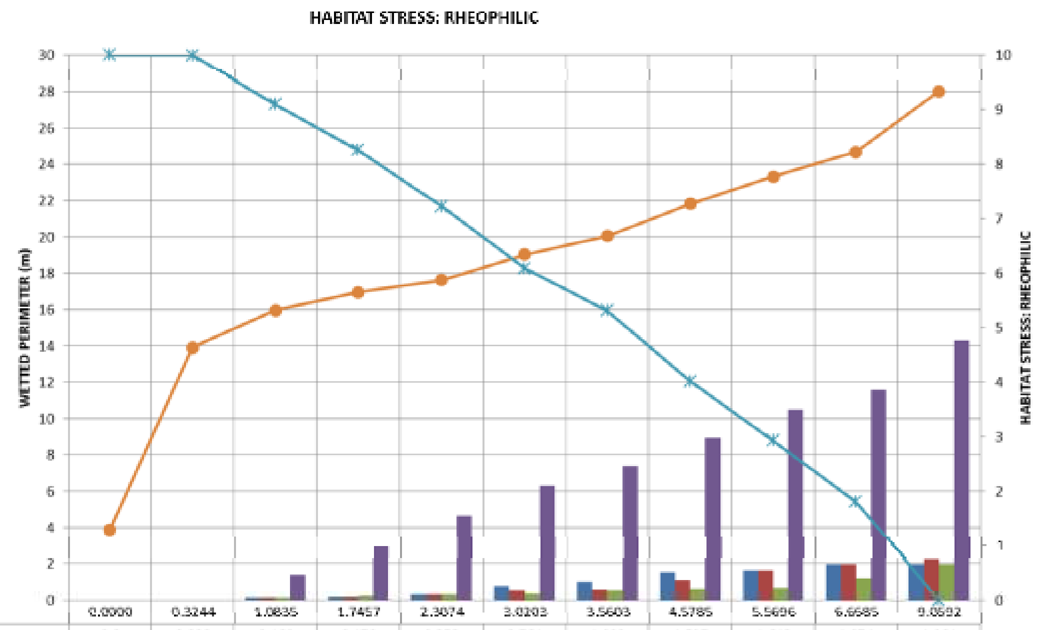
7. For the dry season, a D category could be represented by:

	HN44 EWR7_D	Category
FLOW DURATION	**Flow (cumec)**	**D**
0.10%		
2.40%		
5.00%		
10.00%		
15.00%		
20.00%		
30.00%		
40.00%	4.454	D
50.00%	4.114	D
60.00%	3.625	D
70.00%	3.260	D
80.00%	2.642	D
85.00%	2.500	D
90.00%	2.300	D
95.00%	2.200	D
99.00%	1.800	D
99.90%	1.800	C



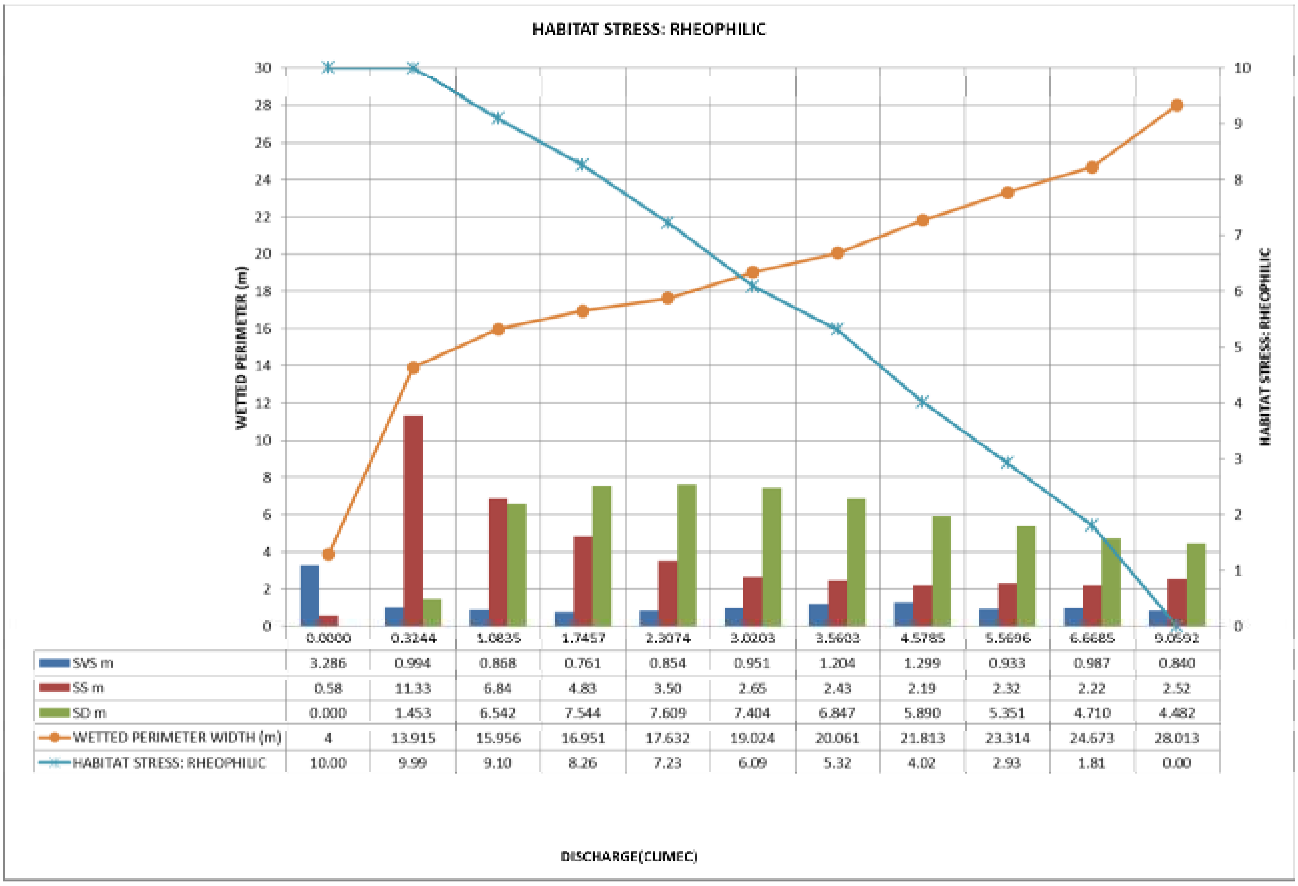
DRY SEASON (SEPTEMBER)

Max natural low flow:= 9.059221 cumec.

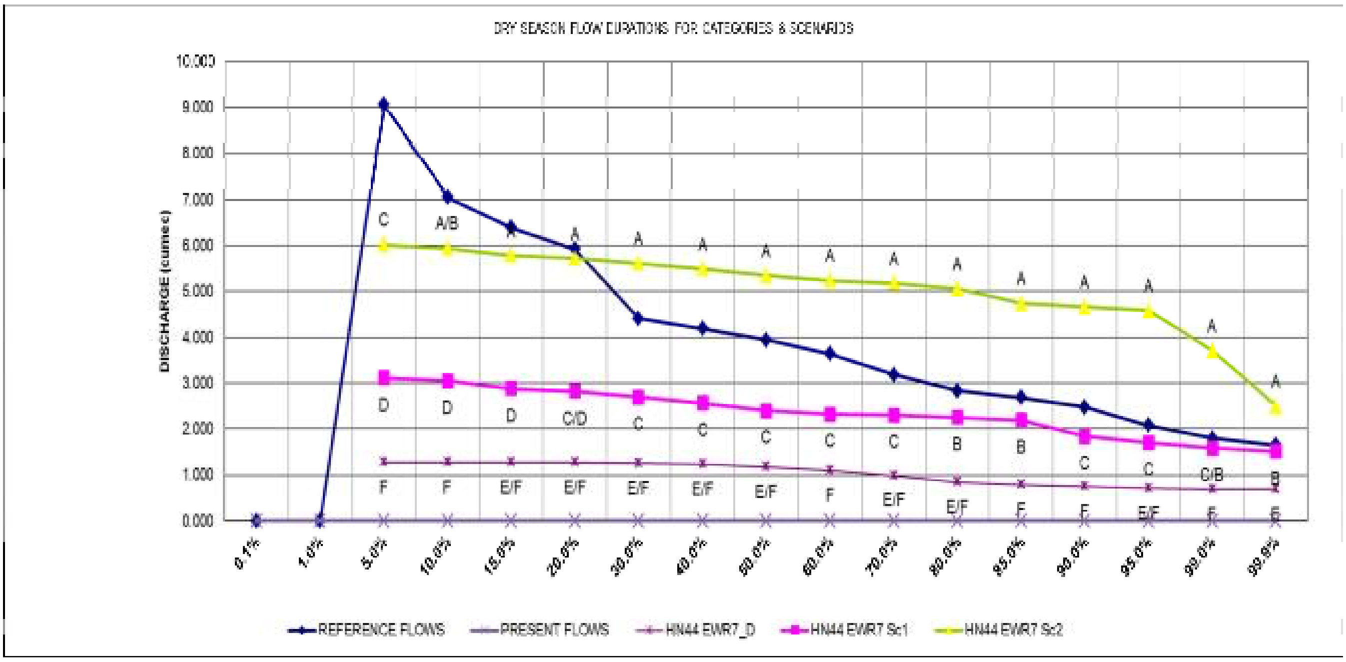


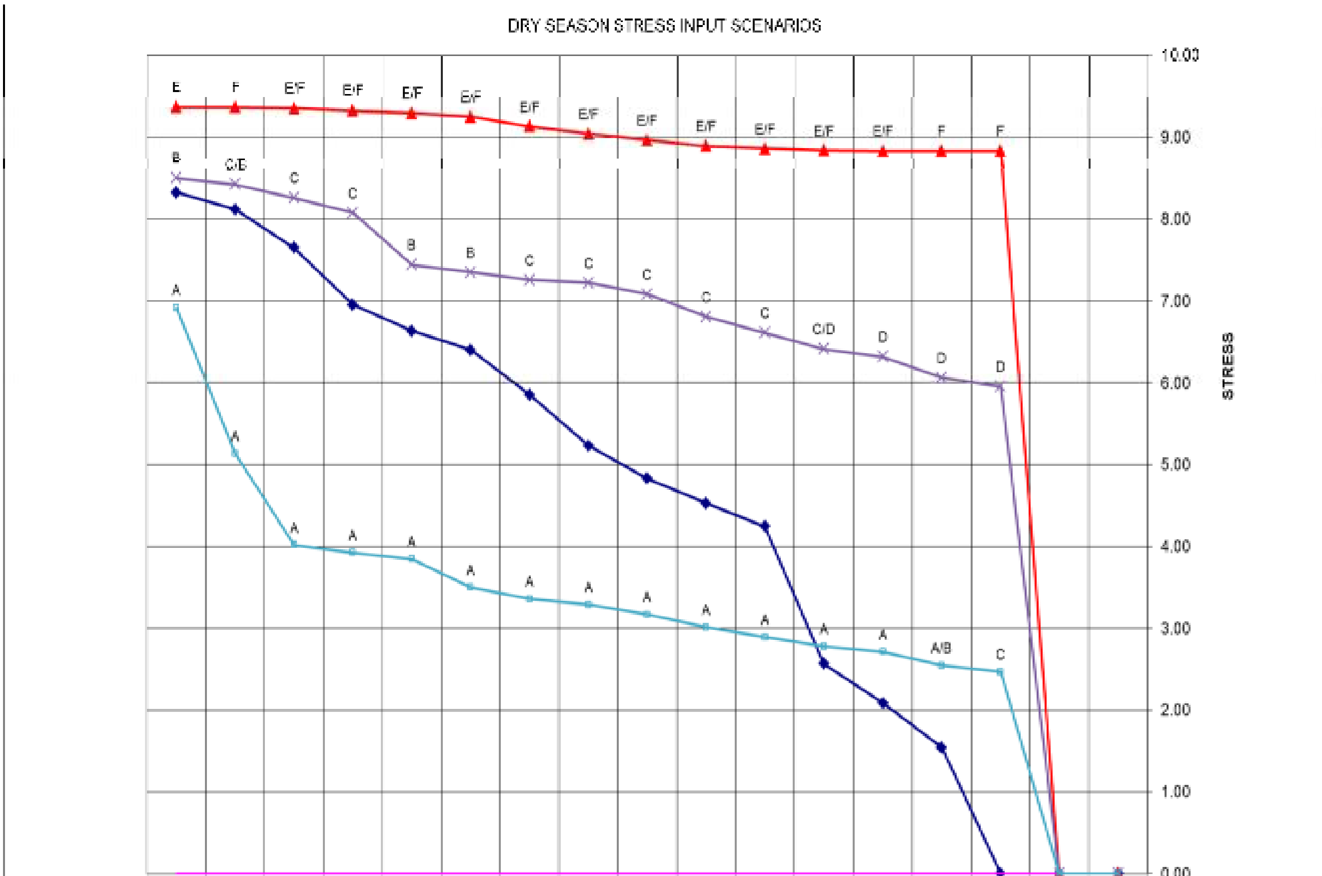
DISCHARGE(CUMEC)	0.0000	0.3244	1.0835	1.7457	2.3074	3.0203	3.5603	4.5785	5.5696	6.6685	9.0592
FVS (m of perimeter)	0.0	0.000	0.160	0.170	0.353	0.761	1.003	1.527	1.643	1.974	1.961
FS (m of perimeter]]	0.0	0.000	0.160	0.170	0.353	0.571	0.602	1.091	1.632	1.974	2.241
FINT (m of perimeter)	0.0	0.000	0.160	0.256	0.353	0.380	0.575	0.654	0.699	1.234	1.961
FD (m of perimeter)	0.0	0.020	1.366	2.968	4.612	6.293	7.396	8.953	10.491	11.574	14.287
WETTED PERIMETER WIDTH (m)	4	13.915	15.956	16.951	17.632	19.024	20.061	21.813	23.314	24.673	28.013
HABITAT STRESS: RHEOPHILIC	10.00	9.99	9.10	8.26	7.23	6.09	5.32	4.02	2.93	1.81	0.00

DISCHARGE(CUMEC)



	0.0000	0.3244	1.0835	1.7457	2.3074	3.0203	3.5603	4.5785	5.5696	6.6685	9.0592
SVS m	3.286	0.994	0.868	0.761	0.854	0.951	1.204	1.299	0.933	0.987	0.840
SS m	0.58	11.33	6.84	4.83	3.50	2.65	2.43	2.19	2.32	2.22	2.52
SD m	0.000	1.453	6.542	7.544	7.609	7.404	6.847	5.890	5.351	4.710	4.482
WETTED PERIMETER WIDTH (m)	4	13.915	15.956	16.951	17.632	19.024	20.061	21.813	23.314	24.673	28.013
HABITAT STRESS: RHEOPHILIC	10.00	9.99	9.10	8.26	7.23	6.09	5.32	4.02	2.93	1.81	0.00

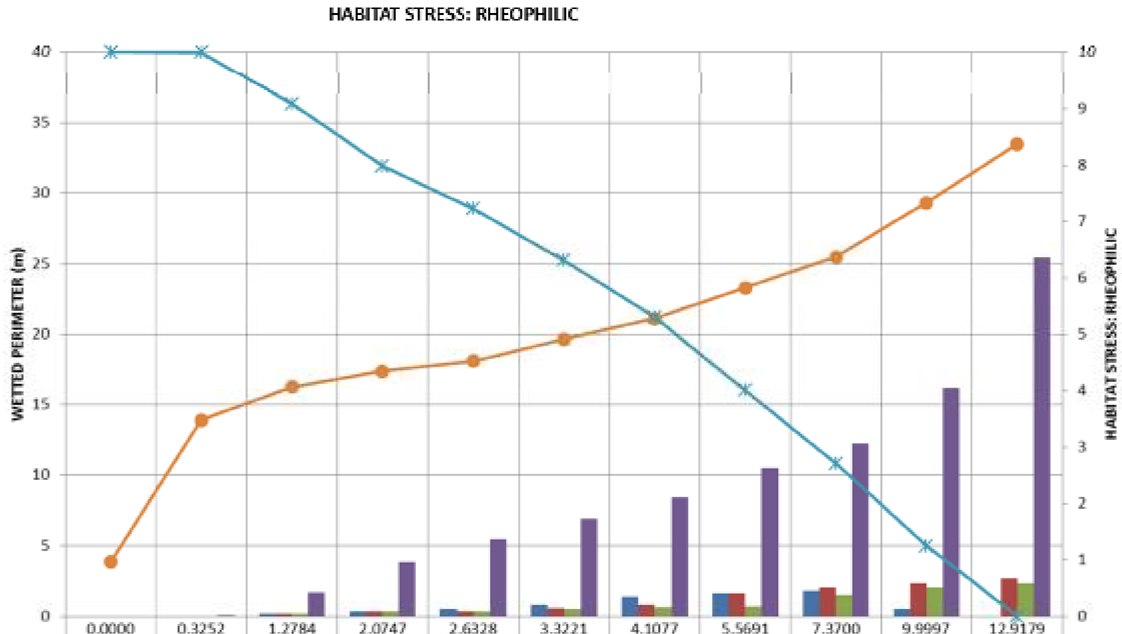




	0.10%	1.00%	5.00%	10.00%	15.00%	20.00%	30.00%	40.00%	50.00%	60.00%	70.00%	80.00%	85.00%	90.00%	95.00%	99.00%	99.90%
NATURAL STRESS	8.33	8.12	7.65	6.96	6.64	6.40	5.86	5.24	4.83	4.53	4.25	2.57	2.09	1.55	0.00	0.00	0.00
PRESENT STRESS	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
HN44 EWR7_D	9.37	9.37	9.36	9.33	9.30	9.25	9.14	9.05	8.97	8.90	8.87	8.84	8.84	8.83	8.83	0.00	0.00
HN44 EWR7 Sc1	8.51	8.43	8.27	8.08	7.44	7.35	7.26	7.22	7.08	6.81	6.61	6.42	6.32	6.06	5.96	0.00	0.00
HN44 EWR7 Sc2	6.92	5.14	4.02	3.92	3.85	3.50	3.36	3.29	3.17	3.01	2.89	2.78	2.72	2.55	2.47	0.00	0.00

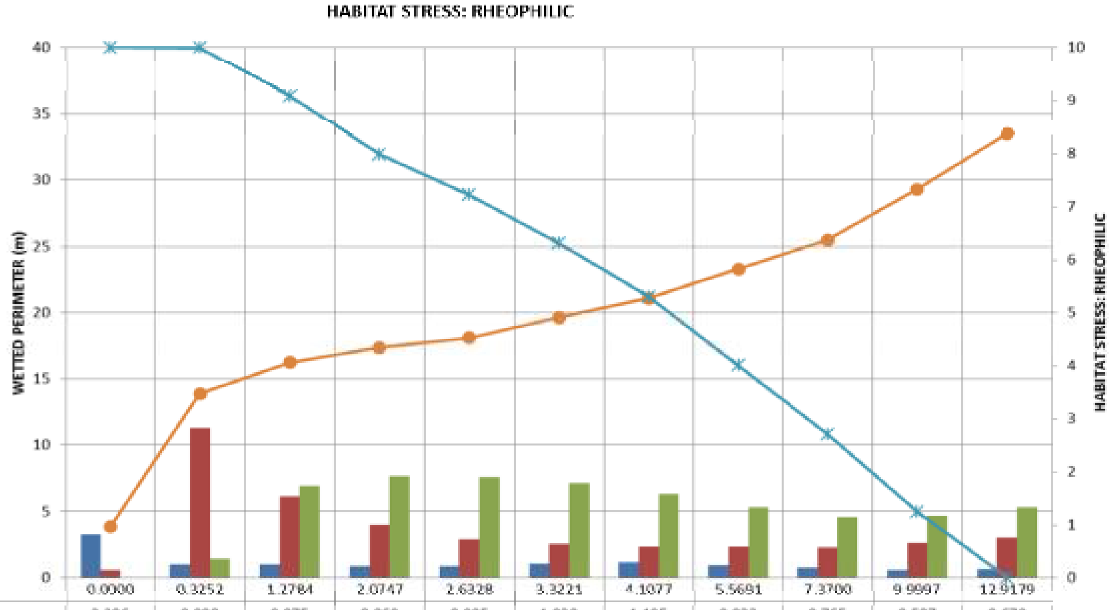
<u>WET SEASON (FEBRUARY)</u>

Max natural low flow:= 12.9179 cumec.



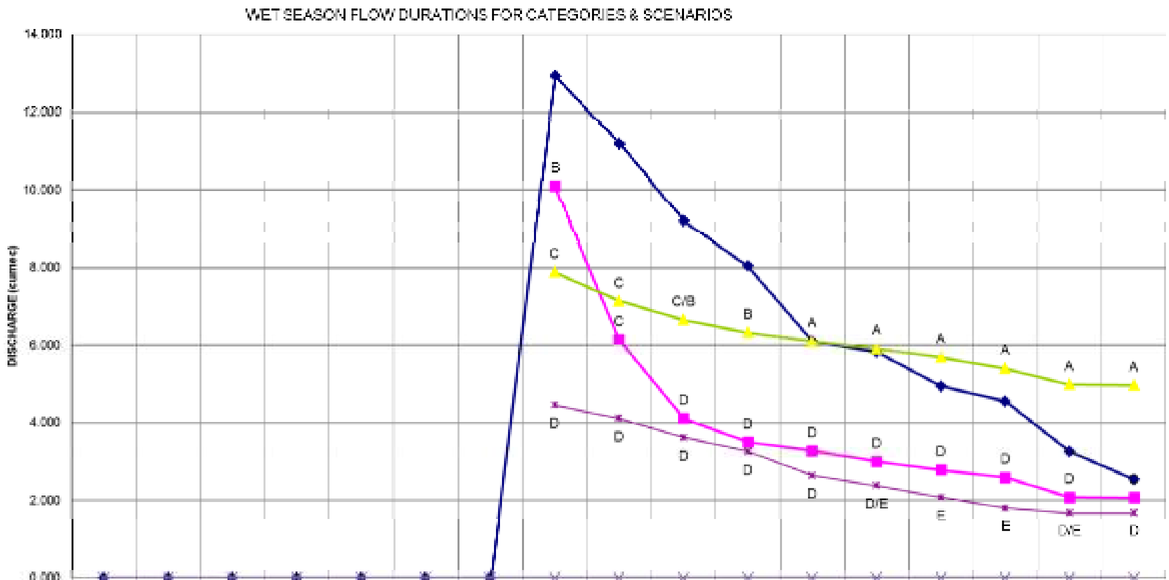
	0.0000	0.3252	1.2784	2.0747	2.6328	3.3221	4.1077	5.5691	7.3700	9.9997	12.9179
FVS (m of perimeter)	0.0	0.000	0.163	0.348	0.543	0.841	1.406	1.642	1.785	0.525	-6.386
FS (m of perimeter))	0.0	0.000	0.163	0.348	0.362	0.590	0.844	1.632	2.040	2.347	2.681
FINT (m of perimeter)	0.0	0.000	0.163	0.348	0.362	0.535	0.633	0.699	1.530	2.054	2.346
FD (m of perimeter)	0.0	0.024	1.715	3.816	5.436	6.935	8.441	10.491	12.238	16.200	25.487
WETTED PERIMETER WIDTH (m)	4	13.917	16.255	17.389	18.107	19.656	21.102	23.313	25.496	29.342	33.511
HABITAT STRESS: RHEOPHILIC	10.00	9.99	9.09	7.99	7.22	6.31	5.31	4.01	2.71	1.24	0.00

DISCHARGE(CUMEC)

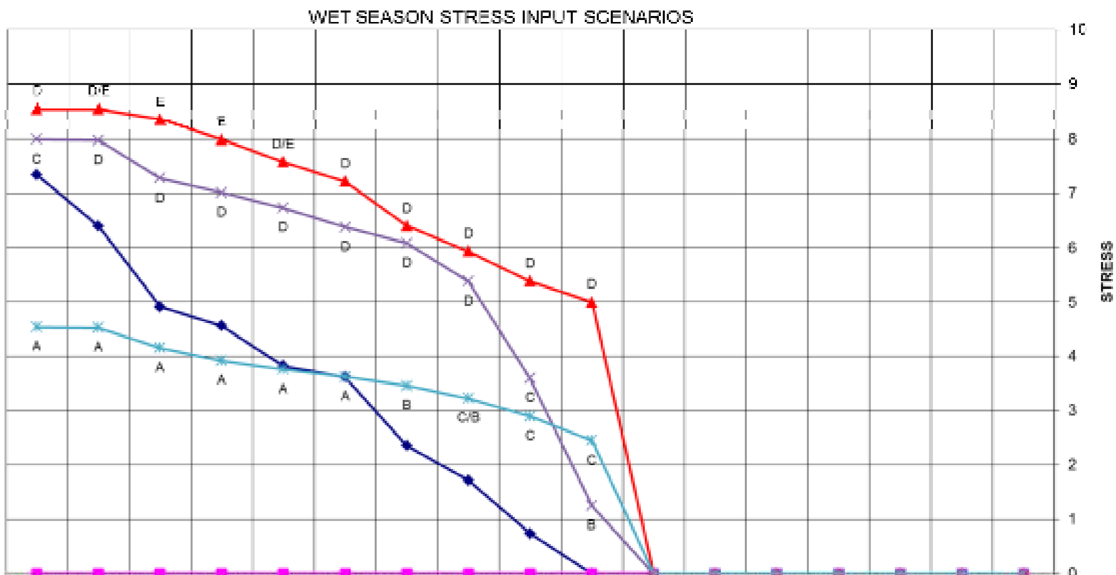


	0.0000	0.3252	1.2784	2.0747	2.6328	3.3221	4.1077	5.5691	7.3700	9.9997	12.9179
SVS m	3.286	0.998	0.975	0.869	0.905	1.038	1.195	0.933	0.765	0.587	0.670
SS m	0.58	11.32	6.16	4.02	2.90	2.56	2.32	2.32	2.29	2.64	3.02
SD m	0.000	1.464	6.990	7.651	7.601	7.163	6.331	5.352	4.589	4.695	5.362
WETTED PERIMETER WIDTH (m)	4	13.917	16.255	17.389	18.107	19.656	21.102	23.313	25.496	29.342	33.511
HABITAT STRESS: RHEOPHILIC	10.00	9.99	9.09	7.99	7.22	6.31	5.31	4.01	2.71	1.24	0.00

DISCHARGE(CUMEC)



	0.1%	2.4%	5.0%	10.0%	15.0%	20.0%	30.0%	40.0%	50.0%	60.0%	70.0%	80.0%	85.0%	90.0%	95.0%	99.0%	99.9%
REFERENCE FLOWS	0.000	0.000	0.000	0.000	0.000	0.000	0.000	12.918	11.179	9.189	8.040	6.102	5.824	4.948	4.548	3.282	2.546
PRESENT FLOWS	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
HN44 EWR7_D								4.454	4.114	3.625	3.260	2.642	2.376	2.076	1.807	1.674	1.674
HN44 EWR7 Sc1								10.0896	6.1360	4.1146	3.5040	3.2784	3.0063	2.7822	2.5862	2.0833	2.0722
HN44 EWR7 Sc2								7.8873	7.1403	6.6521	6.3273	6.0987	5.9100	5.6919	5.4034	4.9846	4.9735



	0.10%	1.00%	5.00%	10.00%	15.00%	20.00%	30.00%	40.00%	50.00%	60.00%	70.00%	80.00%	85.00%	90.00%	95.00%	99.00%	99.90%
NATURAL STRESS	7.35	6.40	4.91	4.56	3.82	3.62	2.36	1.72	0.74	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
PRESENT STRESS	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
HN44 EWR7_D	8.54	8.54	8.36	7.98	7.57	7.22	6.40	5.93	5.38	5.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
HN44 EWR7 Sc1	7.99	7.97	7.27	7.01	6.73	6.38	6.08	5.38	3.60	1.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00
HN44 EWR7 Sc2	4.54	4.53	4.15	3.92	3.76	3.62	3.46	3.23	2.90	2.45	0.00	0.00	0.00	0.00	0.00	0.00	0.00

DURATION

CROC_EWR9: Magalies River downstream Maloney's Eye

	Natural*	Future1**	Future2	EWR 9_B	Sc 1
Fish dry		A	A	C	A
Fish wet		A	B	C/D	A
Fish integrated		*A*	*A/B*	*C*	*A*
Recommendation					

*observed flows as reference; dolomitic outflow; ** current flow less 10%;

Comments:

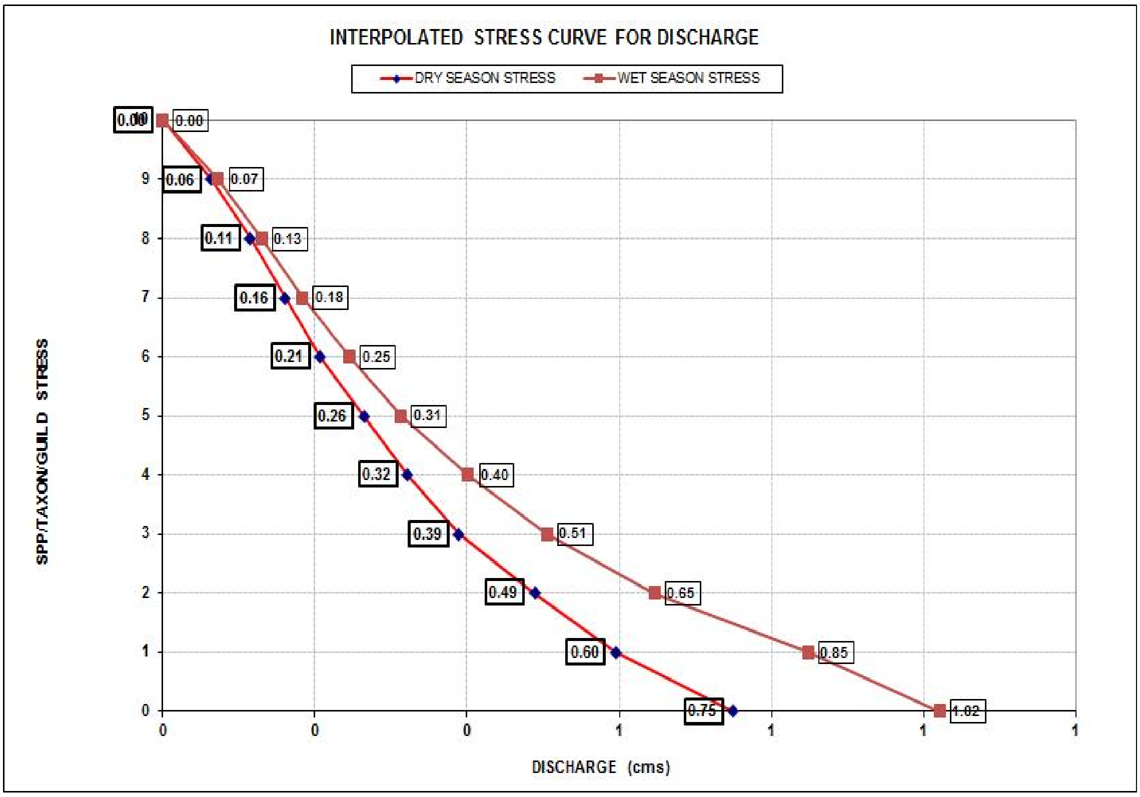
1. Assessment based on requirements of small predominantly rheophilics (Chiloglanis pretoriae or Amphilius uranoscopus)
2. FFHA was run for this guild for all fast flow (>0.3 m/s) types (FVS, FS, FI, FD) for the dry and wet season.
3. The FFHA EWR workshop proposed category B, meets the specification for category C.
4. For the dry season, the flow duration for category B can be presented by:

	HN16 EWR9_B	**CATEGORY**
FLOW DURATION	**FLOW (CUMEC)**	**B**
0.10%		
1.00%		
5.00%	0.410	C/B
10.00%	0.350	C/B
15.00%	0.330	B
20.00%	0.310	B
30.00%	0.310	B
40.00%	0.310	B
50.00%	0.305	B
60.00%	0.300	B
70.00%	0.295	B
80.00%	0.280	B
85.00%	0.270	B
90.00%	0.268	B
95.00%	0.260	A
99.00%	0.215	A
99.90%	0.208	A

5. For the wet season, the flow duration for category B can be presented by:

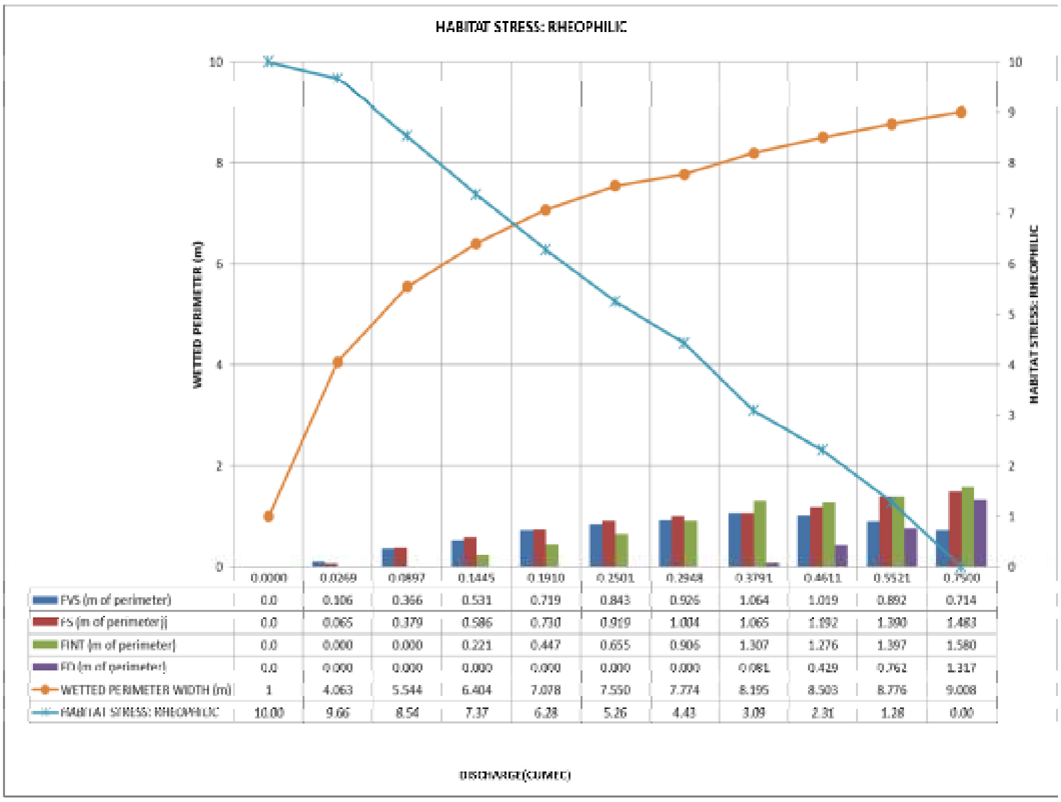
	HN16 EWR9_B	category
FLOW DURATION	**Flow (cumec)**	**B**
0.10%	0.430	C
2.40%	0.430	C
5.00%	0.430	C
10.00%	0.310	C
15.00%	0.310	C
20.00%	0.350	C
30.00%	0.350	C/B
40.00%	0.350	B
50.00%	0.350	B
60.00%	0.360	A/B
70.00%	0.340	A/B
80.00%	0.300	B
85.00%	0.290	B
90.00%	0.250	C
95.00%	0.250	A/B
99.00%	0.205	A
99.90%	0.204	A

6. Dry-wet stress profiles:

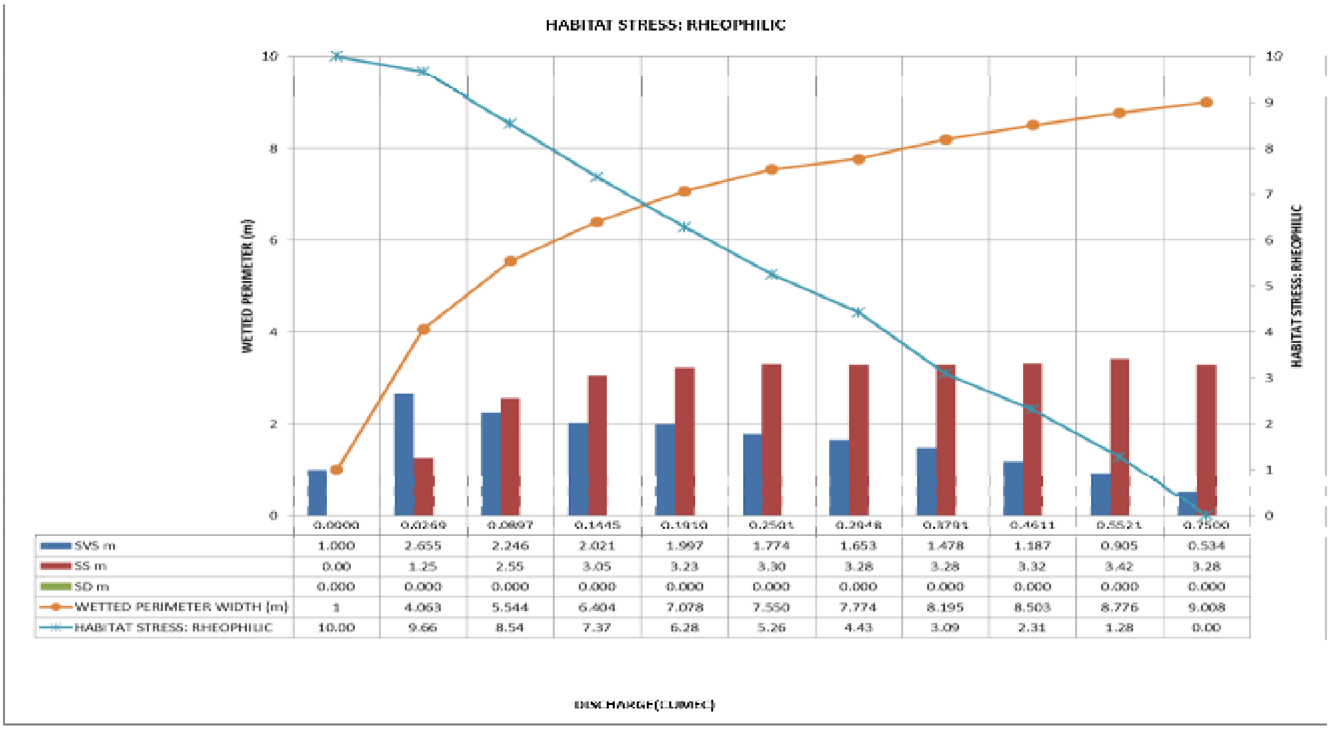


DRY SEASON (SEPTEMBER)

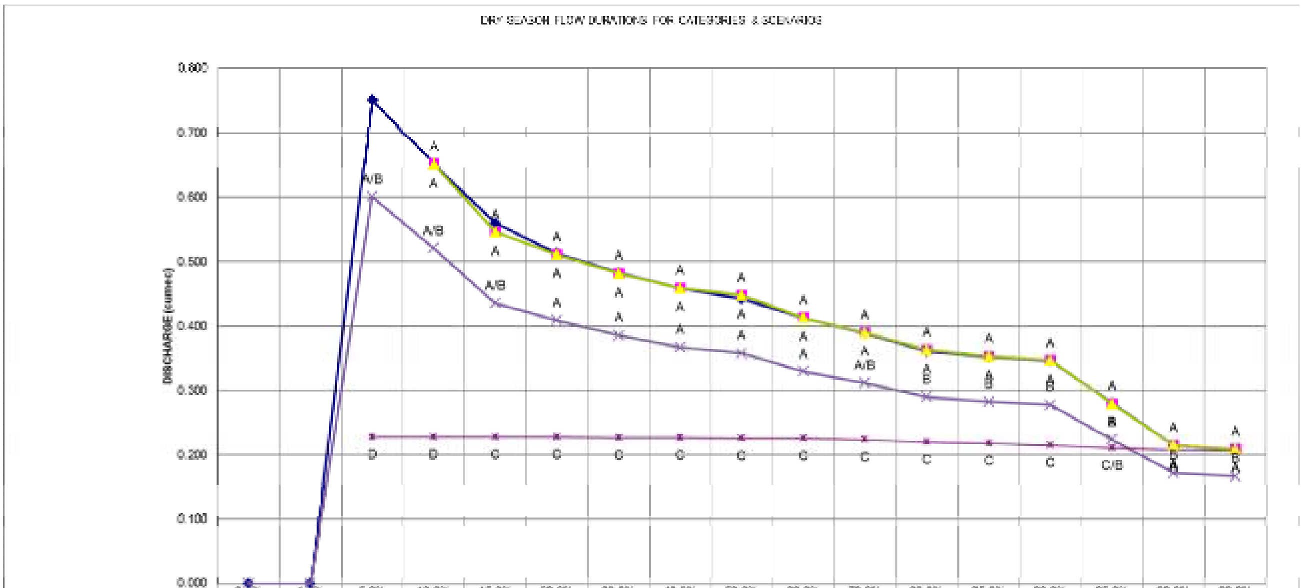
Max natural low flow = 0.7500 cumec



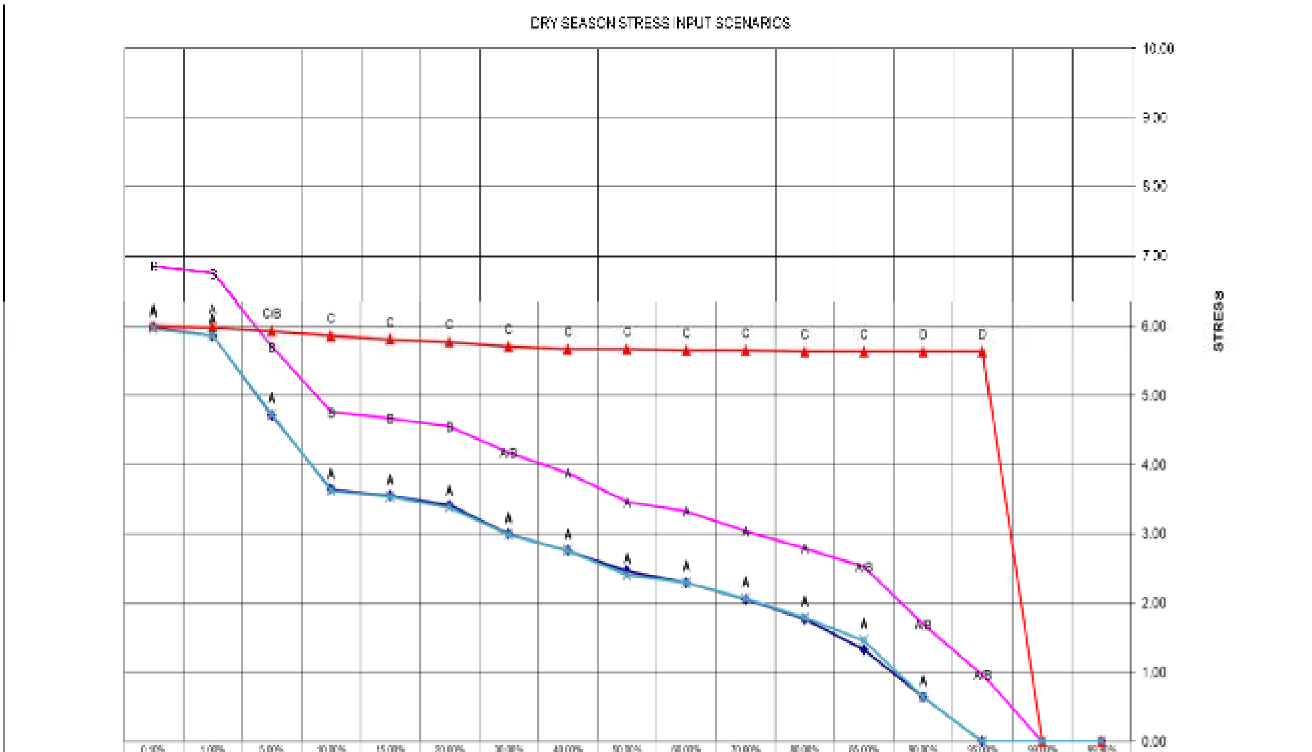
	0.0000	0.0269	0.0897	0.1445	0.1910	0.2501	0.2948	0.3791	0.4611	0.5521	0.7500
FVS (m of perimeter)	0.0	0.106	0.366	0.531	0.719	0.843	0.926	1.064	1.019	0.892	0.714
FS (m of perimeter)	0.0	0.065	0.379	0.586	0.730	0.919	1.004	1.065	1.192	1.390	1.483
FINT (m of perimeter)	0.0	0.000	0.000	0.221	0.447	0.655	0.906	1.307	1.276	1.397	1.580
FD (m of perimeter)	0.0	0.000	0.000	0.000	0.000	0.000	0.000	0.081	0.429	0.762	1.317
WETTED PERIMETER WIDTH (m)	1	4.063	5.544	6.404	7.078	7.550	7.774	8.195	8.503	8.776	9.008
HABITAT STRESS: RHEOPHILIC	10.00	9.66	8.54	7.37	6.28	5.26	4.43	3.09	2.31	1.28	0.00



	0.0000	0.0269	0.0897	0.1445	0.1910	0.2501	0.2948	0.3791	0.4611	0.5521	0.7500
SVS m	1.000	2.655	2.246	2.021	1.997	1.774	1.653	1.478	1.187	0.905	0.534
SS m	0.00	1.25	2.55	3.05	3.23	3.30	3.28	3.28	3.32	3.42	3.28
SD m	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WETTED PERIMETER WIDTH (m)	1	4.063	5.544	6.404	7.078	7.550	7.774	8.195	8.503	8.776	9.008
HABITAT STRESS: RHEOPHILIC	10.00	9.66	8.54	7.37	6.28	5.26	4.43	3.09	2.31	1.28	0.00



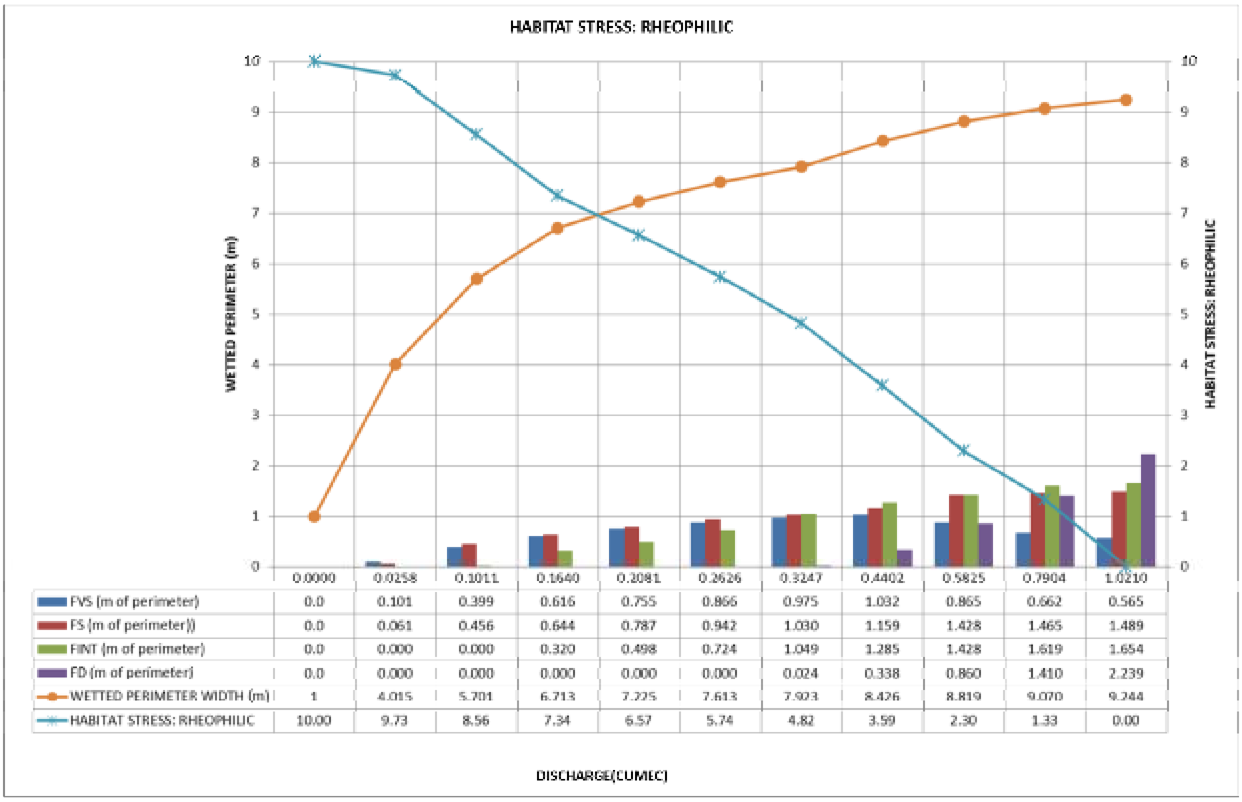
	0.1%	1.0%	5.0%	10.0%	15.0%	20.0%	30.0%	40.0%	50.0%	60.0%	70.0%	80.0%	85.0%	90.0%	95.0%	99.0%	99.9%
NATURAL	0.000	0.000	0.750	0.651	0.560	0.513	0.483	0.459	0.442	0.413	0.389	0.361	0.352	0.346	0.281	0.216	0.208
FUTURE 2	0.000	0.000	0.601	0.521	0.436	0.409	0.386	0.367	0.358	0.330	0.312	0.290	0.283	0.278	0.224	0.172	0.167
HN16 EWR9_B			0.228	0.228	0.228	0.228	0.227	0.227	0.226	0.226	0.224	0.220	0.218	0.215	0.211	0.208	0.207
HN16 EWR9 Sc1				0.6510	0.5460	0.5110	0.4820	0.4590	0.4480	0.4130	0.3900	0.3630	0.3530	0.3470	0.2800	0.2150	0.2090
HN16 EWR9 Sc2				0.6510	0.5460	0.5110	0.4820	0.4590	0.4480	0.4130	0.3900	0.3630	0.3530	0.3470	0.2800	0.2150	0.2090



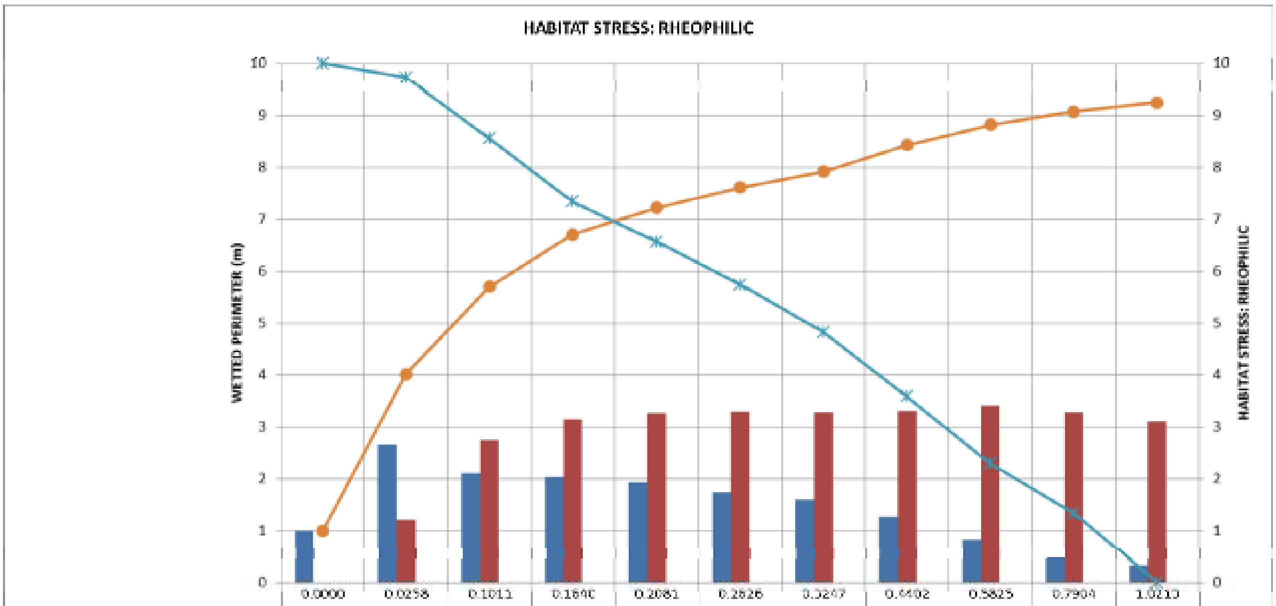
	0.10%	1.00%	5.00%	10.00%	15.00%	20.00%	30.00%	40.00%	50.00%	60.00%	70.00%	80.00%	85.00%	90.00%	95.00%	99.00%	99.90%
NATURALSTRESS	5.98	5.88	4.71	3.64	3.55	3.41	3.03	2.76	2.47	2.30	2.06	1.77	1.33	0.64	0.00	0.00	0.00
FUTURE 2 STRESS	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
HN16 EWR9_B	6.00	5.98	5.93	5.86	5.81	5.77	5.73	5.67	5.67	5.65	5.65	5.63	5.63	5.63	5.63	0.00	0.00
HN16 EWR9 Sc1	5.97	5.88	4.72	3.62	3.53	3.39	2.99	2.76	2.41	2.30	2.07	1.79	1.46	0.64	0.00	0.00	0.00
HN16 EWR9 Sc2	5.97	5.88	4.72	3.62	3.53	3.39	2.99	2.76	2.41	2.30	2.07	1.79	1.46	0.64	0.00	0.00	0.00

WET SEASON (FEBRUARY)

Max natural low flow = 1.0210 cumec

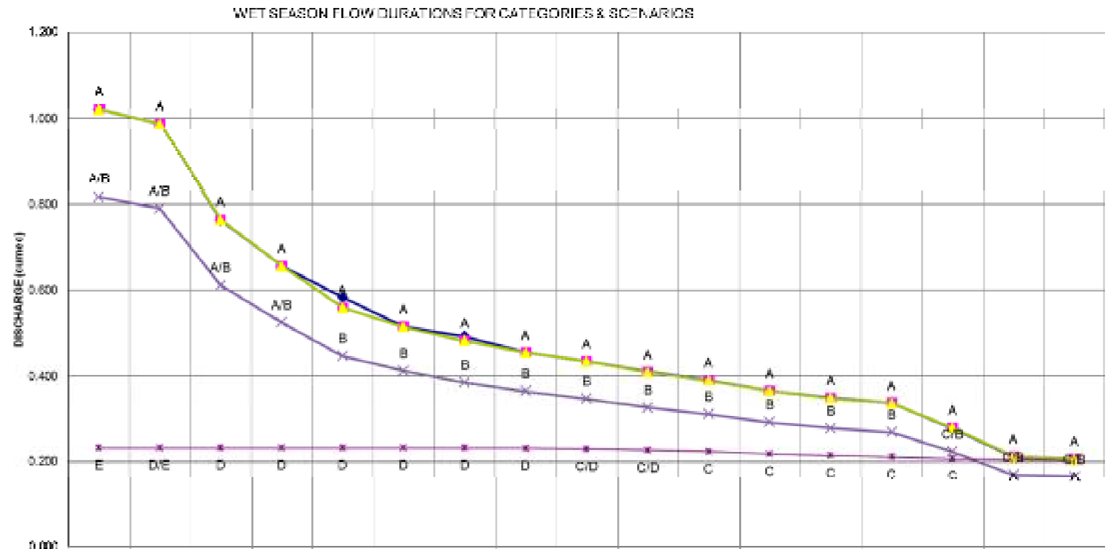


	0.0000	0.0258	0.1011	0.1640	0.2081	0.2626	0.3247	0.4402	0.5825	0.7904	1.0210
FVS (m of perimeter)	0.0	0.101	0.399	0.616	0.755	0.866	0.975	1.032	0.865	0.662	0.565
FS (m of perimeter))	0.0	0.061	0.456	0.644	0.787	0.942	1.030	1.159	1.428	1.465	1.489
FINT (m of perimeter)	0.0	0.000	0.000	0.320	0.498	0.724	1.049	1.285	1.428	1.619	1.654
FD (m of perimeter)	0.0	0.000	0.000	0.000	0.000	0.000	0.024	0.338	0.860	1.410	2.239
WETTED PERIMETER WIDTH (m)	1	4.015	5.701	6.713	7.225	7.613	7.923	8.426	8.819	9.070	9.244
HABITAT STRESS: RHEOPHILIC	10.00	9.73	8.56	7.34	6.57	5.74	4.82	3.59	2.30	1.33	0.00

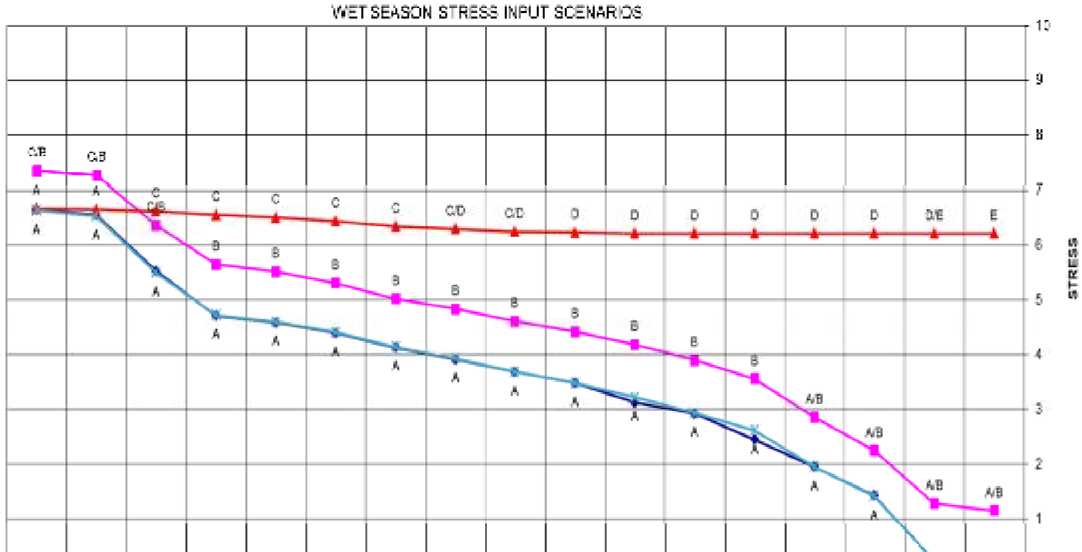


	0.0000	0.0258	0.1011	0.1690	0.2081	0.2626	0.3247	0.4402	0.5825	0.7904	1.0213
SVS m	1.000	2.659	2.109	2.029	1.933	1.741	1.591	1.263	0.832	0.481	0.329
SS m	0.00	1.21	2.74	3.14	3.26	3.29	3.28	3.31	3.41	3.28	3.10
SD m	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WETTED PERIMETER WIDTH (m)	1	4.015	5.701	6.713	7.225	7.613	7.923	8.426	8.819	9.070	9.244
HABITAT STRESS: RHEOPHILIC	10.00	9.73	8.56	7.34	6.57	5.74	4.82	3.59	2.30	1.33	0.00

DISCHARGE(CUMEC)



	0.1%	1.0%	5.0%	10.0%	15.0%	20.0%	30.0%	40.0%	50.0%	60.0%	70.0%	80.0%	85.0%	90.0%	95.0%	99.0%	99.9%
NATURAL	1.021	0.987	0.762	0.656	0.583	0.516	0.492	0.455	0.434	0.411	0.390	0.366	0.349	0.338	0.277	0.211	0.205
FUTURE 2	0.817	0.790	0.611	0.525	0.447	0.412	0.385	0.364	0.347	0.327	0.311	0.292	0.278	0.269	0.223	0.169	0.166
HN16 EWR9_B	0.232	0.232	0.232	0.232	0.232	0.232	0.232	0.231	0.230	0.227	0.224	0.218	0.214	0.211	0.207	0.205	0.204
HN16 EWR9 Sc1	1.0210	0.9870	0.7640	0.6560	0.5590	0.5140	0.4820	0.4550	0.4340	0.4090	0.3890	0.3650	0.3480	0.3370	0.2790	0.2120	0.2060
HN16 EWR9 Sc2	1.0210	0.9870	0.7640	0.6560	0.5590	0.5140	0.4820	0.4550	0.4340	0.4090	0.3890	0.3650	0.3480	0.3370	0.2790	0.2120	0.2060



	0.10%	1.00%	5.00%	10.00%	15.00%	20.00%	30.00%	40.00%	50.00%	60.00%	70.00%	80.00%	85.00%	90.00%	95.00%	99.00%	99.90%
NATURAL STRESS	6.65	6.56	5.53	4.72	4.59	4.40	4.13	3.91	3.69	3.48	3.13	2.92	2.45	1.95	1.43	0.20	0.00
FUTURE 2 STRESS	7.35	7.27	6.36	5.65	5.52	5.31	5.03	4.84	4.61	4.42	4.19	3.90	3.56	2.86	2.25	1.29	1.15
HN16 EWR9_B	6.67	6.65	6.62	6.56	6.51	6.44	6.35	6.30	6.25	6.23	6.22	6.22	6.22	6.22	6.22	6.22	6.22
HN16 EWR9 Sc1	6.64	6.54	5.50	4.73	4.60	4.41	4.14	3.93	3.69	3.48	3.22	2.94	2.62	1.95	1.42	0.20	0.00
HN16 EWR9 Sc2	6.64	6.54	5.50	4.73	4.60	4.41	4.14	3.93	3.69	3.48	3.22	2.94	2.62	1.95	1.42	0.20	0.00

DURATION

CROC_EWR9: Magalies River downstream Maloney's Eye

	Natural*	Future1**	Future2	EWR 9_B	Sc 1
Fish dry		A	A	C	A
Fish wet		A	B	C/D	A
Fish integrated		*A*	*A/B*	*C*	*A*
Recommendation					

*observed flows as reference; dolomitic outflow; ** current flow less 10%;

Comments:

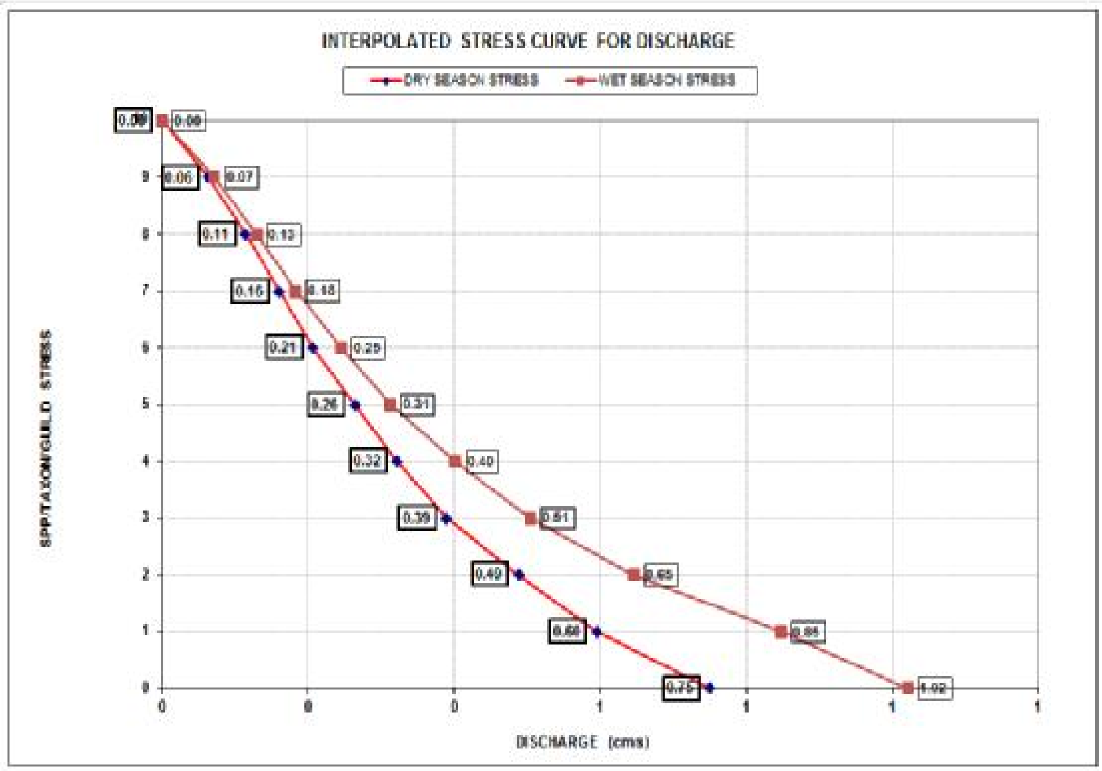
1. Assessment based on requirements of small predominantly rheophilics (Chiloglanis pretoriae or Amphilius uranoscopus)
2. FFHA was run for this guild for all fast flow (>0.3 m/s) types (FVS, FS, FI, FD) for the dry and wet season.
3. The FFHA EWR workshop proposed category B, meets the specification for category C.
4. For the dry season, the flow duration for category B can be presented by:

	HN16 EWR9_B	**CATEGORY**
FLOW DURATION	**FLOW (CUMEC)**	**B**
0.10%		
1.00%		
5.00%	0.410	C/B
10.00%	0.350	C/B
15.00%	0.330	B
20.00%	0.310	B
30.00%	0.310	B
40.00%	0.310	B
50.00%	0.305	B
60.00%	0.300	B
70.00%	0.295	B
80.00%	0.280	B
85.00%	0.270	B
90.00%	0.268	B
95.00%	0.260	A
99.00%	0.215	A
99.90%	0.208	A

5. For the wet season, the flow duration for category B can be presented by:

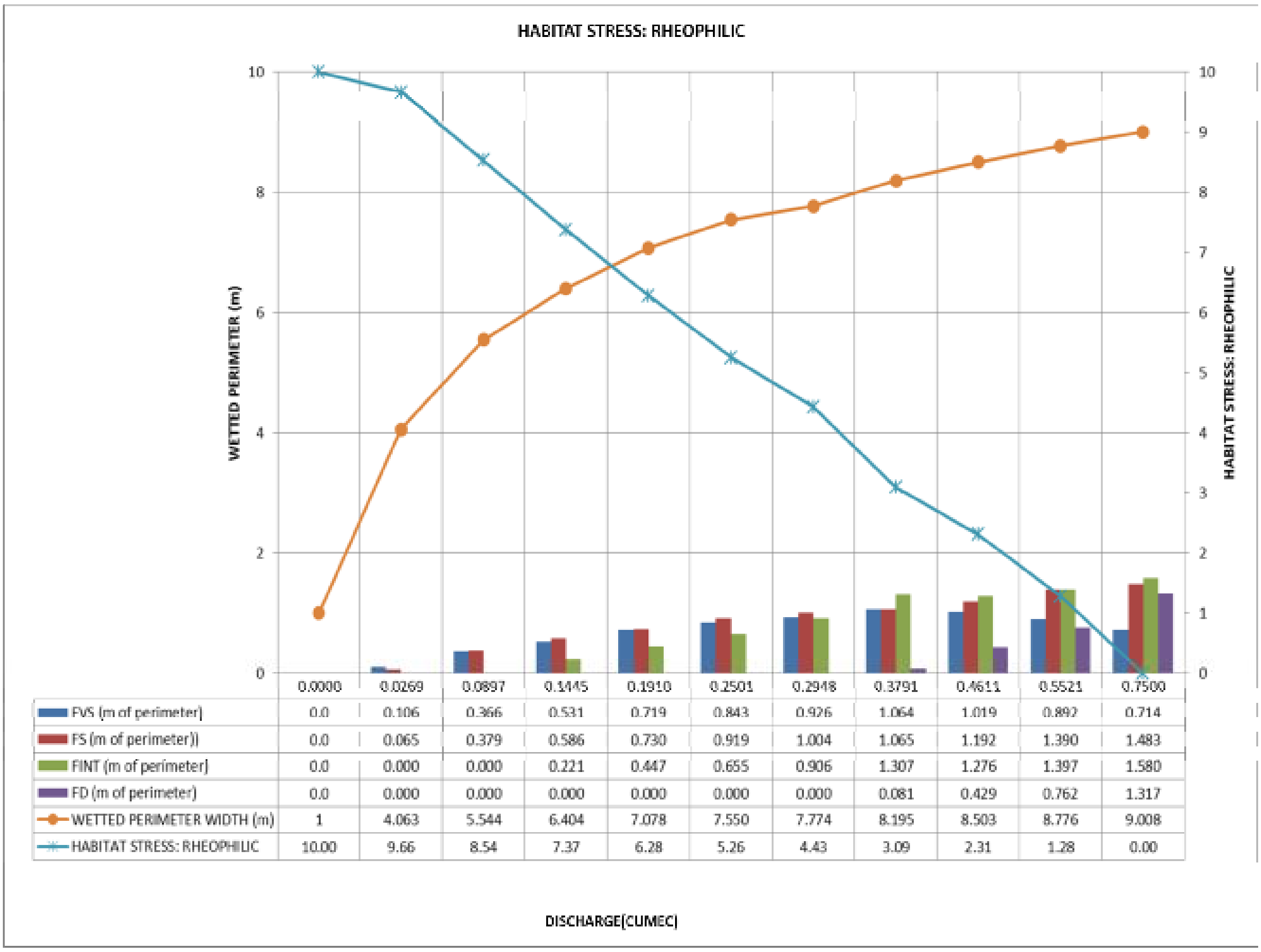
FLOW DURATION	HN16 EWR9_B Flow (cumec)	category B
0.10%	0.430	C
2.40%	0.430	C
5.00%	0.430	C
10.00%	0.310	C
15.00%	0.310	C
20.00%	0.350	C
30.00%	0.350	C/B
40.00%	0.350	B
50.00%	0.350	B
60.00%	0.360	A/B
70.00%	0.340	A/B
80.00%	0.300	B
85.00%	0.290	B
90.00%	0.250	C
95.00%	0.250	A/B
99.00%	0.205	A
99.90%	0.204	A

6. Dry-wet stress profiles:

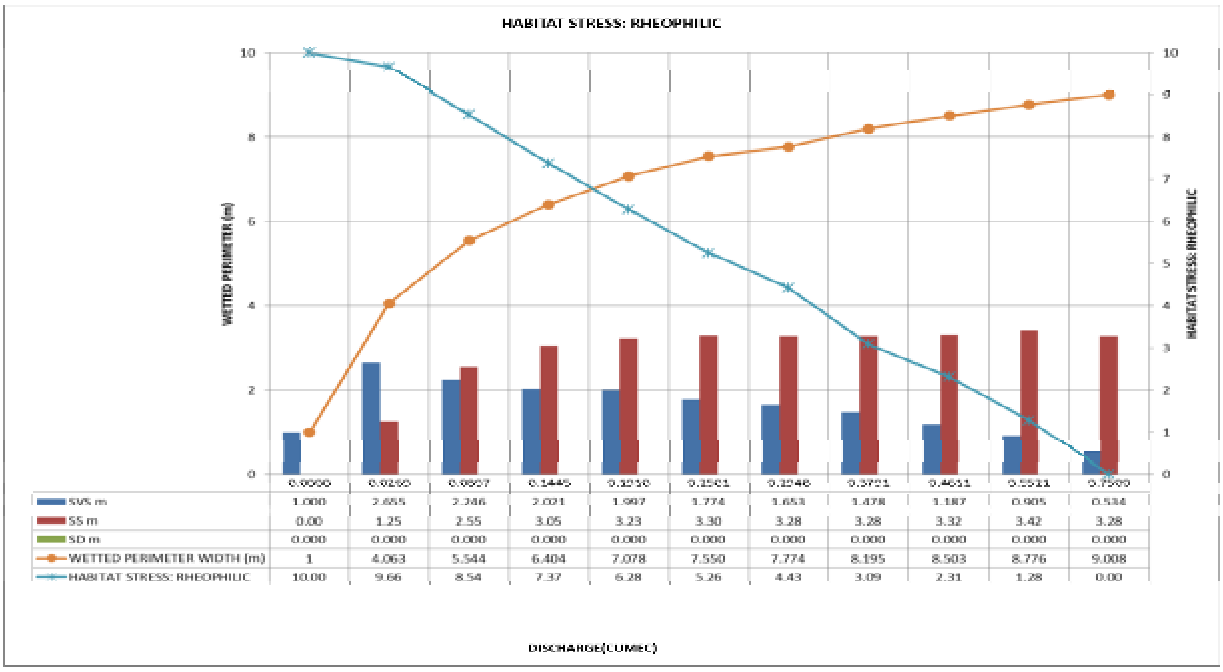


<u>DRY SEASON (SEPTEMBER)</u>

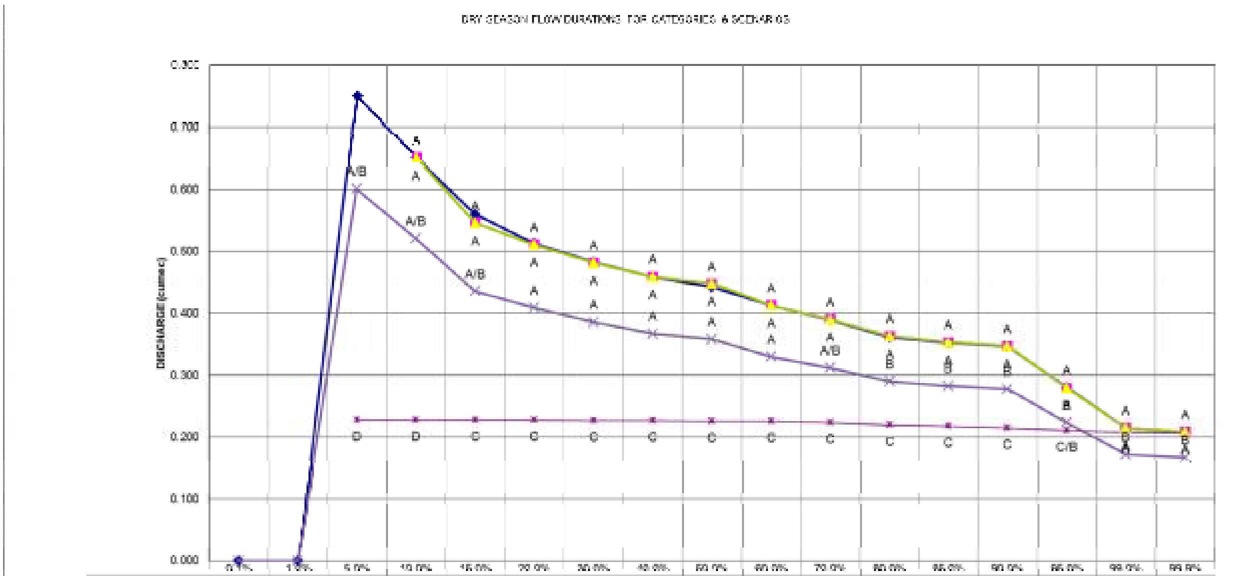
Max natural low flow = 0.7500 cumec



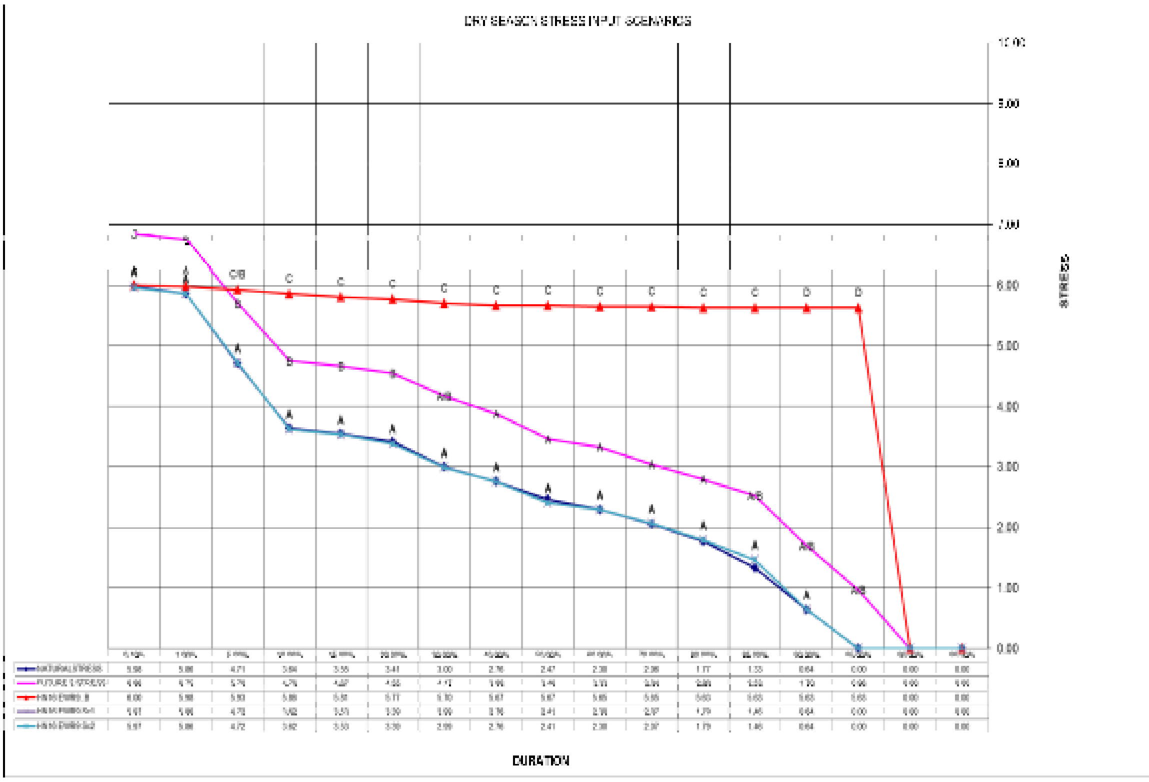
	0.0000	0.0269	0.0897	0.1445	0.1910	0.2501	0.2948	0.3791	0.4611	0.5521	0.7500
FVS (m of perimeter)	0.0	0.106	0.366	0.531	0.719	0.843	0.926	1.064	1.019	0.892	0.714
FS (m of perimeter))	0.0	0.065	0.379	0.586	0.730	0.919	1.004	1.065	1.192	1.390	1.483
FINT (m of perimeter)	0.0	0.000	0.000	0.221	0.447	0.655	0.906	1.307	1.276	1.397	1.580
FD (m of perimeter)	0.0	0.000	0.000	0.000	0.000	0.000	0.000	0.081	0.429	0.762	1.317
WETTED PERIMETER WIDTH (m)	1	4.063	5.544	6.404	7.078	7.550	7.774	8.195	8.503	8.776	9.008
HABITAT STRESS: RHEOPHILIC	10.00	9.66	8.54	7.37	6.28	5.26	4.43	3.09	2.31	1.28	0.00



	0.0000	0.0269	0.0897	0.1445	0.1910	0.2501	0.2948	0.3791	0.4611	0.5521	0.7500
SVS m	1.000	2.655	2.246	2.021	1.997	1.774	1.653	1.478	1.187	0.905	0.534
SS m	0.00	1.25	2.55	3.05	3.23	3.30	3.28	3.28	3.32	3.42	3.28
SD m	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WETTED PERIMETER WIDTH (m)	1	4.063	5.544	6.404	7.078	7.550	7.774	8.195	8.503	8.776	9.008
HABITAT STRESS: RHEOPHILIC	10.00	9.66	8.54	7.37	6.28	5.26	4.43	3.09	2.31	1.28	0.00

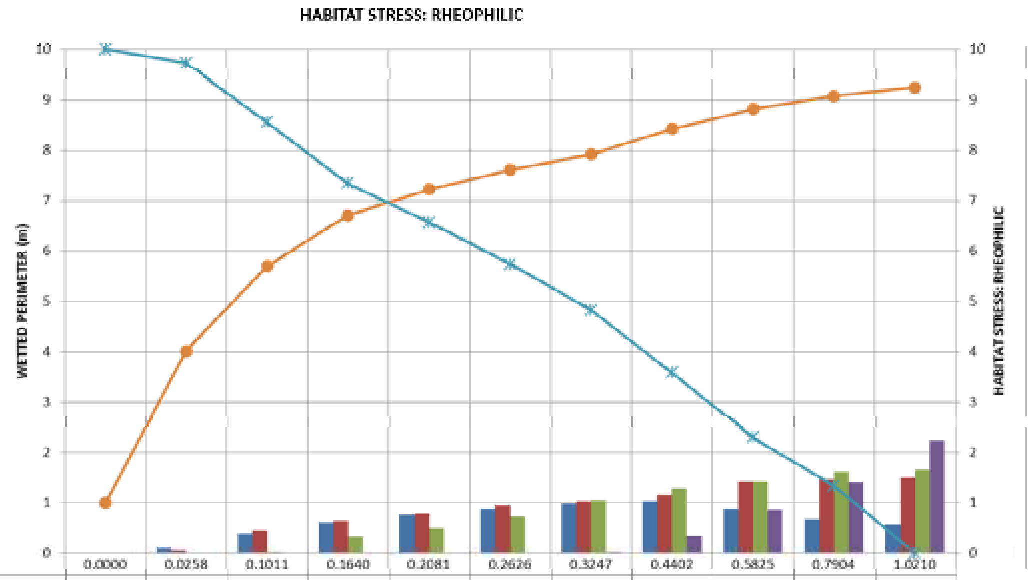


	0.1%	1.0%	5.0%	10.0%	15.0%	20.0%	30.0%	40.0%	50.0%	60.0%	70.0%	80.0%	85.0%	90.0%	95.0%	99.0%	99.9%
NATURAL	0.000	0.000	0.750	0.651	0.560	0.513	0.483	0.459	0.442	0.413	0.389	0.361	0.352	0.346	0.281	0.215	0.208
FUTURE 2	0.000	0.000	0.601	0.521	0.436	0.409	0.386	0.367	0.358	0.330	0.312	0.290	0.283	0.276	0.224	0.172	0.167
HN16 EWR9_B			0.228	0.228	0.228	0.228	0.227	0.227	0.226	0.226	0.224	0.220	0.218	0.215	0.211	0.208	0.207
HN16 EWR9 Sc1				0.6510	0.5460	0.5110	0.4820	0.4590	0.4480	0.4130	0.3900	0.3630	0.3530	0.3470	0.2800	0.2150	0.2090
HN16 EWR9 Sc2				0.6510	0.5460	0.5110	0.4820	0.4590	0.4480	0.4130	0.3900	0.3630	0.3530	0.3470	0.2800	0.2150	0.2090


DRY SEASON STRESS INPUT SCENARIOS
STRESS
DURATION
1.00
2.00
3.00
4.00
5.00
6.00
0.00

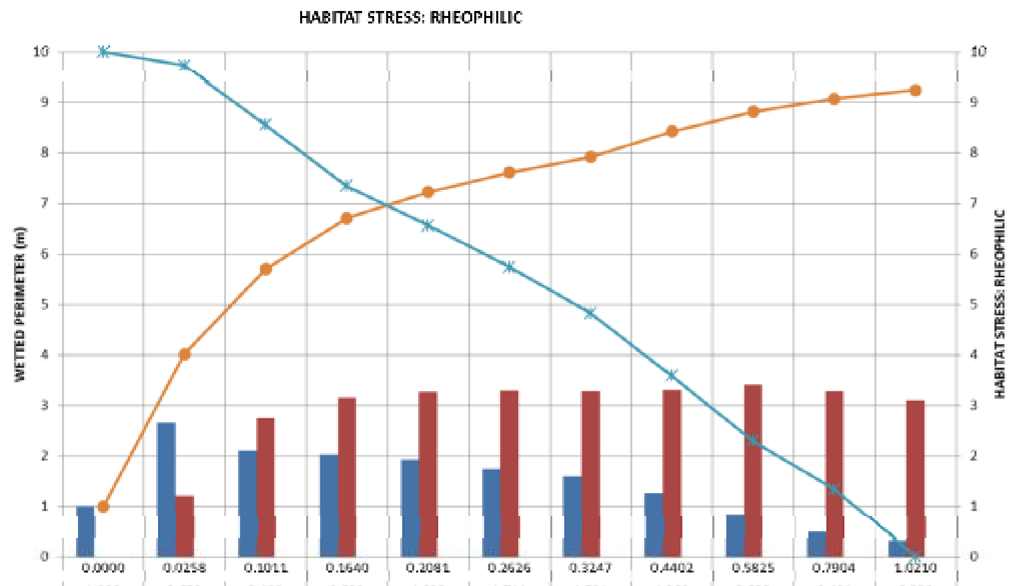
<u>WET SEASON (FEBRUARY)</u>

Max natural low flow = 1.0210 cumec



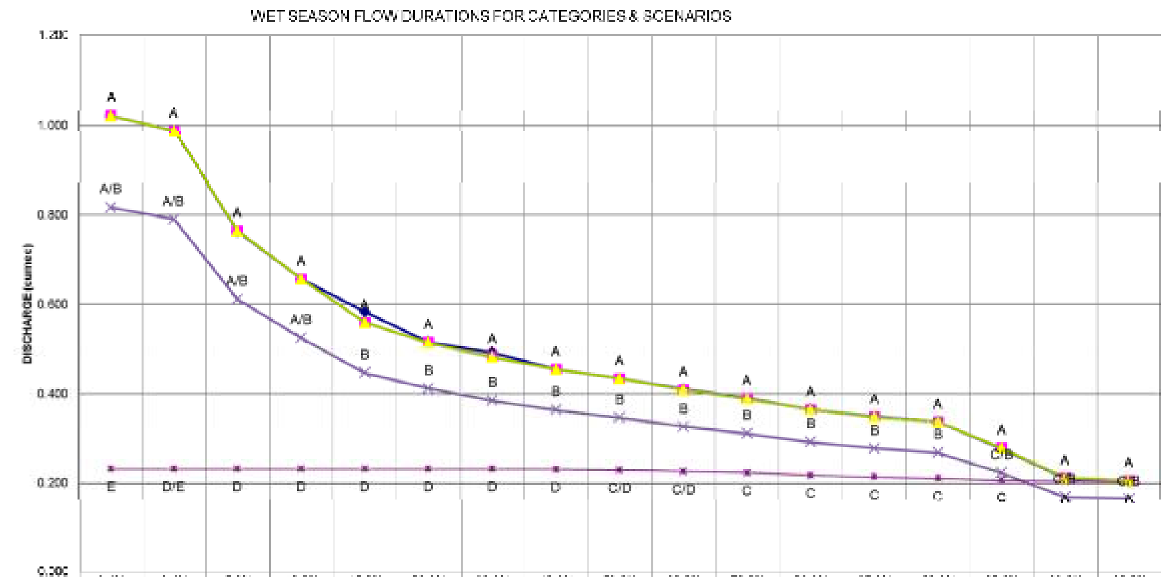
	0.0000	0.0258	0.1011	0.1640	0.2081	0.2626	0.3247	0.4402	0.5825	0.7904	1.0210
FVS (m of perimeter)	0.0	0.101	0.399	0.616	0.755	0.866	0.975	1.032	0.865	0.662	0.565
FS (m of perimeter|)	0.0	0.061	0.456	0.644	0.787	0.942	1.030	1.159	1.428	1.465	1.489
FINT (m of perimeter)	0.0	0.000	0.000	0.320	0.498	0.724	1.049	1.285	1.428	1.619	1.654
FD (m of perimeter)	0.0	0.000	0.000	0.000	0.000	0.000	0.024	0.338	0.860	1.410	2.239
WETTED PERIMETER WIDTH (m)	1	4.015	5.701	6.713	7.225	7.613	7.923	8.426	8.819	9.070	9.244
HABITAT STRESS: RHEOPHILIC	10.00	9.73	8.56	7.34	6.57	5.74	4.82	3.59	2.30	1.33	0.00

DISCHARGE(CUMEC)

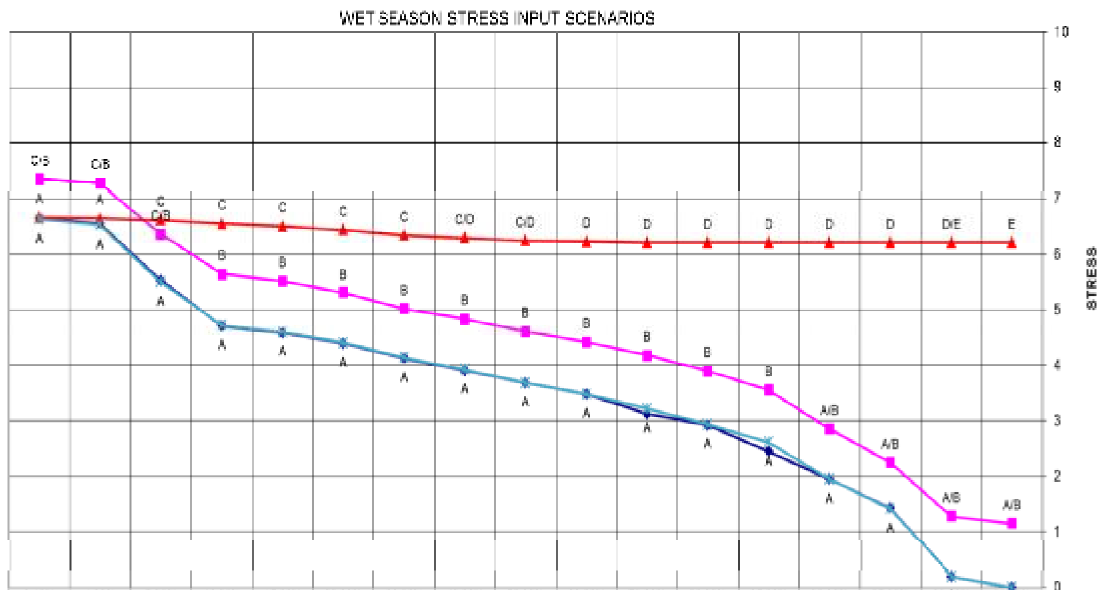


	0.0000	0.0258	0.1011	0.1640	0.2081	0.2626	0.3247	0.4402	0.5825	0.7904	1.0210
SVS m	1.000	2.659	2.109	2.029	1.933	1.741	1.591	1.263	0.832	0.481	0.329
SS m	0.00	1.21	2.74	3.14	3.26	3.29	3.28	3.31	3.41	3.28	3.10
SD m	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WETTED PERIMETER WIDTH (m)	1	4.015	5.701	6.713	7.225	7.613	7.923	8.426	8.819	9.070	9.244
HABITAT STRESS: RHEOPHILIC	10.00	9.73	8.56	7.34	6.57	5.74	4.82	3.59	2.30	1.33	0.00

DISCHARGE(CUMEC)



	0.1%	2.4%	6.0%	10.0%	16.0%	20.0%	30.0%	40.0%	50.0%	60.0%	70.0%	80.0%	85.0%	90.0%	95.0%	99.0%	99.9%
NATURAL	1.021	0.987	0.762	0.656	0.583	0.516	0.492	0.455	0.434	0.411	0.390	0.366	0.349	0.338	0.277	0.211	0.205
FUTURE 2	0.817	0.790	0.611	0.525	0.447	0.412	0.386	0.364	0.347	0.327	0.311	0.292	0.278	0.269	0.223	0.169	0.165
HN16 EWR9_B	0.232	0.232	0.232	0.232	0.232	0.232	0.232	0.231	0.230	0.227	0.224	0.218	0.214	0.211	0.207	0.205	0.204
HN16 EWR9 Sc1	1.0210	0.9870	0.7640	0.6560	0.6590	0.5140	0.4820	0.4550	0.4340	0.4090	0.3890	0.3650	0.3480	0.3370	0.2790	0.2120	0.2060
HN16 EWR9 Sc2	1.0210	0.9870	0.7640	0.6560	0.6590	0.5140	0.4820	0.4550	0.4340	0.4090	0.3890	0.3650	0.3480	0.3370	0.2790	0.2120	0.2060



	0.10%	1.00%	5.00%	10.00%	15.00%	20.00%	30.00%	40.00%	50.00%	60.00%	70.00%	80.00%	85.00%	90.00%	95.00%	99.00%	99.90%
NATURAL STRESS	6.65	6.56	5.53	4.72	4.59	4.40	4.13	3.91	3.69	3.48	3.13	2.92	2.45	1.95	1.43	0.20	0.00
FUTURE 2 STRESS	7.35	7.27	6.38	5.65	5.52	5.31	5.03	4.84	4.61	4.42	4.19	3.90	3.56	2.88	2.25	1.29	1.15
HN16 EWR9_B	6.67	6.65	6.62	6.56	6.51	6.44	6.35	6.30	6.25	6.23	6.22	6.22	6.22	6.22	6.22	6.22	6.22
HN16 EWR9 Sc1	6.64	6.54	5.50	4.73	4.60	4.41	4.14	3.93	3.69	3.48	3.22	2.94	2.62	1.95	1.42	0.20	0.00
HN16 EWR9 Sc2	6.64	6.54	5.50	4.73	4.60	4.41	4.14	3.93	3.69	3.48	3.22	2.94	2.62	1.95	1.42	0.20	0.00

DURATION

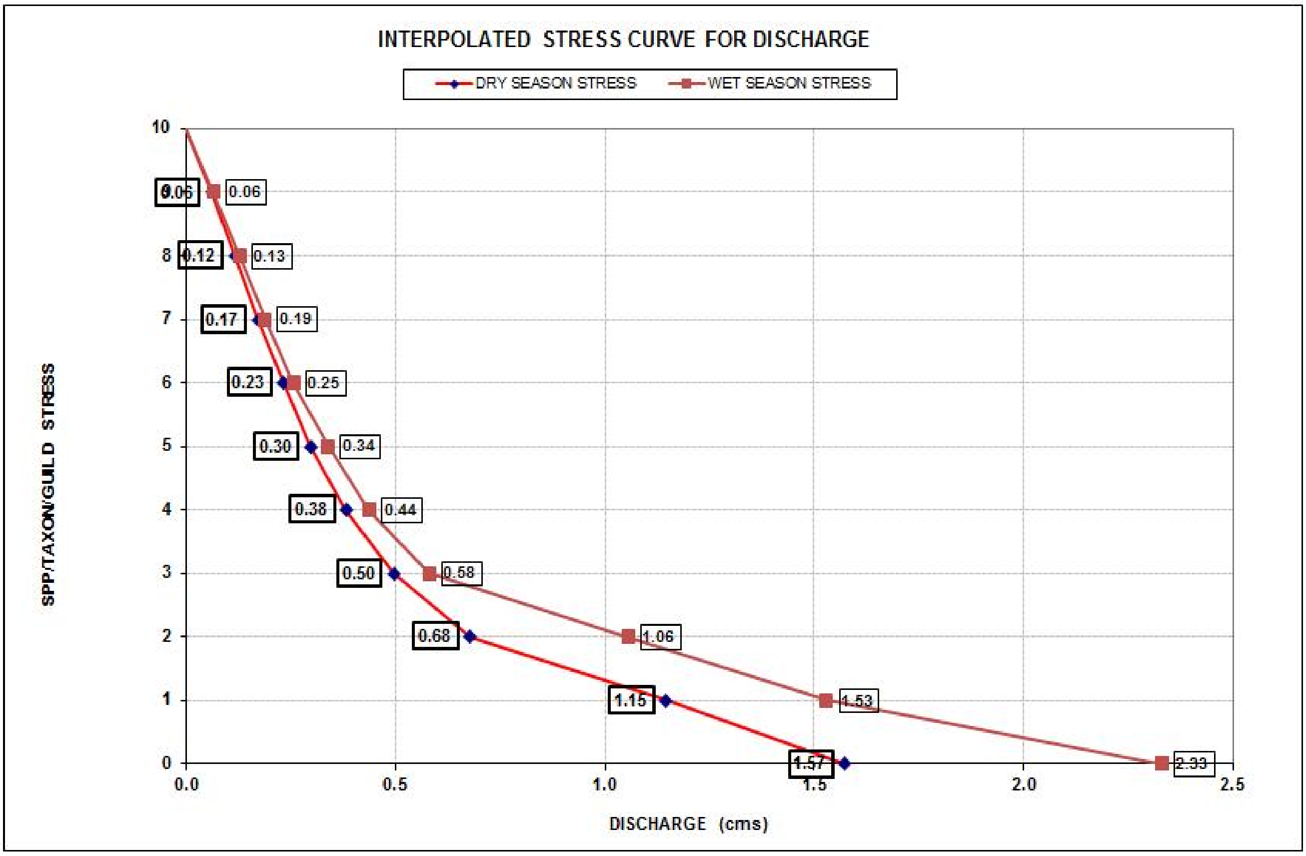
Marico EWR 2

	Natural	Present	EWR 2_B	Sc 1_FULL	Sc1 EWR only	Sc 2
Fish dry		B	A	A/B	A/B	
Fish wet		B	A	A	A	
Fish integrated		*B*	*A*	*A/B*	*A/B*	
Recommendation						

Comments:

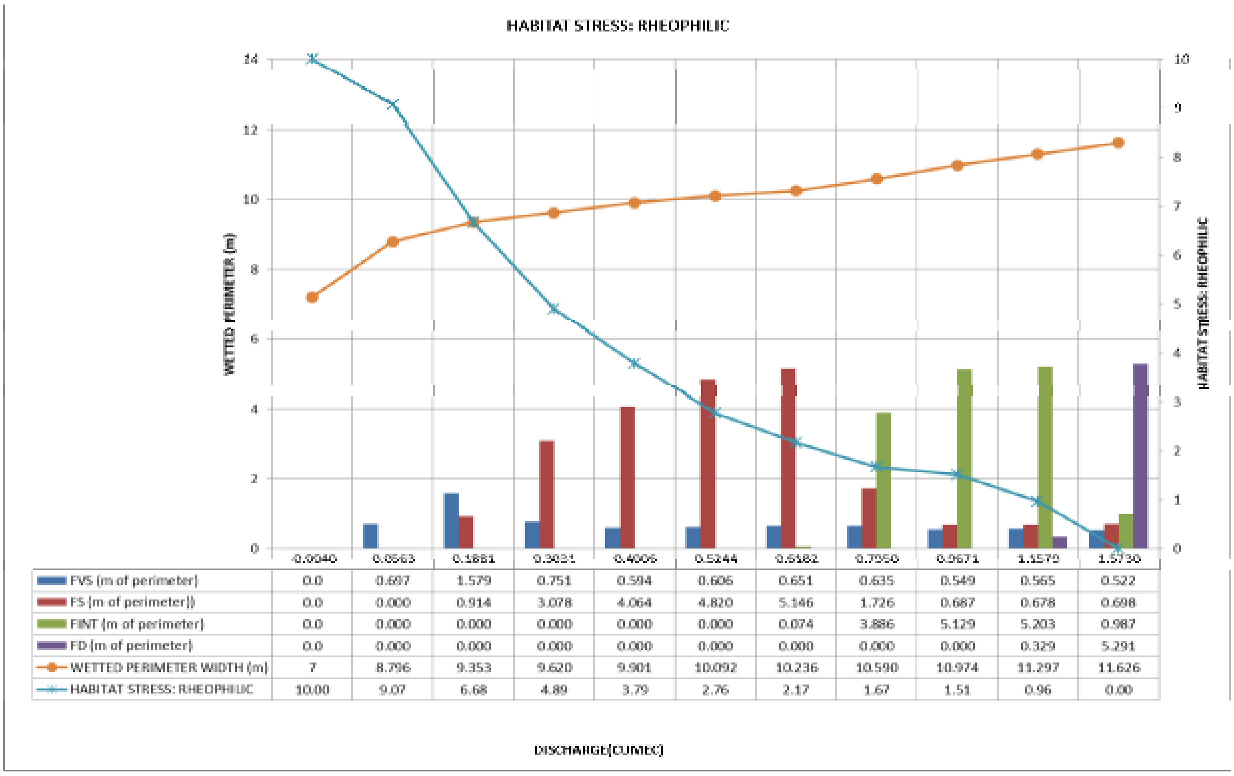
1. Assessment based on requirements of small predominantly rheophilics (Chiloglanis pretoriae or Amphilius uranoscopus)
2. FFHA was run for this guild for all fast flow (>0.3 m/s) types (FVS, FS, FI, FD) for the dry and wet season.

Dry-wet stress profiles:

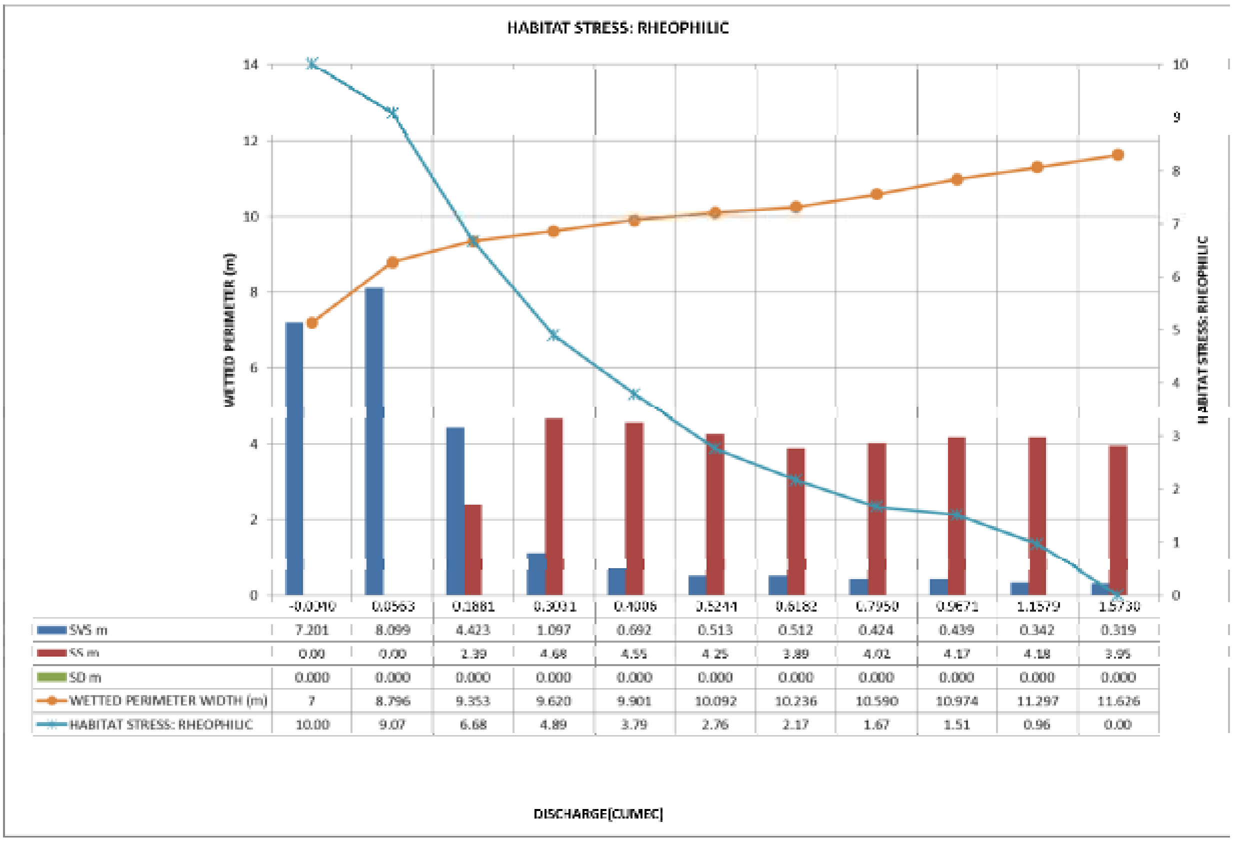


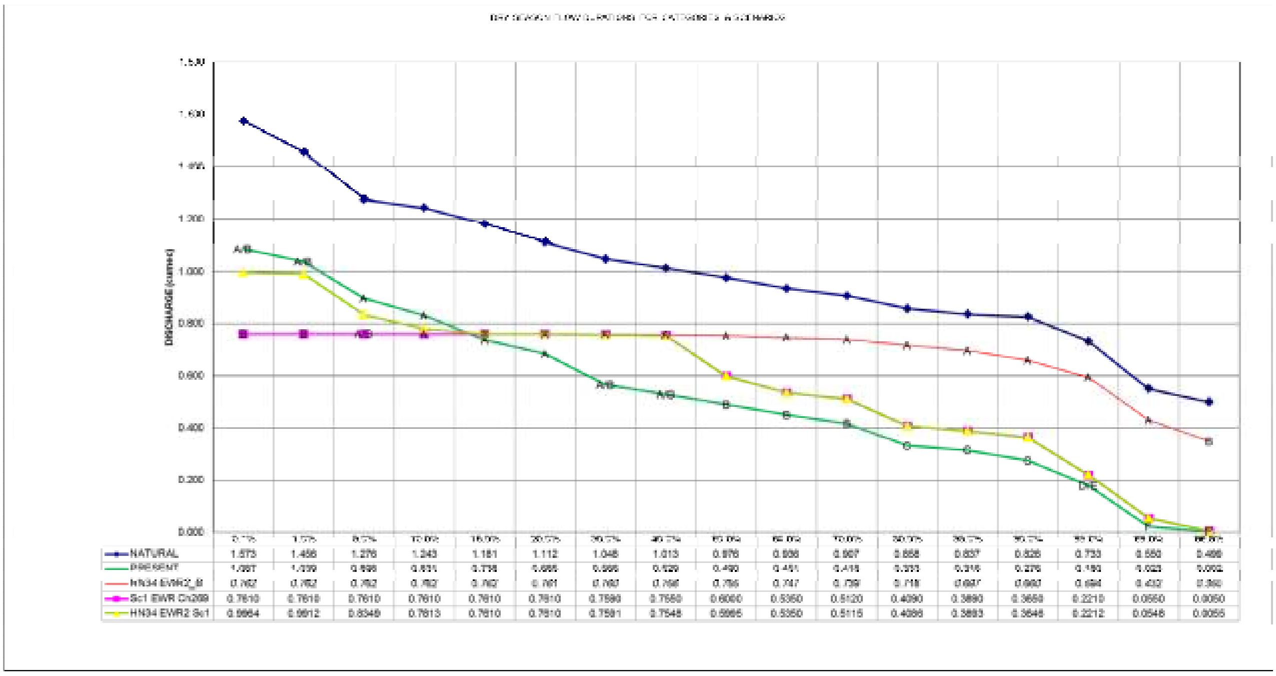
DRY SEASON (SEPTEMBER)

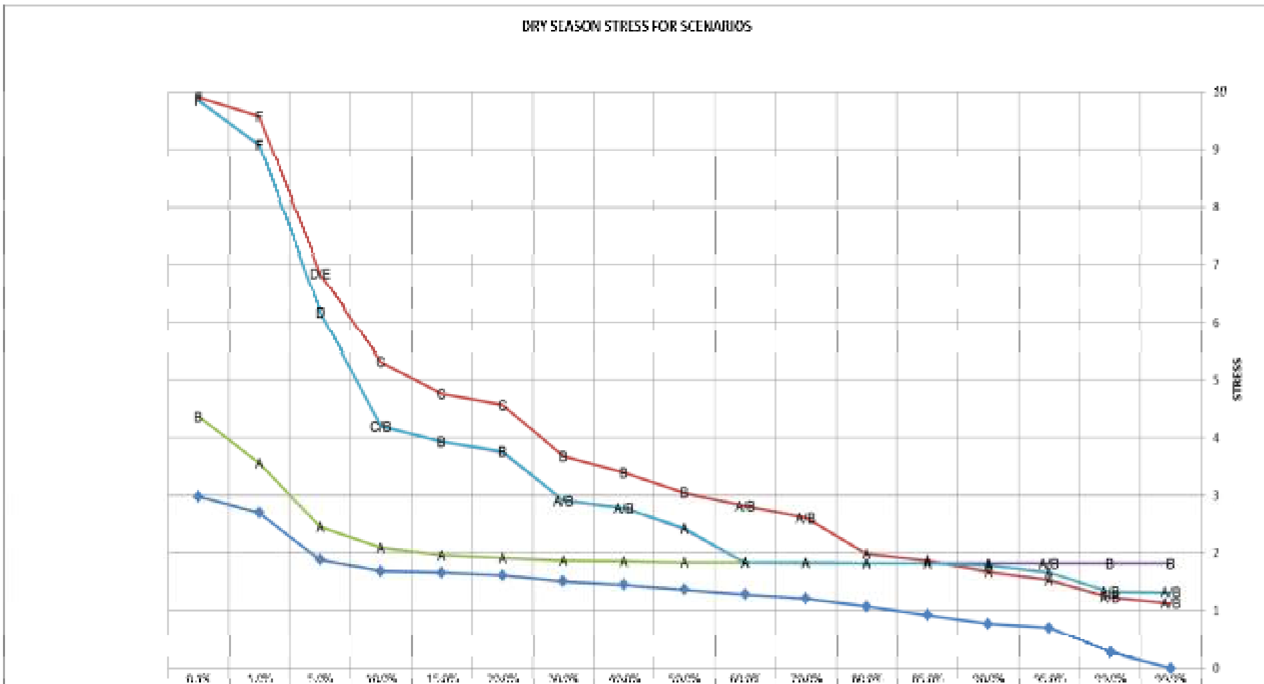
Max natural low flow = 1.5730 cumec



	-0.0040	0.0563	0.1881	0.3031	0.4006	0.5244	0.6182	0.7950	0.9671	1.1570	1.5730
FVS (m of perimeter)	0.0	0.697	1.579	0.751	0.594	0.606	0.651	0.635	0.549	0.565	0.522
FS (m of perimeter))	0.0	0.000	0.914	3.078	4.064	4.820	5.146	1.726	0.687	0.678	0.698
FINT (m of perimeter)	0.0	0.000	0.000	0.000	0.000	0.000	0.074	3.886	5.129	5.203	0.987
FD (m of perimeter)	0.0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.329	5.291
WETTED PERIMETER WIDTH (m)	7	8.796	9.353	9.620	9.901	10.092	10.236	10.590	10.974	11.297	11.626
HABITAT STRESS: RHEOPHILIC	10.00	9.07	6.68	4.89	3.79	2.76	2.17	1.67	1.51	0.96	0.00

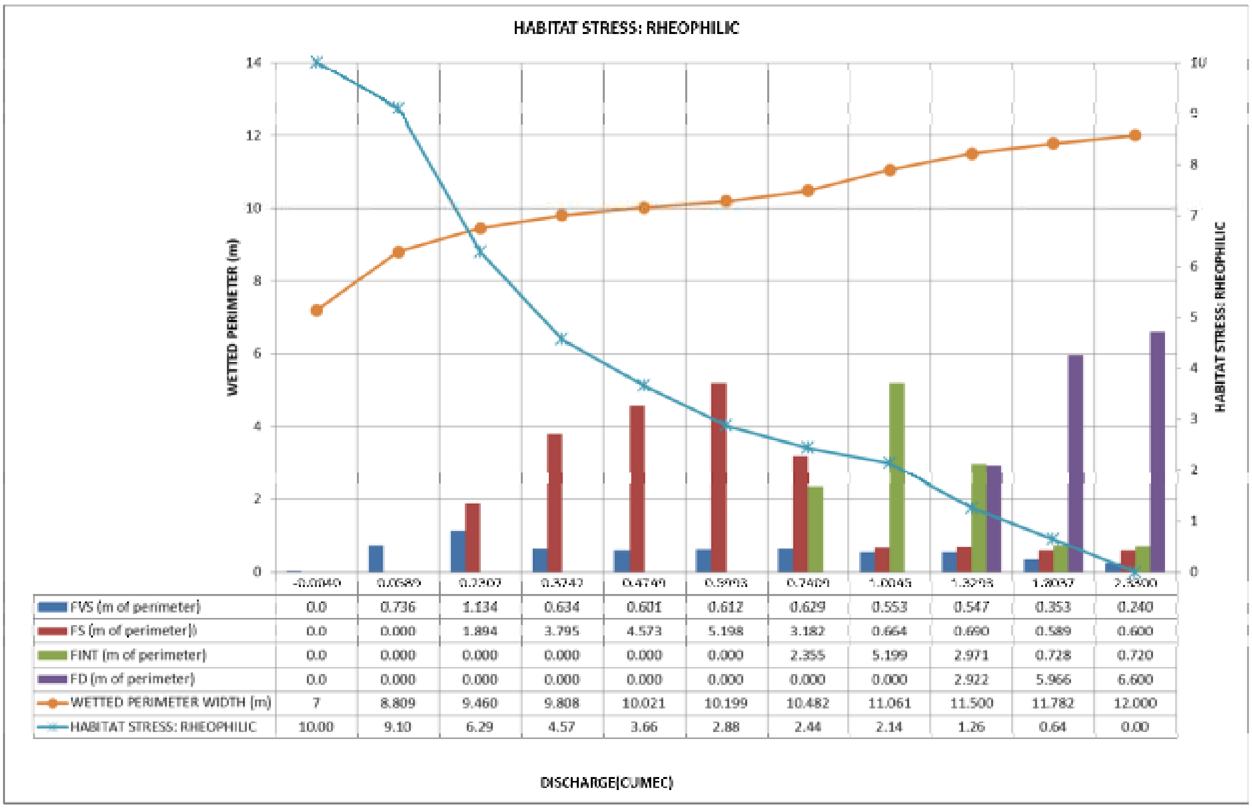

HABITAT STRESS: RHEOPHILIC
WETTED PERIMETER (m)
HABITAT STRESS: RHEOPHILIC
DISCHARGE(CUMEC)
-0.0340 | 0.0563 | 0.1881 | 0.3031 | 0.4006 | 0.5244 | 0.6182 | 0.7950 | 0.9671 | 1.1579 | 1.5730
SVS m | 7.201 | 8.099 | 4.423 | 1.097 | 0.692 | 0.513 | 0.512 | 0.424 | 0.439 | 0.342 | 0.319
SS m | 0.00 | 0.00 | 2.39 | 4.68 | 4.55 | 4.25 | 3.89 | 4.02 | 4.17 | 4.18 | 3.95
SD m | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000
WETTED PERIMETER WIDTH (m) | 7 | 8.796 | 9.353 | 9.620 | 9.901 | 10.092 | 10.236 | 10.590 | 10.974 | 11.297 | 11.626
HABITAT STRESS: RHEOPHILIC | 10.00 | 9.07 | 6.68 | 4.89 | 3.79 | 2.76 | 2.17 | 1.67 | 1.51 | 0.96 | 0.00


DISCHARGE (cumec)
NATURAL
PRESENT
HN34 EWR2_B
Sc1 EWR Ch269
HN34 EWR2 Sc1



	0.1%	1.0%	5.0%	10.0%	15.0%	20.0%	30.0%	40.0%	50.0%	60.0%	70.0%	80.0%	85.0%	90.0%	95.0%	99.0%	99.9%
NATURAL	2.982	2.701	1.881	1.682	1.659	1.614	1.509	1.447	1.362	1.283	1.208	1.071	0.916	0.771	0.694	0.273	0.000
PRESENT	9.907	9.579	6.842	5.314	4.770	4.571	3.683	3.393	3.051	2.817	2.613	1.984	1.870	1.672	1.528	1.227	1.124
HN34 EWR2_B	4.373	3.560	2.459	2.095	1.958	1.913	1.868	1.851	1.834	1.828	1.823	1.821	1.819	1.819	1.819	1.819	1.819
Sc1 EWR Ch269	9.860	9.080	6.175	4.197	3.938	3.762	2.911	2.784	2.426	1.834	1.825	1.821	1.821	1.821	1.821	1.821	1.821
HN34 EWR2 Sc1	9.852	9.084	6.172	4.202	3.935	3.766	2.914	2.784	2.429	1.834	1.825	1.821	1.821	1.778	1.663	1.329	1.318

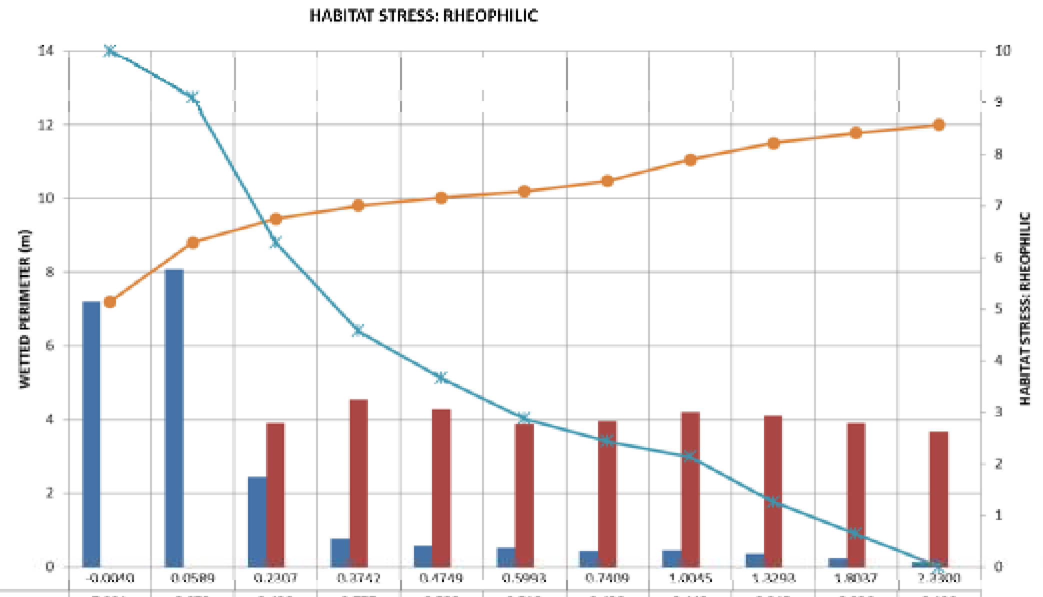
STRESS DURATION



DISCHARGE (CUMEC)	-0.0040	0.0689	0.2202	0.3742	0.4749	0.5993	0.7409	1.0045	1.3293	1.8037	2.3300
FVS (m of perimeter)	0.0	0.736	1.134	0.634	0.601	0.612	0.629	0.553	0.547	0.353	0.240
FS (m of perimeter))	0.0	0.000	1.894	3.795	4.573	5.198	3.182	0.664	0.690	0.589	0.600
FINT (m of perimeter)	0.0	0.000	0.000	0.000	0.000	0.000	2.355	5.199	2.971	0.728	0.720
FD (m of perimeter)	0.0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	2.922	5.966	6.600
WETTED PERIMETER WIDTH (m)	7	8.809	9.460	9.808	10.021	10.199	10.482	11.061	11.500	11.782	12.000
HABITAT STRESS: RHEOPHILIC	10.00	9.10	6.29	4.57	3.66	2.88	2.44	2.14	1.26	0.64	0.00

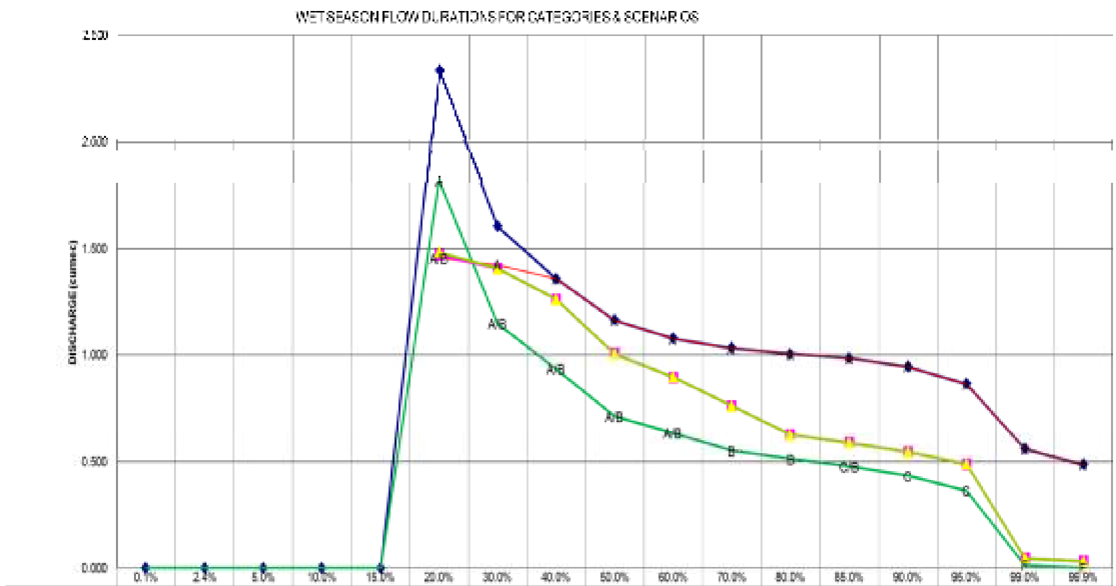
<u>WET SEASON (FEBRUARY)</u>

Max natural low flow = 2.3300 cumec

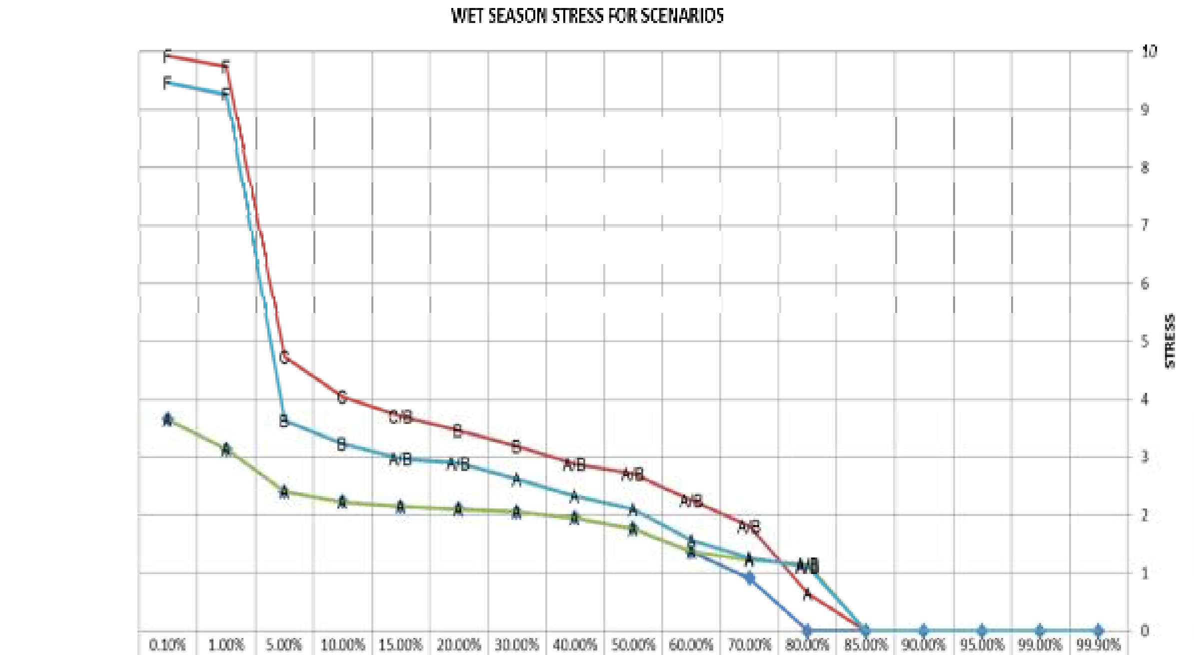


	-0.0040	0.0589	0.2207	0.3742	0.4749	0.5993	0.7409	1.0045	1.3293	1.8037	2.2300
SVS m	7.201	8.073	2.438	0.777	0.580	0.510	0.438	0.442	0.345	0.236	0.120
SS m	0.00	0.00	3.90	4.56	4.29	3.88	3.96	4.20	4.11	3.91	3.68
SD m	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WETTED PERIMETER WIDTH (m)	7	8.809	9.460	9.808	10.021	10.199	10.482	11.061	11.500	11.782	12.000
HABITAT STRESS: RHEOPHILIC	10.00	9.10	6.29	4.57	3.66	2.88	2.44	2.14	1.26	0.64	0.00

DISCHARGE(CUMEC)



	0.1%	2.4%	5.0%	10.0%	15.0%	20.0%	30.0%	40.0%	50.0%	60.0%	70.0%	80.0%	85.0%	90.0%	95.0%	99.0%	99.9%
NATURAL	0.000	0.000	0.000	0.000	0.000	2.330	1.604	1.359	1.164	1.077	1.032	1.005	0.987	0.946	0.865	0.580	0.487
PRESENT	0.000	0.000	0.000	0.000	0.000	1.818	1.149	0.936	0.713	0.635	0.552	0.514	0.479	0.433	0.364	0.014	0.001
HN34 EWR2_B						1.458	1.424	1.359	1.164	1.077	1.032	1.005	0.987	0.946	0.865	0.580	0.487
Sc1 EWR Ch269						1.4700	1.4070	1.2620	1.0070	0.8970	0.7620	0.6260	0.5890	0.5460	0.4890	0.0470	0.0330
HN34 EWR2 Sc1						1.4820	1.4066	1.2624	1.0070	0.8972	0.7615	0.6260	0.5894	0.5463	0.4881	0.0466	0.0326



	0.10%	1.00%	5.00%	10.00%	15.00%	20.00%	30.00%	40.00%	50.00%	60.00%	70.00%	80.00%	85.00%	90.00%	95.00%	99.00%	99.90%
NATURAL	3.652	3.140	2.401	2.230	2.144	2.106	2.050	1.955	1.771	1.360	0.907	0.000	0.000	0.000	0.000	0.000	0.000
PRESENT	9.928	9.739	4.741	4.043	3.708	3.462	3.196	2.884	2.720	2.252	1.803	0.640	0.000	0.000	0.000	0.000	0.000
HN34 EWR2_B	3.652	3.140	2.401	2.230	2.144	2.106	2.050	1.955	1.771	1.360	1.223	1.155	0.000	0.000	0.000	0.000	0.000
Sc1 EWR Ch269	9.463	9.260	3.638	3.238	2.981	2.903	2.617	2.334	2.102	1.565	1.259	1.126	0.000	0.000	0.000	0.000	0.000
HN34 EWR2 Sc1	9.470	9.264	3.637	3.236	2.980	2.903	2.618	2.333	2.102	1.564	1.259	1.100	0.000	0.000	0.000	0.000	0.000

STRESS DURATION

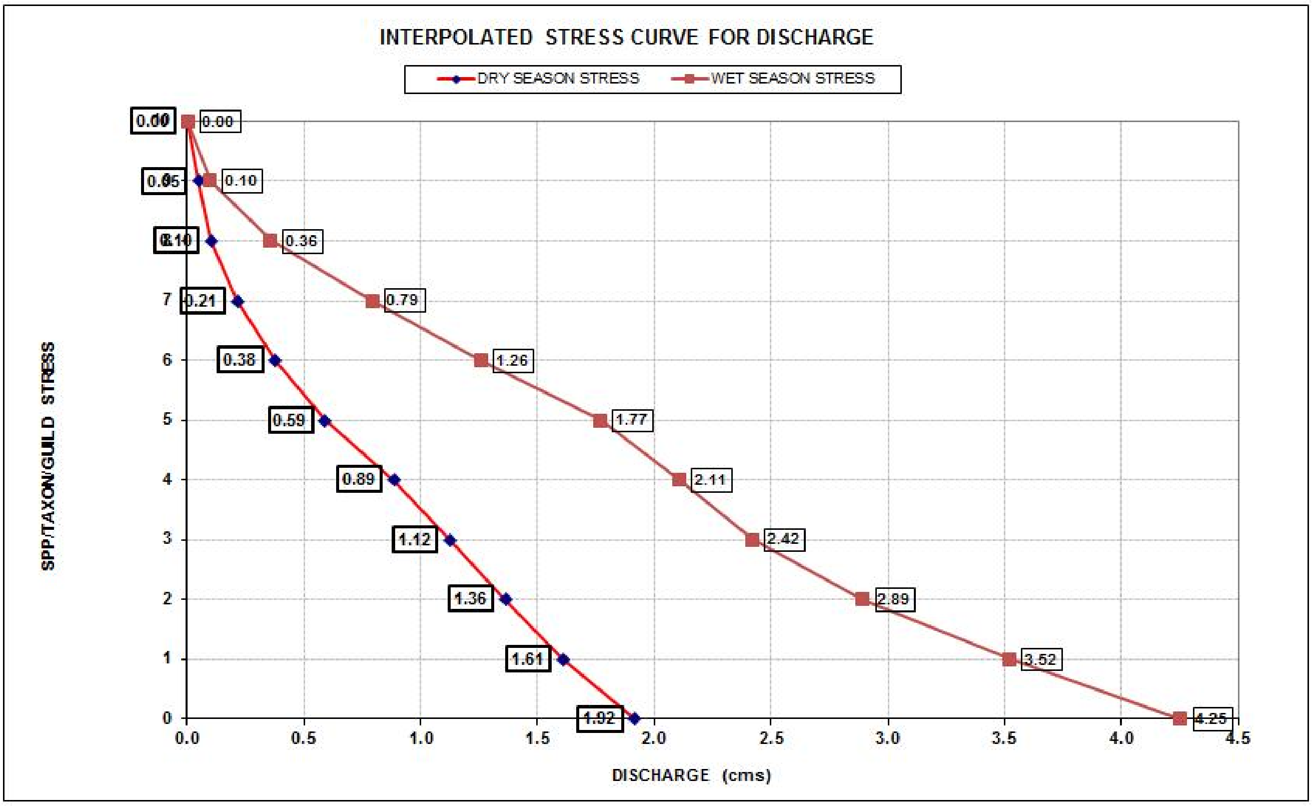
Marico EWR 3: Marico Bosveld Dam

	Natural	Present	HN40 EWR3_CD	HN40 EWR3_C	HN40 Sc1	HN40 Sc3
Fish dry		F	C	C/B	C	C
Fish wet		E/F	A	A	A/B	B
Fish integrated		F	B	A/B	C/B	C/B
Recommendation						

Comments:

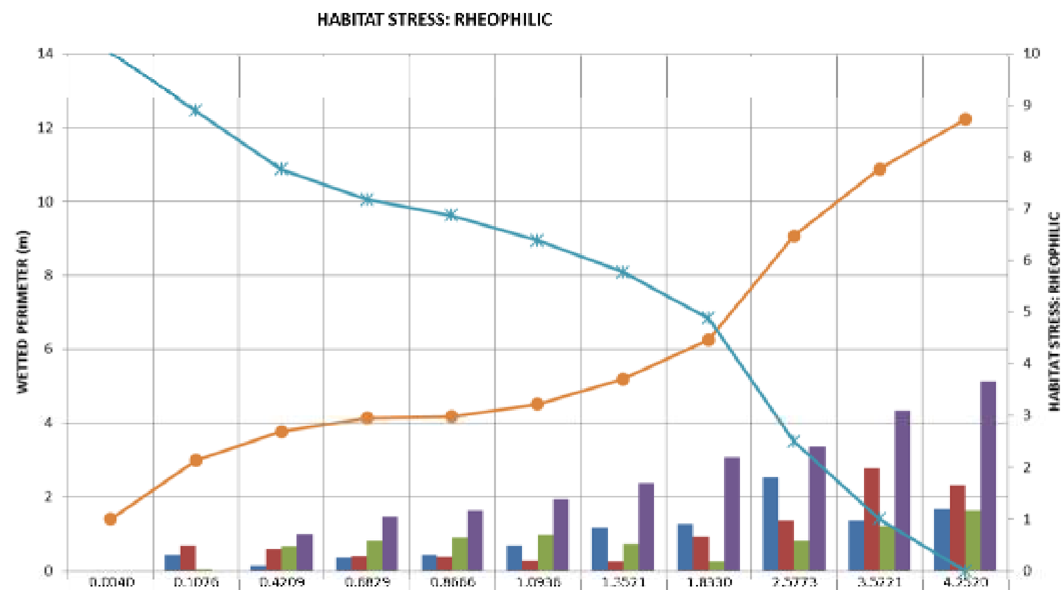
1. Under natural conditions the hydrology indicates that the river is perennial at the site.
2. Rheophilics have not been recorded at the site but are present just upstream from the dam. However, it can be reasonably assumed that rheophilics (Chiloglanis pretoriae and Amphilius uranscopus) would have occurred at the site under natural conditions as suitable hard substrates are available that would have provided habitat for these species given suitable flows.
3. The FFHA were set for all fast flow classes (FVS, FS, FI, FD) for the dry and wet season.

Dry-wet stress profiles:



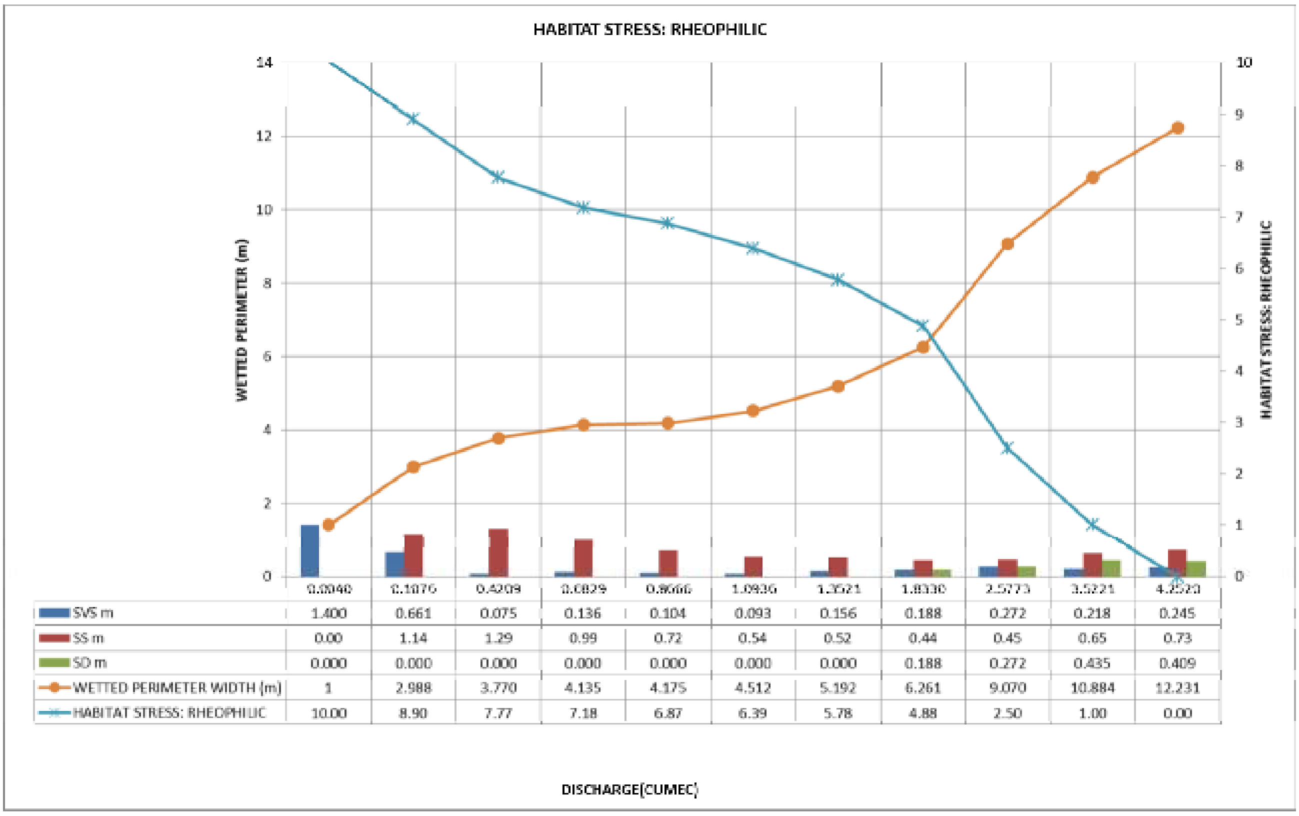
<u>DRY SEASON (SEPTEMBER)</u>

Max natural low flow = 1.9150 cumec

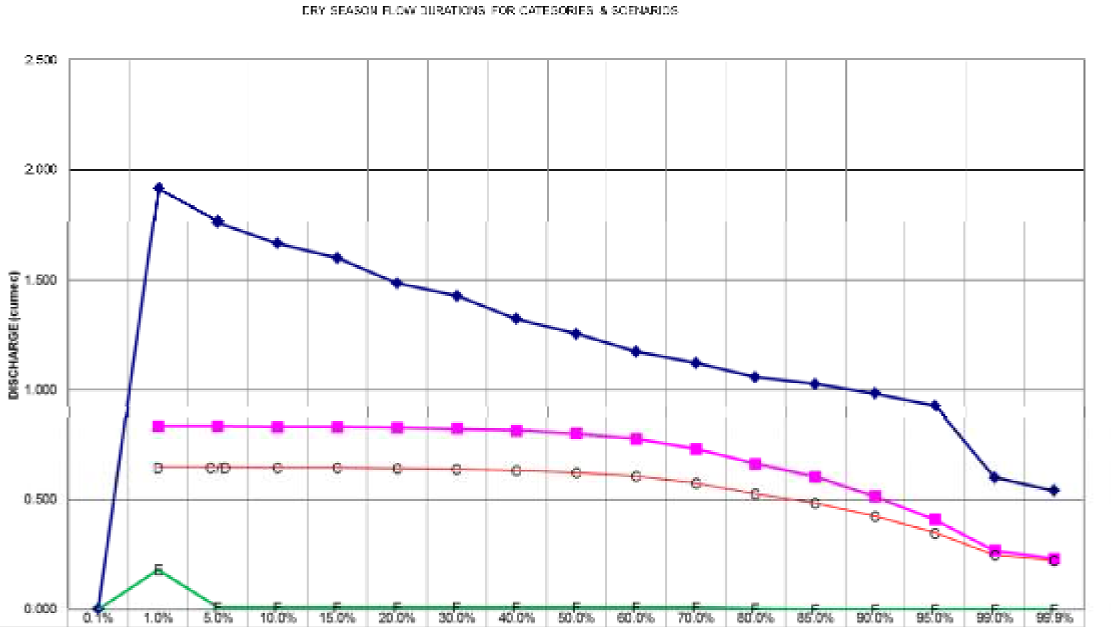


	0.0040	0.1026	0.4209	0.6829	0.8666	1.0936	1.3521	1.8330	2.5773	3.5221	4.2520
FVS (m of perimeter)	0.0	0.441	0.139	0.363	0.450	0.688	1.170	1.276	2.522	1.358	1.670
FS (m of perimeter))	0.0	0.687	0.588	0.399	0.386	0.268	0.260	0.915	1.367	2.778	2.324
FINT (m of perimeter]	0.0	0.053	0.679	0.818	0.909	0.987	0.731	0.250	0.816	1.215	1.632
FD (m of perimeter)	0.0	0.000	0.995	1.455	1.619	1.940	2.384	3.068	3.368	4.336	5.137
WETTED PERIMETER WIDTH (m)	1	2.988	3.770	4.135	4.175	4.512	5.192	6.261	9.070	10.884	12.231
HABITAT STRESS: RHEOPHILIC	10.00	8.90	7.77	7.18	6.87	6.39	5.78	4.88	2.50	1.00	0.00

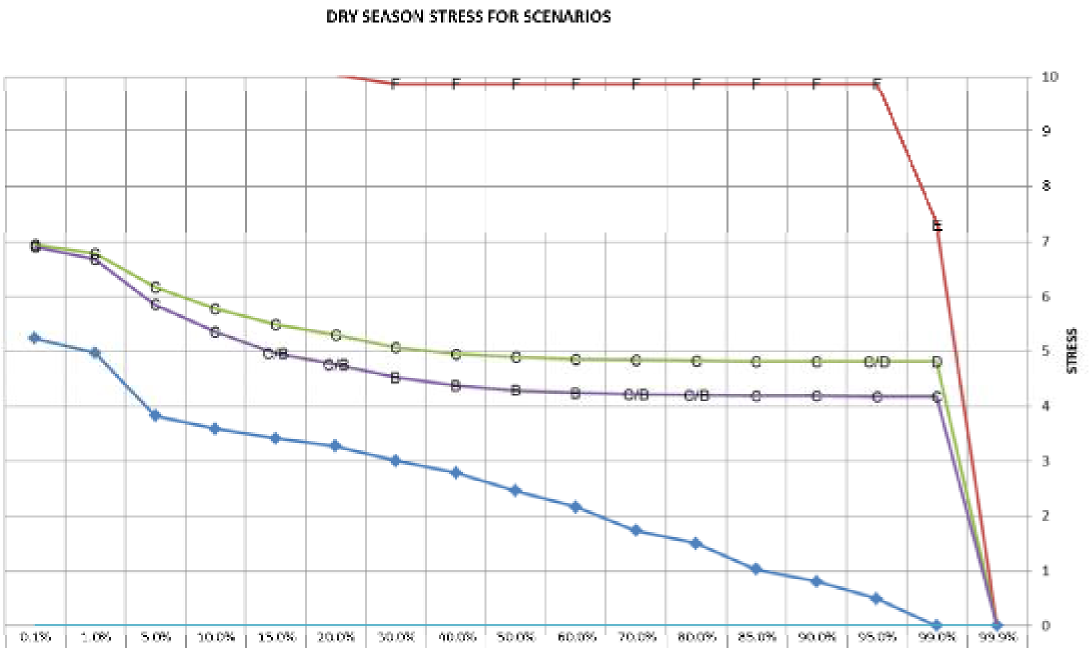
DISCHARGE(CUMEC)



	0.0040	0.1876	0.4209	0.6829	0.8666	1.0936	1.3521	1.8330	2.5773	3.5221	4.2523
SVS m	1.400	0.661	0.075	0.136	0.104	0.093	0.156	0.188	0.272	0.218	0.245
SS m	0.00	1.14	1.29	0.99	0.72	0.54	0.52	0.44	0.45	0.65	0.73
SD m	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.188	0.272	0.435	0.409
WETTED PERIMETER WIDTH (m)	1	2.988	3.770	4.135	4.175	4.512	5.192	6.261	9.070	10.884	12.231
HABITAT STRESS: RHEOPHILIC	10.00	8.90	7.77	7.18	6.87	6.39	5.78	4.88	2.50	1.00	0.00

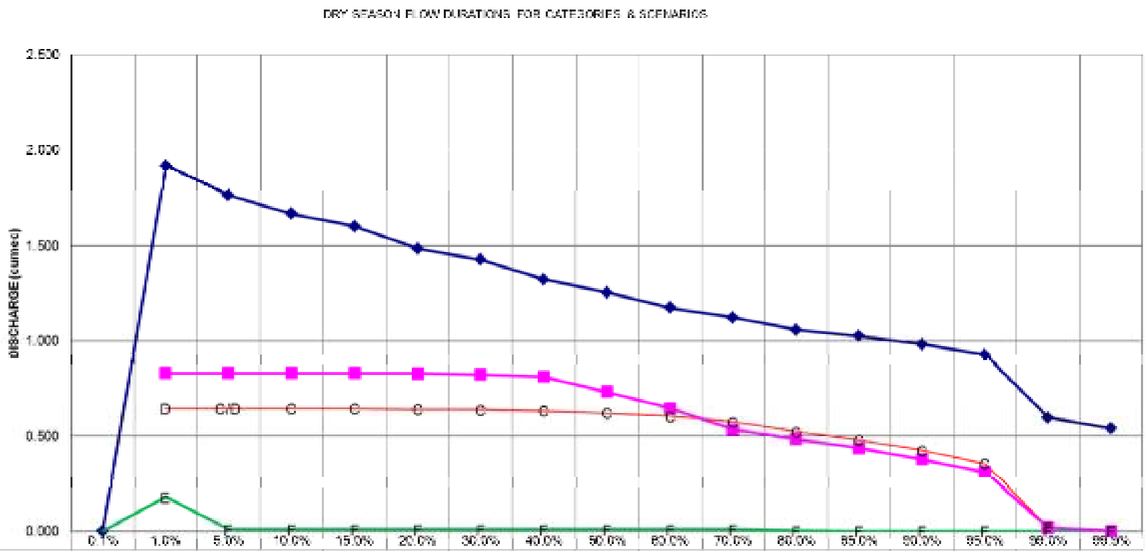


	0.1%	1.0%	5.0%	10.0%	15.0%	20.0%	30.0%	40.0%	50.0%	60.0%	70.0%	80.0%	85.0%	90.0%	95.0%	99.0%	99.9%
NATURAL	0.000	1.915	1.763	1.667	1.601	1.486	1.427	1.323	1.264	1.174	1.122	1.059	1.026	0.983	0.926	0.599	0.539
PRESENT	0.000	0.180	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.002	0.000	0.000	0.000	0.000	0.000
HN40 EWR3_CD		0.647	0.647	0.645	0.645	0.643	0.639	0.633	0.623	0.606	0.576	0.527	0.486	0.423	0.348	0.248	0.222
HN40 EWR3_C		0.8330	0.8330	0.8310	0.8300	0.8270	0.8220	0.8140	0.8000	0.7750	0.7300	0.6830	0.6030	0.5140	0.4080	0.2680	0.2290

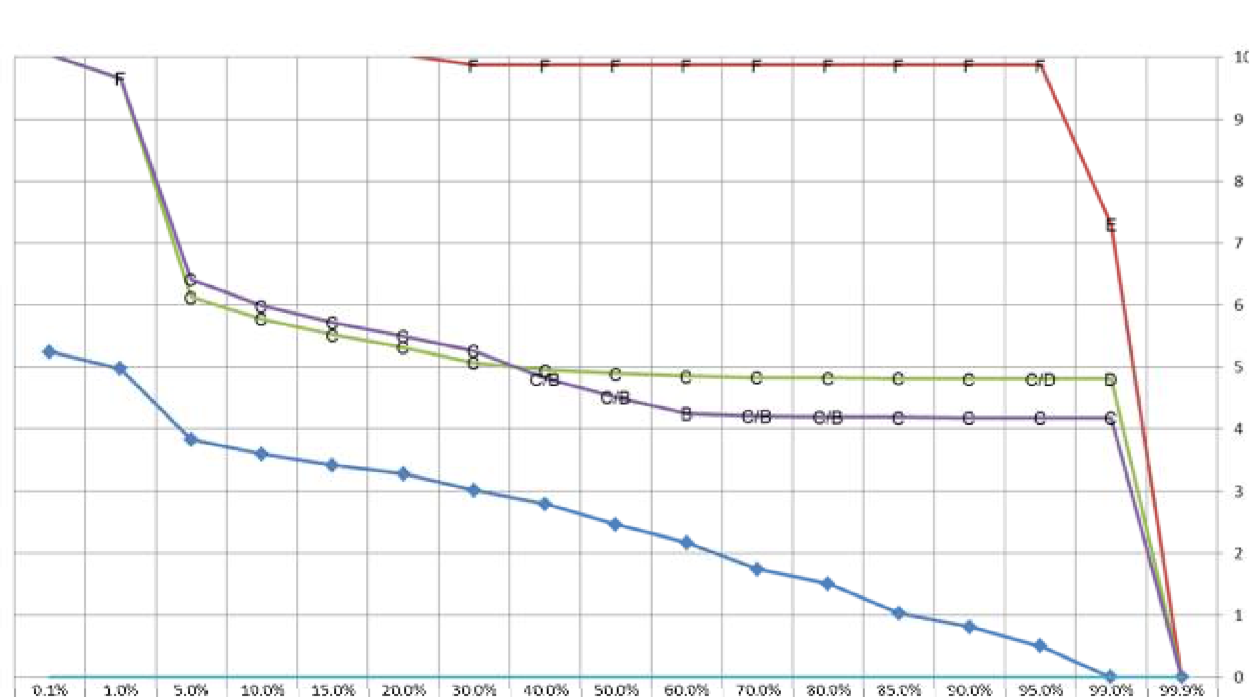


	0.1%	1.0%	5.0%	10.0%	15.0%	20.0%	30.0%	40.0%	50.0%	60.0%	70.0%	80.0%	85.0%	90.0%	95.0%	99.0%	99.9%
NATURAL	5.242	4.974	3.831	3.592	3.412	3.274	3.010	2.791	2.455	2.165	1.737	1.501	1.031	0.809	0.496	0.000	0.000
PRESENT	10.087	10.087	10.087	10.087	10.087	10.043	9.870	9.870	9.870	9.870	9.870	9.870	9.870	9.870	9.870	7.298	0.000
HN40 EWR3_CD	6.946	6.787	6.171	5.781	5.493	5.298	5.075	4.950	4.892	4.858	4.838	4.824	4.817	4.817	4.810	4.810	0.000
HN40 EWR3_C	6.903	6.676	5.851	5.359	4.960	4.756	4.528	4.376	4.291	4.243	4.216	4.199	4.189	4.185	4.179	4.179	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

STRESS DURATION



	0.1%	1.0%	5.0%	10.0%	15.0%	20.0%	30.0%	40.0%	50.0%	60.0%	70.0%	80.0%	85.0%	90.0%	95.0%	99.0%	99.9%
NATURAL	0.000	1.915	1.763	1.667	1.601	1.485	1.427	1.323	1.254	1.174	1.122	1.059	1.026	0.983	0.926	0.599	0.539
PRESENT	0.000	0.180	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.002	0.000	0.000	0.000	0.000	0.000
HN40 Sc1		0.646	0.646	0.646	0.645	0.642	0.640	0.634	0.622	0.605	0.576	0.523	0.479	0.424	0.365	0.020	0.002
HN40 Sc3		0.6310	0.8310	0.8310	0.8300	0.8280	0.8230	0.8120	0.7330	0.6470	0.5340	0.4830	0.4360	0.3780	0.3090	0.0200	0.0020

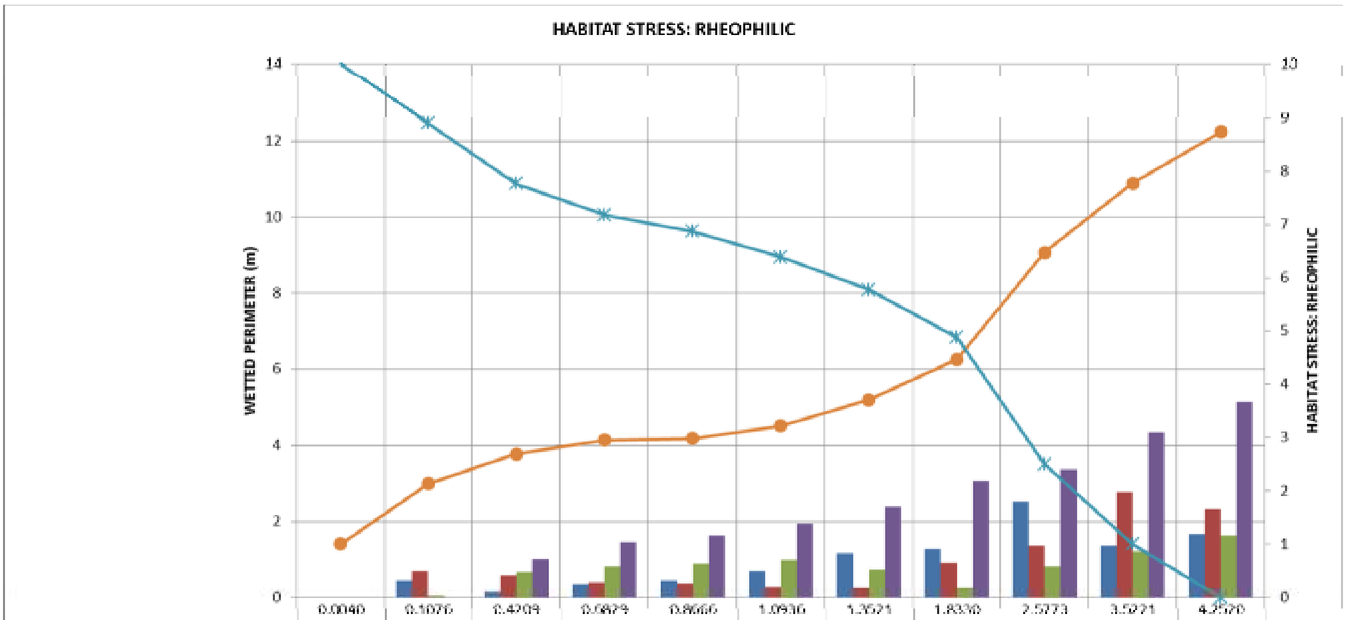


	0.1%	1.0%	5.0%	10.0%	15.0%	20.0%	30.0%	40.0%	50.0%	60.0%	70.0%	80.0%	85.0%	90.0%	95.0%	99.0%	99.9%
NATURAL	5.242	4.974	3.831	3.592	3.412	3.274	3.010	2.791	2.455	2.165	1.737	1.501	1.031	0.809	0.496	0.000	0.000
PRESENT	10.087	10.087	10.087	10.087	10.087	10.043	9.870	9.870	9.870	9.870	9.870	9.870	9.870	9.870	9.870	7.298	0.000
HN40 Sc1	10.043	9.654	6.128	5.776	5.521	5.317	5.071	4.953	4.895	4.855	4.834	4.827	4.817	4.814	4.814	4.814	0.000
HN40 Sc3	10.043	9.654	6.411	5.990	5.721	5.502	5.266	4.810	4.518	4.250	4.212	4.196	4.189	4.185	4.185	4.185	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

STRESS DURATION

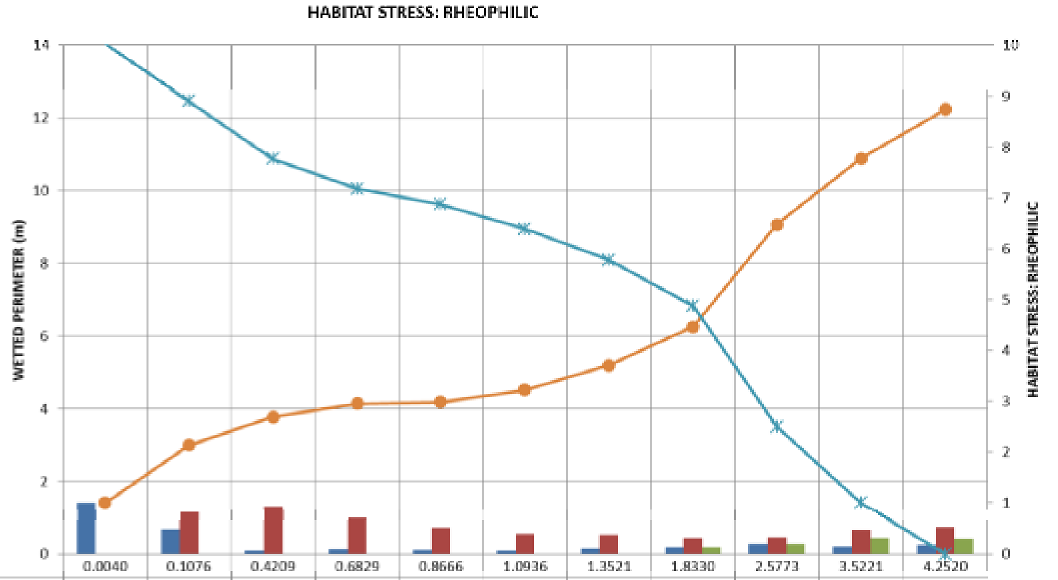
WET SEASON (FEBRUARY)

Max natural low flow = 4.2520 cumec



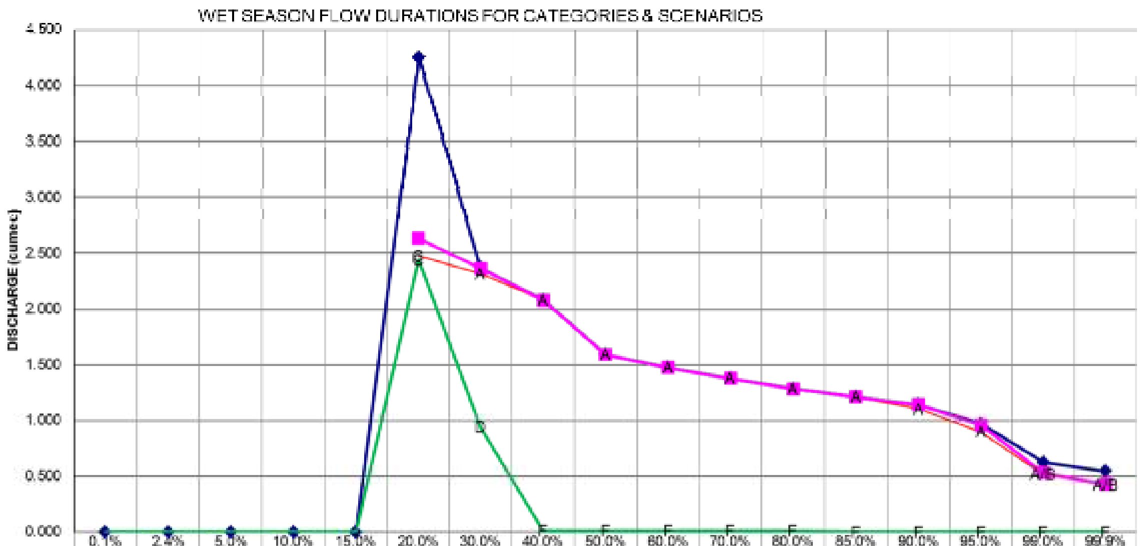
	0.0040	0.1076	0.4209	0.6829	0.8666	1.0936	1.3521	1.8330	2.5773	3.5221	4.2520
FVS (m of perimeter)	0.0	0.441	0.139	0.363	0.450	0.688	1.170	1.276	2.522	1.358	1.670
FS (m of perimeter))	0.0	0.687	0.588	0.399	0.386	0.268	0.260	0.915	1.367	2.778	2.324
FINT (m of perimeter)	0.0	0.053	0.679	0.818	0.909	0.987	0.731	0.250	0.816	1.215	1.632
FD (m of perimeter)	0.0	0.000	0.995	1.455	1.619	1.940	2.384	3.068	3.368	4.336	5.137
WETTED PERIMETER WIDTH (m)	1	2.988	3.770	4.135	4.175	4.512	5.192	6.261	9.070	10.884	12.231
HABITAT STRESS: RHEOPHILIC	10.00	8.90	7.77	7.18	6.87	6.39	5.78	4.88	2.50	1.00	0.00

DISCHARGE(CUMEC)

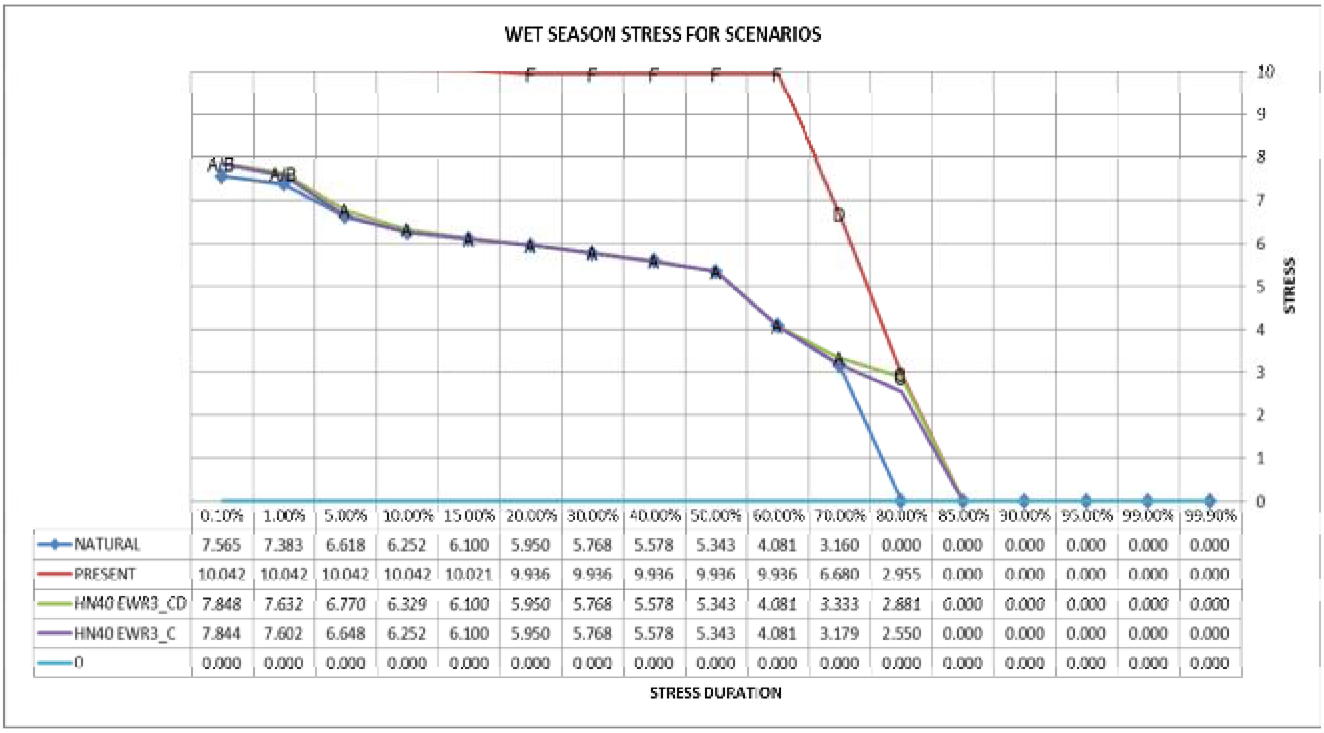


	0.0040	0.1076	0.4209	0.6829	0.8666	1.0936	1.3521	1.8330	2.5773	3.5221	4.2520
SVS m	1.400	0.661	0.075	0.136	0.104	0.093	0.156	0.188	0.272	0.218	0.245
SS m	0.00	1.14	1.29	0.99	0.72	0.54	0.52	0.44	0.45	0.65	0.73
SD m	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.188	0.272	0.435	0.409
WETTED PERIMETER WIDTH (m)	1	2.988	3.770	4.135	4.175	4.512	5.192	6.261	9.070	10.884	12.231
HABITAT STRESS: RHEOPHILIC	10.00	8.90	7.77	7.18	6.87	6.39	5.78	4.88	2.50	1.00	0.00

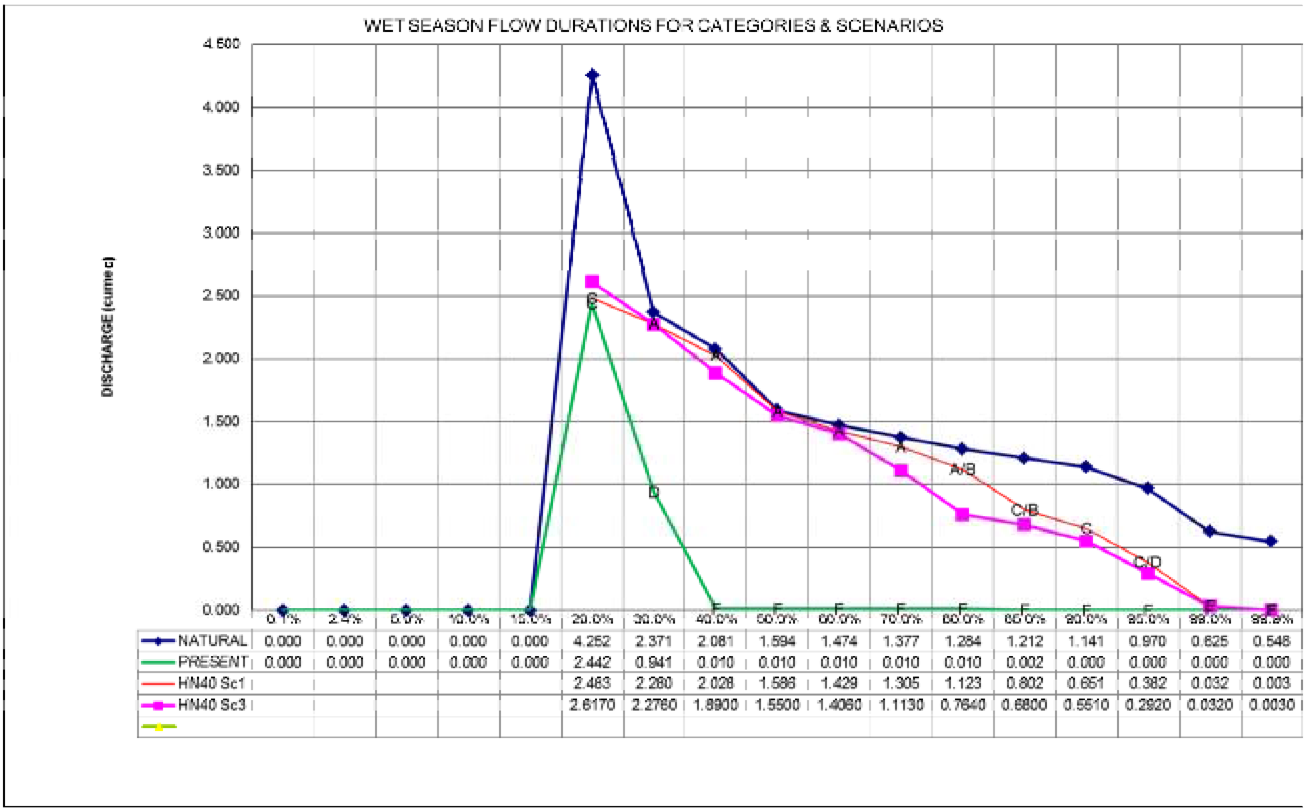
DISCHARGE(CUMEC)



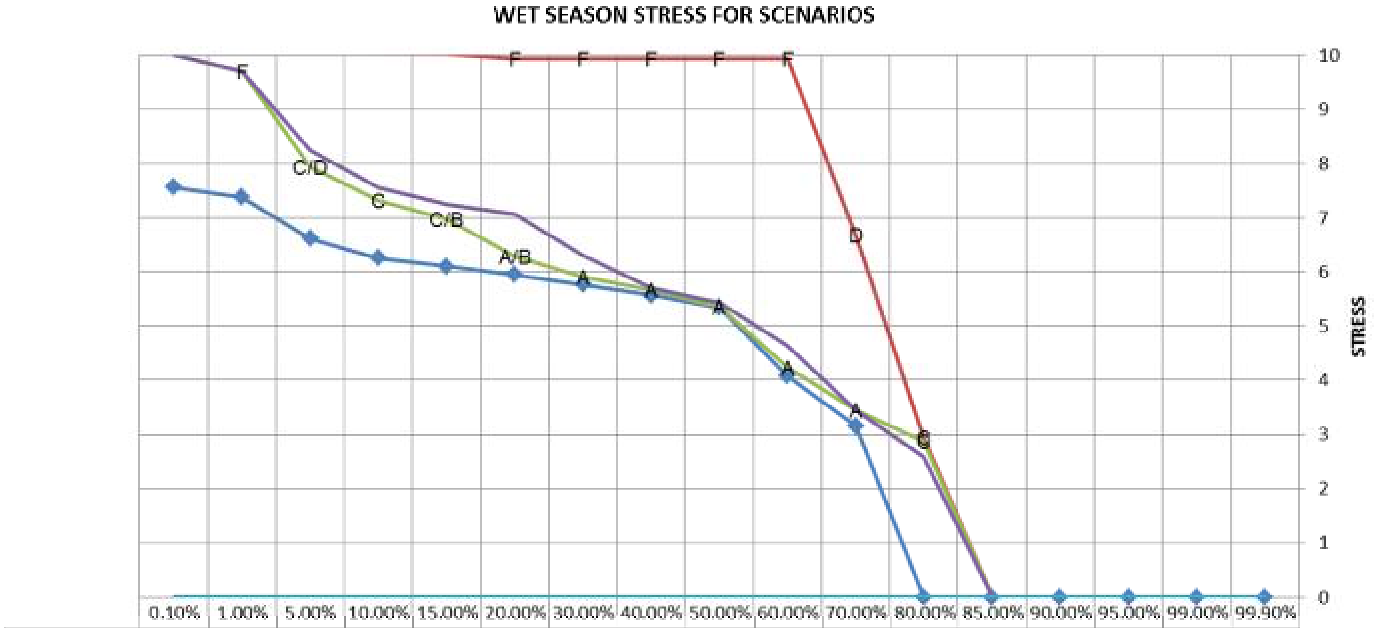
	0.1%	2.4%	5.0%	10.0%	15.0%	20.0%	30.0%	40.0%	50.0%	60.0%	70.0%	80.0%	85.0%	90.0%	95.0%	99.0%	99.9%
NATURAL	0.000	0.000	0.000	0.000	0.000	4.252	2.371	2.081	1.594	1.474	1.377	1.284	1.212	1.141	0.970	0.626	0.546
PRESENT	0.000	0.000	0.000	0.000	0.000	2.442	0.941	0.010	0.010	0.010	0.010	0.010	0.002	0.000	0.000	0.000	0.000
HN40 EWR3_CD						2.477	2.317	2.081	1.594	1.474	1.377	1.284	1.212	1.105	0.899	0.517	0.423
HN40 EWR3_C						2.6330	2.3650	2.0810	1.5940	1.4740	1.3770	1.2840	1.2120	1.1410	0.9680	0.5300	0.4250



	0.10%	1.00%	5.00%	10.00%	15.00%	20.00%	30.00%	40.00%	50.00%	60.00%	70.00%	80.00%	85.00%	90.00%	95.00%	99.00%	99.90%
NATURAL	7.565	7.383	6.618	6.252	6.100	5.950	5.768	5.578	5.343	4.081	3.160	0.000	0.000	0.000	0.000	0.000	0.000
PRESENT	10.042	10.042	10.042	10.042	10.021	9.936	9.936	9.936	9.936	9.936	6.680	2.955	0.000	0.000	0.000	0.000	0.000
HN40 EWR3_CD	7.848	7.632	6.770	6.329	6.100	5.950	5.768	5.578	5.343	4.081	3.333	2.681	0.000	0.000	0.000	0.000	0.000
HN40 EWR3_C	7.844	7.602	6.648	6.252	6.100	5.950	5.768	5.578	5.343	4.081	3.179	2.550	0.000	0.000	0.000	0.000	0.000
0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000



	0.1%	[illegible]	5.0%	10.0%	15.0%	20.0%	30.0%	40.0%	50.0%	60.0%	70.0%	80.0%	85.0%	90.0%	95.0%	99.0%	99.9%
NATURAL	0.000	0.000	0.000	0.000	0.000	4.252	2.371	2.081	1.594	1.474	1.377	1.284	1.212	1.141	0.970	0.625	0.548
PRESENT	0.000	0.000	0.000	0.000	0.000	2.442	0.941	0.010	0.010	0.010	0.010	0.010	0.002	0.000	0.000	0.000	0.000
HN40 Sc1						2.463	2.280	2.028	1.586	1.429	1.305	1.123	0.802	0.651	0.382	0.032	0.003
HN40 Sc3						2.6170	2.2760	1.8900	1.5500	1.4060	1.1130	0.7640	0.6800	0.5510	0.2920	0.0320	0.0030



	0.10%	1.00%	5.00%	10.00%	15.00%	20.00%	30.00%	40.00%	50.00%	60.00%	70.00%	80.00%	85.00%	90.00%	95.00%	99.00%	99.90%
NATURAL	7.565	7.383	6.618	6.252	6.100	5.950	5.768	5.578	5.343	4.081	3.160	0.000	0.000	0.000	0.000	0.000	0.000
PRESENT	10.042	10.042	10.042	10.042	10.021	9.936	9.936	9.936	9.936	9.936	6.680	2.955	0.000	0.000	0.000	0.000	0.000
HN40 Sc1	10.011	9.703	7.943	7.323	6.977	6.290	5.909	5.666	5.358	4.237	3.451	2.868	0.000	0.000	0.000	0.000	0.000
HN40 Sc3	10.011	9.703	8.252	7.554	7.257	7.063	6.312	5.711	5.429	4.643	3.464	2.584	0.000	0.000	0.000	0.000	0.000
0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

STRESS DURATION

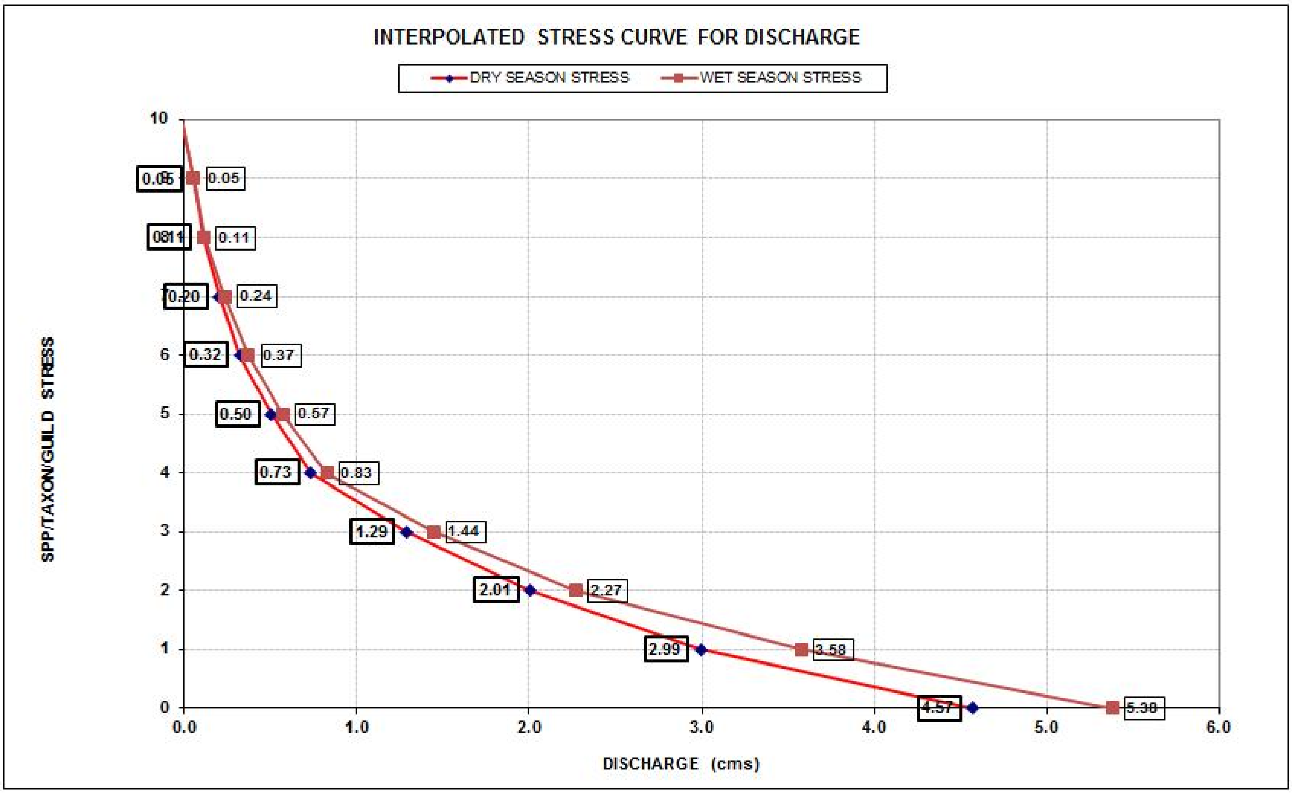
Marico EWR 4: Marico Tswasa weir

	Natural	PRESENT	HN41 EWR4_C	HN41 Sc1
Fish dry		F	C	C
Fish wet		F	C	C
Fish integrated		F	C	C
Recommendation				

<u>Comments:</u>

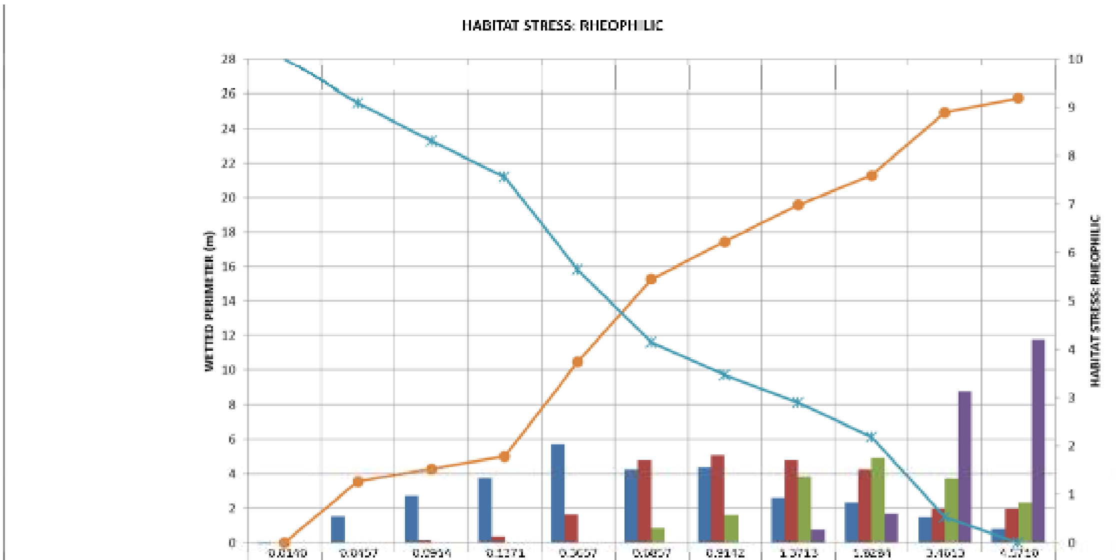
1. Under natural conditions the hydrology indicates that the river is perennial at the site.
2. Rheophilics does not occur at the site. Semirheophilics (e.g. Labeobarbus marequensis and Labeo molybdinus)are present.
3. During droughts, FVS and FS habitats are present. Consequently the FFHA were set for all fast flow classes (FVS, FS, FI, FD) for the dry and wet season.

Dry-wet stress profiles:

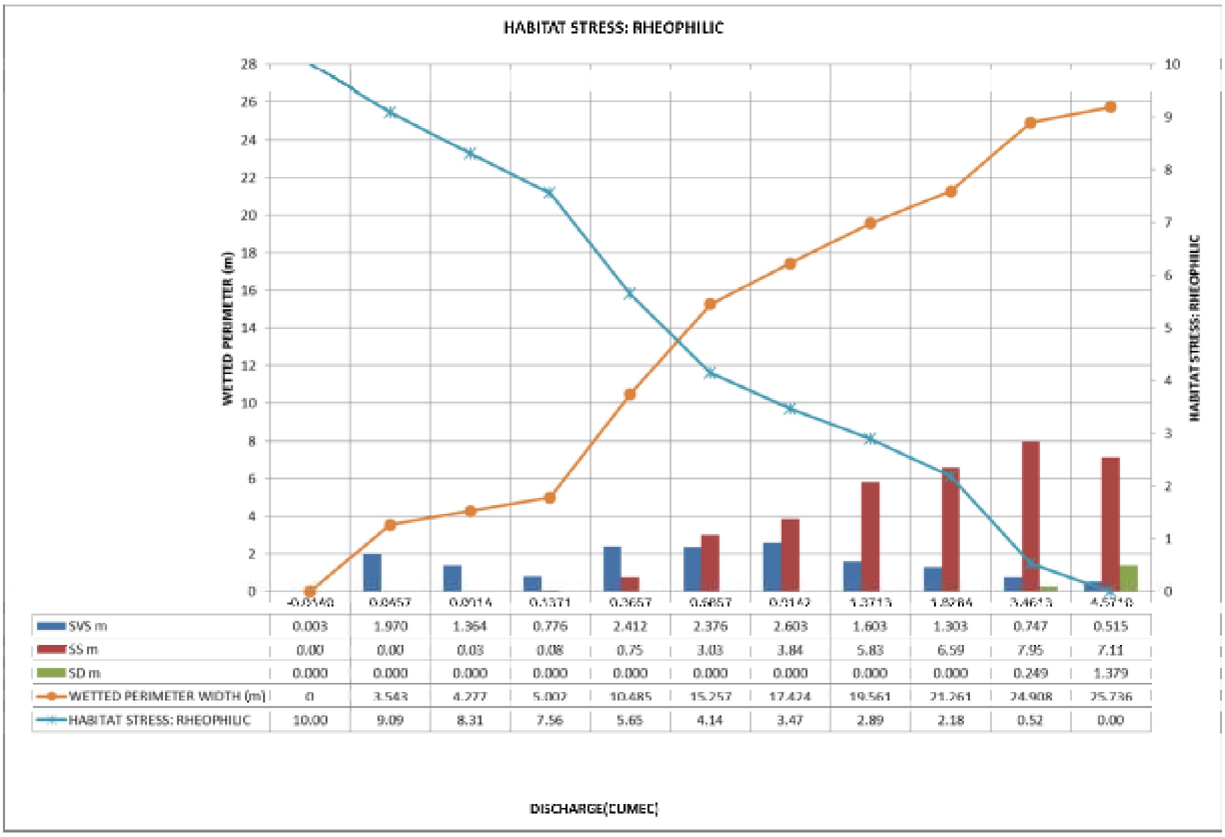


DRY SEASON (SEPTEMBER)

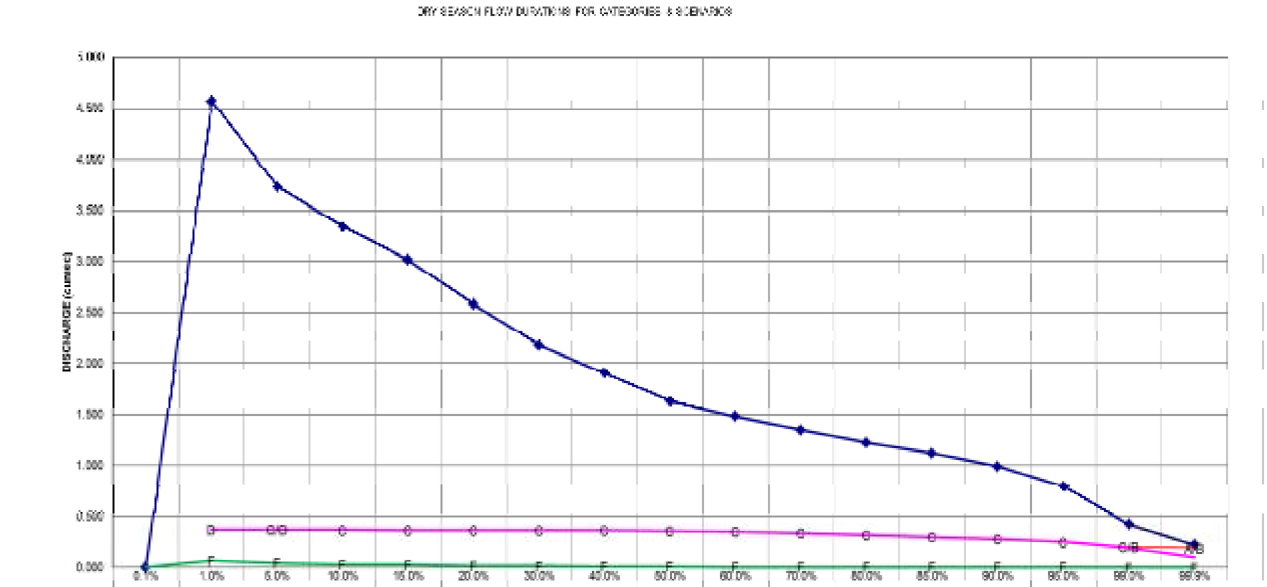
Max natural low flow = 4.5710 cumec



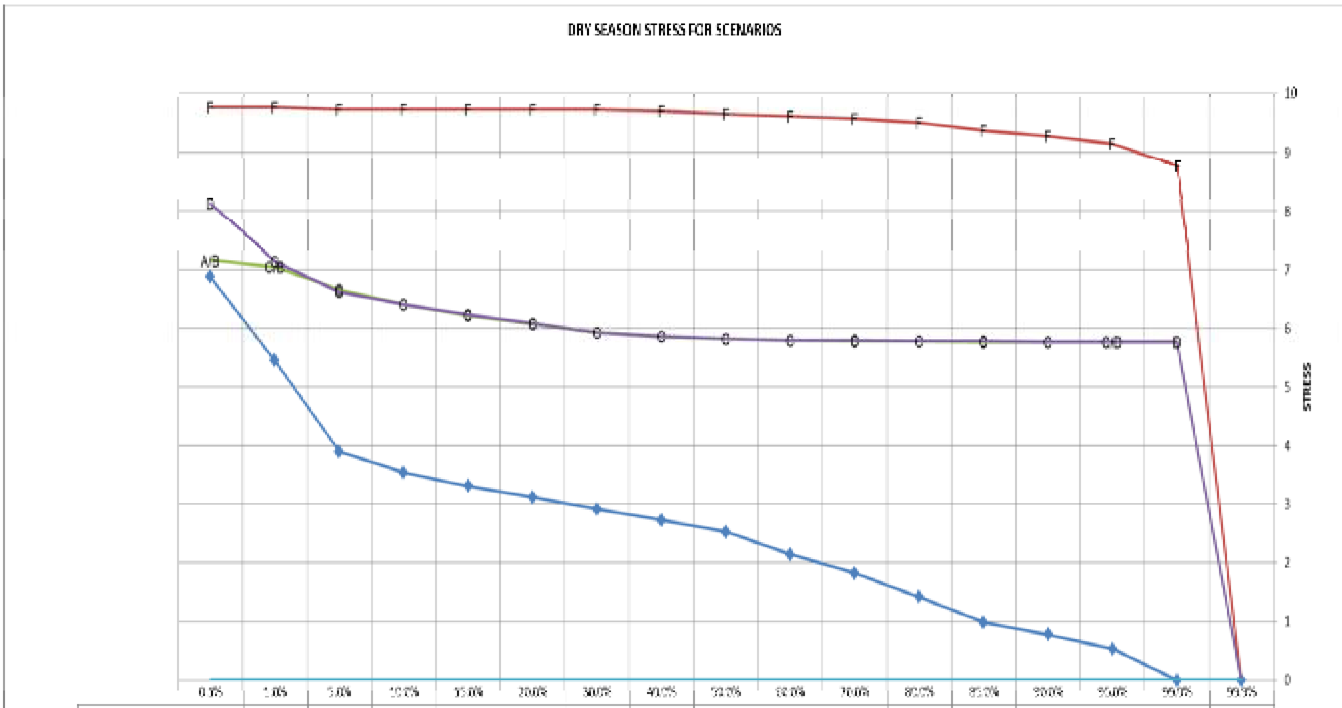
	0.0140	0.0157	0.0914	0.1271	0.3657	0.6857	0.9142	1.3713	1.8284	3.4613	4.5710
FVS (m of perimeter)	0.0	1.531	2.717	3.750	5.692	4.229	4.346	2.600	2.339	1.494	0.772
FS (m of perimeter])	0.0	0.006	0.128	0.351	1.632	4.795	5.053	4.770	4.252	1.993	1.967
FINT (m of perimeter)	0.0	0.000	0.000	0.000	0.000	0.828	1.589	3.818	4.890	3.696	2.316
FD (m of perimeter)	0.0	0.000	0.000	0.000	0.000	0.000	0.000	0.764	1.674	8.758	11.766
WETTED PERIMETER WIDTH (m)	0	3.543	4.277	5.002	10.485	15.257	17.424	19.561	21.261	24.908	25.736
HABITAT STRESS: RHEOPHILIC	10.00	9.09	8.31	7.56	5.65	4.14	3.47	2.80	2.18	0.52	0.00



	-0.0340	0.0457	0.0914	0.1371	0.3657	0.6857	0.9142	1.3713	1.8284	3.4613	4.5718
SVS m	0.003	1.970	1.364	0.776	2.412	2.376	2.603	1.603	1.303	0.747	0.515
SS m	0.00	0.00	0.03	0.08	0.75	3.03	3.84	5.83	6.59	7.95	7.11
SD m	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.249	1.379
WETTED PERIMETER WIDTH (m)	0	3.543	4.277	5.002	10.485	15.257	17.424	19.561	21.261	24.908	25.736
HABITAT STRESS: RHEOPHILIC	10.00	9.09	8.31	7.56	5.65	4.14	3.47	2.89	2.18	0.52	0.00



	0.1%	1.0%	5.0%	10.0%	15.0%	20.0%	30.0%	40.0%	50.0%	60.0%	70.0%	80.0%	85.0%	90.0%	95.0%	99.0%	99.9%
NATURAL	0.000	4.571	3.731	3.344	3.013	2.578	2.179	1.902	1.627	1.480	1.348	1.222	1.118	0.988	0.787	0.422	0.219
PRESENT	0.000	0.065	0.041	0.032	0.026	0.018	0.013	0.011	0.008	0.006	0.003	0.003	0.003	0.003	0.003	0.000	0.000
HN41 EWR4_C		0.365	0.365	0.364	0.364	0.363	0.362	0.359	0.355	0.348	0.336	0.315	0.297	0.274	0.244	0.200	0.169
HN41 Sc1		0.3640	0.3640	0.3640	0.3630	0.3635	0.3610	0.3580	0.3550	0.3470	0.3360	0.3130	0.2960	0.2740	0.2490	0.1910	0.1030

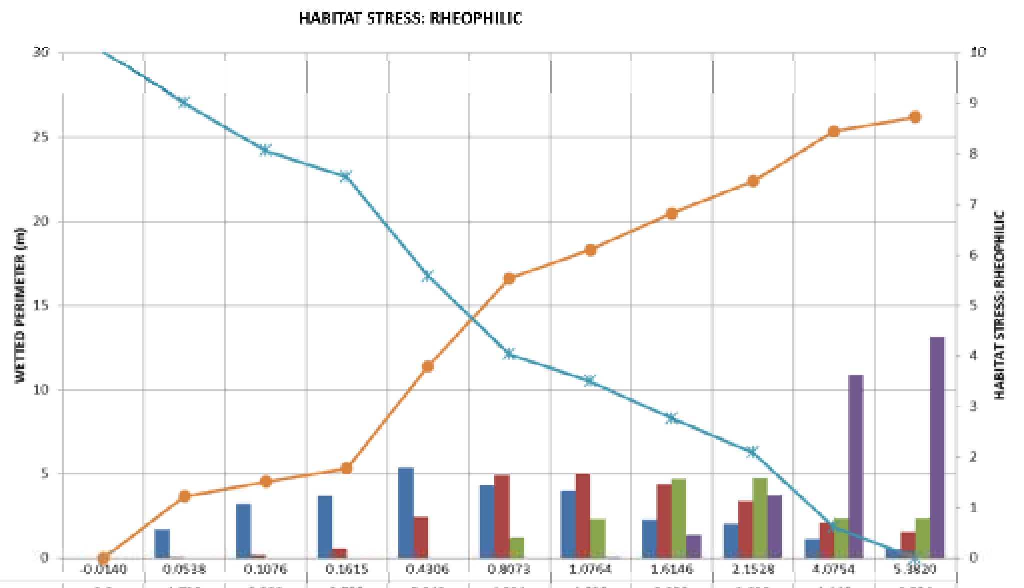


	0.1%	1.0%	5.0%	10.0%	15.0%	20.0%	30.0%	40.0%	50.0%	60.0%	70.0%	80.0%	85.0%	90.0%	95.0%	99.0%	99.9%
NATURAL	6.875	5.451	3.904	3.541	3.306	3.108	2.916	2.732	2.527	2.144	1.824	1.419	0.986	0.777	0.532	0.000	0.000
PRESENT	9.785	9.785	9.738	9.738	9.738	9.738	9.738	9.707	9.661	9.615	9.584	9.506	9.383	9.290	9.151	8.761	0.000
HN41 EWR4_C	7.161	7.044	6.666	6.414	6.221	6.070	5.930	5.863	5.824	5.802	5.785	5.780	5.774	5.774	5.769	5.769	0.000
HN41 Sc1	8.123	7.140	6.624	6.414	6.230	6.087	5.930	5.869	5.824	5.802	5.791	5.780	5.780	5.774	5.774	5.774	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

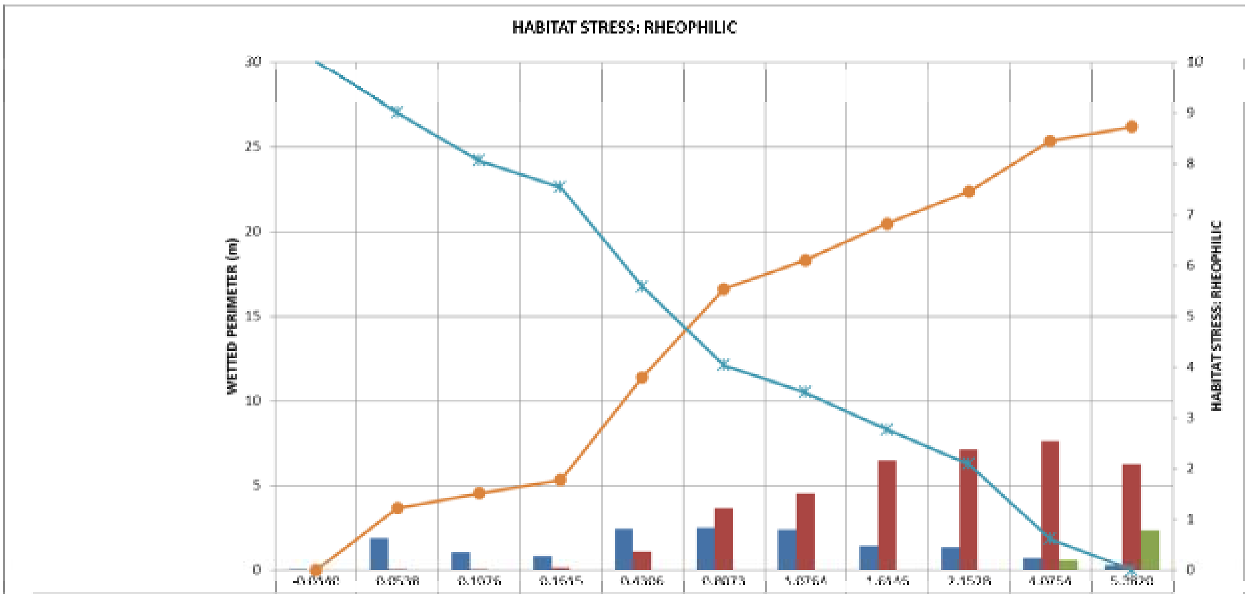
STRESS DURATION

WET SEASON (FEBRUARY)

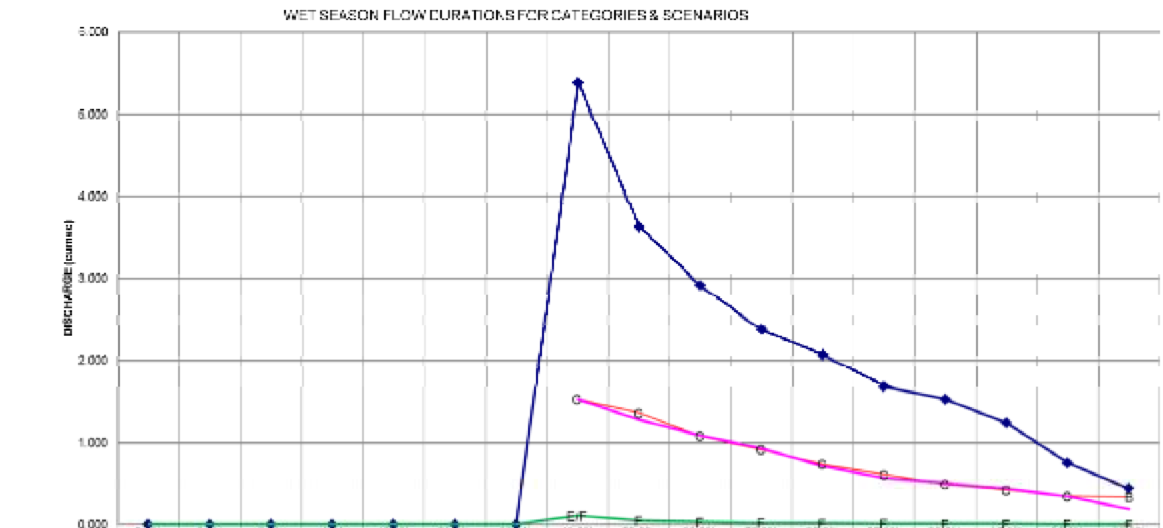
Max natural low flow = 5.3820 cumec



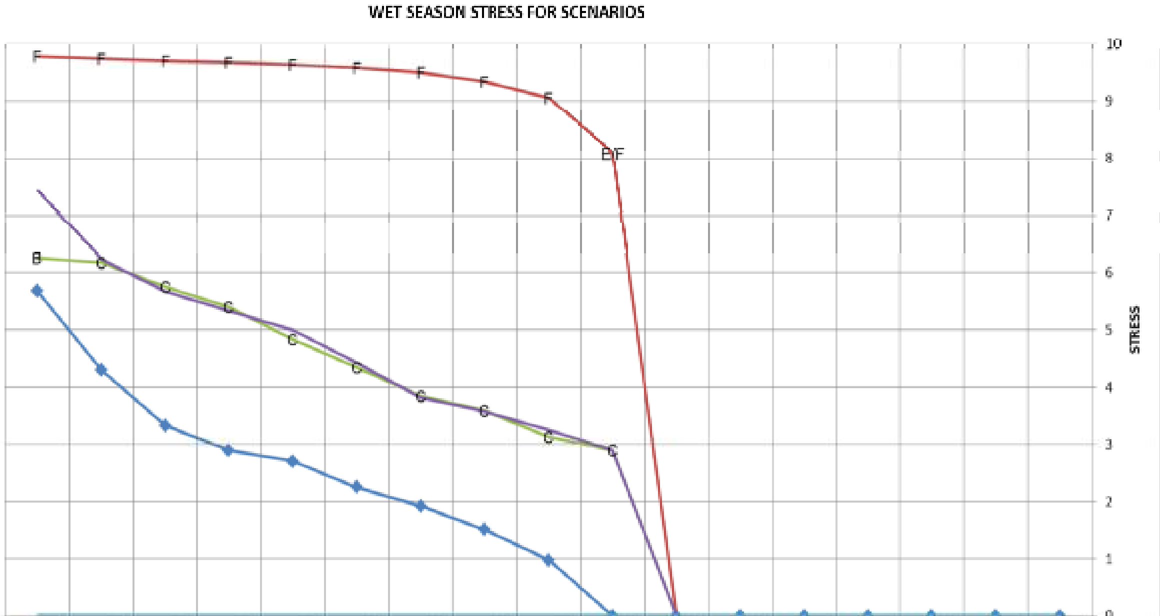
DISCHARGE(CUMEC)	-0.0140	0.0538	0.1076	0.1615	0.4306	0.8073	1.0764	1.6146	2.1528	4.0754	5.3820
FVS (m of perimeter)	0.0	1.720	3.209	3.723	5.343	4.321	4.028	2.253	2.028	1.148	0.524
FS (m of perimeter))	0.0	0.025	0.181	0.593	2.423	4.910	5.003	4.382	3.385	2.088	1.572
FINT (m of perimeter)	0.0	0.000	0.000	0.000	0.000	1.239	2.317	4.711	4.728	2.341	2.341
FD (m of perimeter)	0.0	0.000	0.000	0.000	0.000	0.000	0.060	1.353	3.745	10.899	13.121
WETTED PERIMETER WIDTH (m)	0	3.674	4.537	5.327	11.382	16.619	18.299	20.482	22.374	25.347	26.207
HABITAT STRESS: RHEOPHILIC	10.00	9.01	8.07	7.54	5.58	4.04	3.50	2.77	2.09	0.62	0.00



	[illegible]	0.0538	0.1076	0.1615	0.4306	0.8073	1.0764	1.6145	2.1528	4.0754	5.3820
SVS m	0.002	1.888	1.066	0.852	2.444	2.493	2.379	1.434	1.342	0.701	0.262
SS m	0.00	0.00	0.04	0.13	1.08	3.66	4.51	6.47	7.16	7.60	6.25
SD m	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.567	2.376
WETTED PERIMETER WIDTH (m)	0	3.674	4.537	5.327	11.382	16.619	18.299	20.482	22.374	25.347	26.207
HABITAT STRESS: RHEOPHILIC	10.00	9.01	8.07	7.54	5.58	4.04	3.50	2.77	2.09	0.62	0.00



	0.1%	2.4%	5.0%	10.0%	15.0%	20.0%	30.0%	40.0%	50.0%	60.0%	70.0%	80.0%	85.0%	90.0%	95.0%	99.0%	99.9%
NATURAL	0.000	0.000	0.000	0.000	0.000	0.000	0.000	5.382	3.622	2.912	2.371	2.063	1.684	1.528	1.240	0.751	0.436
PRESENT	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.110	0.050	0.031	0.020	0.014	0.011	0.008	0.006	0.003	0.000
HN41 EWR4_C								1.530	1.363	1.081	0.919	0.739	0.614	0.492	0.422	0.348	0.338
HN41 Sc1								1.5320	1.2850	1.0690	0.9330	0.7180	0.5710	0.5060	0.4380	0.3410	0.1840



	0.10%	1.00%	5.00%	10.00%	15.00%	20.00%	30.00%	40.00%	50.00%	60.00%	70.00%	80.00%	85.00%	90.00%	95.00%	99.00%	99.90%
NATURAL	5.682	4.295	3.331	2.899	2.711	2.252	1.924	1.509	0.974	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
PRESENT	9.795	9.751	9.707	9.678	9.634	9.590	9.502	9.340	9.062	8.078	0.000	0.000	0.000	0.000	0.000	0.000	0.000
HN41 EWR4_C	6.253	6.180	5.752	5.400	4.834	4.342	3.850	3.588	3.132	2.897	0.000	0.000	0.000	0.000	0.000	0.000	0.000
HN41 Sc1	7.427	6.231	5.672	5.330	5.003	4.425	3.827	3.575	3.258	2.894	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

STRESS DURATION

Marico EWR 5 KLEIN MARICO

	Natural	Present	EWR 5_C	Sc1 Full	Sc1 EWR only	Sc2
Fish dry		F	**E**	E/F	F	
Fish wet		E	**C**	D	D/E	
Fish integrated		*F*	***D***	*E*	*E*	
Recommendation						

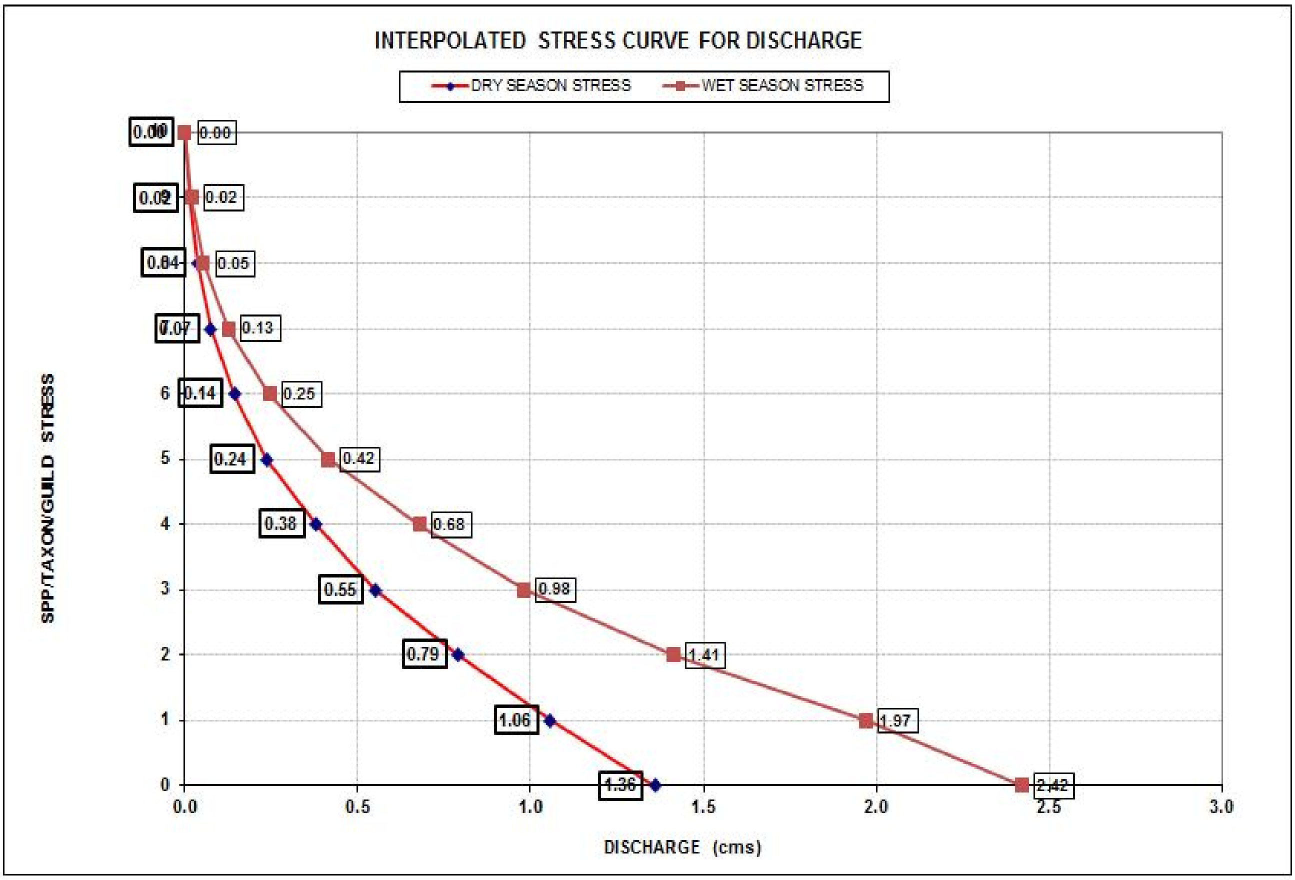
Comments:

1. Under natural conditions the hydrology indicates that the river is perennial at the site.
2. Rheophilics have not been recorded in the reach. Semi-rheophilics (e.g. Labeobarbus marequensis) are present.
3. Although rheophilics are not present, the FFHA were set to include all fast flowing habitats (FVS, FS, FI, FD) for both the dry and wet as even under natural drought conditions at least FVS habitats are present.
4. The EWR workshop derived category C equates to an overall category for fish = D, with the dry season specifically falling in an E category.

A flow duration for a category C for the dry season would be approximated by:

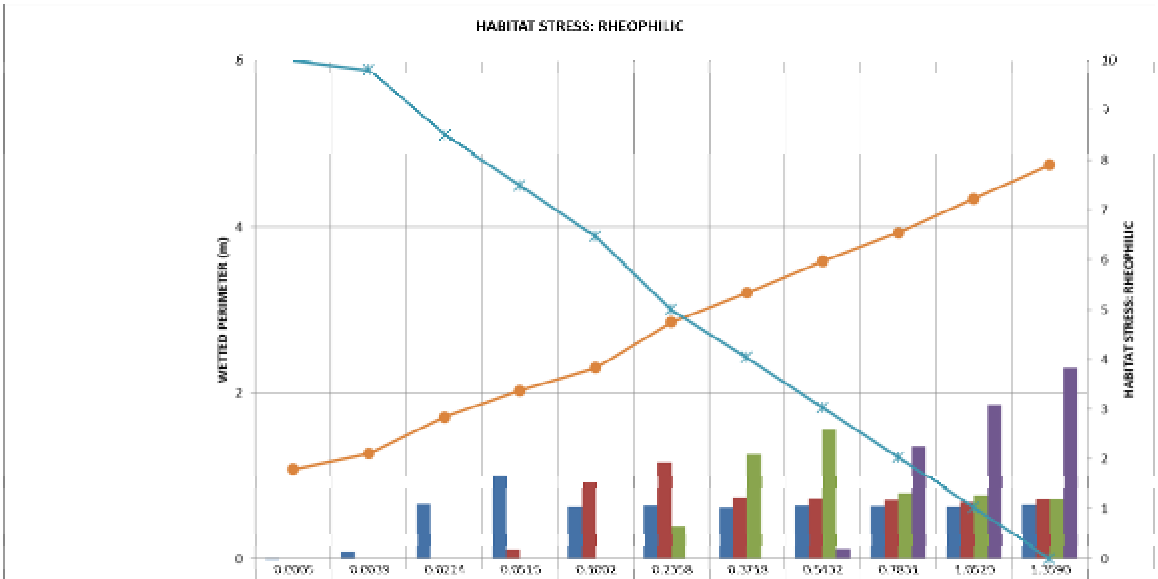
FLOW DURATION	"REAL" HN36 EWR5_C Flow (cumec)	category C
0.10%	0.378	C
1.00%	0.353	C
5.00%	0.212	C
10.00%	0.184	C
15.00%	0.182	C
20.00%	0.164	C
30.00%	0.134	C
40.00%	0.117	C
50.00%	0.107	C
60.00%	0.097	C
70.00%	0.084	C
80.00%	0.076	C
85.00%	0.073	C
90.00%	0.070	C
95.00%	0.070	C
99.00%	0.070	A/B
99.90%	0.070	A

Dry-wet stress profiles:

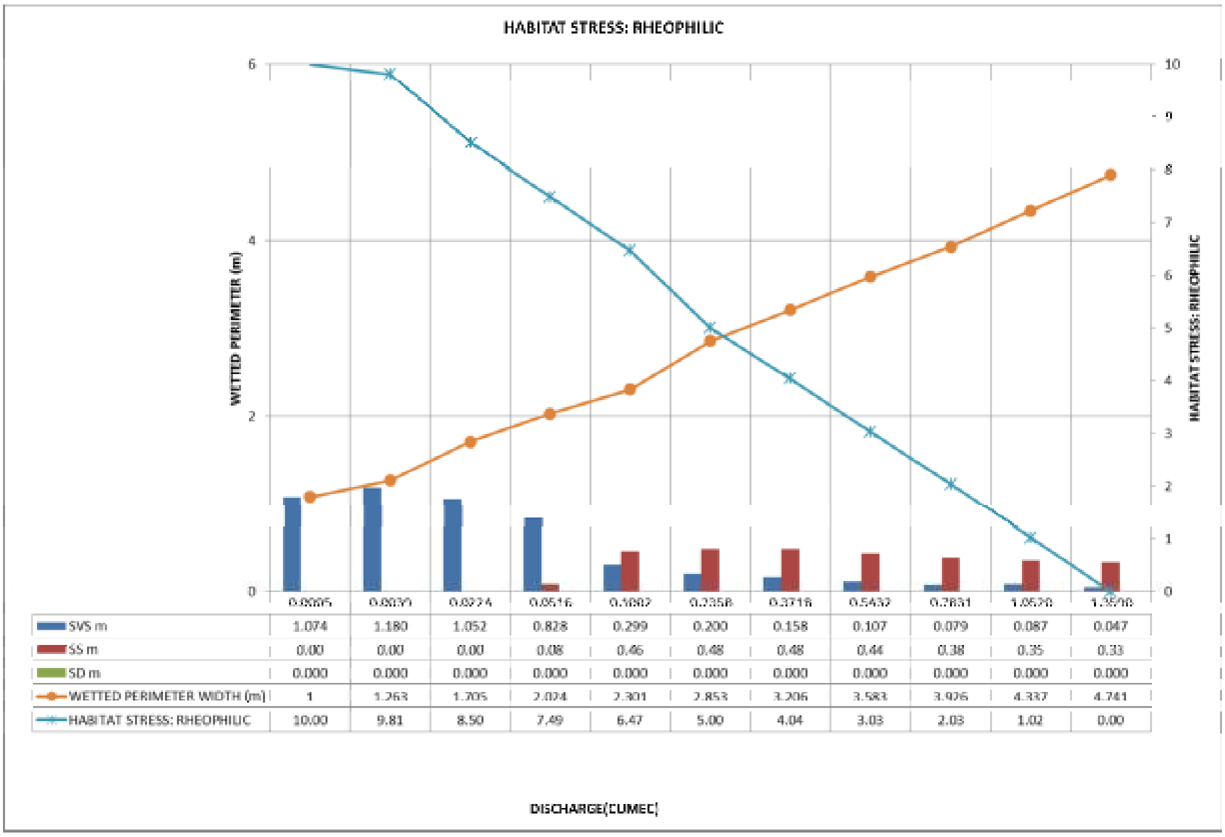


DRY SEASON (SEPTEMBER)

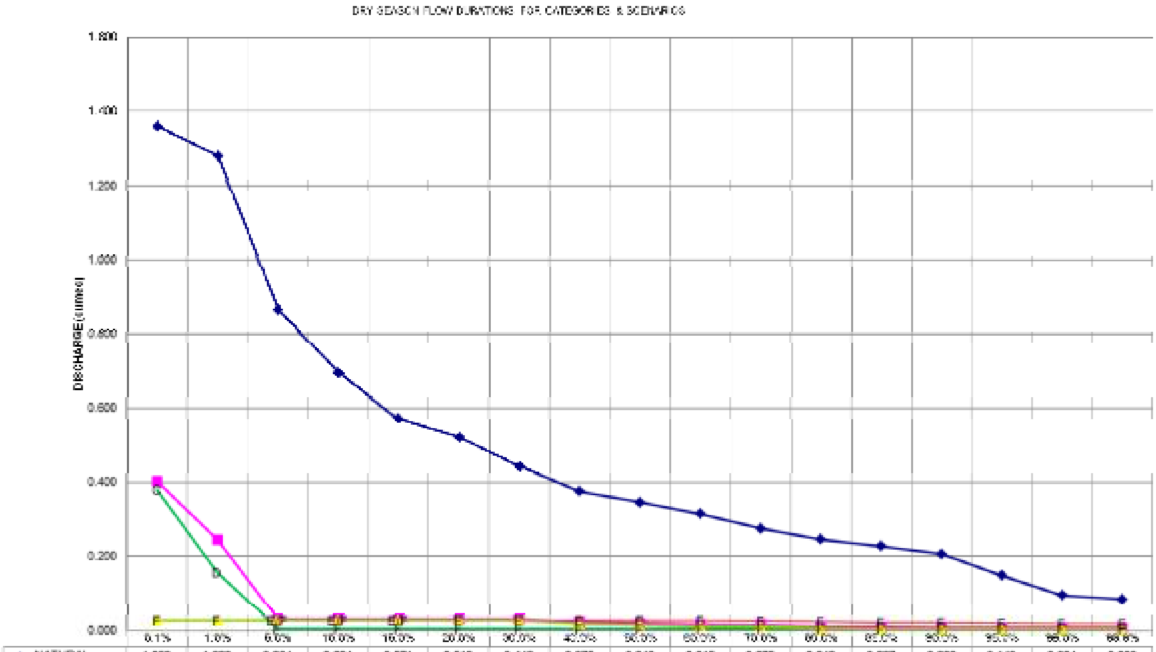
Max natural low flow = 1.3590 cumec



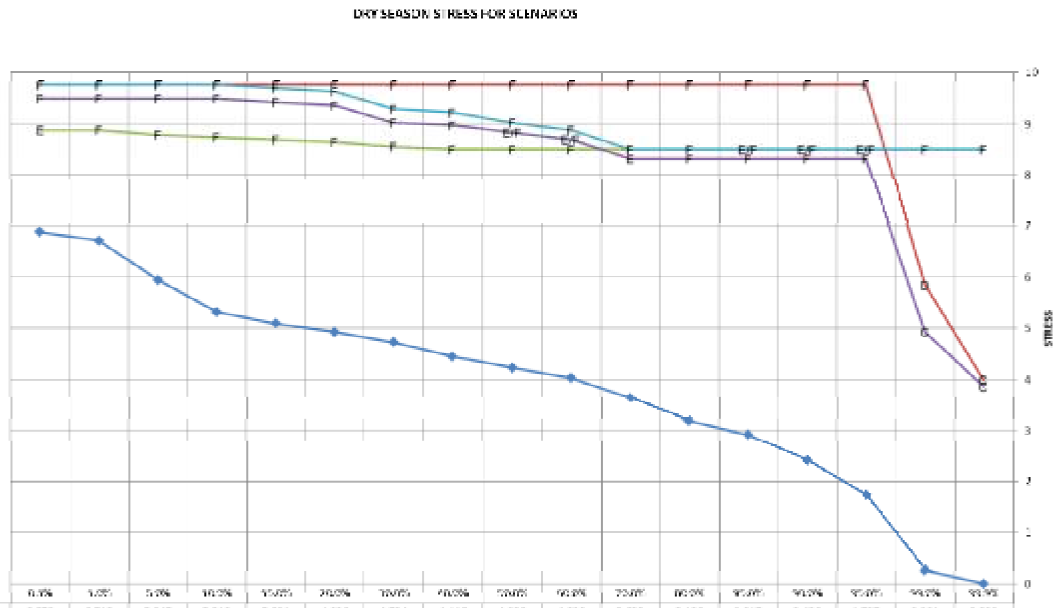
	0.0005	0.0038	0.0214	0.0515	0.1092	0.2358	0.3718	0.5432	0.7831	1.0525	1.3590
FVS (m of perimeter)	0.0	0.083	0.653	0.989	0.621	0.641	0.609	0.639	0.628	0.623	0.644
FS (m of perimeter))	0.0	0.000	0.000	0.108	0.921	1.158	0.735	0.723	0.707	0.678	0.711
FINT (m of perimeter)	0.0	0.000	0.000	0.000	0.000	0.384	1.254	1.559	0.785	0.765	0.711
FD (m of perimeter)	0.0	0.000	0.000	0.000	0.000	0.000	0.000	0.119	1.355	1.853	2.296
WETTED PERIMETER WIDTH (m)	1	1.263	1.705	2.024	2.301	2.853	3.206	3.583	3.926	4.337	4.741
HABITAT STRESS: RHEOPHILIC	10.00	9.81	8.50	7.49	6.47	5.00	4.04	3.03	2.03	1.02	0.00



	0.0005	0.0032	0.0224	0.0516	0.1082	0.2358	0.3718	0.5432	0.7831	1.0520	1.3590
SVS m	1.074	1.180	1.052	0.828	0.299	0.200	0.158	0.107	0.079	0.087	0.047
SS m	0.00	0.00	0.00	0.08	0.46	0.48	0.48	0.44	0.38	0.35	0.33
SD m	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WETTED PERIMETER WIDTH (m)	1	1.263	1.705	2.024	2.301	2.853	3.206	3.583	3.926	4.337	4.741
HABITAT STRESS: RHEOPHILIC	10.00	9.81	8.50	7.49	6.47	5.00	4.04	3.03	2.03	1.02	0.00



	0.1%	1.0%	5.0%	10.0%	15.0%	20.0%	30.0%	40.0%	50.0%	60.0%	70.0%	80.0%	85.0%	90.0%	95.0%	98.0%	99.9%
NATURAL	1.359	1.280	0.864	0.694	0.571	0.519	0.442	0.376	0.346	0.315	0.275	0.246	0.227	0.206	0.148	0.094	0.083
PRESENT	0.380	0.158	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004
HN36 EWR5_C	0.026	0.026	0.026	0.026	0.026	0.026	0.026	0.026	0.026	0.026	0.025	0.023	0.022	0.021	0.020	0.018	0.018
HN36 Sc1	0.4030	0.2450	0.0300	0.0300	0.0300	0.0300	0.0300	0.0220	0.0190	0.0160	0.0150	0.0100	0.0090	0.0080	0.0080	0.0080	0.0080
Sc1 EWR Ch273	0.0260	0.0260	0.0260	0.0260	0.0260	0.0260	0.0260	0.0180	0.0150	0.0120	0.0110	0.0060	0.0050	0.0040	0.0040	0.0040	0.0040

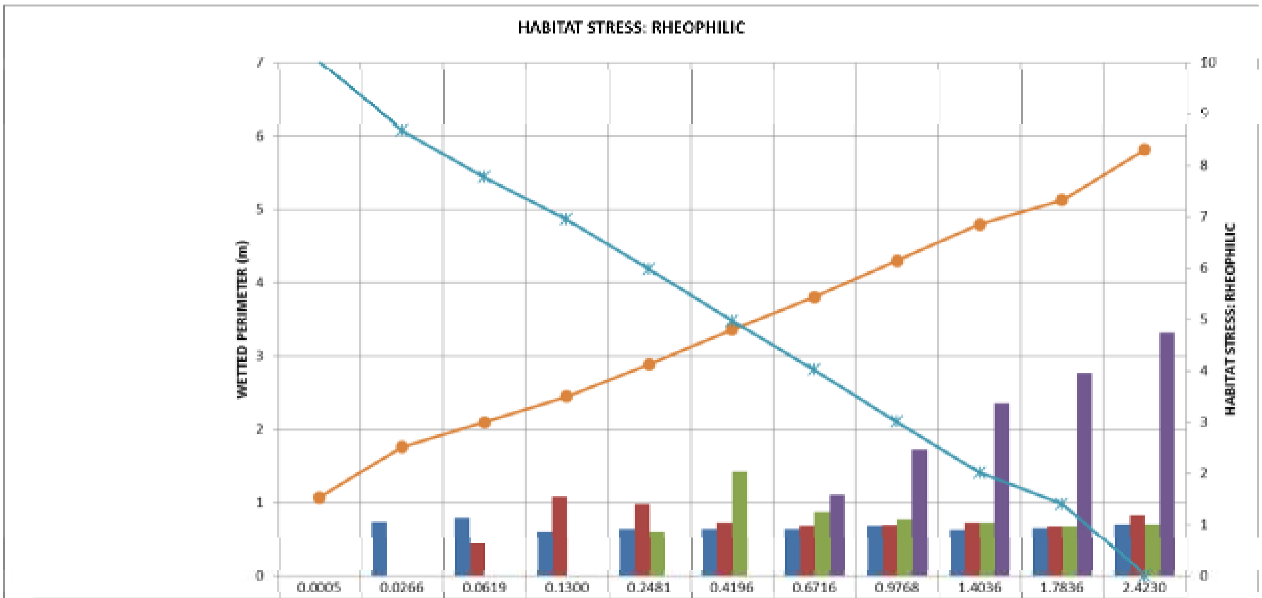


	0.1%	1.0%	5.0%	10.0%	15.0%	20.0%	30.0%	40.0%	50.0%	60.0%	70.0%	80.0%	85.0%	90.0%	95.0%	99.0%	99.9%
NATURAL	6.879	6.718	5.947	5.318	5.091	4.926	4.724	4.446	4.230	4.028	3.633	3.186	2.917	2.406	1.727	0.261	0.000
PRESENT	9.765	9.765	9.765	9.765	9.765	9.765	9.765	9.765	9.765	9.765	9.765	9.765	9.765	9.765	9.765	5.856	3.992
HN36 EWR5_C	8.878	8.878	8.785	8.738	8.692	8.645	8.552	8.505	8.505	8.505	8.505	8.505	8.505	8.505	8.505	8.505	8.505
HN36 Sc1	9.496	9.496	9.496	9.496	9.429	9.362	9.026	8.971	8.832	8.692	8.319	8.319	8.319	8.319	8.319	4.933	3.860
Sc1 EWR Ch273	9.765	9.765	9.765	9.765	9.698	9.631	9.295	9.227	9.026	8.878	8.505	8.505	8.505	8.505	8.505	8.505	8.505

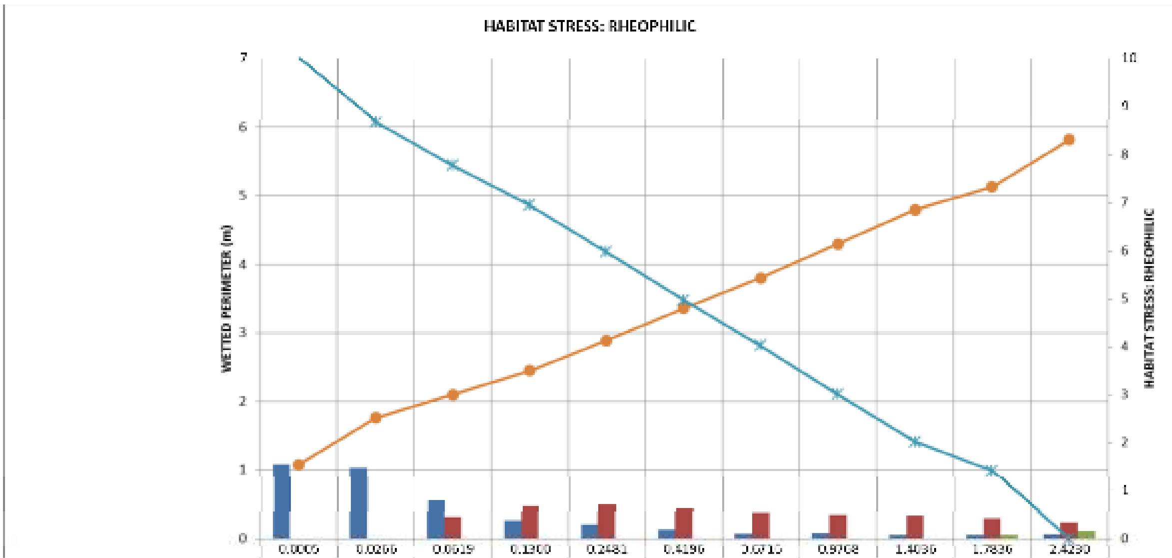
STRESS DURATION

WET SEASON (FEBRUARY)

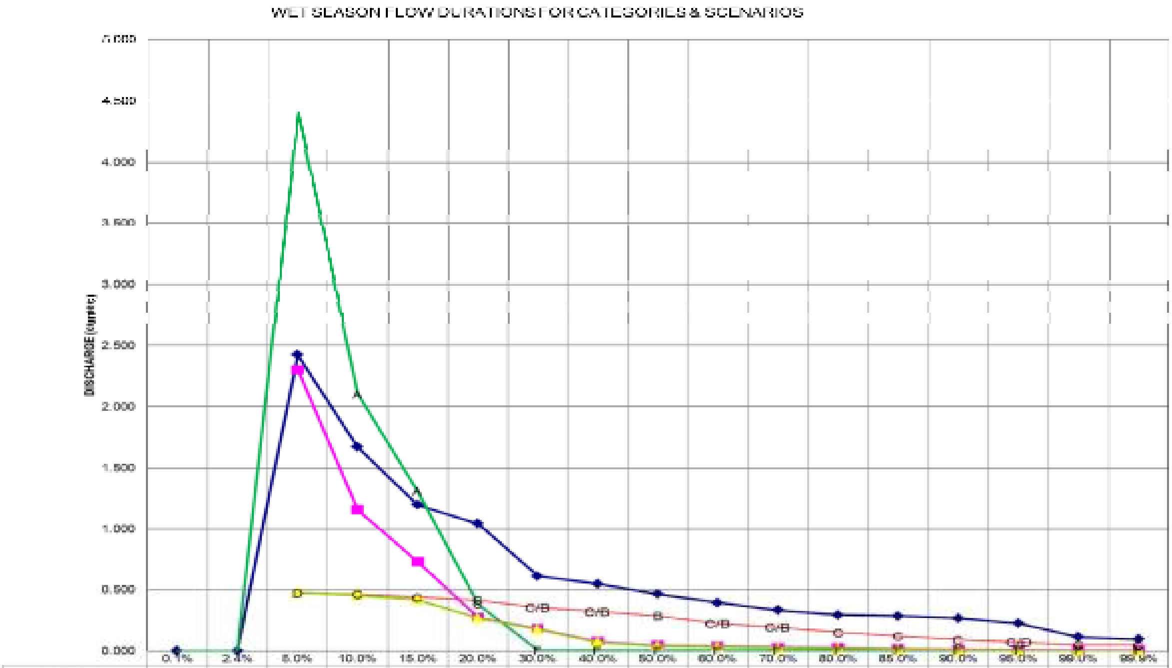
Max natural low flow = 2.4230 cumec



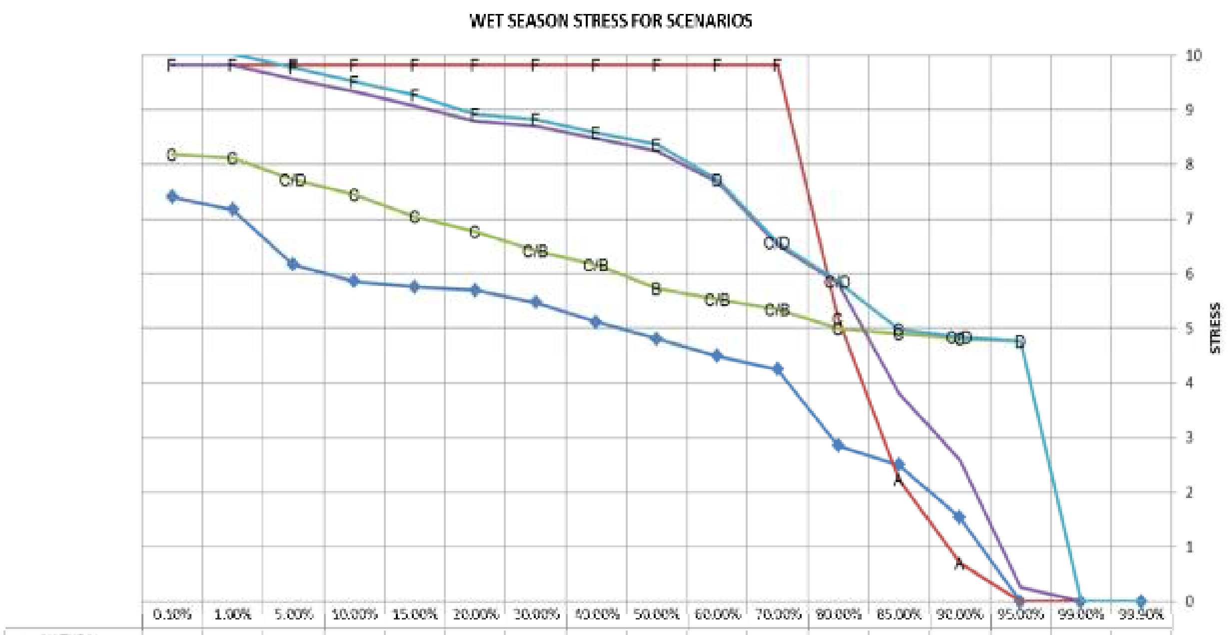
	0.0005	0.0266	0.0619	0.1300	0.2481	0.4196	0.6716	0.9768	1.4036	1.7836	2.4230
FVS (m of perimeter)	0.0	0.729	0.790	0.600	0.638	0.639	0.644	0.678	0.626	0.652	0.698
FS (m of perimeter))	0.0	0.000	0.442	1.090	0.985	0.718	0.686	0.688	0.718	0.667	0.824
FINT (m of perimeter)	0.0	0.000	0.000	0.000	0.603	1.424	0.872	0.774	0.720	0.667	0.698
FD (m of perimeter)	0.0	0.000	0.000	0.000	0.000	0.000	1.107	1.730	2.354	2.770	3.315
WETTED PERIMETER WIDTH (m)	1	1.758	2.100	2.450	2.894	3.365	3.803	4.300	4.800	5.129	5.816
HABITAT STRESS: RHEOPHILIC	10.00	8.68	7.78	6.95	5.98	4.97	4.02	3.01	2.02	1.41	0.00



	0.0005	0.0266	0.0619	0.1300	0.2481	0.4196	0.6716	0.9768	1.4036	1.7836	2.4230
SVS m	1.075	1.029	0.559	0.270	0.203	0.135	0.076	0.086	0.048	0.051	0.058
SS m	0.00	0.00	0.31	0.48	0.49	0.45	0.38	0.34	0.34	0.29	0.23
SD m	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.051	0.116
WETTED PERIMETER WIDTH (m)	1	1.758	2.100	2.450	2.894	3.365	3.803	4.300	4.800	5.129	5.816
HABITAT STRESS: RHEOPHILIC	10.00	8.68	7.78	6.95	5.98	4.97	4.02	3.01	2.02	1.41	0.00



	0.1%	1.0%	5.0%	10.0%	15.0%	20.0%	30.0%	40.0%	50.0%	60.0%	70.0%	80.0%	85.0%	90.0%	95.0%	99.0%	99.9%
NATURAL	0.000	0.000	2.423	1.670	1.196	1.042	0.612	0.548	0.466	0.396	0.335	0.297	0.287	0.269	0.226	0.113	0.096
PRESENT	0.000	0.000	4.396	2.105	1.310	0.385	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004
HN36 EWR5_C			0.476	0.465	0.440	0.415	0.357	0.324	0.290	0.226	0.195	0.152	0.122	0.093	0.073	0.049	0.047
HN36 Sc1			2.3025	1.1546	0.7319	0.2750	0.1812	0.0768	0.0450	0.0378	0.0300	0.0272	0.0190	0.0136	0.0093	0.0040	0.0040
Sc1 EWR Ch273			0.4780	0.4670	0.4210	0.2710	0.1770	0.0730	0.0410	0.0340	0.0360	0.0230	0.0150	0.0100	0.0050	0.0000	0.0000



	0.10%	1.00%	5.00%	10.00%	15.00%	20.00%	30.00%	40.00%	50.00%	60.00%	70.00%	80.00%	85.00%	90.00%	95.00%	99.00%	99.90%
NATURAL	7.408	7.173	6.162	5.861	5.755	5.696	5.472	5.113	4.811	4.495	4.252	2.858	2.503	1.539	0.000	0.000	0.000
PRESENT	9.824	9.824	9.824	9.824	9.824	9.824	9.824	9.824	9.824	9.824	9.824	5.178	2.241	0.701	0.000	0.000	0.000
HN36 EWR5_C	8.188	8.127	7.726	7.450	7.049	6.779	6.420	6.162	5.737	5.537	5.343	5.001	4.906	4.811	4.769	0.000	0.000
HN36 Sc1	9.824	9.824	9.556	9.340	9.067	8.791	8.706	8.468	8.249	7.673	6.536	5.826	3.822	2.598	0.265	0.000	0.000
Sc1 EWR Ch273	10.025	10.025	9.773	9.521	9.269	8.919	8.827	8.584	8.370	7.726	6.571	5.849	4.978	4.841	4.769	0.000	0.000

Marico EWR 6: Polkadraaispruit

	Natural	Present	EWR 6_BC	EWR 6_B	Sc1	
Fish dry		D/E	**E**	**E**	E	
Fish wet		C	**C**	**C**	C	
Fish integrated		*D*	***D***	***D***	*D*	
Recommendation						

Comments:

1. Hydrology indicates that during droughts in the dry season, the stream stops flowing. Rheophilics have been recorded in the stream and it is expected that these recolonize the stream after droughts.
2. Consequently, for both the dry and wet season, the requirements were based on rheophilics (Chiloglanis pretoriae and Amphilius uranoscopus) and the FFHA set to include all fast flowing habitats (FVS, FS, FI, FD)
3. Both EWR 6_BC & EWR 6_B does not attain the objective of respectively B/C or B.

A category B/C would resemble the following flow durations

Dry

	HN34 EWR6_BC category	**category**
FLOW DURATION	**FLOW (cumec)**	**C/B**
0.10%	0.220	C/B
1.00%	0.190	C/B
5.00%	0.160	C/B
10.00%	0.115	C/B
15.00%	0.110	C/B
20.00%	0.100	C/B
30.00%	0.095	C/B
40.00%	0.094	C/B
50.00%	0.093	C/B
60.00%	0.080	C/B
70.00%	0.066	C/B
80.00%	0.048	C/B
85.00%	0.045	C/B
90.00%	0.040	C/B
95.00%	0.023	A
99.00%	0.000	A
99.90%	0.000	A

Wet

FLOW DURATION	HN34 EWR6_BC Flow (cumec)	category C/B
0.10%		
2.40%		
5.00%		
10.00%		
15.00%		
20.00%		
30.00%	0.270	C/B
40.00%	0.220	C/B
50.00%	0.158	C/B
60.00%	0.125	C/B
70.00%	0.108	C/B
80.00%	0.085	C/B
85.00%	0.070	C/B
90.00%	0.053	C/B
95.00%	0.028	B
99.00%	0.013	A
99.90%	0.010	A

A category B would resemble the following flow durations:

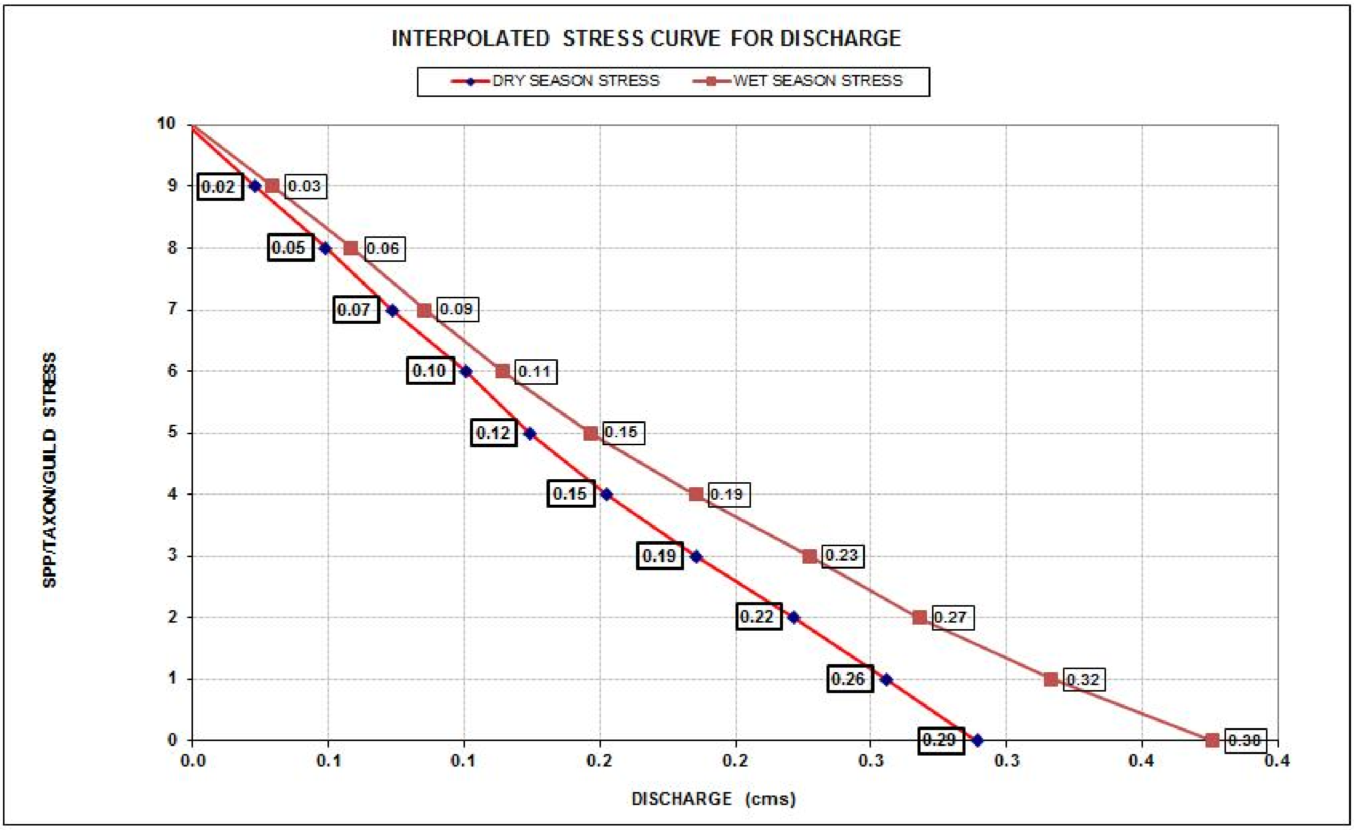
Dry

FLOW DURATION	HN34 EWR6_B Flow (cumec)	category B
0.10%	0.2300	B
1.00%	0.2000	B
5.00%	0.1800	B
10.00%	0.1300	B
15.00%	0.1200	B
20.00%	0.1100	B
30.00%	0.0990	B
40.00%	0.0990	B
50.00%	0.0950	B
60.00%	0.0850	B
70.00%	0.0710	B
80.00%	0.0500	B
85.00%	0.0480	B
90.00%	0.0420	B
95.00%	0.0190	B
99.00%	0.0000	A
99.90%	0.0000	A

Wet

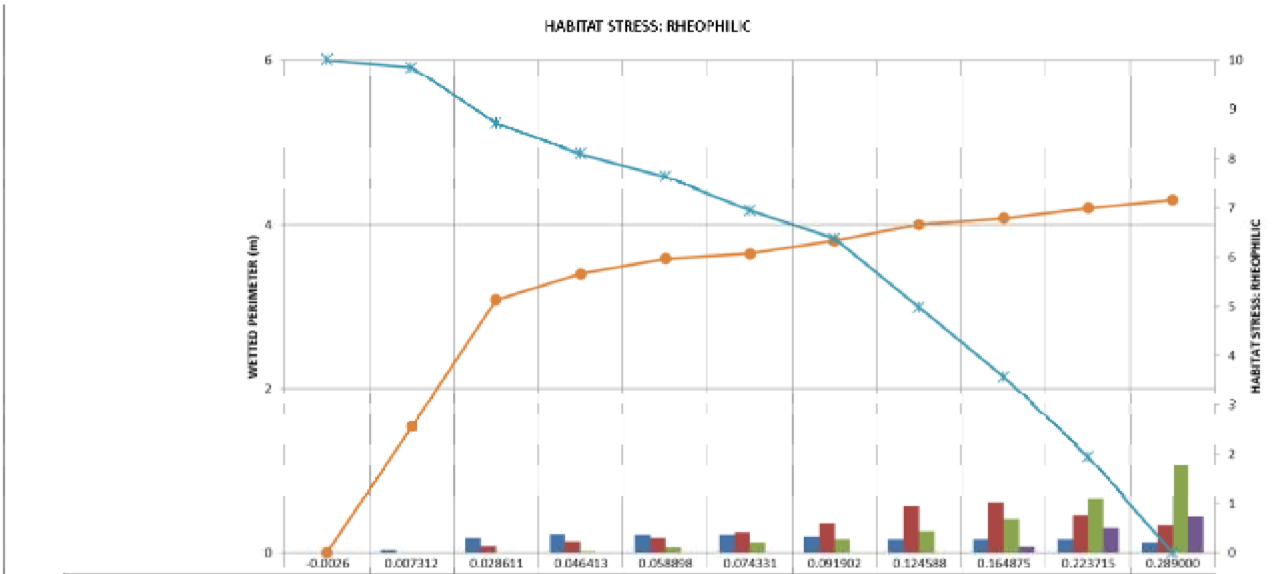
	HN34 EWR6_B	category
FLOW DURATION	**Flow (cumec)**	**B**
0.10%		
2.40%		
5.00%		
10.00%		
15.00%		
20.00%		
30.00%	0.2800	B
40.00%	0.2400	B
50.00%	0.1700	B
60.00%	0.1400	B
70.00%	0.1100	B
80.00%	0.0900	B
85.00%	0.0750	B
90.00%	0.0560	B
95.00%	0.0280	B
99.00%	0.0130	A
99.90%	0.0100	A

Dry-wet stress profiles:

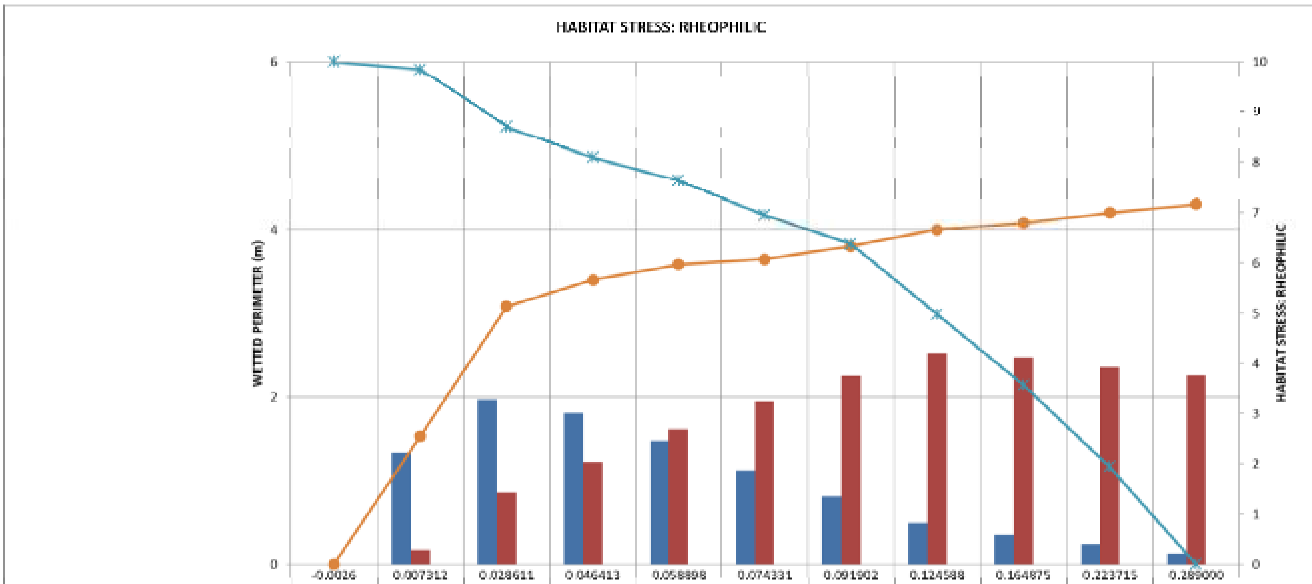


<u>DRY SEASON (SEPTEMBER)</u>

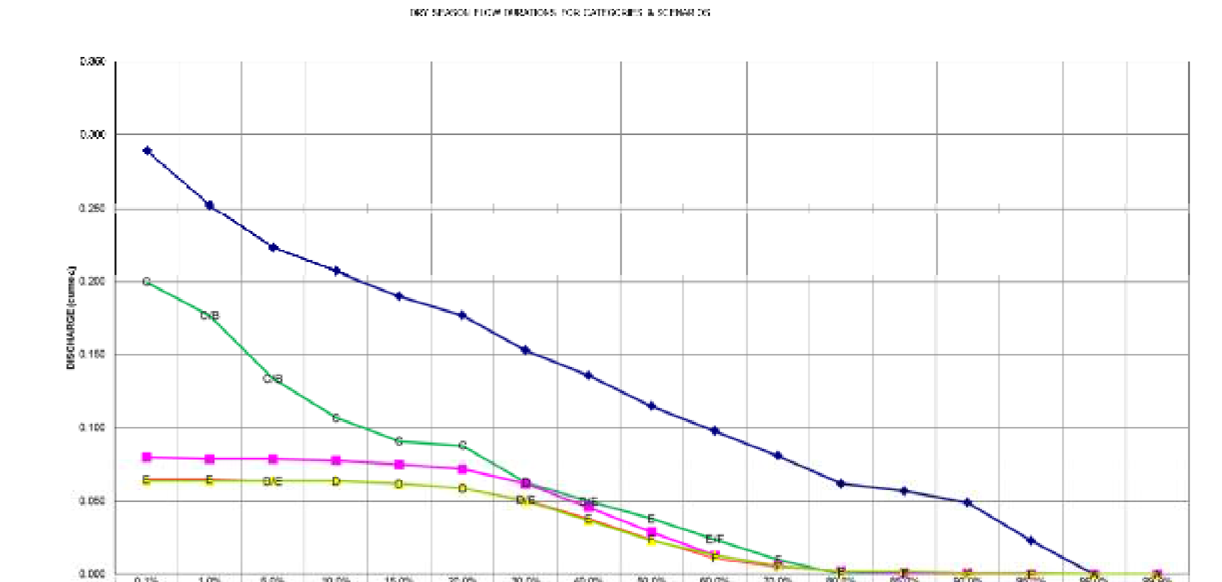
Max natural low flow = 0.289000 cumec



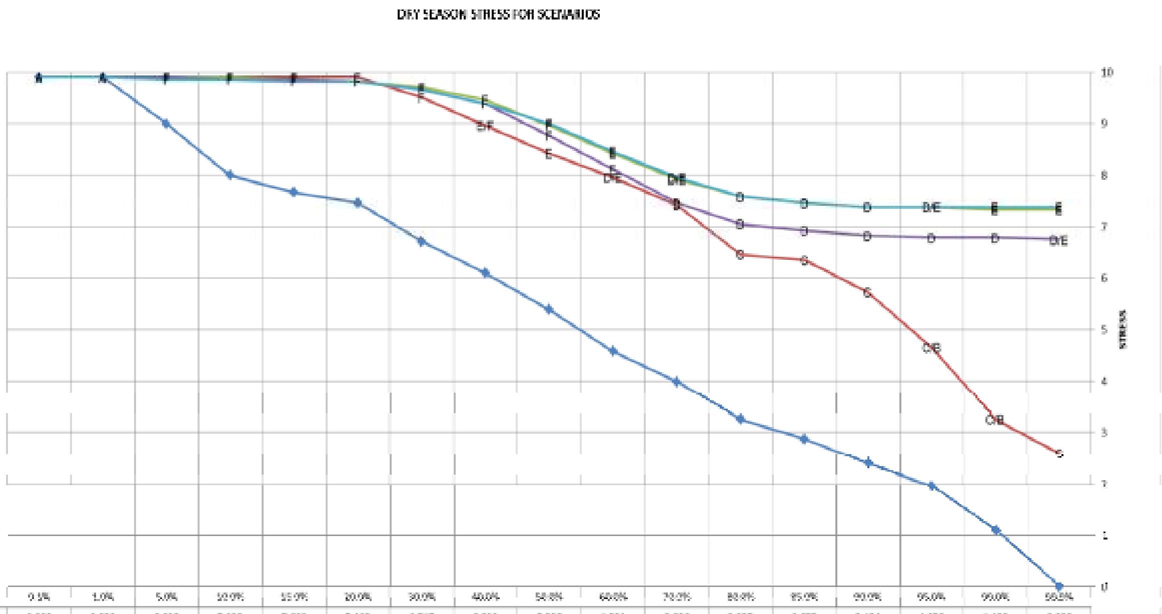
	-0.0026	0.007312	0.028611	0.046413	0.058898	0.074331	0.091902	0.124588	0.164875	0.223715	0.289000
FVS (m of perimeter)	0.0	0.031	0.179	0.226	0.219	0.219	0.190	0.160	0.163	0.160	0.129
FS (m of perimeter)	0.0	0.000	0.075	0.135	0.177	0.250	0.356	0.560	0.611	0.454	0.331
FINT (m of perimeter)	0.0	0.000	0.000	0.011	0.066	0.125	0.159	0.258	0.407	0.653	1.045
FD (m of perimeter)	0.0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.071	0.302	0.443
WETTED PERIMETER WIDTH (m)	0	1.531	3.083	3.396	3.583	3.643	3.800	4.000	4.074	4.200	4.300
HABITAT STRESS: RHEOPHILIC	10.00	9.84	8.70	8.10	7.63	6.95	6.38	4.98	3.57	1.94	0.00



	-0.0026	0.007312	0.028611	0.046413	0.058898	0.074331	0.091902	0.124588	0.164875	0.223715	0.289000
SVS m	0.000	1.325	1.973	1.808	1.473	1.123	0.807	0.502	0.347	0.244	0.129
SS m	0.00	0.17	0.86	1.22	1.62	1.94	2.25	2.52	2.47	2.35	2.25
SD m	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WETTED PERIMETER WIDTH (m)	0	1.531	3.083	3.396	3.583	3.643	3.800	4.000	4.074	4.200	4.300
HABITAT STRESS: RHEOPHILIC	10.00	9.84	8.70	8.10	7.63	6.95	6.38	4.98	3.57	1.94	0.00



	0.1%	1.0%	5.0%	10.0%	15.0%	20.0%	30.0%	40.0%	50.0%	60.0%	70.0%	80.0%	85.0%	90.0%	95.0%	99.0%	99.9%
NATURAL	0.289	0.252	0.223	0.207	0.190	0.177	0.153	0.136	0.115	0.098	0.081	0.062	0.057	0.049	0.023	0.000	0.000
PRESENT	0.200	0.177	0.134	0.107	0.091	0.088	0.063	0.050	0.038	0.024	0.010	0.000	0.000	0.000	0.000	0.000	0.000
HN34 EWR6_BC	0.065	0.065	0.064	0.064	0.062	0.059	0.051	0.038	0.024	0.011	0.005	0.002	0.001	0.000	0.000	0.000	0.000
HN34 EWR6_B	0.0800	0.0790	0.0790	0.0780	0.0750	0.0720	0.0620	0.0460	0.0290	0.0130	0.0060	0.0020	0.0010	0.0010	0.0000	0.0000	0.0000
Sc1 EWR Cr271	0.0640	0.0640	0.0640	0.0640	0.0620	0.0590	0.0500	0.0370	0.0230	0.0130	0.0060	0.0020	0.0020	0.0010	0.0010	0.0000	0.0000



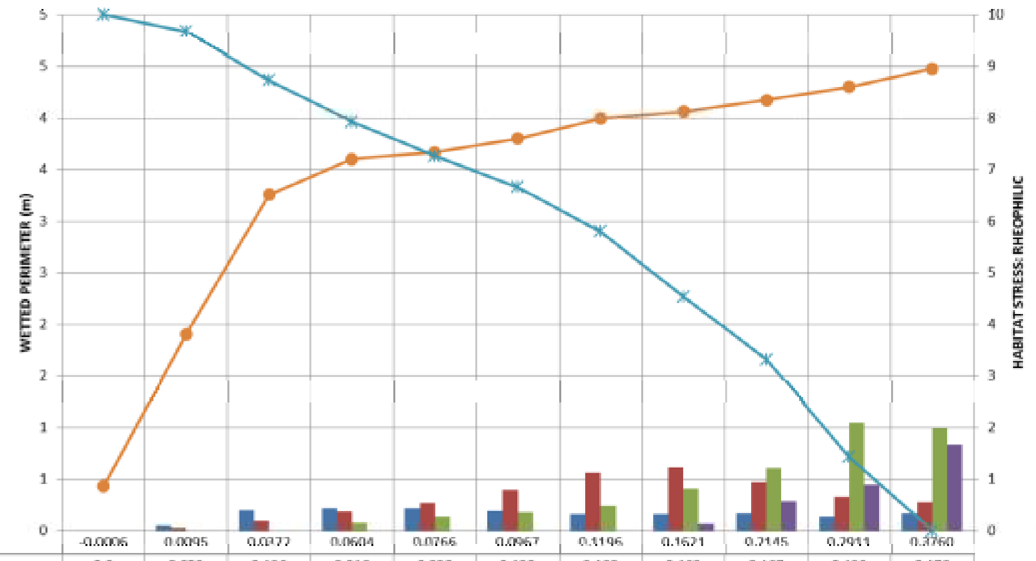
	0.1%	1.0%	5.0%	10.0%	15.0%	20.0%	30.0%	40.0%	50.0%	60.0%	70.0%	80.0%	85.0%	90.0%	95.0%	99.0%	99.9%
NATURAL	9.900	9.900	8.998	7.999	7.669	7.463	6.717	6.099	5.388	4.581	3.986	3.257	2.875	2.404	1.955	1.100	0.000
PRESENT	9.900	9.900	9.900	9.900	9.900	9.900	9.508	8.960	8.422	7.957	7.421	6.462	6.353	5.731	4.651	3.257	2.598
HN34 EWR6_BC	9.900	9.900	9.900	9.900	9.861	9.821	9.704	9.469	8.960	8.422	7.916	7.586	7.463	7.380	7.380	7.339	7.339
HN34 EWR6_B	9.900	9.900	9.900	9.861	9.861	9.821	9.665	9.390	8.757	8.114	7.463	7.050	6.935	6.826	6.790	6.790	6.753
Sc1 EWR Cr271	9.900	9.900	9.861	9.861	9.821	9.821	9.665	9.390	8.998	8.460	7.957	7.586	7.463	7.380	7.380	7.380	7.380

STRESS DURATION

<u>WET SEASON (FEBRUARY)</u>

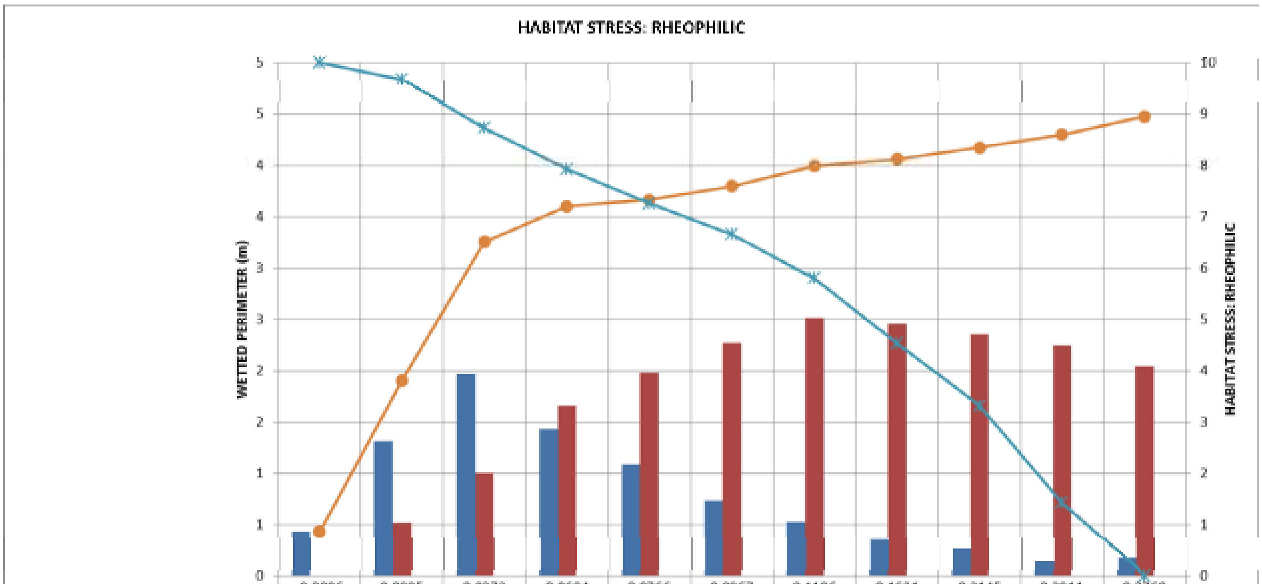
Max natural low flow = 0.3760 cumec

HABITAT STRESS: RHEOPHILIC

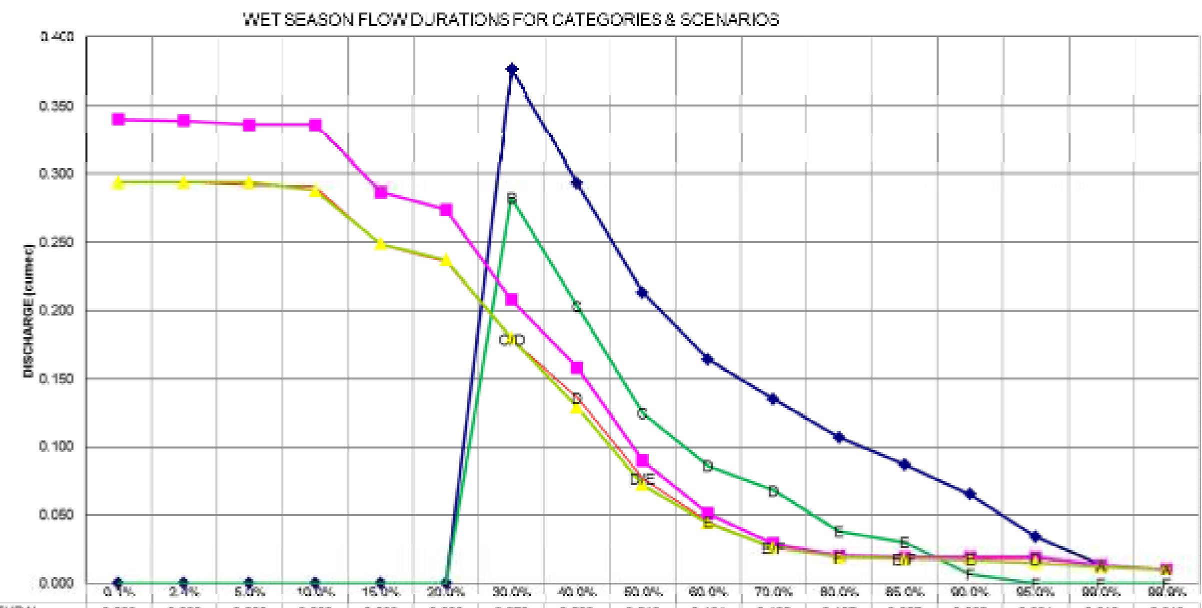


	-0.0006	0.0095	0.0272	0.0604	0.0766	0.0967	0.1196	0.1621	0.2145	0.2911	0.3760
FVS (m of perimeter)	0.0	0.052	0.196	0.216	0.220	0.190	0.160	0.162	0.167	0.129	0.170
FS (m of perimeter))	0.0	0.022	0.093	0.181	0.269	0.393	0.558	0.609	0.470	0.328	0.278
FINT (m of perimeter)	0.0	0.000	0.000	0.073	0.134	0.177	0.238	0.406	0.603	1.048	0.995
FD (m of perimeter)	0.0	0.000	0.000	0.000	0.000	0.000	0.000	0.065	0.281	0.446	0.833
WETTED PERIMETER WIDTH (m)	0	1.903	3.258	3.600	3.666	3.800	3.996	4.060	4.173	4.300	4.480
HABITAT STRESS: RHEOPHILIC	10.00	9.67	8.73	7.93	7.26	6.66	5.80	4.54	3.32	1.43	0.00

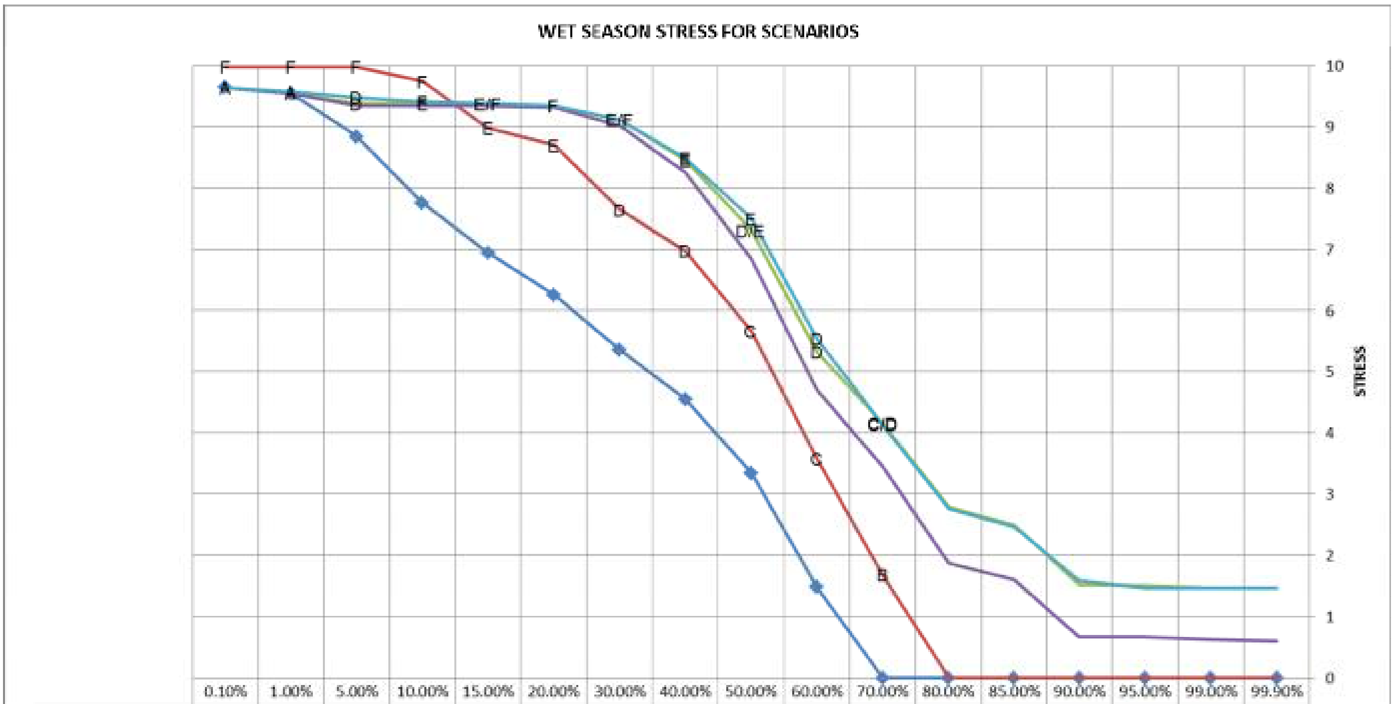
DISCHARGE(CUMEC)



	-0.0006	0.0095	0.0372	0.0604	0.0766	0.0967	0.1196	0.1621	0.2145	0.2911	0.3760
SVS m	0.431	1.311	1.968	1.430	1.088	0.734	0.523	0.357	0.262	0.129	0.170
SS m	0.00	0.51	1.00	1.66	1.98	2.27	2.52	2.46	2.36	2.25	2.04
SD m	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WETTED PERIMETER WIDTH (m)	0	1.903	3.258	3.600	3.666	3.800	3.996	4.060	4.173	4.300	4.480
HABITAT STRESS: RHEOPHILIC	10.00	9.67	8.73	7.93	7.26	6.66	5.80	4.54	3.32	1.43	0.00



	0.1%	2.1%	5.0%	10.0%	15.0%	20.0%	30.0%	40.0%	50.0%	60.0%	70.0%	80.0%	85.0%	90.0%	95.0%	99.0%	99.9%
NATURAL	0.000	0.000	0.000	0.000	0.000	0.000	0.376	0.293	0.213	0.164	0.135	0.107	0.087	0.065	0.034	0.013	0.010
PRESENT	0.000	0.000	0.000	0.000	0.000	0.000	0.283	0.203	0.125	0.086	0.068	0.038	0.030	0.007	0.000	0.000	0.000
HN34 EWR6_BC	0.294	0.294	0.292	0.291	0.248	0.236	0.179	0.136	0.077	0.045	0.026	0.019	0.016	0.016	0.016	0.013	0.010
HN34 EWR6_B	0.3400	0.3390	0.3360	0.3360	0.2870	0.2740	0.2080	0.1580	0.0900	0.0510	0.0290	0.0200	0.0190	0.0190	0.0190	0.0130	0.0100
Sc1 EWR Ch271	0.2940	0.2940	0.2940	0.2880	0.2490	0.2370	0.1800	0.1290	0.0720	0.0440	0.0260	0.0190	0.0180	0.0170	0.0150	0.0120	0.0100



	0.10%	1.00%	5.00%	10.00%	15.00%	20.00%	30.00%	40.00%	50.00%	60.00%	70.00%	80.00%	85.00%	90.00%	95.00%	99.00%	99.90%
NATURAL	9.645	9.545	8.839	7.755	6.944	6.252	5.358	4.549	3.341	1.484	0.000	0.000	0.000	0.000	0.000	0.000	0.000
PRESENT	9.979	9.979	9.979	9.745	8.977	8.702	7.644	6.978	5.668	3.578	1.689	0.000	0.000	0.000	0.000	0.000	0.000
HN34 EWR6_BC	9.645	9.545	9.378	9.378	9.378	9.345	9.111	8.461	7.310	5.327	4.161	2.787	2.491	1.525	1.504	1.463	1.463
HN34 EWR6_B	9.645	9.545	9.345	9.345	9.345	9.311	9.011	8.255	6.840	4.705	3.459	1.874	1.607	0.672	0.672	0.622	0.605
Sc1 EWR Ch271	9.645	9.578	9.478	9.411	9.378	9.345	9.111	8.495	7.496	5.544	4.135	2.762	2.466	1.586	1.463	1.463	1.463

STRESS DURATION

MOKOLO EWR 1a: VAALWATER

	Natural	PRESENT	HN52 EWR1a_CD	HN52 EWR1a_BC	Sc1 HN52	Sc3 HN52
Fish dry		E	F	F	E	E
Fish wet		C	C	C	C	C
Fish integrated		D	D/E	D	D	D
Recommendation						

Comments:

1. Under natural conditions the hydrology indicates that the river is perennial at the site.
2. Two hydraulic cross sections were provided. It was decided to use xsection EWR1A 1 for this evaluation as it represents a shallow and faster flowing habitat (i.e it would be more sensitive to flow decreases).
3. rheophilics (Chiloglanis pretoriae and Amphilius uranscopus) occur at the site during suitable flow conditions.
4. During natural drought flows, FVS habitats are present.
5. Consequently the FFHA were set for all fast flow classes (FVS, FS, FI, FD) for the dry and wet season.
6. The natural max low flow for the wet season appears to be too low (2.9200 cumec at 30%tile). However, the 20% tile indicates a flow of 11.7970 cumec that is likely to include some flood events. It is suggested that the max low flow for the wet season be reconsidered.
7. Both HN52 EWR1a_C/D & HN52 EWR1a_BC does not attain the objective of respectively CD or B/C.
8. A category C/D would resemble the following flow durations:

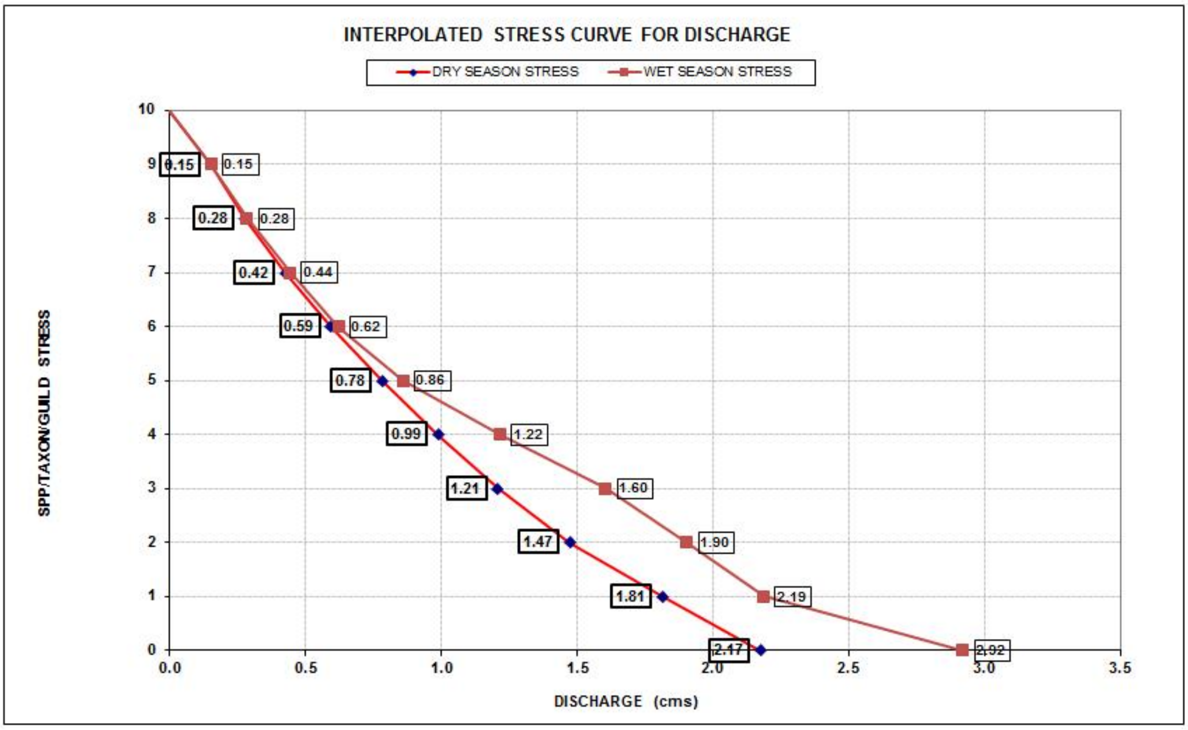
	DRY "real" HN52 EWR1a_CD	dry season	WET "real" HN52 EWR1a_CD	wet season
FLOW DURATION	**flow (cumec)**	**category C/D**	**flow (cumec)**	**C/D**
0.10%				
1.00%	0.800	C/D		
5.00%	0.700	C/D		
10.00%	0.600	C/D		
15.00%	0.520	C/D		
20.00%	0.510	C/D		
30.00%	0.480	C/D	1.200	C/D
40.00%	0.450	C/D	1.000	C/D
50.00%	0.440	C/D	0.750	C/D
60.00%	0.430	C/D	0.700	C/D
70.00%	0.420	C/D	0.650	C/D
80.00%	0.380	C/D	0.580	C/D
85.00%	0.360	C/D	0.530	C/D
90.00%	0.350	C/D	0.480	C/D
95.00%	0.350	C	0.460	C
99.00%	0.350	A	0.450	C
99.90%	0.240	A	0.450	A

9. A category B/C would resemble the following flow durations:

	DRY "REAL" HN52 EWR1a_BC	DRY CATEGORY	WET "REAL" HN52 EWR1a_BC	WET CATEGORY
FLOW DURATION	**flow (cumec)**	**C/B**	**flow (cumec)**	**C/B**
0.10%				
1.00%	1.7000	C/B		
5.00%	1.5000	C/B		
10.00%	1.3000	C/B		

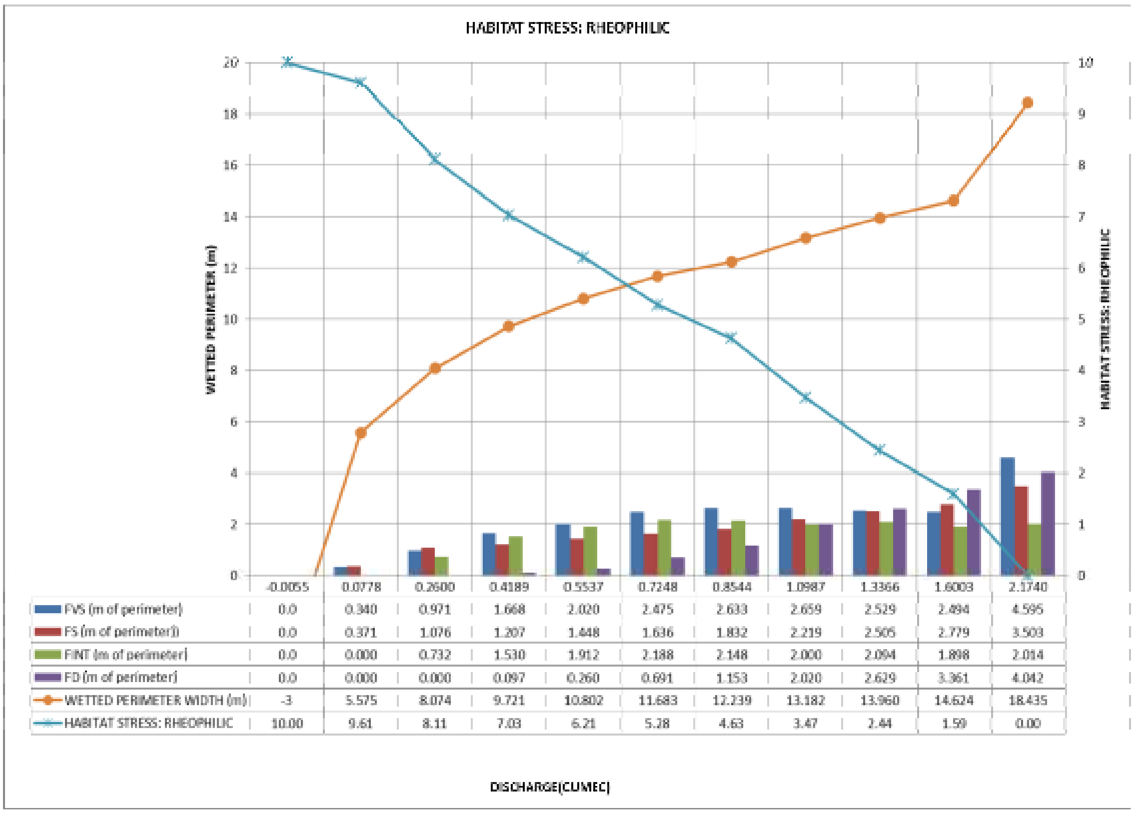
15.00%	0.9000	C/B		
20.00%	0.8800	C/B		
30.00%	0.8000	C/B	1.9000	C/B
40.00%	0.7000	C/B	1.6000	C/B
50.00%	0.6800	C/B	1.3000	C/B
60.00%	0.6500	C/B	1.1000	C/B
70.00%	0.6000	C/B	1.0000	C/B
80.00%	0.5000	C/B	0.9000	C/B
85.00%	0.4800	C/B	0.8000	C/B
90.00%	0.4500	C/B	0.7000	C/B
95.00%	0.4000	C/B	0.6500	C/B
99.00%	0.3500	A	0.6100	A
99.90%	0.2400	A	0.5000	A

Dry-wet stress profiles:

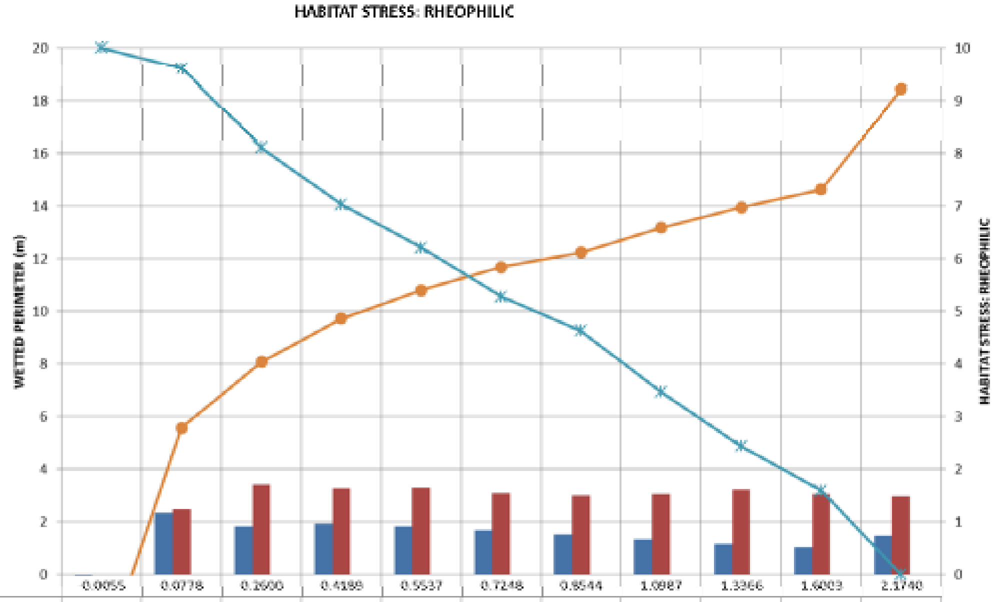


DRY SEASON (OCTOBER)

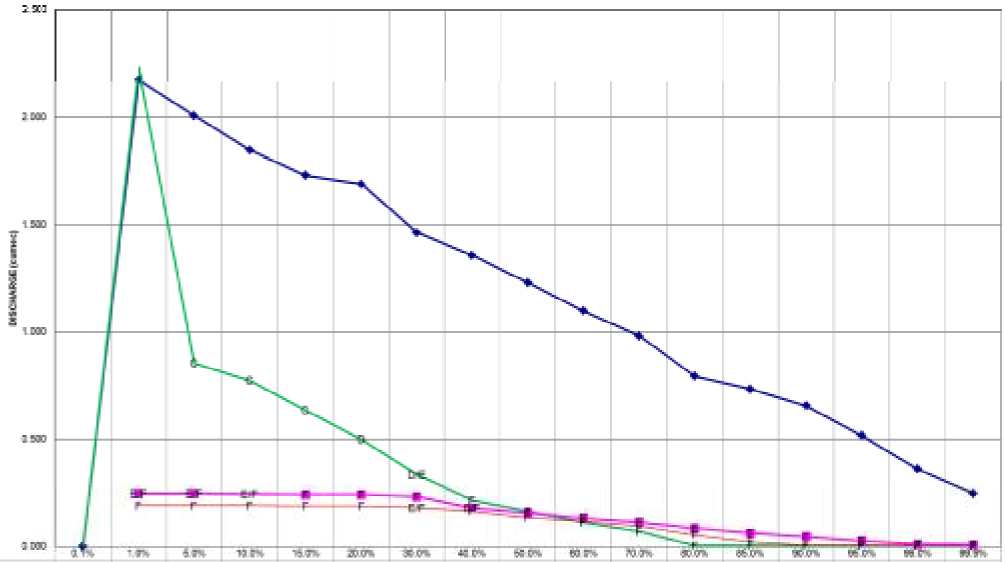
Max natural low flow = 2.1740 cumec



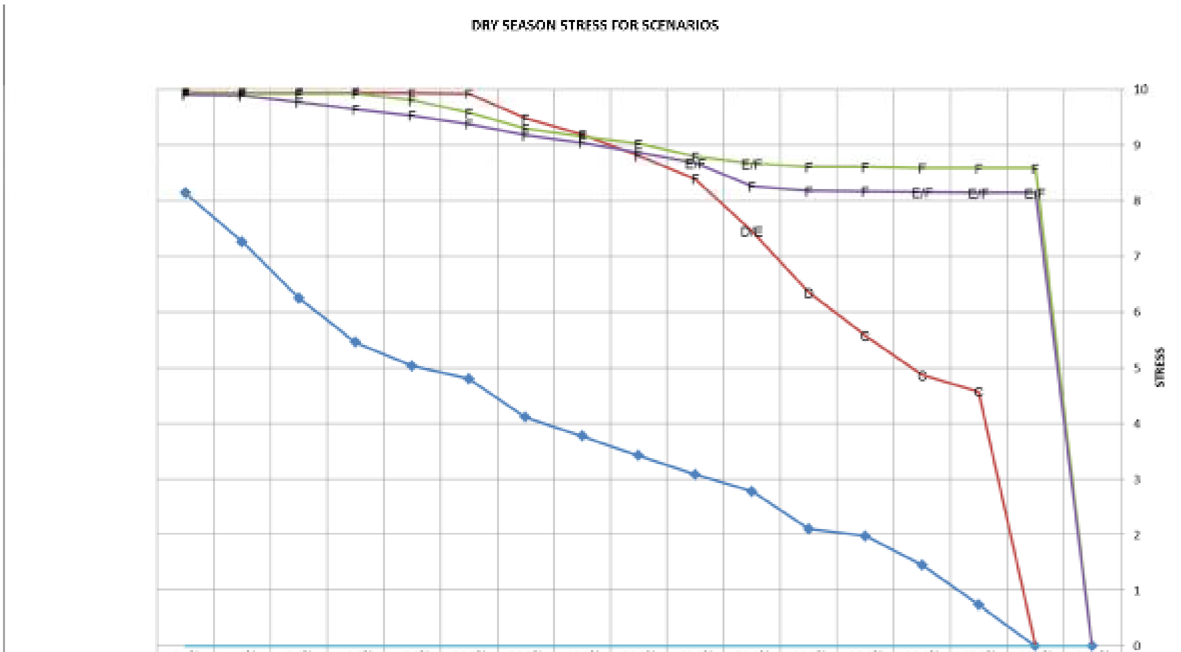
	-0.0055	0.0778	0.2600	0.4189	0.5537	0.7248	0.8544	1.0987	1.3366	1.6003	2.1740
FVS (m of perimeter)	0.0	0.340	0.971	1.668	2.020	2.475	2.633	2.659	2.529	2.494	4.595
FS (m of perimeter))	0.0	0.371	1.076	1.207	1.448	1.636	1.832	2.219	2.505	2.779	3.503
FINT (m of perimeter)	0.0	0.000	0.732	1.530	1.912	2.188	2.148	2.000	2.094	1.898	2.014
FD (m of perimeter)	0.0	0.000	0.000	0.097	0.260	0.691	1.153	2.020	2.629	3.361	4.042
WETTED PERIMETER WIDTH (m)	-3	5.575	8.074	9.721	10.802	11.683	12.239	13.182	13.960	14.624	18.435
HABITAT STRESS: RHEOPHILIC	10.00	9.61	8.11	7.03	6.21	5.28	4.63	3.47	2.44	1.59	0.00



	0.0055	0.0778	0.2600	0.4189	0.5537	0.7248	0.8544	1.0987	1.3366	1.6003	2.1740
SVS m	-3.356	2.344	1.828	1.929	1.825	1.699	1.536	1.340	1.133	1.025	1.475
SS m	0.00	2.49	3.41	3.27	3.31	3.08	3.00	3.05	3.21	3.07	2.96
SD m	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WETTED PERIMETER WIDTH (m)	-3	5.575	8.074	9.721	10.802	11.683	12.239	13.182	13.960	14.624	18.435
HABITAT STRESS: RHEOPHILIC	10.00	9.61	8.11	7.03	6.21	5.28	4.63	3.47	2.44	1.59	0.00

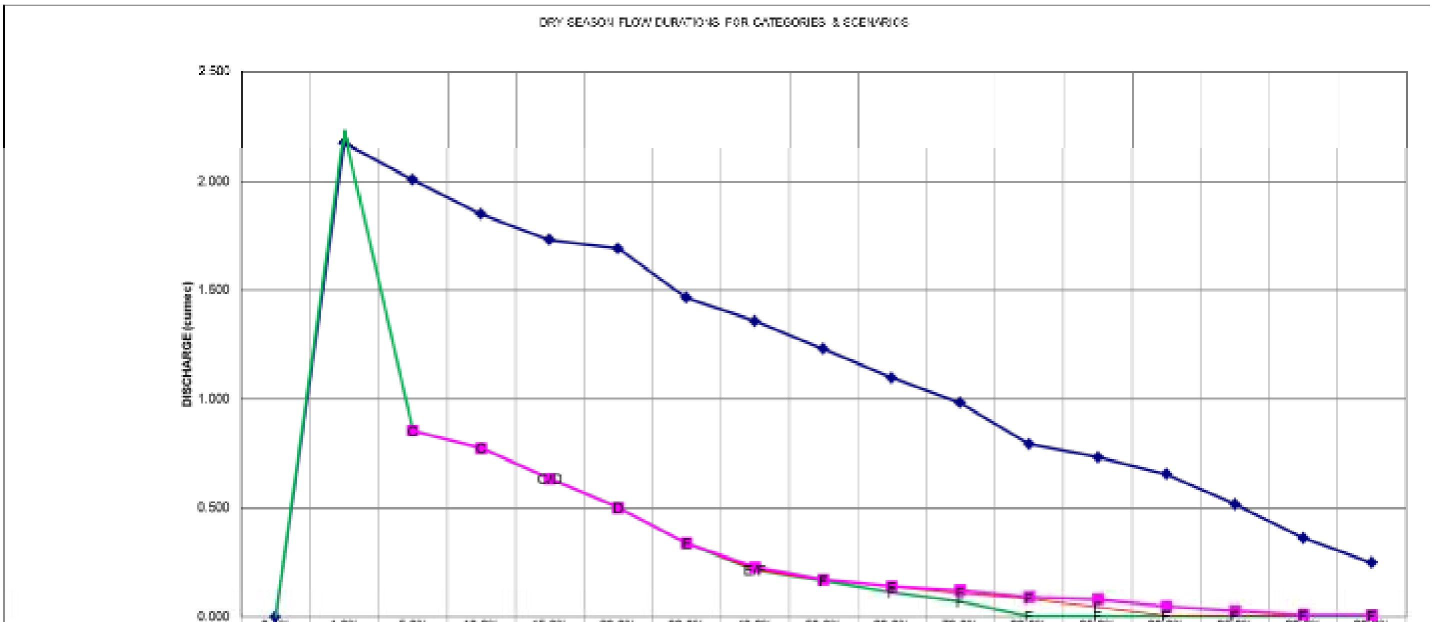


	0.1%	1.0%	5.0%	10.0%	15.0%	20.0%	30.0%	40.0%	50.0%	60.0%	70.0%	80.0%	85.0%	90.0%	95.0%	99.0%	99.9%
NATURAL	0.000	2.174	2.008	1.849	1.731	1.691	1.464	1.358	1.230	1.098	0.982	0.793	0.733	0.655	0.517	0.362	0.248
PRESENT	0.000	2.228	0.855	0.774	0.634	0.500	0.337	0.216	0.164	0.112	0.070	0.004	0.004	0.003	0.003	0.003	0.002
HN62 EWR1a_CD		0.192	0.192	0.191	0.189	0.189	0.181	0.166	0.136	0.117	0.096	0.056	0.022	0.006	0.006	0.006	0.005
HN62 EWR1a_BC		0.2470	0.2470	0.2458	0.2430	0.2426	0.2324	0.1802	0.1580	0.1332	0.1138	0.0846	0.0627	0.0462	0.0276	0.0105	0.0082

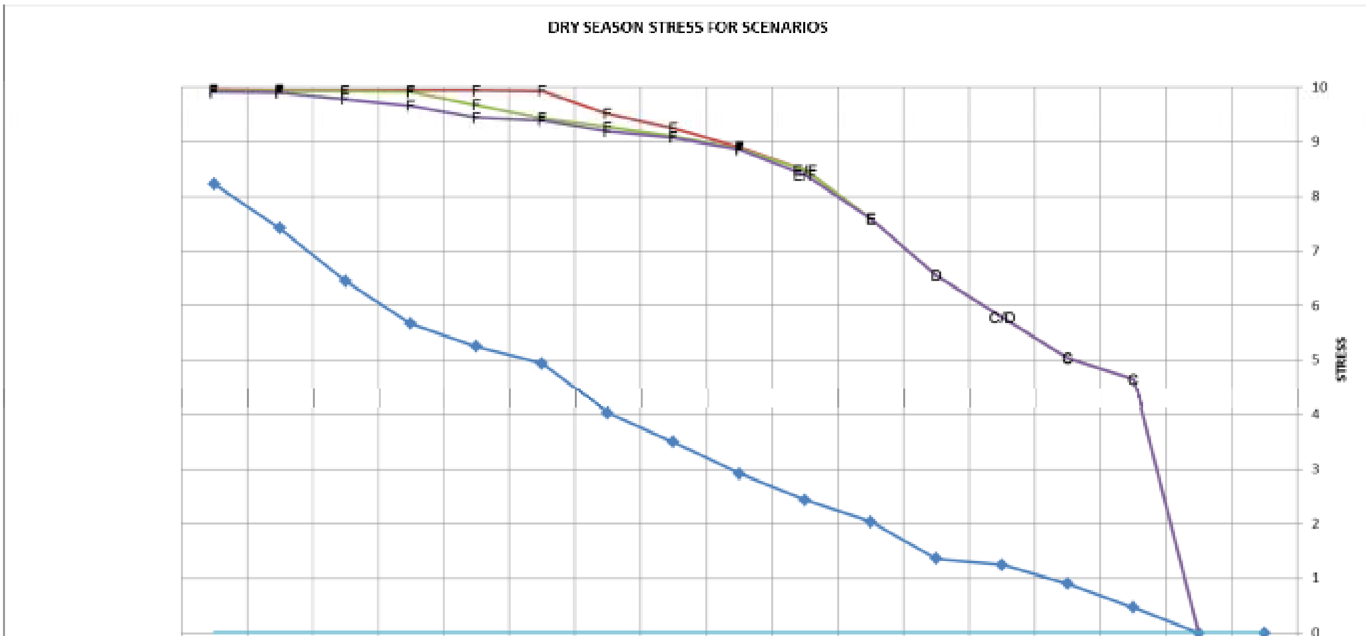


	0.1%	1.0%	5.0%	10.0%	15.0%	20.0%	30.0%	40.0%	50.0%	60.0%	70.0%	80.0%	85.0%	90.0%	95.0%	99.0%	99.9%
NATURAL	8.135	7.255	6.245	5.462	5.036	4.803	4.108	3.770	3.420	3.080	2.776	2.103	1.976	1.450	0.741	0.000	0.000
PRESENT	9.948	9.943	9.942	9.940	9.935	9.932	9.482	9.189	8.807	8.394	7.408	6.348	5.575	4.874	4.576	0.000	0.000
HN52 EWR1a_CD	9.927	9.922	9.921	9.921	9.809	9.587	9.299	9.155	9.027	8.794	8.668	8.607	8.607	8.591	8.583	8.583	0.000
HN52 EWR1a BC	9.906	9.890	9.773	9.645	9.531	9.380	9.180	9.046	8.871	8.677	8.260	8.178	8.175	8.152	8.143	8.143	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

STRESS DURATION



	0.1%	1.0%	5.0%	10.0%	15.0%	20.0%	30.0%	40.0%	50.0%	60.0%	70.0%	80.0%	85.0%	90.0%	95.0%	99.0%	99.9%
NATURAL	0.000	2.174	2.008	1.849	1.731	1.691	1.464	1.358	1.230	1.098	0.982	0.793	0.733	0.656	0.517	0.362	0.248
PRESENT	0.000	2.228	0.856	0.774	0.634	0.500	0.337	0.216	0.164	0.112	0.070	0.004	0.004	0.003	0.003	0.003	0.002
Sc1 HN52			0.856	0.773	0.634	0.500	0.336	0.216	0.167	0.136	0.110	0.083	0.045	0.007	0.006	0.006	0.005
Sc3 HN52			0.8548	0.7738	0.6343	0.5004	0.3368	0.2274	0.1700	0.1398	0.1216	0.0898	0.0809	0.0470	0.0276	0.0105	0.0082

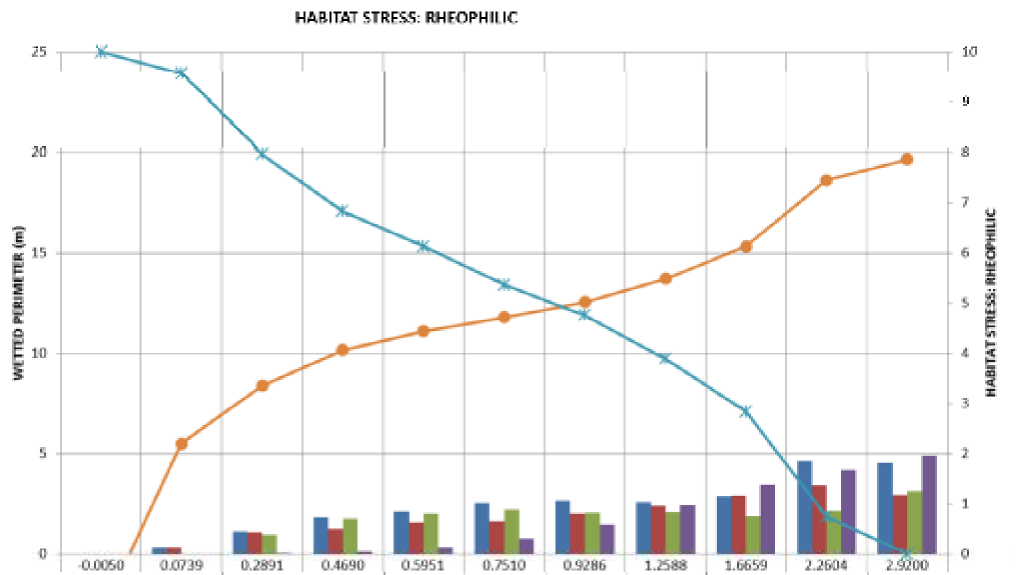


	0.1%	1.0%	5.0%	10.0%	15.0%	20.0%	30.0%	40.0%	50.0%	60.0%	70.0%	80.0%	85.0%	90.0%	95.0%	99.0%	99.9%
NATURAL	8.227	7.422	6.450	5.668	5.253	4.939	4.027	3.499	2.916	2.434	2.035	1.360	1.243	0.902	0.461	0.000	0.000
PRESENT	9.952	9.947	9.946	9.945	9.940	9.937	9.522	9.252	8.904	8.488	7.592	6.549	5.778	5.035	4.642	0.000	0.000
Sc1 HN52	9.933	9.928	9.927	9.920	9.681	9.440	9.269	9.103	8.880	8.488	7.596	6.549	5.778	5.038	4.641	0.000	0.000
Sc3 HN52	9.913	9.899	9.790	9.667	9.452	9.395	9.193	9.078	8.855	8.393	7.592	6.549	5.778	5.035	4.641	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

STRESS DURATION

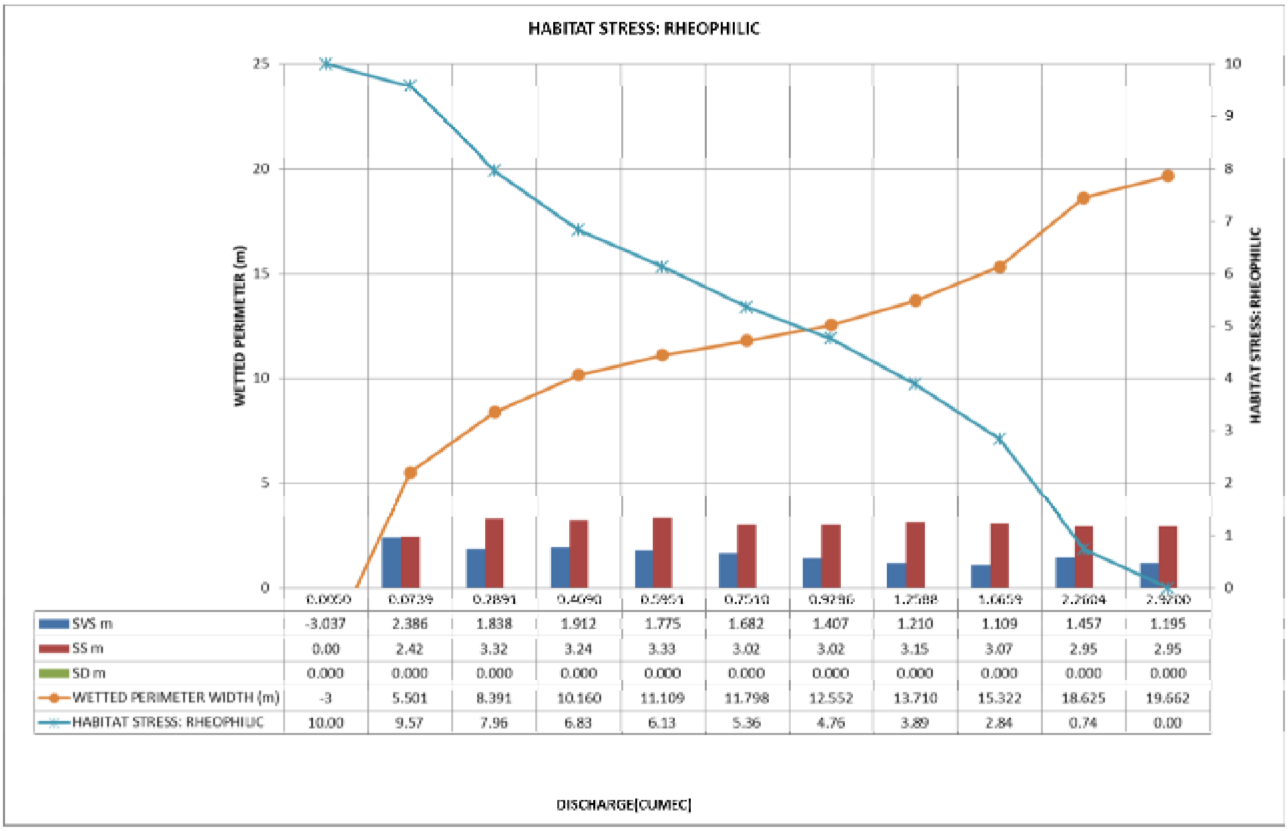
WET SEASON (FEBRUARY)

Max natural low flow = 2.9200 cumec (cf. comments)

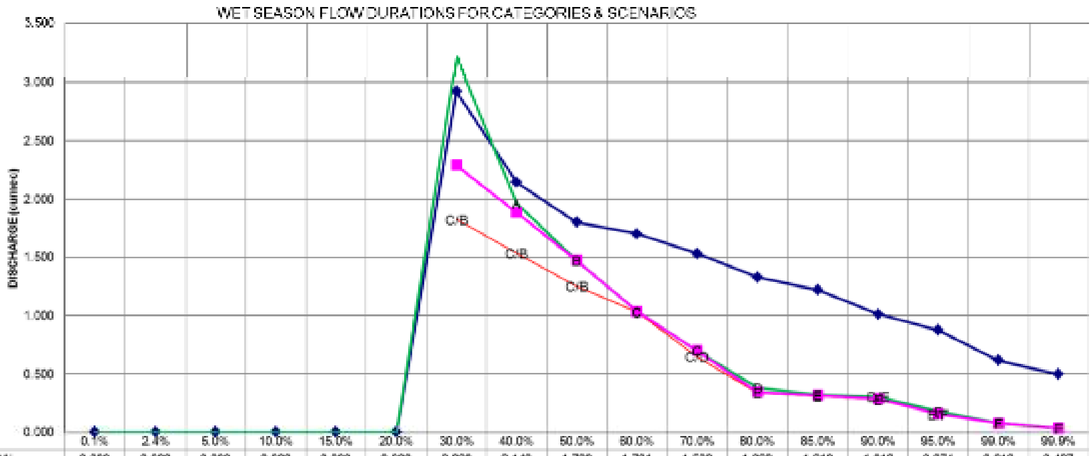


	-0.0050	0.0739	0.2891	0.4690	0.5951	0.7510	0.9286	1.2588	1.6659	2.2604	2.9200
FVS (m of perimeter)	0.0	0.319	1.116	1.835	2.115	2.551	2.645	2.581	2.863	4.656	4.552
FS (m of perimeter))	0.0	0.342	1.091	1.231	1.555	1.652	1.991	2.411	2.911	3.406	2.949
FINT (m of perimeter)	0.0	0.000	0.948	1.733	2.001	2.227	2.034	2.057	1.881	2.148	3.116
FD (m of perimeter)	0.0	0.000	0.008	0.114	0.338	0.766	1.463	2.435	3.450	4.164	4.901
WETTED PERIMETER WIDTH (m)	-3	5.501	8.391	10.160	11.109	11.798	12.552	13.710	15.322	18.625	19.662
HABITAT STRESS: RHEOPHILIC	10.00	9.57	7.96	6.83	6.13	5.36	4.76	3.89	2.84	0.74	0.00

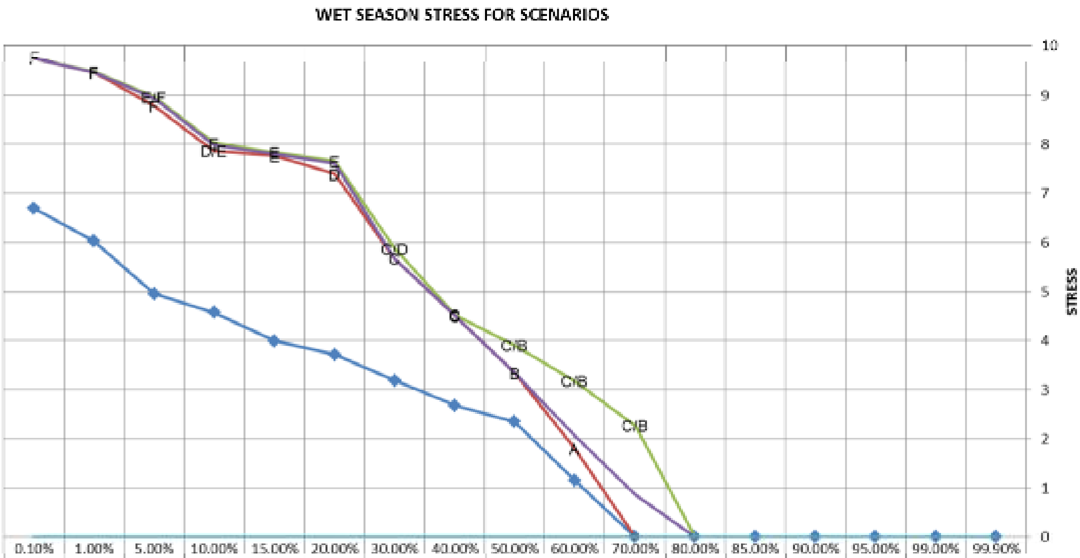
DISCHARGE(CUMEC)



	0.0050	0.0739	0.2891	0.4690	0.5951	0.7510	0.9296	1.2588	1.6659	2.2604	2.9700
SVS m	-3.037	2.386	1.838	1.912	1.775	1.682	1.407	1.210	1.109	1.457	1.195
SS m	0.00	2.42	3.32	3.24	3.33	3.02	3.02	3.15	3.07	2.95	2.95
SD m	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
WETTED PERIMETER WIDTH (m)	-3	5.501	8.391	10.160	11.109	11.798	12.552	13.710	15.322	18.625	19.662
HABITAT STRESS: RHEOPHILIC	10.00	9.57	7.96	6.83	6.13	5.36	4.76	3.89	2.84	0.74	0.00

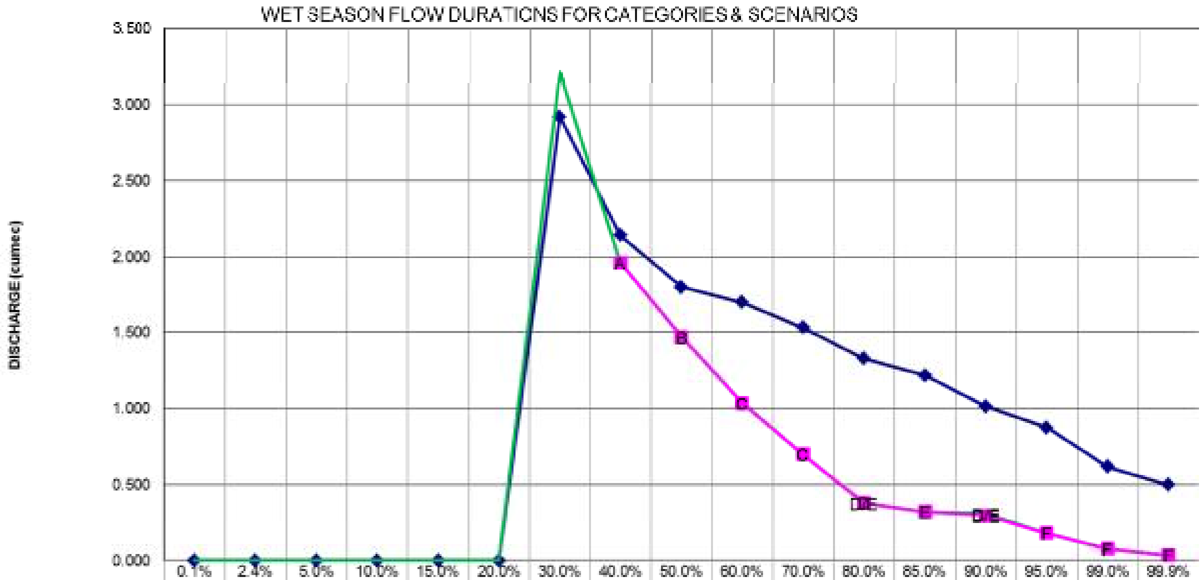


	0.1%	1.0%	5.0%	10.0%	15.0%	20.0%	30.0%	40.0%	50.0%	60.0%	70.0%	80.0%	85.0%	90.0%	95.0%	99.0%	99.9%
NATURAL	0.000	0.000	0.000	0.000	0.000	0.000	2.920	2.143	1.799	1.701	1.532	1.326	1.219	1.012	0.874	0.616	0.497
PRESENT	0.000	0.000	0.000	0.000	0.000	0.000	3.213	1.961	1.471	1.036	0.699	0.381	0.321	0.306	0.179	0.079	0.034
HN52 EWR1a_CD							1.824	1.533	1.251	1.029	0.650	0.338	0.310	0.281	0.156	0.077	0.034
HN52 EWR1a_BC							2.2894	1.8822	1.4710	1.0356	0.6990	0.3452	0.3164	0.2874	0.1576	0.0774	0.0338

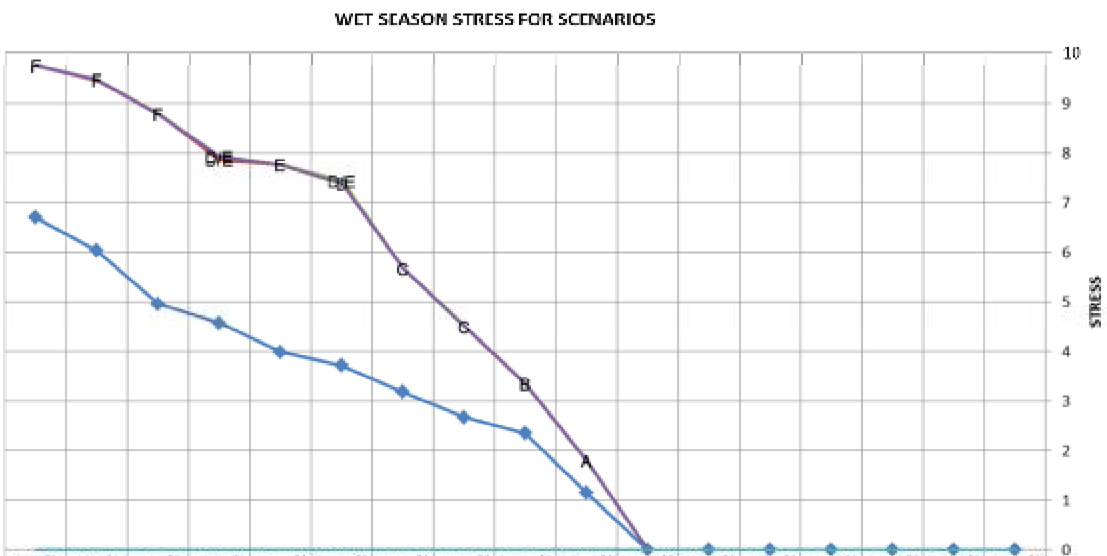


	0.10%	1.00%	5.00%	10.00%	15.00%	20.00%	30.00%	40.00%	50.00%	60.00%	70.00%	80.00%	85.00%	90.00%	95.00%	99.00%	99.90%
NATURAL	6.695	6.029	4.955	4.570	3.994	3.713	3.188	2.679	2.351	1.153	0.000	0.000	0.000	0.000	0.000	0.000	0.000
PRESENT	9.749	9.460	8.785	7.862	7.764	7.389	5.671	4.504	3.345	1.797	0.000	0.000	0.000	0.000	0.000	0.000	0.000
HN52 EWR1a_CD	9.751	9.475	8.965	8.022	7.834	7.656	5.879	4.524	3.911	3.186	2.269	0.000	0.000	0.000	0.000	0.000	0.000
HN52 EWR1a_BC	9.750	9.470	8.947	7.978	7.801	7.613	5.671	4.504	3.345	2.073	0.859	0.000	0.000	0.000	0.000	0.000	0.000
0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

STRESS DURATION



	0.1%	2.4%	5.0%	10.0%	15.0%	20.0%	30.0%	40.0%	50.0%	60.0%	70.0%	80.0%	85.0%	90.0%	95.0%	99.0%	99.9%
NATURAL	0.000	0.000	0.000	0.000	0.000	0.000	2.920	2.143	1.799	1.701	1.532	1.328	1.219	1.012	0.874	0.616	0.497
PRESENT	0.000	0.000	0.000	0.000	0.000	0.000	3.213	1.961	1.471	1.036	0.699	0.381	0.321	0.306	0.179	0.079	0.034
Sc1 HN52								1.961	1.471	1.036	0.699	0.374	0.321	0.295	0.179	0.077	0.034
Sc3 HN52								1.9612	1.4710	1.0356	0.6990	0.3802	0.3213	0.2954	0.1801	0.0774	0.0338



	0.10%	1.00%	5.00%	10.00%	15.00%	20.00%	30.00%	40.00%	50.00%	60.00%	70.00%	80.00%	85.00%	90.00%	95.00%	99.00%	99.90%
NATURAL	6.695	6.029	4.955	4.570	3.994	3.713	3.188	2.679	2.351	1.153	0.000	0.000	0.000	0.000	0.000	0.000	0.000
PRESENT	9.749	9.460	8.785	7.862	7.764	7.389	5.671	4.504	3.345	1.797	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Sc1 HN52	9.751	9.475	8.785	7.927	7.764	7.434	5.671	4.504	3.345	1.798	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Sc3 HN52	9.750	9.470	8.778	7.927	7.764	7.392	5.671	4.504	3.345	1.797	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

STRESS DURATION

MOKOLO EWR 2: BELOW MOKOLO DAM

	Natural	PRESENT	HN57 EWR3_BC	HN57 EWR3_B	Sc1 HN57	Sc3 HN57	Sc1 Ch62	Sc3 Ch62
Fish dry		F	E	E	E	E	F	F
Fish wet		E	D/E	D/E	D	D	F	F
Fish integrated		F	E	E	E	E	F	F
Recommendation								

Comments:

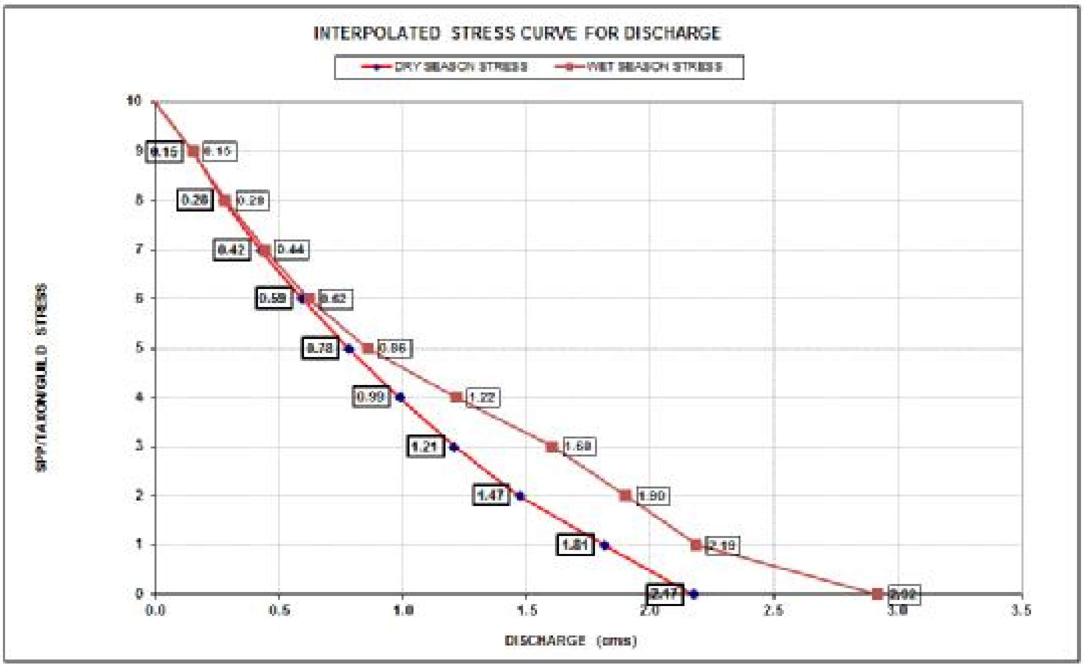
1. Under natural conditions the hydrology indicates that the river is perennial at the site.
2. A rheophilic (Chiloglanis pretoriae) occur at the site during suitable flow conditions.
3. During natural drought flows, FVS habitats are present.
4. Consequently the FFHA were set for all fast flow classes (FVS, FS, FI, FD) for the dry and wet season.
5. Under present conditions, releases from the dam are ceased for weeks at a time (water are released for downstream needs (7-10 days, ~ 5 cumec??). During cessation of dam leases, leakages form the dam maintain a very small population of rheophilics below chutes where flows are concentrated.The impact of these flows on other instream biota as well as riparian vegetation have not been monitored.
6. Both HN57 EWR3_BC & HN57 EWR3_B does not attain the objective of respectively B/C or B
7. A category B/C would resemble the following flow durations:

	"REAL" DRY HN57 EWR3_BC	**CATEGORY**	**"REAL" WET HN57 EWR3_BC**	**CATEGORY**
FLOW DURATION	**FLOW (CUMEC)**	**C/B**	**FLOW (CUMEC)**	**C/B**
0.10%				
1.00%	1.650	C/B		
5.00%	1.550	C/B		
10.00%	1.450	C/B		
15.00%	1.390	C/B		
20.00%	1.360	C/B		
30.00%	1.330	C/B		
40.00%	1.320	C/B	3.000	C/B
50.00%	1.315	C/B	2.300	C/B
60.00%	1.310	C/B	1.900	C/B
70.00%	1.250	C/B	1.800	C/B
80.00%	1.100	C/B	1.700	C/B
85.00%	1.000	C/B	1.600	C/B
90.00%	0.900	C/B	1.550	C/B
95.00%	0.730	C/B	1.500	C/B
99.00%	0.730	A	1.400	A/B
99.90%	0.730	A	1.350	A/B

A category B would resemble the following flow durations:

	"REAL" DRY SEASON HN57 EWR3_B	CATEGORY	"REAL" WET SEASON HN57 EWR3_B	CATEGORY
FLOW DURATION	**FLOW (CUMEC)**	**B**	**FLOW (CUMEC)**	**B**
0.10%				
1.00%	1.8240	B		
5.00%	1.6442	B		
10.00%	1.5744	B		
15.00%	1.5442	B		
20.00%	1.5285	B		
30.00%	1.5082	B		
40.00%	1.4864	B	3.5511	B
50.00%	1.4792	B	2.5329	B
60.00%	1.4513	B	2.1407	B
70.00%	1.3976	B	2.0573	B
80.00%	1.1935	B	1.9014	B
85.00%	1.0967	B	1.7982	B
90.00%	0.9575	B	1.7235	B
95.00%	0.7909	B	1.6222	B
99.00%	0.6695	B	1.4000	A/B
99.90%	0.5277	C	1.3500	A/B

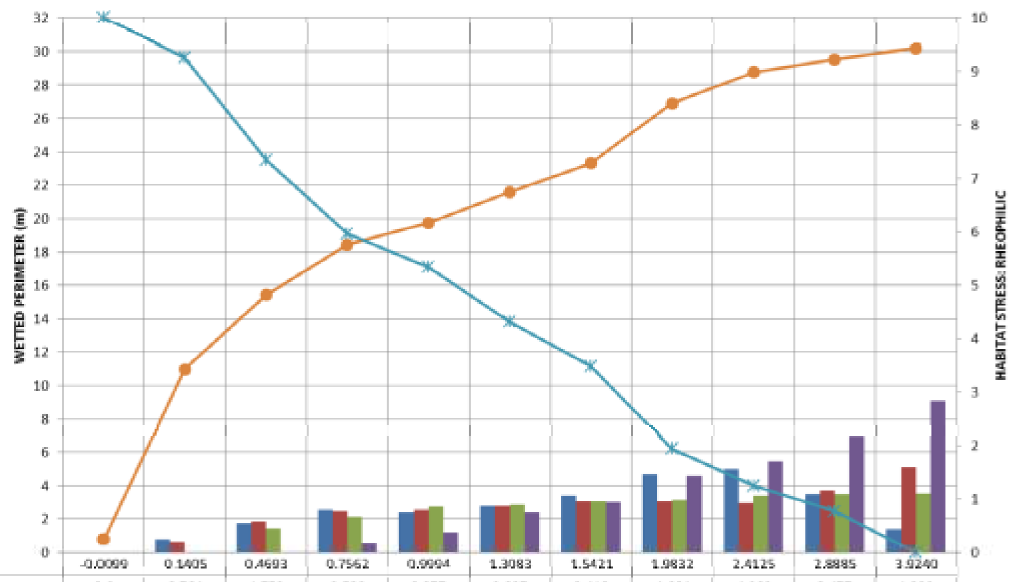
Dry-wet stress profiles:


INTERPOLATED STRESS CURVE FOR DISCHARGE
DRY SEASON STRESS
WET SEASON STRESS
SPP/TAXON/GUILD STRESS
DISCHARGE (cms)
0.28
0.42
0.44
0.59
0.78
0.86
0.99
1.22
1.21
1.47
1.90

<u>DRY SEASON (SEPTEMBER)</u>

Max natural low flow = 3.9240 cumec

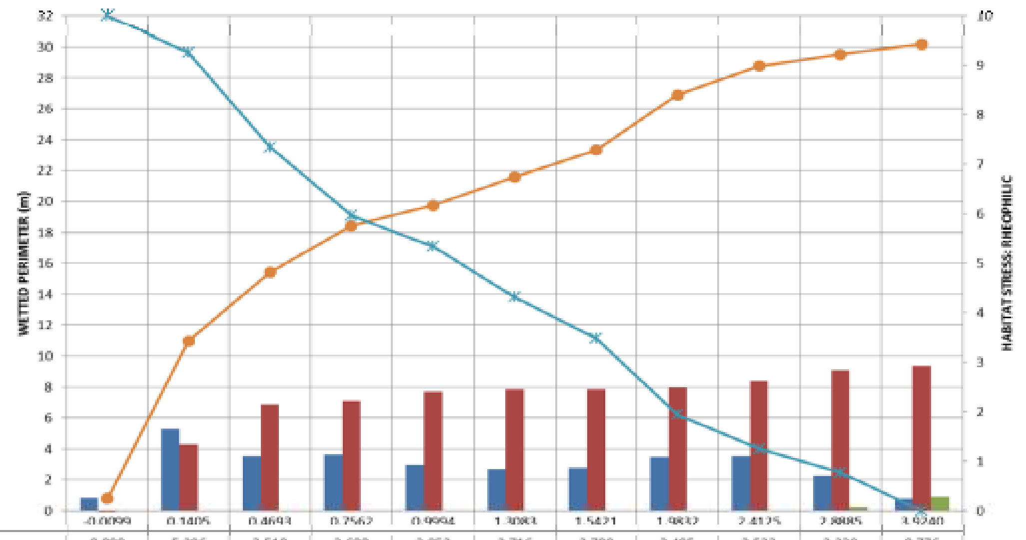
HABITAT STRESS: RHEOPHILIC



DISCHARGE(CUMEC)	-0.0099	0.1405	0.4693	0.7562	0.9994	1.3083	1.5421	1.9832	2.4125	2.8885	3.9240
FVS (m of perimeter)	0.0	0.764	1.752	2.580	2.377	2.807	3.418	4.664	4.960	3.477	1.380
FS (m of perimeter))	0.0	0.647	1.850	2.483	2.566	2.807	3.032	3.045	2.947	3.723	5.129
FINT (m of perimeter)	0.0	0.000	1.444	2.114	2.763	2.870	3.032	3.132	3.378	3.485	3.534
FD (m of perimeter)	0.0	0.000	0.028	0.543	1.209	2.404	2.992	4.576	5.461	6.970	9.094
WETTED PERIMETER WIDTH (m)	1	10.968	15.418	18.426	19.738	21.595	23.324	26.883	28.749	29.522	30.171
HABITAT STRESS: RHEOPHILIC	10.00	9.26	7.35	5.97	5.34	4.31	3.48	1.94	1.25	0.77	0.00

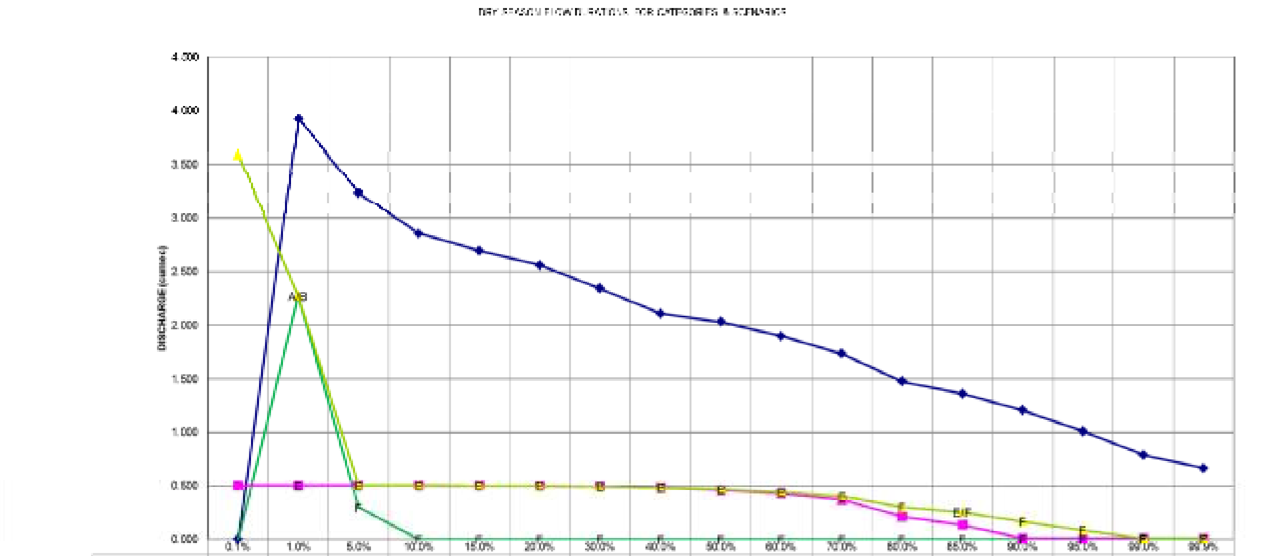
DISCHARGE(CUMEC)

HABITAT STRESS: RHEOPHILIC

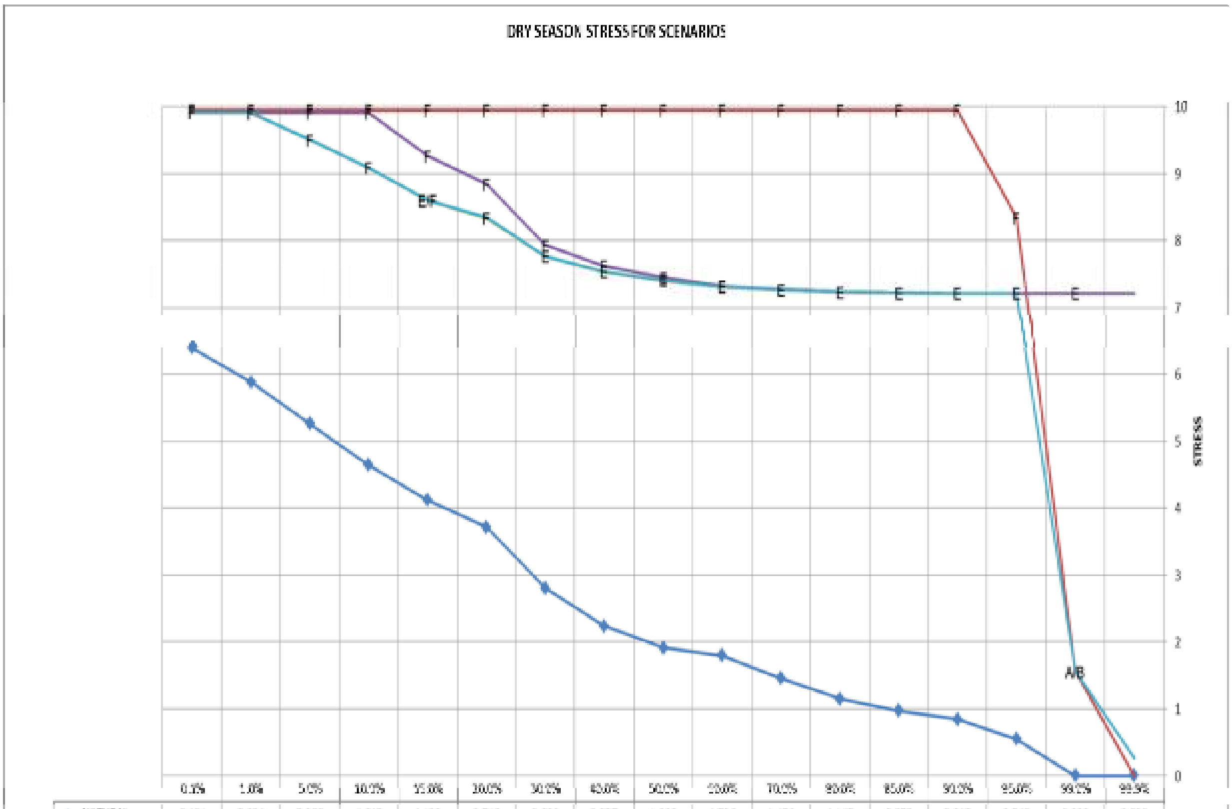


DISCHARGE(CUMEC)	-0.0099	0.1405	0.4693	0.7562	0.9994	1.3083	1.5421	1.9832	2.4125	2.8885	3.9240
SVS m	0.808	5.296	3.518	3.608	2.952	2.716	2.799	3.495	3.523	2.239	0.776
SS m	-0.03	4.26	6.85	7.09	7.68	7.84	7.82	7.97	8.41	9.09	9.35
SD m	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.238	0.905
WETTED PERIMETER WIDTH (m)	1	10.968	15.418	18.426	19.738	21.595	23.324	26.883	28.749	29.522	30.171
HABITAT STRESS: RHEOPHILIC	10.00	9.26	7.35	5.97	5.34	4.31	3.48	1.94	1.25	0.77	0.00

DISCHARGE(CUMEC)

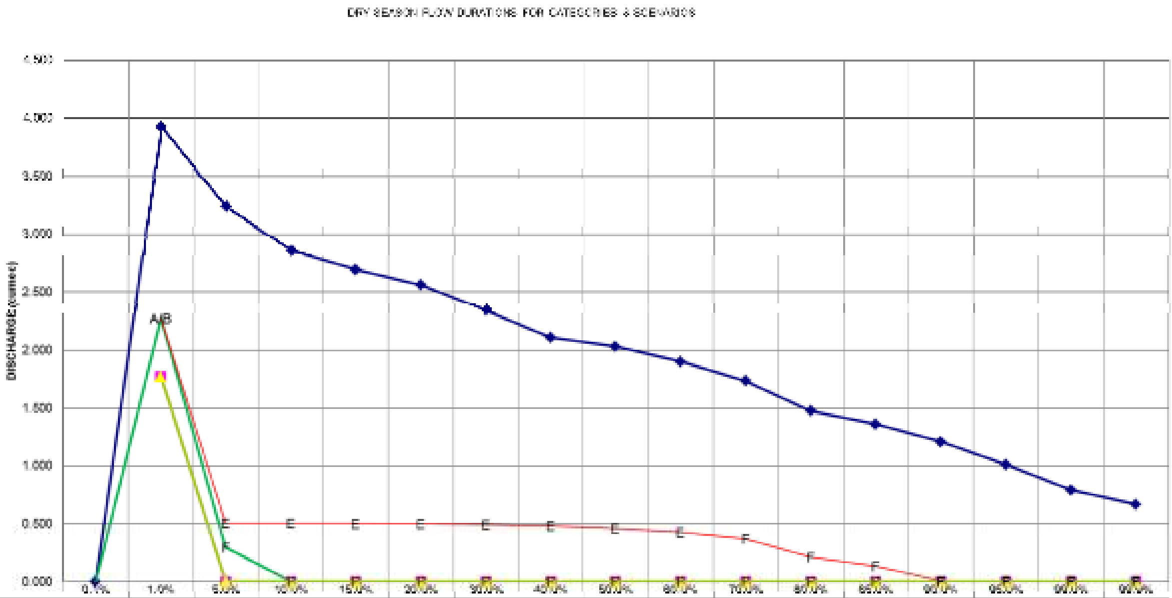


	0.1%	1.0%	5.0%	10.0%	15.0%	20.0%	30.0%	40.0%	50.0%	60.0%	70.0%	80.0%	85.0%	90.0%	95.0%	99.0%	99.9%
NATURAL	0.000	3.924	3.232	2.858	2.696	2.561	2.343	2.109	2.031	1.899	1.736	1.476	1.360	1.209	1.010	0.790	0.666
PRESENT	0.000	2.274	0.298	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
HN57 EWR3_BC	0.503	0.503	0.503	0.503	0.502	0.499	0.493	0.485	0.467	0.442	0.400	0.299	0.254	0.168	0.066	0.008	0.007
HN57 EWR3_B	0.5030	0.5030	0.5030	0.5030	0.5017	0.4896	0.4822	0.4624	0.4590	0.4270	0.3896	0.2124	0.1336	0.0080	0.0080	0.0078	0.0071
Sc1 HN57	3.5907	2.2741	0.5030	0.5030	0.5017	0.4890	0.4802	0.4852	0.4670	0.4424	0.4004	0.2986	0.2536	0.1678	0.0864	0.0078	0.0071

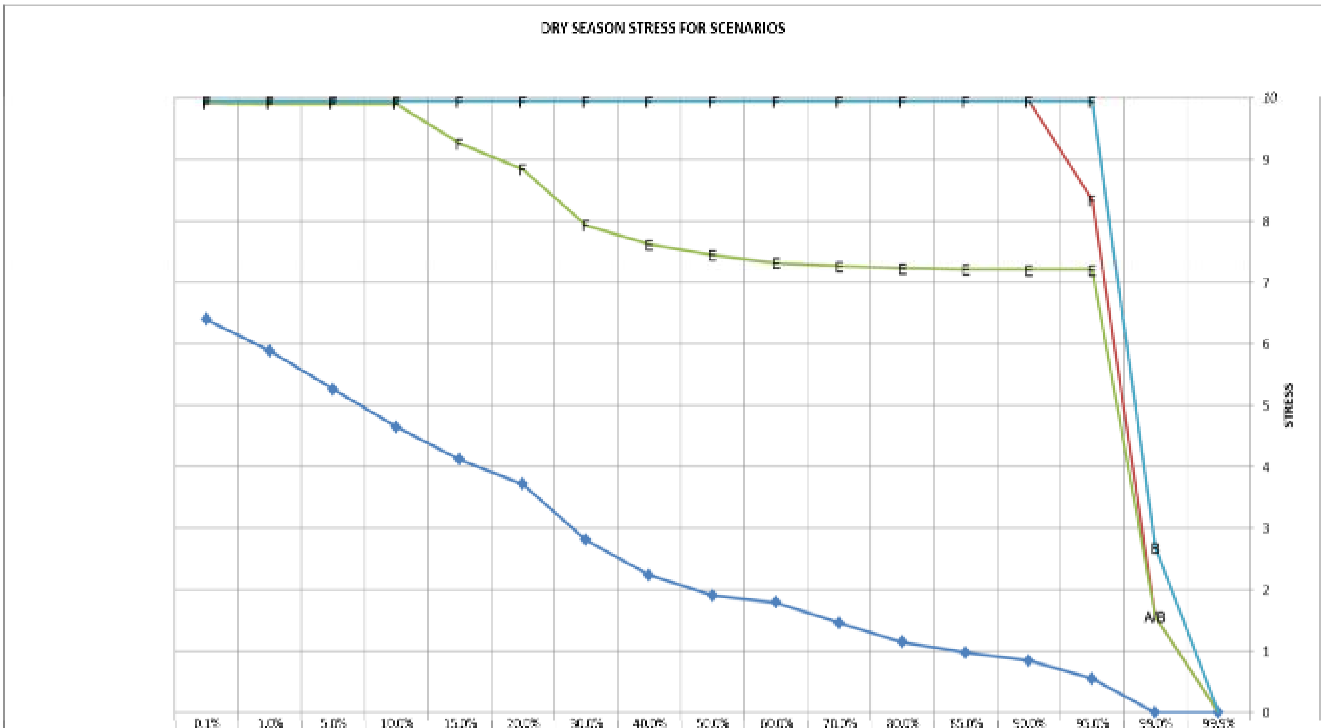


	0.1%	1.0%	5.0%	10.0%	15.0%	20.0%	30.0%	40.0%	50.0%	60.0%	70.0%	80.0%	85.0%	90.0%	95.0%	99.0%	99.9%
NATURAL	6.401	5.884	5.260	4.645	4.122	3.718	2.809	2.237	1.908	1.796	1.459	1.145	0.973	0.845	0.548	0.000	0.000
PRESENT	9.949	9.949	9.949	9.949	9.949	9.949	9.949	9.949	9.949	9.949	9.949	9.949	9.949	9.949	8.345	1.558	0.000
HN57 EWR3_BC	9.914	9.909	9.510	9.090	8.602	8.340	7.769	7.541	7.405	7.308	7.264	7.232	7.215	7.210	7.210	7.210	7.210
HN57 EWR3_B	9.913	9.909	9.909	9.909	9.266	8.844	7.934	7.622	7.449	7.322	7.269	7.232	7.217	7.210	7.210	7.210	7.210
Sc1 HN57	9.913	9.909	9.507	9.091	8.604	8.342	7.767	7.539	7.405	7.307	7.263	7.232	7.217	7.210	7.210	1.558	0.264

STRESS DURATION



	0.1%	1.0%	5.0%	10.0%	15.0%	20.0%	30.0%	40.0%	50.0%	60.0%	70.0%	80.0%	85.0%	90.0%	95.0%	98.0%	99.0%
NATURAL	0.000	3.924	3.232	2.858	2.696	2.561	2.343	2.109	2.031	1.899	1.735	1.476	1.360	1.206	1.010	0.790	0.666
PRESENT	0.000	2.274	0.298	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Sc3 HN57		2.274	0.503	0.503	0.502	0.499	0.492	0.482	0.469	0.427	0.370	0.212	0.134	0.008	0.008	0.008	0.007
Sc1 Ch62		1.7711	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Sc3 Ch62		1.7711	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

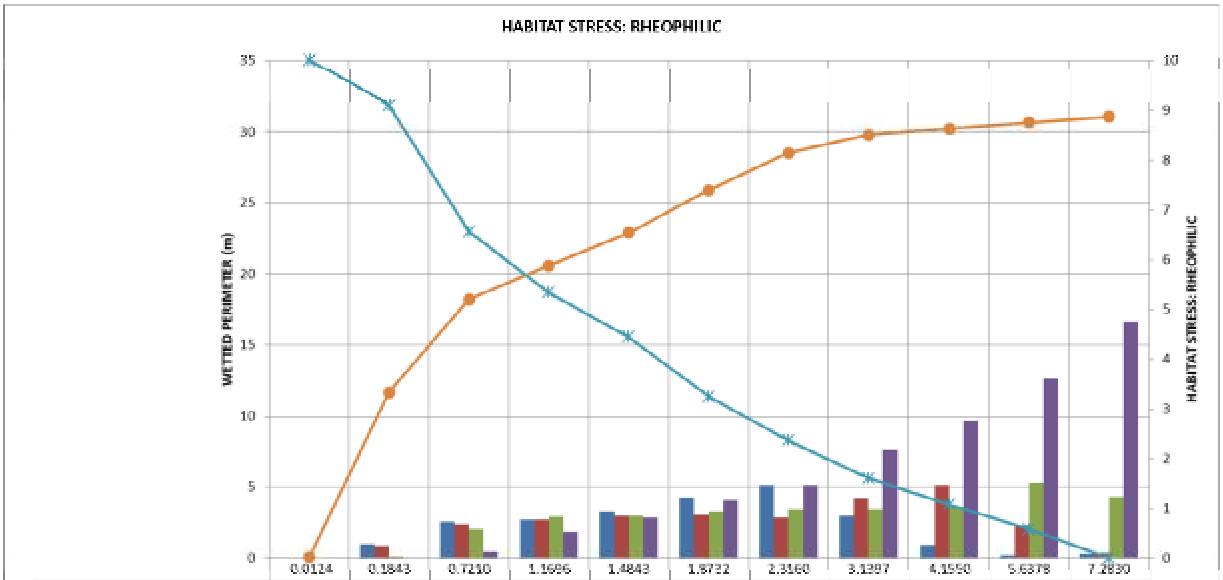


	0.1%	1.0%	5.0%	10.0%	15.0%	20.0%	30.0%	40.0%	50.0%	60.0%	70.0%	80.0%	85.0%	90.0%	95.0%	99.0%	99.9%
NATURAL	6.401	5.884	5.260	4.645	4.122	3.718	2.809	2.237	1.908	1.796	1.459	1.145	0.973	0.845	0.548	0.000	0.000
PRESENT	9.949	9.949	9.949	9.949	9.949	9.949	9.949	9.949	9.949	9.949	9.949	9.949	9.949	9.949	8.345	1.558	0.000
Sc3 HN57	9.913	9.909	9.909	9.909	9.266	8.844	7.934	7.622	7.449	7.322	7.269	7.232	7.217	7.210	7.210	1.558	0.000
Sc1 Ch62	9.949	9.949	9.949	9.949	9.949	9.949	9.949	9.949	9.949	9.949	9.949	9.949	9.949	9.949	9.949	2.683	0.000
Sc3 Ch62	9.949	9.949	9.949	9.949	9.949	9.949	9.949	9.949	9.949	9.949	9.949	9.949	9.949	9.949	9.949	2.683	0.000

STRESS DURATION

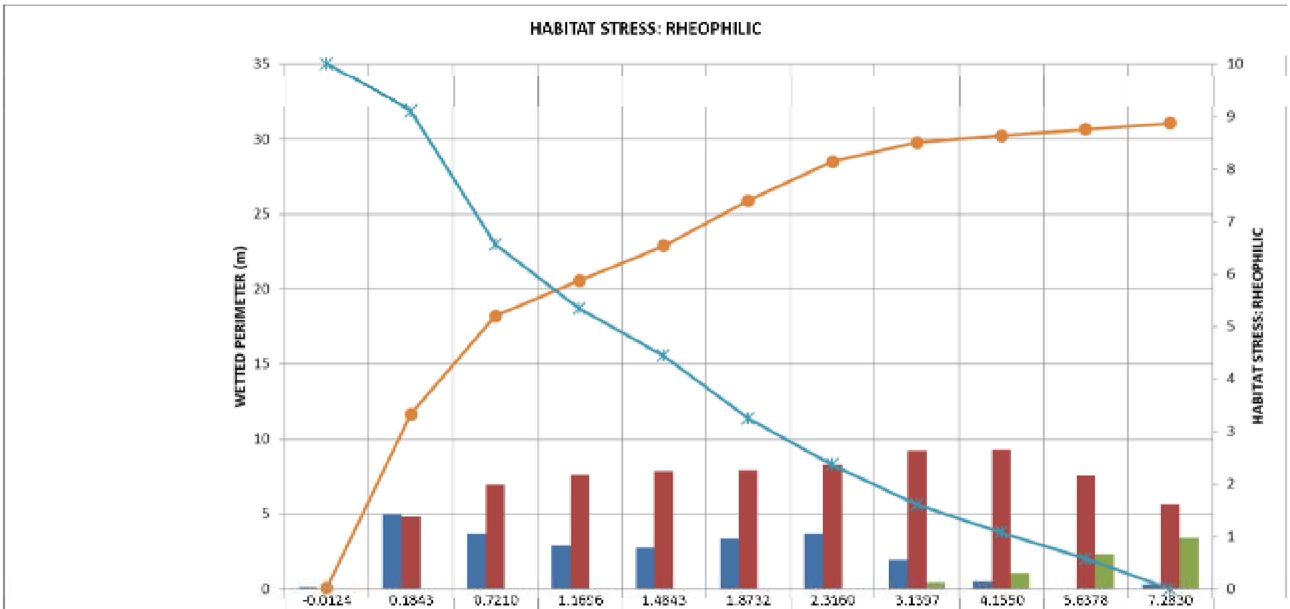
<u>DRY SEASON (FEBRUARY)</u>

Max natural low flow = 7.2830 cumec



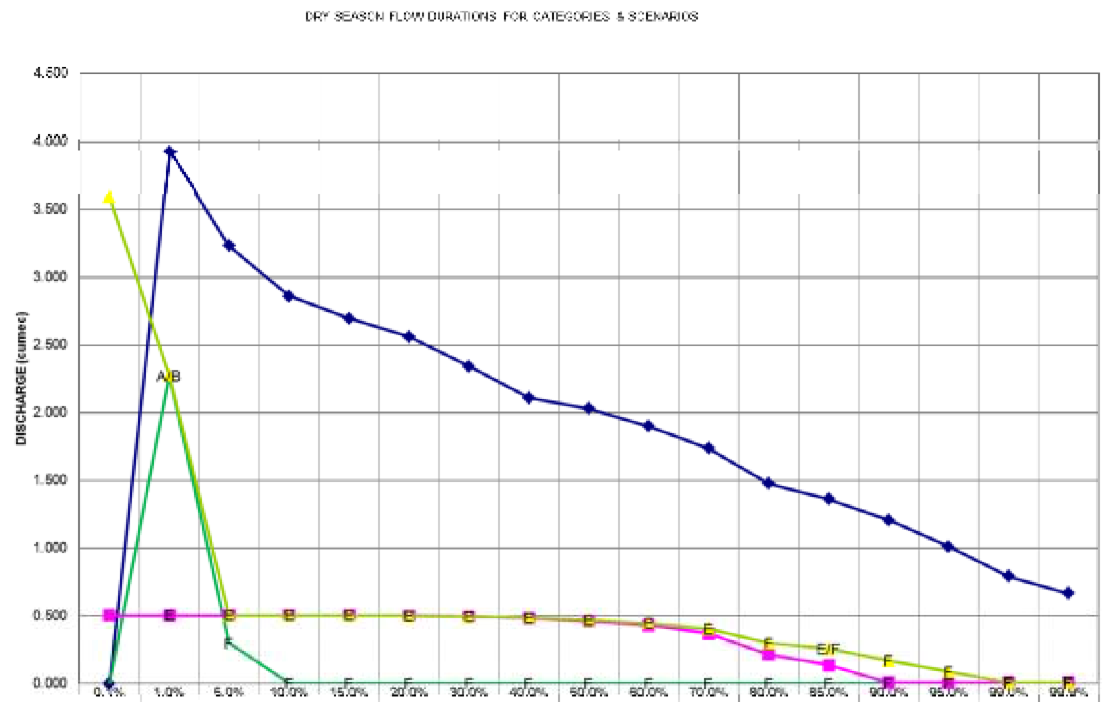
	0.0124	0.1843	0.7210	1.1696	1.4843	1.8732	2.3160	3.1397	4.1550	5.6378	7.2830
FVS (m of perimeter)	0.0	0.990	2.549	2.679	3.231	4.274	5.133	2.941	0.940	0.196	0.311
FS (m of perimeter))	0.0	0.873	2.409	2.679	2.976	3.049	2.876	4.203	5.139	2.282	0.381
FINT (m of perimeter)	0.0	0.087	2.044	2.884	2.976	3.246	3.398	3.406	3.628	5.299	4.322
FD (m of perimeter)	0.0	0.000	0.448	1.856	2.875	4.077	5.133	7.644	9.641	12.658	16.669
WETTED PERIMETER WIDTH (m)	0	11.667	18.206	20.605	22.892	25.930	28.516	29.768	30.230	30.664	31.077
HABITAT STRESS: RHEOPHILIC	10.00	9.10	6.56	5.34	4.44	3.25	2.37	1.61	1.08	0.58	0.00

DISCHARGE(CUMEC)

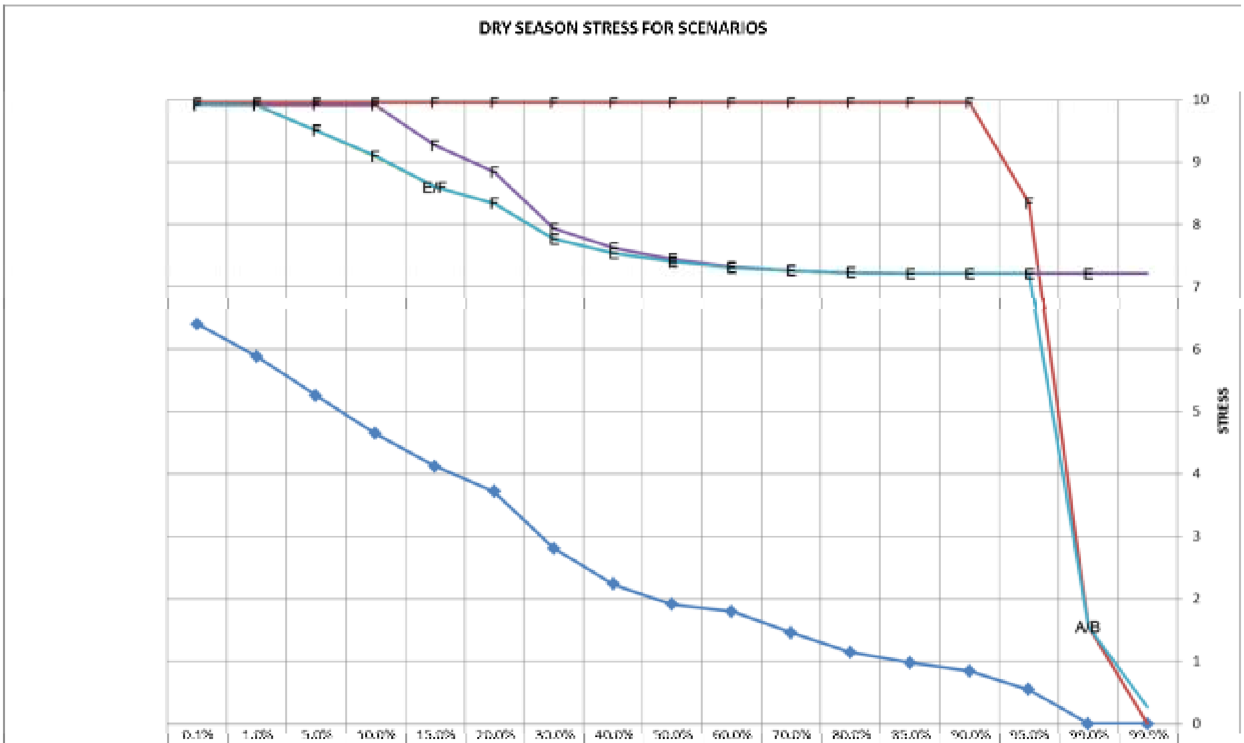


	-0.0124	0.1843	0.7210	1.1696	1.4843	1.8732	2.3160	3.1397	4.1550	5.6378	7.2830
SVS m	0.117	4.995	3.698	2.883	2.747	3.371	3.707	1.917	0.515	0.000	0.311
SS m	-0.01	4.81	6.96	7.62	7.86	7.91	8.27	9.23	9.28	7.58	5.66
SD m	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.464	1.087	2.343	3.419
WETTED PERIMETER WIDTH (m)	0	11.667	18.206	20.605	22.892	25.930	28.516	29.768	30.230	30.664	31.077
HABITAT STRESS: RHEOPHILIC	10.00	9.10	6.56	5.34	4.44	3.25	2.37	1.61	1.08	0.58	0.00

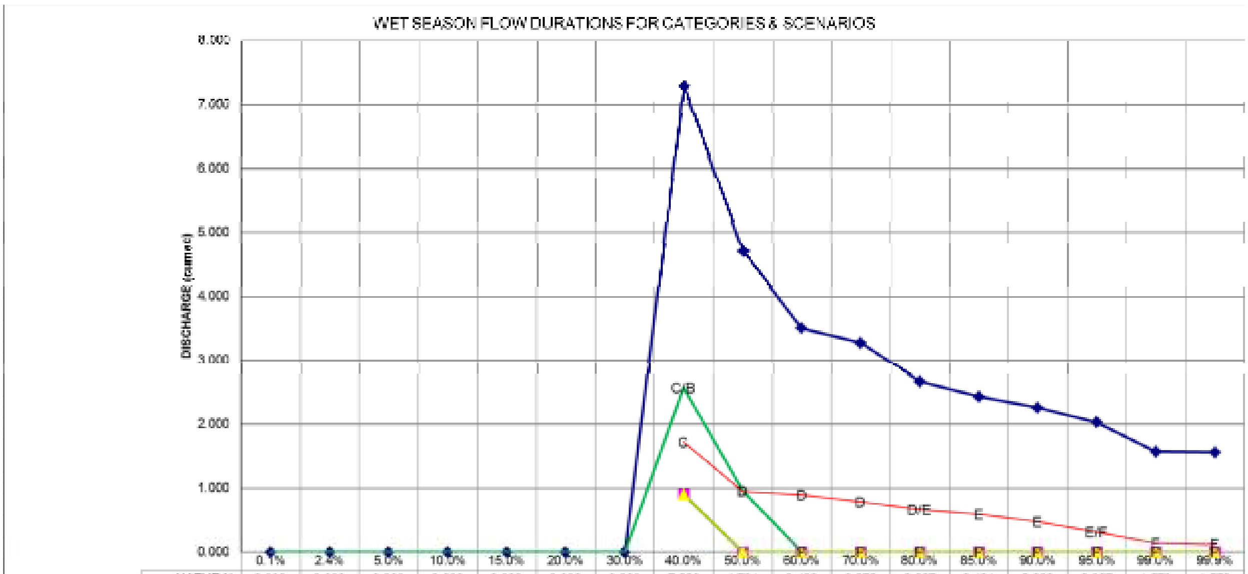
DISCHARGE(CUMEC)



	0.1%	1.0%	5.0%	10.0%	15.0%	20.0%	30.0%	40.0%	50.0%	60.0%	70.0%	80.0%	85.0%	90.0%	95.0%	99.0%	99.9%
NATURAL	0.000	3.924	3.232	2.858	2.696	2.561	2.343	2.109	2.031	1.899	1.735	1.476	1.360	1.206	1.010	0.790	0.666
PRESENT	0.000	2.274	0.298	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
HN57 EWR3_BC	0.503	0.503	0.503	0.503	0.502	0.499	0.493	0.485	0.467	0.442	0.400	0.299	0.254	0.168	0.086	0.008	0.007
HN57 EWR3_B	0.5030	0.5030	0.5030	0.5030	0.5017	0.4990	0.4922	0.4824	0.4590	0.4270	0.3696	0.2124	0.1336	0.0080	0.0080	0.0078	0.0071
Sc1 HN57	3.5907	2.2741	0.5030	0.5030	0.5017	0.4990	0.4932	0.4852	0.4870	0.4424	0.4004	0.2986	0.2536	0.1678	0.0864	0.0078	0.0071

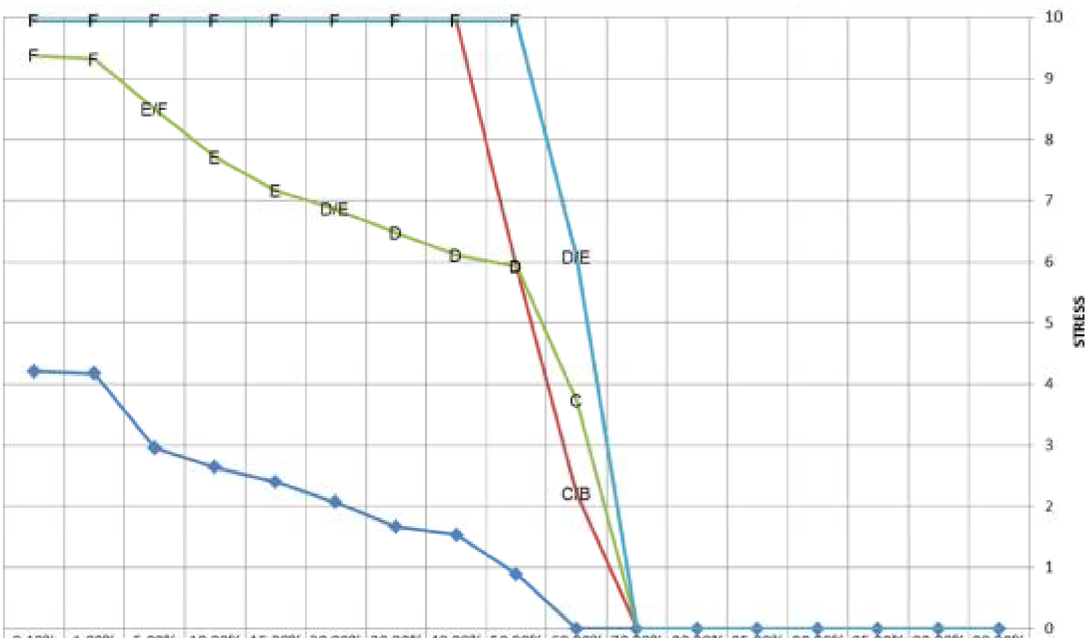


	0.1%	1.0%	5.0%	10.0%	15.0%	20.0%	30.0%	40.0%	50.0%	60.0%	70.0%	80.0%	85.0%	90.0%	95.0%	99.0%	99.9%
NATURAL	6.401	5.884	5.260	4.645	4.122	3.718	2.809	2.237	1.908	1.796	1.459	1.145	0.973	0.845	0.548	0.000	0.000
PRESENT	9.949	9.949	9.949	9.949	9.949	9.949	9.949	9.949	9.949	9.949	9.949	9.949	9.949	9.949	8.345	1.558	0.000
HN57 EWR3_BC	9.914	9.909	9.510	9.090	8.602	8.340	7.769	7.541	7.405	7.308	7.264	7.232	7.215	7.210	7.210	7.210	7.210
HN57 EWR3_B	9.913	9.909	9.909	9.909	9.266	8.844	7.934	7.622	7.449	7.322	7.269	7.232	7.217	7.210	7.210	7.210	7.210
Sc1 HN57	9.913	9.909	9.507	9.091	8.604	8.342	7.767	7.539	7.405	7.307	7.263	7.232	7.217	7.210	7.210	1.558	0.264



	0.1%	2.4%	5.0%	10.0%	15.0%	20.0%	30.0%	40.0%	50.0%	60.0%	70.0%	80.0%	85.0%	90.0%	95.0%	99.0%	99.9%
NATURAL	0.000	0.000	0.000	0.000	0.000	0.000	0.000	7.283	4.701	3.499	3.272	2.667	2.431	2.260	2.027	1.570	1.558
PRESENT	0.000	0.000	0.000	0.000	0.000	0.000	0.000	2.588	0.980	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Sc3 HN57								1.726	0.953	0.897	0.786	0.671	0.594	0.479	0.311	0.137	0.124
Sc1 Ch62								0.9044	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Sc3 Ch62								0.9044	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

WET SEASON STRESS FOR SCENARIOS



	0.10%	1.00%	5.00%	10.00%	15.00%	20.00%	30.00%	40.00%	50.00%	60.00%	70.00%	80.00%	85.00%	90.00%	95.00%	99.00%	99.90%
NATURAL	4.205	4.170	2.959	2.636	2.399	2.071	1.668	1.531	0.891	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
PRESENT	9.943	9.943	9.943	9.943	9.943	9.943	9.943	9.943	5.912	2.208	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Sc3 HN57	9.373	9.315	8.501	7.707	7.166	6.860	6.476	6.103	5.932	3.733	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Sc1 Ch62	9.943	9.943	9.943	9.943	9.943	9.943	9.943	9.943	9.943	6.080	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Sc3 Ch62	9.943	9.943	9.943	9.943	9.943	9.943	9.943	9.943	9.943	6.080	0.000	0.000	0.000	0.000	0.000	0.000	0.000

STRESS DURATION

MOKOLO EWR 10: STERKSPRUIT

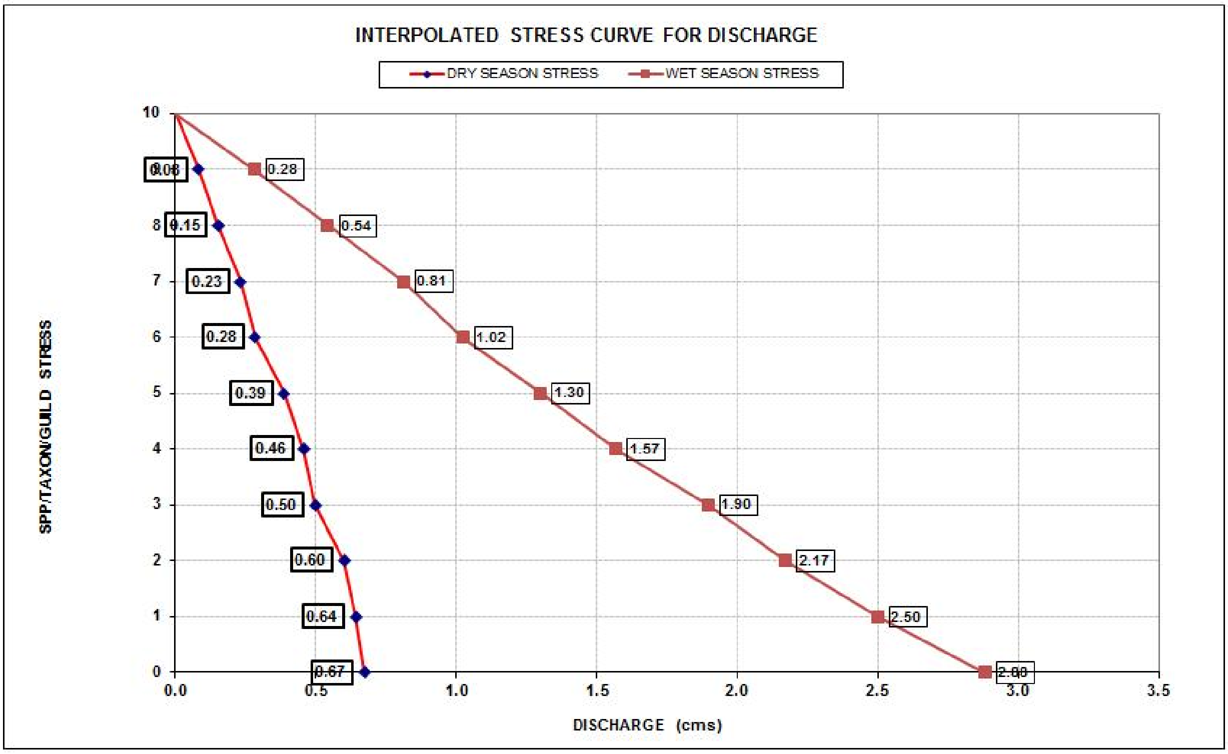
	Natural	PRESENT	HN54 EWR10_BC	Sc1 HN54	"REAL" HN54 EWR10_BC
Fish dry		E	D	D	C/B
Fish wet		A	A	A	C/B
Fish integrated		A	A	A	C/B
Recommendation					

Comments:

1. Under natural conditions the hydrology indicates that the river is perennial at the site.
2. The rheophilics Amphilius uranoscopus and Chiloglanis pretoriae occur in the
3. During natural drought flows, FVS & FS habitats are present.
4. Consequently the FFHA were set for all fast flow classes (FVS, FS, FI, FD) for the dry and wet season.
5. HN54 EWR10_BC does not equate to a B/C category.
6. A category B/C would resemble the following flow durations:

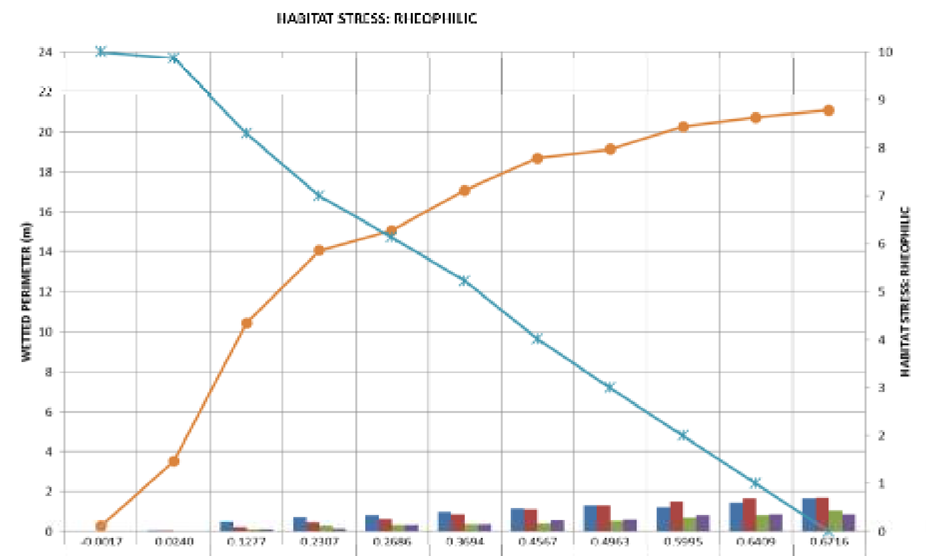
	"REAL" DRY HN54 EWR10_BC	CATEGORY	"REAL" WET HN54 EWR10_BC	CATEGORY
FLOW DURATION	**FLOW (CUMEC)**	**C/B**	**FLOW (CUMEC)**	**C/B**
0.10%				
1.00%				
5.00%	0.2600	C/B		
10.00%	0.2500	C/B		
15.00%	0.2400	C/B		
20.00%	0.2380	C/B		
30.00%	0.2300	C/B	1.0000	C/B
40.00%	0.2200	C/B	0.4000	C/B
50.00%	0.2150	C/B	0.3700	C/B
60.00%	0.2100	C/B	0.3000	C/B
70.00%	0.1900	C/B	0.2800	C/B
80.00%	0.1600	C/B	0.2200	C/B
85.00%	0.1400	C/B	0.2100	C/B
90.00%	0.1150	C/B	0.2000	C/B
95.00%	0.1050	C/B	0.2000	A/B
99.00%	0.1040	A	0.1600	A
99.90%	0.0840	A	0.1400	A

Dry-wet stress profiles:



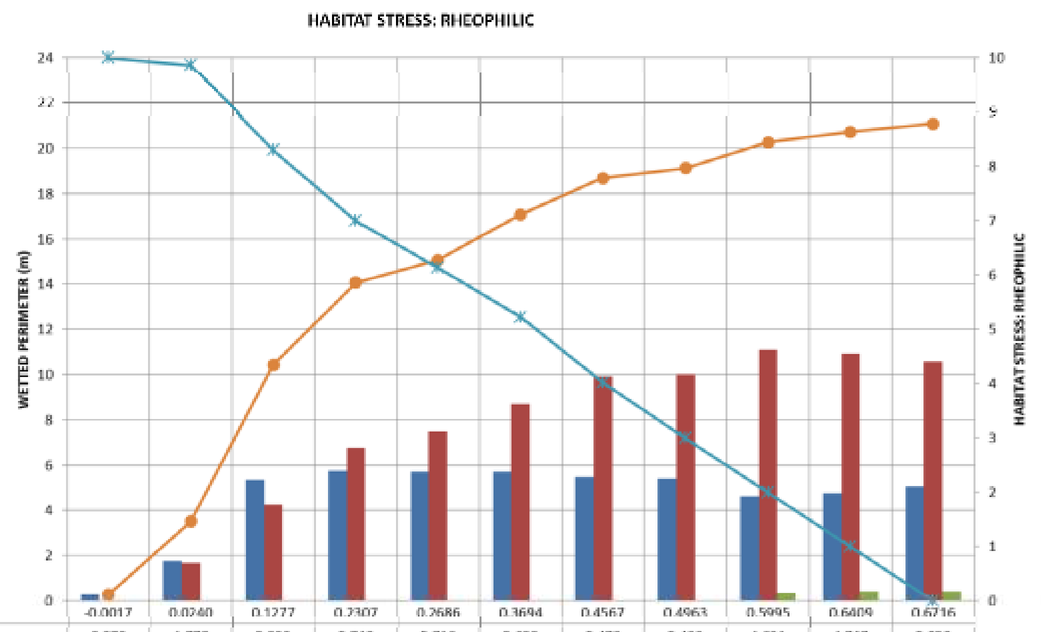
DRY SEASON (OCTOBER)

Max natural low flow = 0.6716 cumec



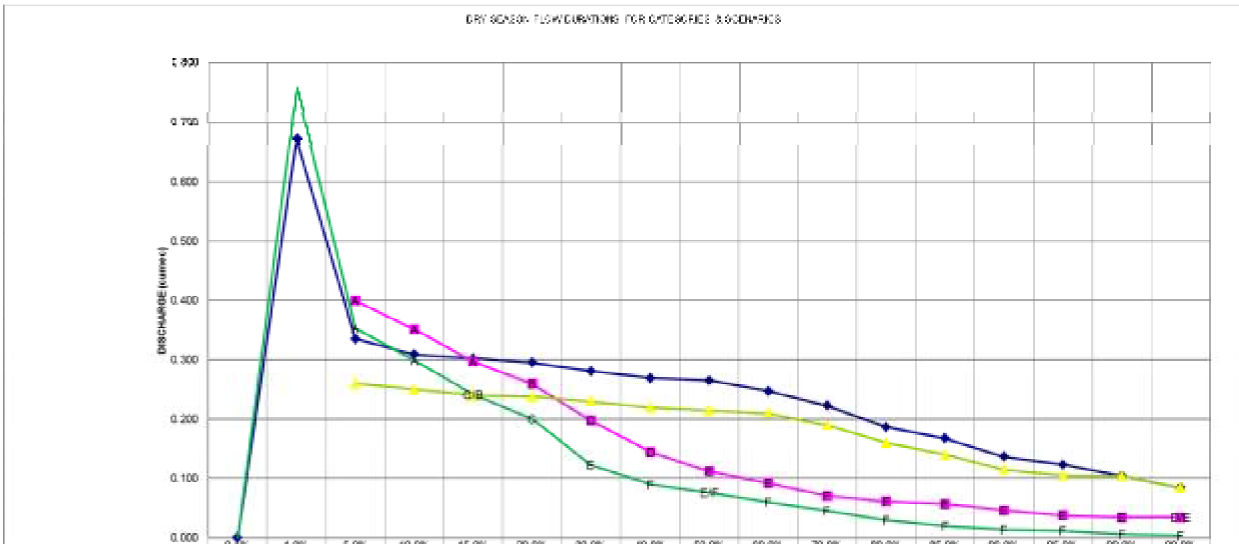
	-0.0017	0.0240	0.1277	0.2307	0.2686	0.3694	0.4567	0.4963	0.5995	0.6409	0.6716
FVS (m of perimeter)	0.0	0.035	0.475	0.713	0.823	0.971	1.121	1.289	1.216	1.430	1.677
FS (m of perimeter)	0.0	0.035	0.209	0.431	0.603	0.854	1.103	1.289	1.508	1.659	1.687
FINT (m of perimeter)	0.0	0.000	0.104	0.281	0.301	0.342	0.374	0.523	0.665	0.807	1.044
FD (m of perimeter)	0.0	0.000	0.104	0.150	0.301	0.342	0.543	0.574	0.811	0.829	0.843
WETTED PERIMETER WIDTH (m)	0	3.508	10.433	14.065	15.075	17.076	18.687	19.137	20.274	20.735	21.084
HABITAT STRESS: RHEOPHILIC	10.00	9.87	8.30	7.00	6.14	5.22	4.02	3.00	2.00	1.00	0.00

DISCHARGE(CUMEC)

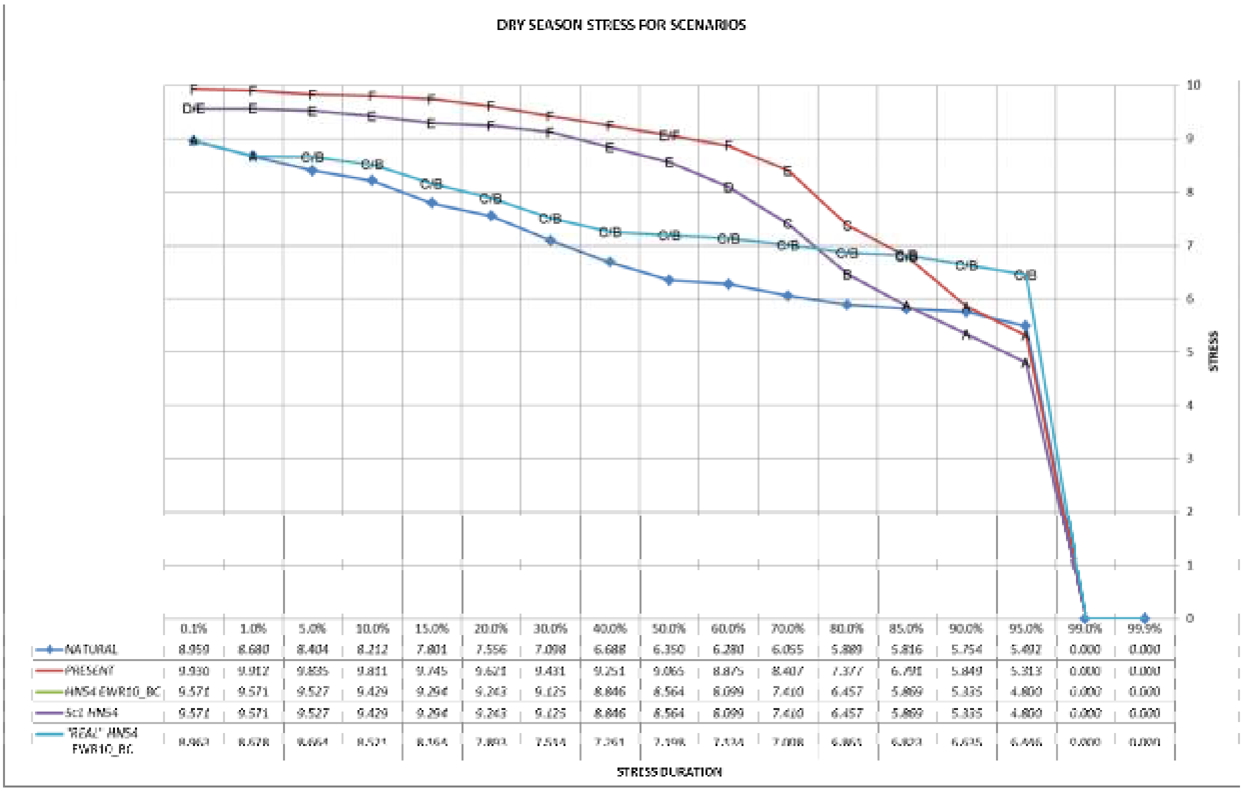


	-0.0017	0.0240	0.1277	0.2307	0.2686	0.3694	0.4567	0.4963	0.5995	0.6409	0.6716
SVS m	0.279	1.770	5.332	5.748	5.716	5.699	5.473	5.409	4.631	4.747	5.050
SS m	0.00	1.65	4.27	6.76	7.47	8.70	9.90	10.00	11.09	10.94	10.57
SD m	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.348	0.415	0.422
WETTED PERIMETER WIDTH (m)	0	3.508	10.433	14.065	15.075	17.076	18.687	19.137	20.274	20.735	21.084
HABITAT STRESS: RHEOPHILIC	10.00	9.87	8.30	7.00	6.14	5.22	4.02	3.00	2.00	1.00	0.00

DISCHARGE(CUMEC)



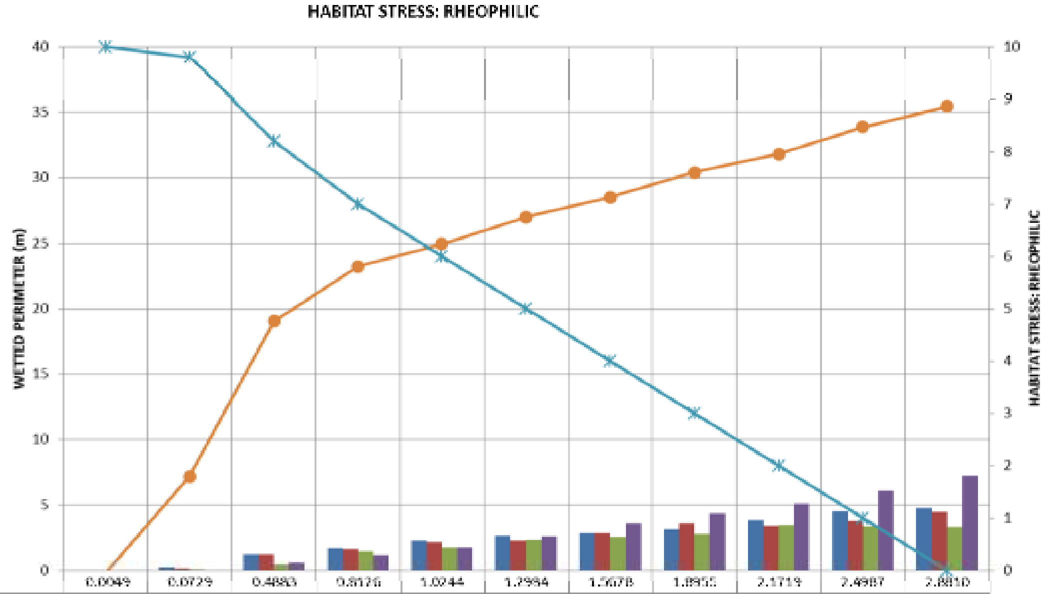
	0.1%	1.0%	5.0%	10.0%	15.0%	20.0%	30.0%	40.0%	50.0%	60.0%	70.0%	80.0%	85.0%	90.0%	95.0%	99.0%	99.9%
NATURAL	0.000	0.672	0.335	0.309	0.302	0.295	0.281	0.269	0.265	0.247	0.223	0.187	0.167	0.137	0.123	0.104	0.084
PRESENT	0.000	0.758	0.354	0.299	0.242	0.201	0.123	0.090	0.076	0.061	0.046	0.030	0.020	0.014	0.012	0.006	0.004
HN54 EWR10_BC			0.400	0.351	0.297	0.259	0.198	0.145	0.112	0.092	0.071	0.061	0.057	0.046	0.038	0.034	0.034
Sc1 HN54			0.3999	0.3514	0.2970	0.2594	0.1982	0.1446	0.1120	0.0922	0.0710	0.0612	0.0570	0.0458	0.0376	0.0340	0.0340
"REAL" HN54 EWR10_BC			0.2600	0.2500	0.2400	0.2380	0.2300	0.2200	0.2150	0.2100	0.1900	0.1600	0.1400	0.1150	0.1050	0.1040	0.0840



	0.1%	1.0%	5.0%	10.0%	15.0%	20.0%	30.0%	40.0%	50.0%	60.0%	70.0%	80.0%	85.0%	90.0%	95.0%	99.0%	99.9%
NATURAL	8.959	8.680	8.404	8.212	7.801	7.556	7.098	6.688	6.350	6.280	6.055	5.889	5.816	5.754	5.492	0.000	0.000
PRESENT	9.930	9.912	9.835	9.811	9.745	9.621	9.431	9.251	9.065	8.875	8.407	7.377	6.791	5.849	5.313	0.000	0.000
HN54 EWR10_BC	9.571	9.571	9.527	9.429	9.294	9.243	9.125	8.846	8.564	8.099	7.410	6.457	5.869	5.335	4.800	0.000	0.000
Sc1 HN54	9.571	9.571	9.527	9.429	9.294	9.243	9.125	8.846	8.564	8.099	7.410	6.457	5.869	5.335	4.800	0.000	0.000
"REAL" HN54 EWR10_BC	8.963	8.678	8.664	8.521	8.164	7.893	7.514	7.261	7.198	7.134	7.008	6.865	6.823	6.635	6.446	0.000	0.000

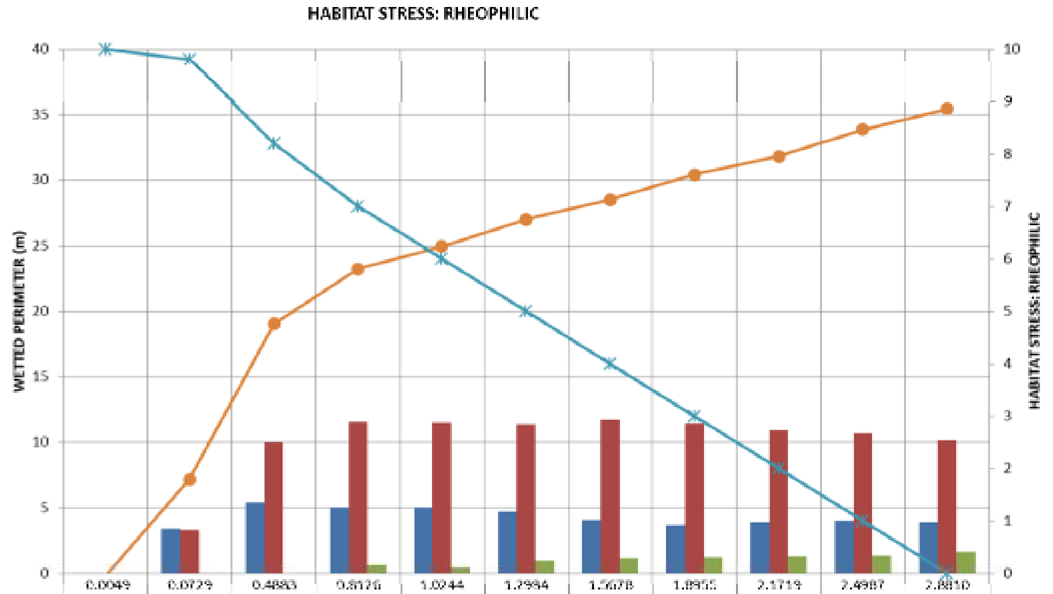
<u>WET SEASON (FEBRUARY)</u>

Max natural low flow = 2.8810 cumec



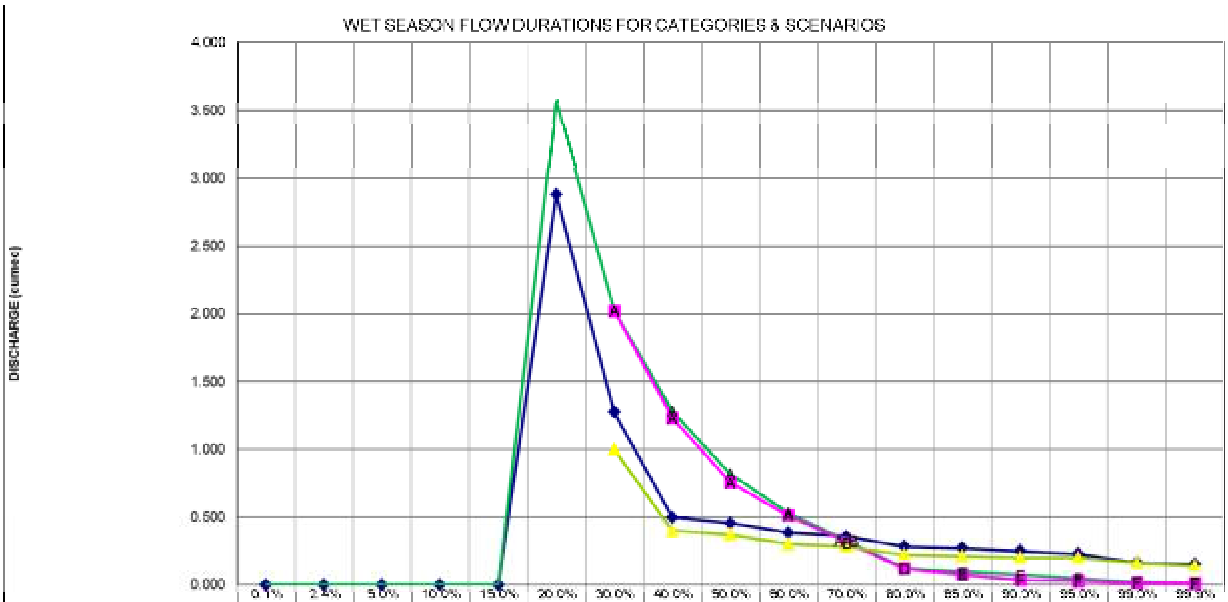
	0.0049	0.0729	0.4883	0.8126	1.0244	1.2994	1.5678	1.8955	2.1719	2.4987	2.8810
FVS (m of perimeter)	0.0	0.216	1.251	1.690	2.247	2.702	2.852	3.121	3.818	4.558	4.754
FS (m of perimeter))	0.0	0.114	1.251	1.627	2.175	2.263	2.852	3.577	3.426	3.764	4.464
FINT (m of perimeter)	0.0	0.072	0.489	1.458	1.747	2.330	2.567	2.817	3.500	3.389	3.336
FD (m of perimeter)	0.0	0.000	0.571	1.162	1.747	2.600	3.603	4.339	5.090	6.101	7.236
WETTED PERIMETER WIDTH (m)	0	7.197	19.047	23.246	24.963	27.020	28.525	30.448	31.814	33.894	35.457
HABITAT STRESS: RHEOPHILIC	10.00	9.80	8.20	7.00	6.00	5.00	4.00	3.00	2.00	1.00	0.00

DISCHARGE(CUMEC)

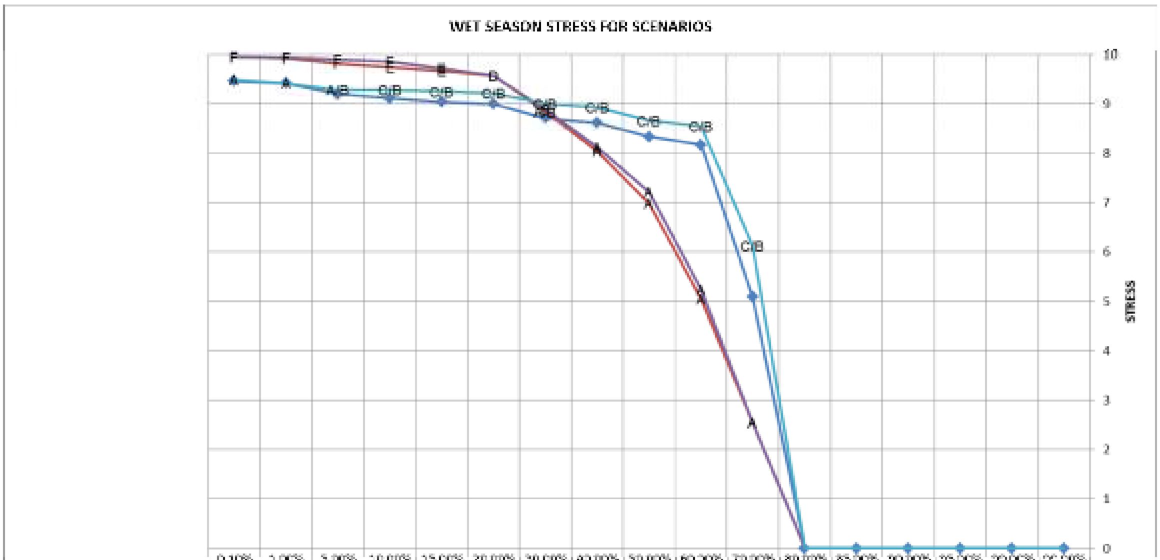


	0.0049	0.0729	0.4883	0.8126	1.0244	1.2994	1.5678	1.8955	2.1719	2.4987	2.8810
SVS m	-0.162	3.442	5.415	5.051	5.028	4.695	4.046	3.692	3.891	4.031	3.900
SS m	0.00	3.32	9.99	11.56	11.52	11.35	11.70	11.46	10.89	10.69	10.14
SD m	0.000	0.000	0.000	0.634	0.499	0.979	1.194	1.218	1.273	1.356	1.628
WETTED PERIMETER WIDTH (m)	0	7.197	19.047	23.246	24.963	27.020	28.525	30.448	31.814	33.894	35.457
HABITAT STRESS: RHEOPHILIC	10.00	9.80	8.20	7.00	6.00	5.00	4.00	3.00	2.00	1.00	0.00

DISCHARGE(CUMEC)



	0.1%	2.?%	5.0%	10.0%	15.0%	20.0%	30.0%	40.0%	50.0%	60.0%	70.0%	80.0%	85.0%	90.0%	95.0%	99.0%	99.9%
NATURAL	0.000	0.000	0.000	0.000	0.000	2.881	1.273	0.498	0.455	0.382	0.356	0.281	0.270	0.248	0.225	0.161	0.149
PRESENT	0.000	0.000	0.000	0.000	0.000	3.569	2.023	1.286	0.816	0.532	0.324	0.119	0.092	0.069	0.047	0.017	0.010
HN54 EWR10_BC							2.023	1.232	0.765	0.512	0.311	0.117	0.074	0.036	0.025	0.013	0.009
Sc1 HN54							2.0226	1.2324	0.7650	0.5122	0.3110	0.1166	0.0742	0.0368	0.0250	0.0131	0.0094
"REAL" HN54 EWR10_BC							1.0000	0.4000	0.3700	0.3000	0.2800	0.2200	0.2100	0.2000	0.2000	0.1600	0.1400



	0.10%	1.00%	5.00%	10.00%	15.00%	20.00%	30.00%	40.00%	50.00%	60.00%	70.00%	80.00%	85.00%	90.00%	95.00%	99.00%	99.50%
NATURAL	9.461	9.418	9.192	9.112	9.034	8.997	8.709	8.612	8.334	8.168	5.093	0.000	0.000	0.000	0.000	0.000	0.000
PRESENT	9.948	9.922	9.820	9.740	9.661	9.565	8.834	8.038	6.984	5.045	2.540	0.000	0.000	0.000	0.000	0.000	0.000
HN54 EWR10_BC	9.950	9.937	9.895	9.857	9.722	9.574	8.882	8.115	7.213	5.241	2.540	0.000	0.000	0.000	0.000	0.000	0.000
Sc1 HN54	9.950	9.937	9.895	9.857	9.722	9.574	8.882	8.115	7.213	5.241	2.540	0.000	0.000	0.000	0.000	0.000	0.000
"REAL" HN54 EWR10_BC	9.492	9.422	9.281	9.281	9.246	9.211	9.001	8.924	8.657	8.543	6.115	0.000	0.000	0.000	0.000	0.000	0.000

STRESS DURATION

APPENDIX B: ECOLOGICAL CONSEQUENCES

Invertebrate Frequency Habitat Assessment (IFHA)

CROCODILE WEST CATCHMENT

SITE	SCENARIO	DRY	WET	INTEGRATED
EWR 2: Jukskei	Present	-	-	-
	EWR_D	C/D	B	C
	Sc1	A	E	C
	Sc2	A	D/E	C
EWR 3: Crocodile below Hartbeespoort Dam	Present	D/E	A	C
	EWR_C/D	D	A	C
	Sc1	D	C	C/D
	Sc2	A	A	A
EWR 4: Pienaars downstream Roodeplaat Dam	Present	D/E	B	C/D
	EWR _C	C/D	C	C
	Sc1	A	A	A
	Sc2	A	A	A
EWR 6: Hex River	Present	F	E	E/F
	EWR_D	E/F	A/B	D
	Sc 1	F	A/B	D
	Sc 2	F	A/B	D
EWR 7: Crocodile, upstream Bierspruit	Present	-	-	-
	EWR_D	-	-	-
	Sc 1	-	-	-
	Sc 2	-	-	-
EWR 9: Magalies, downstream Maloney's Eye	Future (current flow less 10%)	A	A	A
	EWR_B	C	C/D	C
	Sc 1	A	A	A
EWR 13: Elands River downstream LindleyspoortDam	Present	-	-	-
	EWR_C	D/E	C	D
	Sc 1	F	E	E
	Sc 2	F	E	E

MARICO CATCHMENT

SITE	SCENARIO	DRY	WET	INTEGRATED
EWR 2: Koedoes	PRESENT	AB	B	B
	B	AB	A	A
	SC1	B	A	AB
	SC2	B	AB	B
EWR 3:Riekerts	PRESENT	F	F	F
	CD	CD	A	C
	C	CD	A	BC
	SC1	CD	AB	C
	SC3	C	B	C
EWR 4: Tswaza	PRESENT	F	F	F
	C	CD	C	C
	SC1	CD	C	C
	SC1 EWR	F	F	F
EWR 5: Klein Marico	PRESENT	F	E	F
	C	D	BC	C
	SC1 TOTAL	E	D	E
	SC1 EWR	E	D	E
EWR 6: Polkadraai	PRESENT	E	C	D
	BC	E	D	DE
	B	DE	D	D
	SC1	E	D	DE
	SC3	DE	D	D

MOKOLO

SITE	SCENARIO	DRY	WET	INTEGRATED
EWR1A: Vaalwater cross section 1	PRESENT	E	CD	D
	BC	F	C	DE
	CD	F	C	D
	SC1	E	CD	D
	SC3	E	CD	D
EWR 1a: Vaalwater	PRESENT	F	D	E

SITE	SCENARIO	DRY	WET	INTEGRATED
cross section 2	BC	F	CD	E
	CD	F	C	DE
	SC1	EF	D	E
	SC3	EF	D	E
EWR3: Mokolo Dam	PRESENT	F	E	F
	BC	F	C	DE
	CD	F	C	D
	SC1	E	C	D
	SC3	E	C	D
EWR10: Sterkspruit	PRESENT	E	A	C
	BC	D	A	C
	SC1	D	A	C

APPENDIX C: WATER QUALITY ASSESSMENT

Fitness for use results

Monitoring Point ID	IUA	Quaternary catchment		Sodium	Potassium	Calcium	Magnesium	pH	Electrical Conductivity	Total Dissolved Solids (calc)	Chloride	Sulphate	Total alkalinity	Fluoride	Phosphate	Ammonia	Nitrate
			Units	mg/l	mg/l	mg/l	mg/l		mS/m	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
			RWQO (Acceptable range)	92.5	50	80	100	6.5-8.0	50	260*	120	165	97.5	1	0.015	0.044	10
88737: Crocodile River D/S confluence With Jukskei River	1	A21H	Min	nd	nd	nd	nd	7.3	34	221.00	33	36	nd	nd	0.05	0.05	0.5
			Max	nd	nd	nd	nd	8.7	66	429.00	69	73	nd	nd	1.9	3.7	9.3
			Ave	nd	nd	nd	nd	7.96	52.83	343.40	51.39	55.04	nd	nd	0.67	0.64	4.93
			0.95	nd	nd	nd	nd	8.4	61	396.50	63	63	nd	nd	1.68	1.78	7.1
			0.9	nd	nd	nd	nd	8.4	60	390.00	59	62	nd	nd	1.52	1.52	6.5
			Med	nd	nd	nd	nd	8	55	357.50	52.5	55	nd	nd	0.5	0.4	5
			0.05	nd	nd	nd	nd	7.43	36.5	237.25	38	46	nd	nd	0.05	0.05	2.83
			n	nd	nd	nd	nd	46	46		46	46	nd	nd	45	45	46
A2H006: Pienaarsrivier 90 JR At Klipdrift on Pienaarsrivier	1	A23B	Min	12.3	0.72	8.7	4.9	6.87	17.5	113.75	9	4.92	46.6	nd	0	0.02	0.02
			Max	102.2	15.19	50.8	34.9	9.41	88.6	575.90	87.6	84.3	259.1	nd	2.94	0.44	3.59
			Ave	39.07	6.21	30.08	17.86	8.22	48.86	317.59	41.27	31.97	149.06	nd	0.08	0.05	0.41
			0.95	53.96	8.44	36.4	21.9	8.54	58.58	380.77	59.36	43.44	189.06	nd	0.19	0.12	1.26
			0.9	50.7	8.04	34.83	21.1	8.43	55.32	359.58	54.27	40.2	177.2	nd	0.15	0.09	1.02
			Med	38.15	6.02	30.53	18.01	8.24	49.4	321.10	41.46	32.01	148.87	nd	0.06	0.03	0.27
			0.05	26.3	4.16	23.08	13.21	7.83	37.46	243.49	23.41	19.8	112.9	nd	0.01	0.02	0.02
			n	745	745	745	745	745	745		745	745	745	nd	745	744	745
A2H012: Kalkheuwel 493 JQ on Crocodile River	1	A21H	Min	2.8	0.35	10.7	5.4	5.41	16.1	104.65	3.2	2	19.5	nd	0	0.02	0.02
			Max	178.3	17.85	73.2	34.52	10	147	955.50	312.7	139	238.4	nd	2.95	4.74	18.09
			Ave	52.41	10.07	42.65	16.72	8.04	61.55	400.08	58.78	77.24	115.79	nd	0.56	0.16	6.82
			0.95	71.4	13.18	51.86	22.1	8.51	75.86	493.09	80.2	112.76	151.78	nd	1.47	0.65	11.57

Monitoring Point ID	IUA	Quaternary catchment	Units	Sodium	Potassium	Calcium	Magnesium	pH	Electrical Conductivity	Total Dissolved Solids (calc)	Chloride	Sulphate	Total alkalinity	Fluoride	Phosphate	Ammonia	Nitrate
			Units	mg/l	mg/l	mg/l	mg/l		mS/m	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
			RWQO (Acceptable range)	92.5	50	80	100	6.5-8.0	50	260*	120	165	97.5	1	0.015	0.044	10
			0.9	69.2	12.55	49.8	21.2	8.42	73.1	475.15	76.32	105.12	145.07	nd	1.16	0.35	10.6
			Med	52.7	10.26	43.2	16.7	8.15	62.2	404.30	57.3	76.6	117.2	nd	0.41	0.06	6.48
			0.05	29.94	6.55	31.21	11	7.33	43.62	283.53	34.36	45.53	73.52	nd	0.11	0.02	2.88
			n	1509	1509	1509	1509	1509	1509		1509	1509	1509	nd	1509	1509	1509
A2H014: Schurveberg 488 JQ At Skurweberg On Hennops River	1	A21H	Min	5.8	0.58	4.8	2.6	6.8	8	52.00	5	5.1	26.5	nd	0.01	0.02	0.02
			Max	387	28.47	135	35.4	9.18	287	1865.50	771.4	139.2	219	nd	7.73	10.08	12.59
			Ave	52.25	9.44	44.36	19.64	8.14	64.24	417.56	58.98	56.17	156.38	nd	0.66	0.32	4.96
			0.95	75.63	12.85	54.11	25	8.44	77.51	503.82	102.32	90	194.6	nd	1.72	1.77	8.63
			0.9	64.98	11.93	52.4	24.45	8.37	73.2	475.80	80.19	79.87	188.9	nd	1.36	0.63	7.84
			Med	49.9	9.38	44.7	19.71	8.2	64.3	417.95	50.25	52.81	160.35	nd	0.49	0.05	4.66
			0.05	33.31	6.06	32.09	12.59	7.58	47.19	306.74	35.56	35.14	100.65	nd	0.16	0.02	1.85
			n	760	760	760	759	760	760		760	760		nd	760	760	760
A2H023: Nietgedacht 535 JQ DWJ26 on Jukskei River	1	A21C	Min	21.57	6.43	26.7	6.17	6.82	34.2	222.30	26.76	27.58	65.42	nd	0.02	0	0.18
			Max	62.11	13.2	55.15	16.8	8.96	66.2	430.30	74.8	90.51	147.3	nd	3.89	3.65	13.35
			Ave	46.92	10.13	38.63	10.93	7.78	55.52	360.88	52.31	51.05	108.4	nd	0.56	0.42	5.34
			0.95	57.38	12.27	48.77	14.85	8.1	63	409.50	65.99	70.79	135.06	nd	1.94	1.39	8.84
			0.9	55.68	11.86	46.3	14.05	8.06	61.55	400.08	60.53	60.77	128.97	nd	1.37	1.15	7.77
			Med	49.06	10.29	37.82	10.64	7.86	56.55	367.58	53.21	49.76	107.42	nd	0.25	0.17	4.94
			0.05	32.32	7.7	31.21	8.04	7.08	45.95	298.68	39.51	38.79	82.88	nd	0.08	0.02	3.54
			n	116	116	116	116	116	116		116	116	116	nd	116	116	116

Monitoring Point ID	IUA	Quaternary catchment		Sodium	Potassium	Calcium	Magnesium	pH	Electrical Conductivity	Total Dissolved Solids (calc)	Chloride	Sulphate	Total alkalinity	Fluoride	Phosphate	Ammonia	Nitrate
			Units	mg/l	mg/l	mg/l	mg/l		mS/m	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
			RWQO (Acceptable range)	92.5	50	80	100	6.5-8.0	50	260*	120	165	97.5	1	0.015	0.044	10
A2H030: Roodeplaat Spruit at Roodeplaat/Louwsbak en Se Loop	1	A23B	Min	0.1	0.15	1.8	1	6.8	2.4	15.60	3	2	8.5	nd	0.01	0.02	0.02
			Max	179.1	16.54	84.55	59.03	9.13	140	910.00	75.85	247.68	531	nd	0.56	1.55	1.48
			Ave	107.42	7.23	46.57	29.9	8.35	85.35	554.78	29	129.18	294.75	nd	0.06	0.08	0.12
			0.95	148.17	12.26	66.4	40.11	8.66	109.52	711.88	56.44	210.1	391.55	nd	0.26	0.19	0.66
			0.9	140.88	11.31	61.82	37.94	8.56	103.48	672.62	49.68	201.48	370.48	nd	0.12	0.09	0.29
			Med	113.4	6.94	46.4	30.5	8.37	88.4	574.60	24.47	127.7	305.6	nd	0.03	0.02	0.04
			0.05	44.81	3.69	31.64	18.2	8.03	52.89	343.79	12.35	41.69	171.46	nd	0.01	0.02	0.02
			n	223	223	223	223	223	223		223	223	223	nd	223	222	223
A2H058: Ifafa 457 JQ at Rietfontein / Syferfontein on Swartspruit	1	A21H	Min	0.1	0.3	10.4	5.6	7.1	12.4	80.60	3.5	6.1	30.7	nd	0	0.02	0.02
			Max	131.38	19.74	82.7	53.4	9.22	114	741.00	134.82	103.7	360.9	nd	7.75	7.69	4.82
			Ave	55.27	8.09	50.11	29.01	8.29	70.59	458.84	59.39	54.09	227.1	nd	1.38	0.33	0.71
			0.95	94.84	16.45	72.27	42.59	8.79	92.68	602.42	106.19	90.66	318.69	nd	4.26	2.44	2.52
			0.9	86.53	14.69	66.49	39.44	8.64	89.77	583.51	100.16	79.21	295.08	nd	3.62	0.3	1.94
			Med	54.56	6.66	49.77	28.63	8.3	72.75	472.88	57.6	54.2	226.18	nd	0.91	0.05	0.31
			0.05	19.44	2.2	27.06	15.85	7.73	37.35	242.78	15.88	24.61	131.57	nd	0.02	0.02	0.02
			n	304	304	304	304	304	304		304	304	304	nd	304	304	304
A2H059: Vaalkop 192 JQ at Atlanta on Crocodile River	13	A24A	Min	22.59	3.55	18.27	6.9	6.97	27.5	178.75	17.76	24.5	64.44	nd	0	0.02	0.02
			Max	134.2	12.34	79	58.7	8.9	864	5616.00	242.2	165.8	288.1	nd	0.5	0.58	2.88
			Ave	70.59	6.97	45.79	29.61	8.2	77.91	506.42	89.31	90.44	175.18	nd	0.03	0.05	0.51
			0.95	105.41	8.99	59.37	40.8	8.5	109.2	709.80	135.16	134.74	225	nd	0.08	0.12	1.55

Monitoring Point ID	IUA	Quaternary catchment		Sodium	Potassium	Calcium	Magnesium	pH	Electrical Conductivity	Total Dissolved Solids (calc)	Chloride	Sulphate	Total alkalinity	Fluoride	Phosphate	Ammonia	Nitrate
			Units	mg/l	mg/l	mg/l	mg/l		mS/m	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
			RWQO (Acceptable range)	92.5	50	80	100	6.5-8.0	50	260*	120	165	97.5	1	0.015	0.044	10
			0.9	96.81	8.49	56.92	38.3	8.43	93.27	606.26	123.41	124.6	213.22	nd	0.05	0.09	1.16
			Med	70.3	6.95	45.8	29.07	8.23	73.7	479.05	85.98	87.2	174.4	nd	0.02	0.05	0.4
			0.05	37.79	5.08	32.85	18.06	7.8	54.62	355.03	49.49	56.53	121.62	nd	0	0.02	0.02
			n	779	779	779	779	842	342		779	779	779	nd	837	840	842
A2H060: Crocodile River at Nooitgedacht	13	A24H	Min	3.8	0.15	9	3.5	6.5	9.6	62.40	12.8	10.7	16.4	nd	0	0.02	0.02
			Max	111.8	17.08	60.09	45.04	9.2	103.2	670.80	165	141.7	243.16	nd	3.84	1.02	9.85
			Ave	63.83	8.96	39.67	22.74	8.22	67.93	441.55	73.23	69.76	163.35	nd	0.15	0.07	0.4
			0.95	92.7	12.81	50.3	32.62	8.63	90.09	585.59	105.8	100.29	206.19	nd	0.41	0.18	1.13
			0.9	87.39	11.97	48.11	29.21	8.54	84.2	547.30	97.3	90.3	197.18	nd	0.31	0.13	0.89
			Med	64.73	8.69	40.28	22.9	8.29	68.7	446.55	73.5	69.82	169.55	nd	0.11	0.05	0.28
			0.05	32.32	5.78	25.8	11.8	7.5	42.12	273.78	36.81	38.87	97.67	nd	0.02	0.02	0.02
			n	922	922	922	922	922	922		922	922	922	nd	922	922	922
A2H083: Hartbeespoort Dam On orocodile River: D/s weir	1	A21H	Min	19.5	4.7	18.1	7.8	5.09	27.7	180.05	23.5	22.2	73.2	nd	0	0.02	0.02
			Max	66.2	23.05	50.2	28.19	9.5	73	474.50	75.9	135.2	156.18	nd	2.31	5.28	3.65
			Ave	43.09	8.71	33.86	16.17	8.21	53.28	346.32	48.68	60.92	118.69	nd	0.14	0.33	1.54
			0.95	56.16	11.29	42.67	19.8	8.75	63.96	415.74	60.54	84.94	143.59	nd	0.35	1.26	2.89
			0.9	53.78	10.63	40.71	19.2	8.62	59.92	389.48	57.29	77.82	136.91	nd	0.25	0.83	2.56
			Med	42.32	8.81	33.6	15.9	8.25	52.9	343.85	48.42	58.4	119.05	nd	0.08	0.16	1.47
			0.05	31.64	6.06	24.86	12.9	7.42	45.69	296.99	37.98	42.77	94.99	nd	0.02	0.02	0.36
			n	530	530		530	530	530		529	529	530	nd	530	530	530

Monitoring Point ID	IUA	Quaternary catchment		Sodium	Potassium	Calcium	Magnesium	pH	Electrical Conductivity	Total Dissolved Solids (calc)	Chloride	Sulphate	Total alkalinity	Fluoride	Phosphate	Ammonia	Nitrate
			Units	mg/l	mg/l	mg/l	mg/l		mS/m	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
			RWQO (Acceptable range)	92.5	50	80	100	6.5-8.0	50	260*	120	165	97.5	1	0.015	0.044	10
A2H094: Tweedepoort 289 JQ d/s weir for Bospoort Dam on Hex River			Min	16	3.7	25	12	7.32	30.5	198.25	23	37	66	0.1	0.02	0.02	0.02
			Max	94	16.9	70	41	9.28	111.9	727.35	179	122	206	0.4	0.5	0.61	5.2
			Ave	45.21	7.44	47.43	25.22	8.42	66.72	433.68	78.44	79.35	137.44	0.2	0.2	0.06	0.67
			0.95	79	13.31	66.9	39.9	9.08	95.28	619.32	126.7	102.7	177.7	0.3	0.44	0.25	1.93
			0.9	64.2	10.04	60.8	37.6	8.92	84.9	551.85	117.4	98.6	173.6	0.3	0.36	0.13	1.64
			Med	44	6.7	46	24	8.49	64.6	419.90	76	79	139	0.2	0.2	0.02	0.26
			0.05	24.3	4.42	31.2	16	7.61	43.17	280.61	32.5	53	94.2	0.1	0.02	0.02	0.02
			n	63	63	63	63	63	63		63	63	63	63	62	62	63
A2H106: Klipvoor Dam on Pienaars River: d/s Weir	14	A23J	Min	18	4.5	19	8	7.43	29.1	189.15	21	17	81	0.4	0.03	0.02	0.02
			Max	102	15.9	48	24	9	82.6	536.90	87	80	231	0.7	1.94	1.01	1.3
			Ave	63.72	11.43	36.47	18.07	8.41	63.76	414.44	60.18	50.5	177.94	0.5	0.65	0.17	0.16
			0.95	91	14.94	44	21.35	8.92	79.17	514.61	82	68.35	223.35	0.6	1.47	0.67	0.82
			0.9	87.4	14.5	42.7	21	8.82	76.97	500.31	79	66.4	214.4	0.6	1.21	0.53	0.28
			Med	62.5	11.35	37	18.5	8.45	65.6	426.40	61	50	182	0.5	0.53	0.07	0.06
			0.05	33.65	7.87	27.3	13	7.85	44.02	286.13	34.65	33	116	0.4	0.17	0.02	0.02
			n	154	154	154	154	154	154		154	154	154	154	154	154	154
A2R001: Hartbeespoort Dam on Crocodile River near dam wall	1	A21H	Min	29.87	6.65	16.22	10.65	6.98	43	279.50	38.05	30.99	74.11	nd	0.01	0.02	0.02
			Max	62.15	13.26	45.92	19.29	9.71	74.3	482.95	71.17	86.86	224.77	nd	3.4	20.12	6.14
			Ave	45.02	9	31.58	14.59	8.37	52.6	341.90	52.89	48.87	118.94	nd	0.16	0.32	1.06
			0.95	53.12	10.22	41	16.93	9.28	58.7	381.55	63.07	58.7	142.13	nd	0.39	1.11	2.2

Monitoring Point ID	IUA	Quaternary catchment		Sodium	Potassium	Calcium	Magnesium	pH	Electrical Conductivity	Total Dissolved Solids (calc)	Chloride	Sulphate	Total alkalinity	Fluoride	Phosphate	Ammonia	Nitrate
			Units	mg/l	mg/l	mg/l	mg/l		mS/m	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
			RWQO (Acceptable range)	92.5	50	80	100	6.5-8.0	50	260*	120	165	97.5	1	0.015	0.044	10
			0.9	51.26	9.99	39.6	16.27	9.08	57.2	371.80	61.43	55.86	135.07	nd	0.33	0.6	2.02
			Med	45.25	8.99	32.12	14.56	8.26	53	344.50	52.49	48.22	120.73	nd	0.09	0.1	1.1
			0.05	36.53	7.73	20.56	12.37	7.67	46.5	302.25	43.76	40.26	90.96	nd	0.02	0.02	0.04
			n	1016	1016	1016	1016	1016	1016		1016	1015	1016	nd	1015	1016	1016
A2R009: Roodeplaat Dam on Pienaars River near dam wall	1	A23A	Min	17.07	2.86	14.49	10.07	6.57	29.2	189.80	19.78	2	67.28	nd	0.01	0.02	0.02
			Max	53.03	13.86	39.43	19.56	9.93	61.7	401.05	60.79	111.98	192.64	nd	2.34	3.95	12.45
			Ave	36.21	7.7	26.76	14.87	8.33	46.08	299.52	41.68	34.34	119.62	nd	0.14	0.4	0.61
			0.95	47.43	9.8	34.1	17.57	9.55	53.23	346.00	51.93	45.16	144.84	nd	0.28	1.33	1.49
			0.9	45	9.4	32.57	17.01	9.28	51.2	332.80	50.49	41.88	138.42	nd	0.22	0.99	1.4
			Med	36.83	7.84	26.7	14.93	8.17	47	305.50	42.66	34.03	118.78	nd	0.13	0.24	0.51
			0.05	22.47	5.14	19.25	12.27	7.58	37.48	243.62	26.1	24.43	97.95	nd	0.04	0.02	0.02
			n	996	996	996	996	998	996		996	996	996	nd	995	995	996
			Max	54	10.2	36	19	9.72	55.9	363.35	58	68	147	0.4	0.22	1.12	1.78
			Ave	37.23	7.83	26	15	8.51	46.21	300.37	42.95	34.44	118.94	0.3	0.11	0.22	0.57
			0.95	48	9.84	33	17	9.52	52.48	341.12	52	43.4	140	0.3	0.2	0.76	1.4
			0.9	45	9.48	32	17	9.34	50.8	330.20	51	41	136	0.3	0.19	0.58	1.34
			Med	38	7.9	27	15	8.42	47	305.50	44	34	119	0.3	0.11	0.09	0.5
			0.05	27	5.86	18	13	7.74	39.24	255.06	33	26	100	0.26	0.03	0.02	0.02
			n	133	133	133	133	133	133		133	133	133	133	133	133	133
A3R001: Marico-	6	A31B	Min	3	0.8	12	10	7.78	18.2	118.30	2	2	85	0.2	0.01	0.02	0.02

Monitoring Point ID	IUA	Quaternary catchment		Sodium	Potassium	Calcium	Magnesium	pH	Electrical Conductivity	Total Dissolved Solids (calc)	Chloride	Sulphate	Total alkalinity	Fluoride	Phosphate	Ammonia	Nitrate
			Units	mg/l	mg/l	mg/l	mg/l		mS/m	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
			RWQO (Acceptable range)	92.5	50	80	100	6.5-8.0	50	260*	120	165	97.5	1	0.015	0.044	10
Bosveld Dam At Doornkraal 110 JP on Groot-Marico River near dam wall			Max	8	1.8	33	24	8.68	38.1	247.65	8	23	179	0.3	0.1	0.15	0.31
			Ave	5.78	1.22	25	18	8.28	29.99	194.94	5.16	7.99	140	0.23	0.02	0.04	0.07
			95%	8	1.6	31	22	8.56	37.38	242.97	7	14.2	168	0.3	0.06	0.11	0.2
			90%	7	1.5	29	22	8.48	36.72	238.68	7	12	164	0.3	0.04	0.08	0.12
			Med	6	1.3	26	19	8.28	30.7	199.55	5	7	145	0.2	0.02	0.02	0.06
			5%	4	0.8	17.4	13	7.99	20.34	132.21	2	3	95.6	0.2	0.01	0.02	0.03
			n	69	69	69	69	69	69		69	69	69	69	69	69	69
188039: downstream A3H029 on Groor Marico: Downstream Marico Bosveld Dam	11b	A32D	Min	5.47	nd	19.77	13	8.06	24	156.00	2.5	2	101.05	0.15	0.01	0.02	0.04
			Max	6.54	nd	25.89	19.82	8.38	30.8	200.20	6.74	7.44	144.49	0.26	0.5	0.12	0.12
			Ave	6.09	nd	23.65	17.38	8.19	28.57	185.71	5.28	4.83	131.5	0.22	0.08	0.05	0.05
			95%	6.45	nd	25.71	19.51	8.36	30.64	199.16	6.49	7.44	143.72	0.25	0.33	0.11	0.09
			90%	6.36	nd	25.53	19.2	8.34	30.48	198.12	6.23	7.44	142.96	0.25	0.16	0.11	0.07
			Med	6.06	nd	24.09	17.77	8.19	29.2	189.80	5.48	6.06	130.85	0.23	0.02	0.02	0.04
			5%	5.65	nd	20.38	14.35	8.06	25.04	162.76	3.48	2	111.45	0.17	0.01	0.02	0.04
			n	9	nd	9	9	9	9		9	9	9	9	9	9	9
188041: at EWR 1: Kaaloog-se-Loop: Below gorge	7	A31A	Min	2.12	0.15	28.2	16	8.09	27.7	180.05	2	2	134.84	0.1	0.01	0.02	0.04
			Max	3.49	0.55	29.48	17.82	8.5	32.1	208.65	4.72	4.66	144.9	0.14	0.04	0.18	0.22
			Ave	2.59	0.32	28.83	17.03	8.3	28.8	187.20	2.41	2.8	139.78	0.11	0.02	0.06	0.13
			95%	3.34	0.51	29.47	17.82	8.45	31.06	201.89	3.83	4.61	144.69	0.13	0.04	0.15	0.2
			90%	3.2	0.46	29.46	17.82	8.4	30.02	195.13	2.94	4.55	144.48	0.12	0.03	0.12	0.19

Monitoring Point ID	IUA	Quaternary catchment		Sodium	Potassium	Calcium	Magnesium	pH	Electrical Conductivity	Total Dissolved Solids (calc)	Chloride	Sulphate	Total alkalinity	Fluoride	Phosphate	Ammonia	Nitrate
			Units	mg/l	mg/l	mg/l	mg/l		mS/m	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
			RWQO (Acceptable range)	92.5	50	80	100	6.5-8.0	50	260*	120	165	97.5	1	0.015	0.044	10
			Med	2.3	0.36	28.7	16.96	8.3	28.6	185.90	2	2	138.1	0.11	0.02	0.02	0.13
			5%	2.15	0.15	28.29	16.23	8.15	27.7	180.05	2	2	135.82	0.1	0.01	0.02	0.06
			n	9	9	8	9	9	9		9	9	9	9	9	9	9
100000763: Rietvlei 03 u/s of WWTW close to bridge	1	A21A	Min	70	nd	nd	nd	7.1	27	175.50	65	42	194	nd	0.7	0.05	0.8
			Max	70	nd	nd	nd	8.3	90	585.00	75	133	198	nd	7.8	17.9	5.4
			Ave	70	nd	nd	nd	7.79	68.18	443.17	70	65.55	196	nd	2.82	4.35	2.96
			95%	70	nd	nd	nd	8.12	82.3	534.95	74.5	95.4	197.8	nd	5.61	12.89	4.38
			90%	70	nd	nd	nd	8.1	78.3	508.95	74	80.6	197.6	nd	4.28	9.01	4.02
			Med	70	nd	nd	nd	7.8	69	448.50	70	62	196	nd	2.7	3.35	2.8
			5%	70	nd	nd	nd	7.39	52.55	341.58	65.5	47.55	194.2	nd	0.97	0.26	1.17
			n	1	nd	nd	nd	38	38		2	38	2	nd	38	38	35
188034: upstream EWR 1: Kaaloog-se-Loop: Below gorge	7	A31A	Min	1	0.2	29	16	8.06	27.9	181.35	2	2	136	0.1	0.01	0.02	0.14
			Max	4	0.7	33	18	8.53	29.9	194.35	5	5	150	0.2	0.31	0.12	0.24
			Ave	2.38	0.35	30.25	17.13	8.24	29.11	189.22	2.88	2.63	142.13	0.13	0.05	0.04	0.2
			95%	3.65	0.63	32.3	18	8.48	29.87	194.16	4.65	4.3	149.65	0.2	0.21	0.09	0.24
			90%	3.3	0.56	31.6	18	8.43	29.83	193.90	4.3	3.6	149.3	0.2	0.11	0.06	0.24
			Med	2	0.3	30	17	8.23	29.3	190.45	2.5	2	142	0.1	0.02	0.02	0.2
			5%	1.35	0.2	29	16.35	8.07	28.04	182.26	2	2	136.35	0.1	0.01	0.02	0.14
			n	8	8	8	8	8	8		8	8	8	8	8	8	8
188035: EWR 2: Groot	6b	A31B	Min	3	0.4	21	14	8.02	23.7	154.05	2	2	101	0.1	0.01	0.02	0.04

Monitoring Point ID	IUA	Quaternary catchment		Sodium	Potassium	Calcium	Magnesium	pH	Electrical Conductivity	Total Dissolved Solids (calc)	Chloride	Sulphate	Total alkalinity	Fluoride	Phosphate	Ammonia	Nitrate
			Units	mg/l	mg/l	mg/l	mg/l		mS/m	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
			RWQO (Acceptable range)	92.5	50	80	100	6.5-8.0	50	260*	120	165	97.5	1	0.015	0.044	10
Marico: Upstream confluence with Sterkstroom			Max	4	0.7	34	20	8.42	35.5	230.75	5	9	154	0.2	0.06	0.13	0.18
			Ave	3.25	0.53	28.88	17.88	8.19	29.95	194.68	3.63	4.38	142.13	0.13	0.02	0.05	0.11
			95%	4	0.67	32.95	19.65	8.38	34.1	221.65	5	7.95	153.65	0.2	0.05	0.13	0.16
			90%	4	0.63	31.9	19.3	8.34	32.7	212.55	5	6.9	153.3	0.2	0.04	0.12	0.15
			Med	3	0.5	29.5	18	8.2	30.7	199.55	3.5	4	148	0.1	0.02	0.02	0.11
			5%	3	0.4	23.45	15.05	8.02	24.86	161.59	2	2	113.95	0.1	0.01	0.02	0.05
			n	8	8	8	8	8	8		8	8	8	8	8	8	8
188252: EWR 6: Polkadraaispruit before confluence with Marico	6b	A31B	Min	4	0.5	8	7	7.63	12.3	79.95	2	2	54	0.1	0.02	0.02	0.04
			Max	5	1.4	10	9	7.97	16	104.00	5	7	67	0.2	0.14	0.07	0.44
			Ave	4.67	0.93	9	8.17	7.85	14.35	93.28	4	3.67	60.33	0.15	0.05	0.04	0.12
			95%	5	1.38	10	9	7.96	15.8	102.70	5	7	66.25	0.2	0.13	0.07	0.36
			90%	5	1.35	10	9	7.94	15.6	101.40	5	7	65.5	0.2	0.12	0.07	0.28
			Med	5	0.85	9	8	7.88	14.5	94.25	5	2	61	0.15	0.03	0.02	0.04
			5%	4	0.55	8	7.25	7.69	12.63	82.10	2	2	54.25	0.1	0.02	0.02	0.04
			n	6	6	6	6	6	6		6	6	6	6	6	6	6
188258: downstream 188252 on Groot Marico: Upstream confluence with Sterkstroom	6b	A31B	Min	3	0.8	29	18	7.81	31.1	202.15	2	6	142	0.2	0.02	0.02	0.11
			Max	4	1.1	33	20	8.35	33.6	218.40	5	8	165	0.2	0.02	0.15	0.36
			Ave	3.2	0.96	31.4	18.6	8.08	32.6	211.90	4	6.6	150.4	0.2	0.02	0.08	0.18
			95%	3.8	1.1	33	19.8	8.34	33.54	218.01	5	7.8	162.2	0.2	0.02	0.14	0.33
			90%	3.6	1.1	33	19.6	8.32	33.48	217.62	5	7.6	159.4	0.2	0.02	0.13	0.29

Monitoring Point ID	IUA	Quaternary catchment		Sodium	Potassium	Calcium	Magnesium	pH	Electrical Conductivity	Total Dissolved Solids (calc)	Chloride	Sulphate	Total alkalinity	Fluoride	Phosphate	Ammonia	Nitrate
			Units	mg/l	mg/l	mg/l	mg/l		mS/m	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
			RWQO (Acceptable range)	92.5	50	80	100	6.5-8.0	50	260*	120	165	97.5	1	0.015	0.044	10
			Med	3	0.9	31	18	8.07	33	214.50	4	6	148	0.2	0.02	0.09	0.12
			5%	3	0.82	29.4	18	7.82	31.28	203.32	2.4	6	142.8	0.2	0.02	0.02	0.11
			n	5	5	5	5	5	5		5	5	5	5	5	5	5
A3R001: EWR 3: Groot Marico: Downstream Marico Bosveld Dam	11a	A31F	Min	3	0.8	12	10	7.78	18.2	118.30	2	2	85	0.2	0.01	0.02	0.02
			Max	8	1.8	33	24	8.68	38.1	247.65	8	23	179	0.3	0.1	0.15	0.31
			Ave	5.78	1.22	25.12	18.32	8.28	29.99	194.94	5.16	7.99	139.78	0.23	0.02	0.04	0.07
			95%	8	1.6	31	22.6	8.56	37.38	242.97	7	14.2	168	0.3	0.06	0.11	0.2
			90%	7	1.5	29	22	8.48	36.72	238.68	7	12	164	0.3	0.04	0.08	0.12
			Med	6	1.3	26	19	8.28	30.7	199.55	5	7	145	0.2	0.02	0.02	0.06
			5%	4	0.8	17.4	13	7.99	20.34	132.21	2	3	95.6	0.2	0.01	0.02	0.03
			n	69	69	69	69	69	69		69	69	69	69	69	69	69
A3H028: downstream EWR 3 on Groot Marico: Downstream Marico Bosveld Dam	11a	A31F	Min	3	0.8	13	9	7.35	16.7	108.55	2	2	72	0.1	0.01	0.02	0.02
			Max	9	2.6	32	25	8.55	38.3	248.95	9	17	176	0.5	0.33	0.16	0.7
			Ave	5.84	1.33	25.91	18.67	8.17	30.17	196.11	5.5	8.22	143.02	0.24	0.03	0.05	0.08
			95%	8	1.7	31	23	8.44	37.3	242.45	8	14	171.6	0.3	0.06	0.12	0.19
			90%	7	1.6	30	22	8.38	36.02	234.13	7	12	166.6	0.3	0.05	0.1	0.17
			Med	6	1.3	27	19	8.19	30.8	200.20	5	8	148	0.2	0.02	0.05	0.06
			5%	4	0.9	18	12	7.8	20.45	132.93	3	4	100.1	0.2	0.01	0.02	0.04
			n	116	115	115	115	140	139		116	116	115	116	140	140	139
A3H029: downstream	11a	A31F	Min	6	2.5	10	5	7.94	12.3	79.95	4	9	43	0.3	0.02	0.02	0.02

Monitoring Point ID	IUA	Quaternary catchment		Sodium	Potassium	Calcium	Magnesium	pH	Electrical Conductivity	Total Dissolved Solids (calc)	Chloride	Sulphate	Total alkalinity	Fluoride	Phosphate	Ammonia	Nitrate
			Units	mg/l	mg/l	mg/l	mg/l		mS/m	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
			RWQO (Acceptable range)	92.5	50	80	100	6.5-8.0	50	260*	120	165	97.5	1	0.015	0.044	10
A3H028: Groot Marico: Downstream Marico Bosveld Dam			Max	10	3.1	36	26	8.62	38.5	250.25	7	14	194	0.6	0.04	0.1	0.74
			Ave	7.83	2.78	26.17	19	8.29	29.68	192.92	5.17	11	144.5	0.38	0.02	0.04	0.16
			95%	10	3.08	35.75	26	8.6	38.35	249.28	6.75	13.25	192.75	0.55	0.03	0.09	0.58
			90%	10	3.05	35.5	26	8.58	38.2	248.30	6.5	12.5	191.5	0.5	0.03	0.07	0.42
			Med	7.5	2.75	25.5	19.5	8.32	30.3	196.95	5	11	148	0.35	0.02	0.02	0.06
			5%	6	2.53	13.75	8.25	7.96	16.43	106.80	4	9.25	68.5	0.3	0.02	0.02	0.02
			n	6	6	6	6	6	6		6	6	6	6	6	6	6
188039: downstream A3H029 on Groor Marico: Downstream Marico Bosveld Dam	11a	A31G	Min	5.47	0.9	19.77	13	8.06	24	156.00	2.5	2	101.05	0.15	0.01	0.02	0.04
			Max	6.54	1.49	25.89	19.82	8.38	30.8	200.20	6.74	7.44	144.49	0.26	0.5	0.12	0.12
			Ave	6.09	1.15	23.65	17.38	8.19	28.57	185.71	5.28	4.83	131.5	0.22	0.08	0.05	0.05
			95%	6.45	1.44	25.71	19.51	8.36	30.64	199.16	6.49	7.44	143.72	0.25	0.33	0.11	0.09
			90%	6.36	1.39	25.53	19.2	8.34	30.48	198.12	6.23	7.44	142.96	0.25	0.16	0.11	0.07
			Med	6.06	1.06	24.09	17.77	8.19	29.2	189.80	5.48	6.06	130.85	0.23	0.02	0.02	0.04
			5%	5.65	0.91	20.38	14.35	8.06	25.04	162.76	3.48	2	111.45	0.17	0.01	0.02	0.04
			n	9	9	9	9	9	9		9	9	9	9	9	9	9
A3H040: EWR 4: Groot Marico: Downstream Tswasa Weir	11b		Min	5	3	12	8	7.26	20.2	131.30	5	8	75	0.2	0.01	0.02	0.02
			Max	19	10	53	66	8.7	66.6	432.90	17	44	348	1.2	0.5	0.15	0.36
			Ave	10.18	5.67	29.17	25.01	8.29	39.03	253.70	8.09	18.32	171.46	0.39	0.03	0.04	0.05
			95%	17	9.31	40.1	38	8.52	54.2	352.30	14	26	247	0.6	0.05	0.1	0.1
			90%	14	8.1	37	36.1	8.48	52.7	342.55	13	24	229	0.5	0.03	0.08	0.08

Monitoring Point ID	IUA	Quaternary catchment		Sodium	Potassium	Calcium	Magnesium	pH	Electrical Conductivity	Total Dissolved Solids (calc)	Chloride	Sulphate	Total alkalinity	Fluoride	Phosphate	Ammonia	Nitrate
			Units	mg/l	mg/l	mg/l	mg/l		mS/m	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
			RWQO (Acceptable range)	92.5	50	80	100	6.5-8.0	50	260*	120	165	97.5	1	0.015	0.044	10
			Med	10	5.6	28	23	8.31	37.4	243.10	7.5	18	162	0.4	0.02	0.02	0.04
			5%	6	3.9	20	17	8.03	28.5	185.25	5	12	122	0.2	0.01	0.02	0.02
			n	180	180	180	180	181	181		180	181	181	181	181	181	180
188072: Klein Marico Downstream Klein Maricopoort Dam	6a	A31E	Min	4	0.6	4	3	7.22	7.2	46.80	5	2	23	0.1	0.02	0.02	0.04
			Max	5	1.2	6	5	7.91	9.7	63.05	7	7	36	0.3	0.03	0.45	0.11
			Ave	4.25	0.95	4.75	3.75	7.63	8.58	55.77	5.75	4.25	28.5	0.2	0.02	0.13	0.08
			95%	4.85	1.19	5.85	4.85	7.88	9.7	63.05	6.85	6.85	35.1	0.29	0.03	0.39	0.11
			90%	4.7	1.17	5.7	4.7	7.85	9.7	63.05	6.7	6.7	34.2	0.27	0.03	0.32	0.1
			Med	4	1	4.5	3.5	7.7	8.7	56.55	5.5	4	27.5	0.2	0.02	0.02	0.09
			5%	4	0.65	4	3	7.29	7.28	47.32	5	2	23.3	0.12	0.02	0.02	0.05
			n	4	4	4	4	4	4		4	4	4	4	4	4	4
A2H107: Brakfontein 404 JP d/s weir for Swartruggens Dam On Elands River	5	A22A	Min	3	0.8	4	3	6.78	7.5	48.75	3	2	19	0.1	0.01	0.02	0.02
			Max	10	3.6	14	8	8.22	18.6	120.90	9	17	83	0.3	0.12	0.31	0.39
			Ave	4.72	1.56	6.68	4.71	7.68	10.51	68.32	5.51	6.52	35.58	0.14	0.02	0.05	0.09
			95%	7	2.88	10	6.4	8.05	14.53	94.45	7.5	11.5	52.45	0.2	0.05	0.1	0.22
			90%	6	2.3	9	6	7.99	13.37	86.91	7	10	49	0.2	0.04	0.09	0.18
			Med	5	1.4	6	5	7.68	9.9	64.35	5	7	34	0.1	0.02	0.04	0.06
			5%	3	0.9	4	3	7.18	7.96	51.74	3	2	22	0.1	0.01	0.02	0.02
			n	93	93	92	93	93	92		91	91	92	93	93	93	92
A2R013: Swartruggens	5	A22A	Min	3	0.8	4	2	7.18	7.5	48.75	2	2	22	0.1	0.01	0.02	0.02

Monitoring Point ID	IUA	Quaternary catchment		Sodium	Potassium	Calcium	Magnesium	pH	Electrical Conductivity	Total Dissolved Solids (calc)	Chloride	Sulphate	Total alkalinity	Fluoride	Phosphate	Ammonia	Nitrate
			Units	mg/l	mg/l	mg/l	mg/l		mS/m	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
			RWQO (Acceptable range)	92.5	50	80	100	6.5-8.0	50	260*	120	165	97.5	1	0.015	0.044	10
Dam at Brakfontein 404 JP on Elands River near dam wall			Max	7	4.3	10	7	8.13	15.7	102.05	10	15	58	0.2	0.08	0.33	0.63
			Ave	5.02	1.57	6.69	4.77	7.72	10.92	70.98	5.47	6.27	37.03	0.15	0.02	0.06	0.09
			95%	7	2.3	9	6	7.98	14.69	95.49	8	10.95	49.95	0.2	0.05	0.25	0.25
			90%	6	2.09	9	6	7.97	13.65	88.73	7	9	48	0.2	0.04	0.1	0.21
			Med	5	1.45	7	5	7.74	10.45	67.93	5	6.5	37	0.1	0.02	0.02	0.06
			5%	4	0.9	5	3.05	7.42	7.9	51.35	2	2	24.05	0.1	0.01	0.02	0.02
			n	62	62	62	62	62	62		62	62	62	62	62	62	61
A3H031: Kalkdam 241 JP on left canal from Klein-Maricopoort Dam	6	A31D	Min	5	1.1	29	13	7.54	31.4	204.10	9	12	127	0.2	0	0.02	0.02
			Max	39	7.8	68	80	8.69	90	585.00	62	205	234	0.6	0.19	1.51	0.96
			Ave	21.01	4.4	48.87	47.11	8.18	68.45	444.93	32.06	121.31	190.67	0.47	0.03	0.33	0.25
			95%	35	6	62	63.2	8.44	83.41	542.17	52.2	178	224.6	0.52	0.08	0.72	0.66
			90%	32.4	5.7	59	60	8.38	80.52	523.38	50	168	215	0.5	0.05	0.55	0.45
			Med	22	4.4	49	51	8.19	73.7	479.05	33	140	194	0.5	0.03	0.33	0.22
			5%	8	3.1	34.8	17.8	7.91	35.6	231.40	10.8	20.8	141	0.4	0.01	0.02	0.02
			n	157	157	157	157	180	180		157	157	157	157	180	180	180
A4H002: Mokolo River at Zandrivier/Vaalwater	15	A42C	Min	2.1	0.06	2.8	0.8	6.4	5.5	35.75	5	0.4	nd	0.03	0.01	0.02	0.01
			Max	16.4	3.8	9.7	6.5	8.7	18	117.00	18	19	nd	0.5	4.8	0.17	0.5
			Ave	5.8	1.4	5.7	2.8	7.5	9	58.50	6.3	5.2	nd	0.15	0.06	0.03	0.14
			95%	8.4	2.7	8.5	4	7.8	11	71.50	10	10.5	nd	0.2	0.04	0.08	0.3
			90%	7.6	2.3	7.3	3.6	7.8	11	71.50	9	10	nd	0.18	0.03	0.05	0.3

Monitoring Point ID	IUA	Quaternary catchment		Sodium	Potassium	Calcium	Magnesium	pH	Electrical Conductivity	Total Dissolved Solids (calc)	Chloride	Sulphate	Total alkalinity	Fluoride	Phosphate	Ammonia	Nitrate
			Units	mg/l	mg/l	mg/l	mg/l		mS/m	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
			RWQO (Acceptable range)	92.5	50	80	100	6.5-8.0	50	260*	120	165	97.5	1	0.015	0.044	10
			Med	5.6	1.1	5.3	2.8	7.6	8.7	56.55	5	5	nd	0.15	0.02	0.02	0.11
			5%	3.8	0.7	4	1.9	7.1	7.2	46.80	5	1.5	nd	0.07	0.01	0.02	0.02
			n	103	103	104	104	115	114		102	103	nd	93	113	113	112
A4H008: Sterkstroom River at Doornspruit	15	A42D	Min	0.2	0.15	0.5	0.5	5.1	2.2	14.30	1.6	0.4	nd	0.03	0.01	0.02	0.01
			Max	22	2.6	15	8	8.1	27	175.50	35	13	nd	0.5	0.09	0.2	3.4
			Ave	3.1	0.7	3	1.1	7.2	5	32.50	5	3.4	nd	0.1	0.02	0.03	0.09
			95%	6.6	1.7	8.2	2.3	7.8	9	58.50	7	8	nd	0.2	0.04	0.08	0.2
			90%	4.9	1.5	6	1.8	7.6	7	45.50	6	7	nd	0.2	0.03	0.06	0.09
			Med	2.6	0.5	2.2	0.8	7.2	4	26.00	5	2	nd	0.1	0.01	0.02	0.04
			5%	0.9	0.15	1.1	0.5	6.5	2.5	16.25	2.5	1.5	nd	0.05	0.01	0.02	0.01
			n	122	123	123	123	133	132		123	123	nd	109	131	131	131
A4R001: Mokolo Dam on Mokolo River near dam wall	15	A42F	Min	0.2	0.9	2	0.8	6.3	5.4	35.10	4	1	nd	0.03	0.01	0.02	0.01
			Max	10	3	6	3	8.3	11	71.50	12	13	nd	0.3	0.4	0.3	0.4
			Ave	5	1.5	4	2	7.5	7.2	46.80	6	4	nd	0.12	0.03	0.04	0.06
			95%	8	3	5	2.6	7.8	9	58.50	8	10	nd	0.28	0.08	0.1	0.2
			90%	7	2.5	5.2	2.5	7.7	8.4	54.60	7	8	nd	0.17	0.03	0.09	0.13
			Med	5	1	4	2.1	7.5	7	45.50	5	2	nd	0.12	0.01	0.03	0.03
			5%	2	0.9	2.3	0.8	7.1	6	39.00	4.5	1.5	nd	0.03	0.01	0.02	0.02
			n	56	57	56	56	58	58		57	57	nd	56	58	58	56
A4H010: Mokolo Dam	16	A42G	Min	2.7	0.9	2.2	0.5	5.9	5	32.50	3.7	1.5	nd	0.05	0	0.02	0.02

Monitoring Point ID	IUA	Quaternary catchment		Sodium	Potassium	Calcium	Magnesium	pH	Electrical Conductivity	Total Dissolved Solids (calc)	Chloride	Sulphate	Total alkalinity	Fluoride	Phosphate	Ammonia	Nitrate
			Units	mg/l	mg/l	mg/l	mg/l		mS/m	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
			RWQO (Acceptable range)	92.5	50	80	100	6.5-8.0	50	260*	120	165	97.5	1	0.015	0.044	10
on Mokolo River: D/s weir			Max	10	9	20	4.6	8.6	18	117.00	18	13	nd	0.5	0.17	0.29	1.03
			Ave	5.2	1.7	5.1	2.4	7.1	8	52.00	6.7	4.7	nd	0.14	0.02	0.04	0.12
			95%	7.9	2.7	12	3.6	7.9	14	91.00	11	9	nd	0.3	0.06	0.09	0.45
			90%	7.2	2.6	8	3.1	7.75	11	71.50	10	8	nd	0.25	0.02	0.08	0.27
			Med	5.1	1.6	4.4	2.3	7.2	7.3	47.45	6.2	4.5	nd	0.13	0.01	0.02	0.06
			5%	3	0.9	2.6	1.5	6.34	5.6	36.40	4.1	2	nd	0.05	0	0.02	0.02
			n	91	91	90	90	91	91		90	90	nd	89	90	90	89
A4H007: Tambotie River at Blakeney	16	A42H	Min	4.4	0.5	1.3	0.5	5.5	5.5	35.75	10	1.5	nd	0.03	0.01	0.02	0.02
			Max	8	2	5.3	1.7	7.7	9	58.50	18	10	nd	0.5	0.14	0.23	0.11
			Ave	6.5	0.8	2.4	1.3	6.7	7	45.50	13	3.7	nd	0.13	0.02	0.05	0.03
			95%	8	1.5	4.4	1.7	7.6	9	58.50	17	9	nd	0.24	0.05	0.19	0.05
			90%	7.6	1.4	3.8	1.6	7.5	9	58.50	15	7	nd	0.22	0.04	0.09	0.04
			Med	6.8	0.6	2	1.4	6.9	6.4	41.60	12	2	nd	0.11	0.01	0.02	0.02
			5%	4.8	0.5	1.4	0.5	6.5	5.4	35.10	11	1.5	nd	0.05	0.01	0.02	0.02
			n	22	22	21	22	22	22		22	22	nd	22	22	22	22
A4H013: Mokolo River at Moorddrift/Vught	16	A42J	Min	4	0.4	2.2	0.8	7.1	6	39.00	4.4	1.5	nd	0.03	0.01	0.02	0.02
			Max	18	5	20	12	8.2	27	175.50	23	12	nd	0.4	0.11	0.62	0.51
			Ave	6.7	1.3	4.6	2.6	7.5	9	58.50	9	4.7	nd	0.15	0.02	0.04	0.06
			95%	8.7	2.7	6.2	3.4	7.9	12	78.00	13	8.7	nd	0.3	0.07	0.09	0.36
			90%	8	2.6	5.4	3	7.7	10	65.00	13	8.3	nd	0.2	0.04	0.07	0.1

Monitoring Point ID	IUA	Quaternary catchment		Sodium	Potassium	Calcium	Magnesium	pH	Electrical Conductivity	Total Dissolved Solids (calc)	Chloride	Sulphate	Total alkalinity	Fluoride	Phosphate	Ammonia	Nitrate
			Units	mg/l	mg/l	mg/l	mg/l		mS/m	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
			RWQO (Acceptable range)	92.5	50	80	100	6.5-8.0	50	260*	120	165	97.5	1	0.015	0.044	10
			Med	6.5	1.03	4.3	2.4	7.5	8.4	54.60	10	4.5	nd	0.14	0.02	0.02	0.02
			5%	4.2	0.4	3	1.7	7.2	6.7	43.55	5	1.5	nd	0.1	0.01	0.02	0.02
			n	54	54	54	54	56	56		54	54	nd	54	56	56	56
A4H004: Matlabas River at Haarlem East	17b	A41B	Min	0.22	0.33	1.4	0.8	6.3	3	19.50	2	nd	nd	0.03	0.01	0.02	0.02
			Max	38	2.5	11	5.7	8.1	29	188.50	36	nd	nd	0.4	0.18	0.15	1.4
			Ave	7.2	1.2	4	2.1	7.4	8	52.00	8	nd	nd	0.15	0.02	0.04	0.08
			95%	20	2.3	7	4.6	7.9	16	104.00	17	nd	nd	0.3	0.04	0.13	0.09
			90%	17	2	6.7	4.1	7.8	15	97.50	16	nd	nd	0.27	0.03	0.09	0.06
			Med	3.5	1	4	1.8	7.3	6	39.00	5.5	nd	nd	0.13	0.01	0.03	0.03
			5%	1.1	0.4	1.8	0.8	6.9	3.2	20.80	2.7	nd	nd	0.03	0.01	0.02	0.02
			n	29	29	44	29	29	28		29	nd	nd	24	29	29	28
A2H013Q01: Mokolo River at Moorddrift	16	A42J	Min	2	0.2	22	10	7.64	26.4	171.60	5	3	90	0.1	0.01	0.02	0.04
			Max	11	9.3	45	33	8.67	50.7	329.55	36	29	225	0.4	0.19	0.25	2.55
			Ave	7.19	1	36.84	26.06	8.22	41.45	269.43	7.98	13.33	186.19	0.18	0.03	0.05	1.03
			0.95	10	1.9	42	30	8.49	46.27	300.76	12	21.8	209	0.2	0.05	0.11	1.54
			0.9	9	1.6	41	29.6	8.4	45.24	294.06	12	20	205	0.2	0.04	0.09	1.41
			Med	7	0.8	37	26	8.22	41.6	270.40	8	13	189	0.2	0.02	0.04	1.05
			0.05	4	0.4	29.4	21	7.99	36.01	234.07	5	8	152.8	0.1	0.01	0.02	0.45
			n	204	205	205	205	205	204		205	205	205	205	204	204	205

***relates to TWQR for irrigation**

APPENDIX D: ACID MINE DRAINAGE SCENARIOS

TDS modelling undertaken using the WRPM

Western Basin AMD Decant/treatment Scenarios – WRPM analysis

To Support the Feasibility Study conducted by the DWA on Long Term solutions for AMD decant in the Western Basin, the Reconciliation Strategy Support Team assessed various scenarios using the Water Resources Planning Model (WRPM). The focus of the analyses was on the impact on salinity (TDS), by the various possible longer term solution options. The analysis assessed the salinity impact at key locations down the river, below the different possible decant or return of treated decant locations, down to Hartbeespoort Dam.

The following scenarios were requested:

Scenario	Quantity (Ml/d)/(Mm3/a)	TDS (mg/l	Timing
1. Immediate solution, discharge neutralised water into Tweeloopiespruit upstream of Krugerdorp Game Reserve (upstream of dolomite)	21.2 / 7.7	2776	2013 -->>
2. Mintails option, as for Scen 1 for 2013, then then	21.2 / 7.7 33.1 / 12.1 21.2 / 7.7	2776	2013 2014 – 2018 2019 - ->>
3. As for Scen 2 but with discharge downstream of dolomite			
4. As for Scen 3 but with discharge into tributary just downstream of Percy Steward WWTW.			
5. Pilot plants then LTS – discharge downstream of dolomites. (Higher discharge till WL down to ECL)	21.2 / 7.7 33.1 / 12.1 33.1 / 12.1 21.2 / 7.7	2776 2776 2776 1000	2013 2014 - 2015 2016 - 2017 2018 -->>
6. Desalinate and Reuse: As for Scen 5, then treated water reused (not discharged to river)	21.2 / 7.7 33.1 / 12.1 33.1 / 12.1 0	2776 2776 2776 0	2013 2014 - 2015 2016 - 2017 2018 -->>

Scenarios 3 and 4 assumed a spatial resolution within the WRPM configuration that could differentiate between the location below the dolomites and that of Percy Stewart. Currently the WRPM set-up has the return flows from Percy Stewart joining the river in between the dolomite compartments (of which there are three). As such, scenario 3 and 4 were lumped together with the AMD returned to the River below the bottom dolomite compartment.

As a note, the dolomite compartments were included in the WRPM, during the salinity calibration task using recorded streamflow salinity downstream. The downstream record did not show the increase in salinity expected due to the AMD decant which begun in the early 2000s. The dolomite compartments were intercepting and somewhat attenuating the salinity of the AMD decant. For this purpose, three dolomite compartments were added to the WRPM, and used the process of mixing in the model used to simulate the attenuation effect of these dolomites. The size of these compartments in the WRPM has not yet been calibrated, and currently are 50 million m^3 each. The inclusion of these dolomites, and the number and sizing of these was conducted by Dr. Chris Herold, in an iterative manner, for the purposes of calibrating the WQT model with limited data and time.

The WRPM was run using the historic streamflow sequence and the flow and TDS concentration at key points along the river reach down to Hartbeespoort Dam output. This was done for each scenario, together with the necessary changes in the AMD decant location, volume and salinity.

The catchment development level that was used for the assessment of these scenarios was the dynamic projected future developments in the catchment, as per the reconciliation Strategy scenario presented at the 5th Strategy Steering Committee Meeting.

Monthly time series of flows and TDS concentration for the period from 2013 to 2042 were output and will be provided electronically as **Appendix A** to this document. For the purposes of interpretation of the results, annual load and average TDS values were plotted.

As the decant of AMD in the western basin has been occurring from the early 2000s, the dolomites are already likely to have a higher salinity level. This was evident by the end conditions estimated for 2004 during the WQT model calibration. To better capture the continued effect of the AMD decant between the end of 2004 and the start of 2013, an initial run was conducted to estimate the increase in salinity levels for a period of about 8 years. The end 2004 salinity levels in the dolomites from the WQT model calibration were used as starting points. The initial 8 year simulation showed TDS values increasing to about 2000, 1100 and 700 mg/L for the three dolomite compartments, with the highest values for the most upstream compartments. These TDS values were then used as estimated 2013 starting values for the scenario analyses.

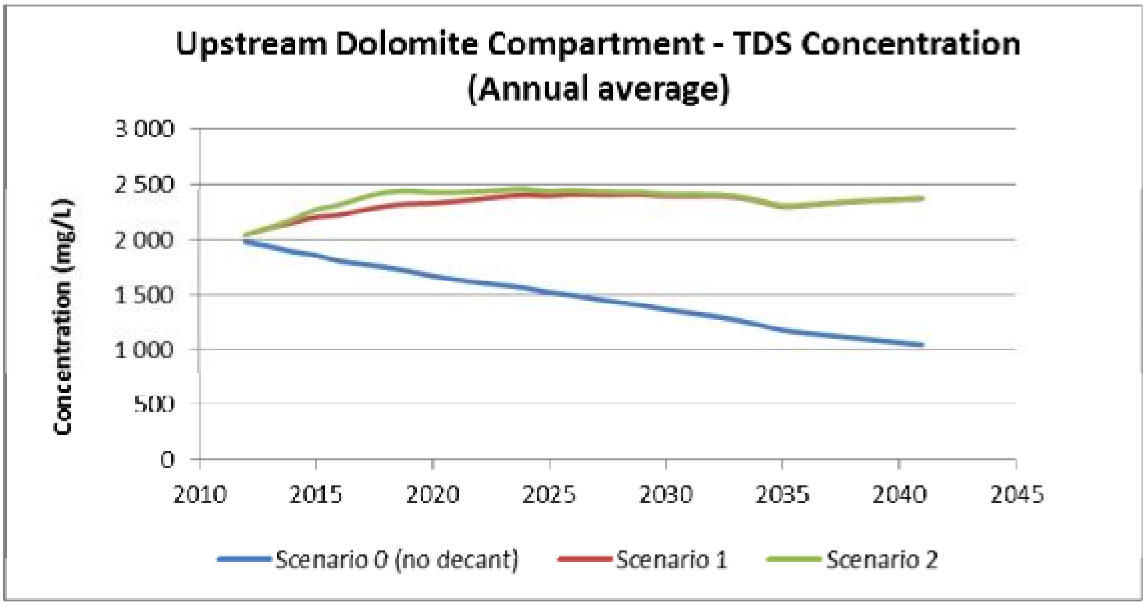
Interpretation of Results

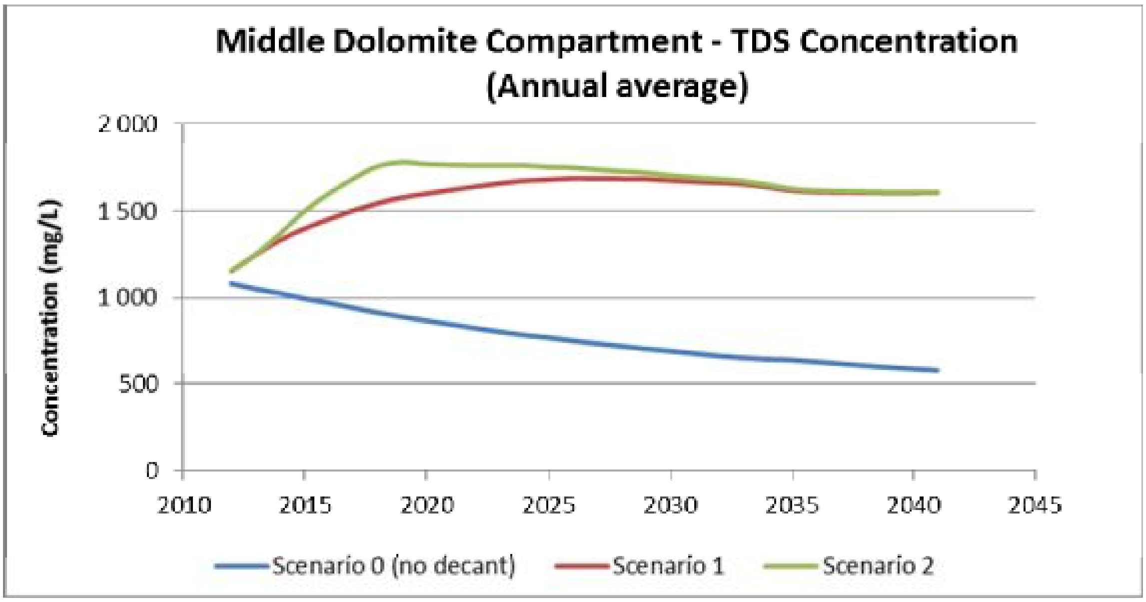
A schematic of the results was presented to allow easier spatial interpretation of the output. This is presented in **Appendix B**.

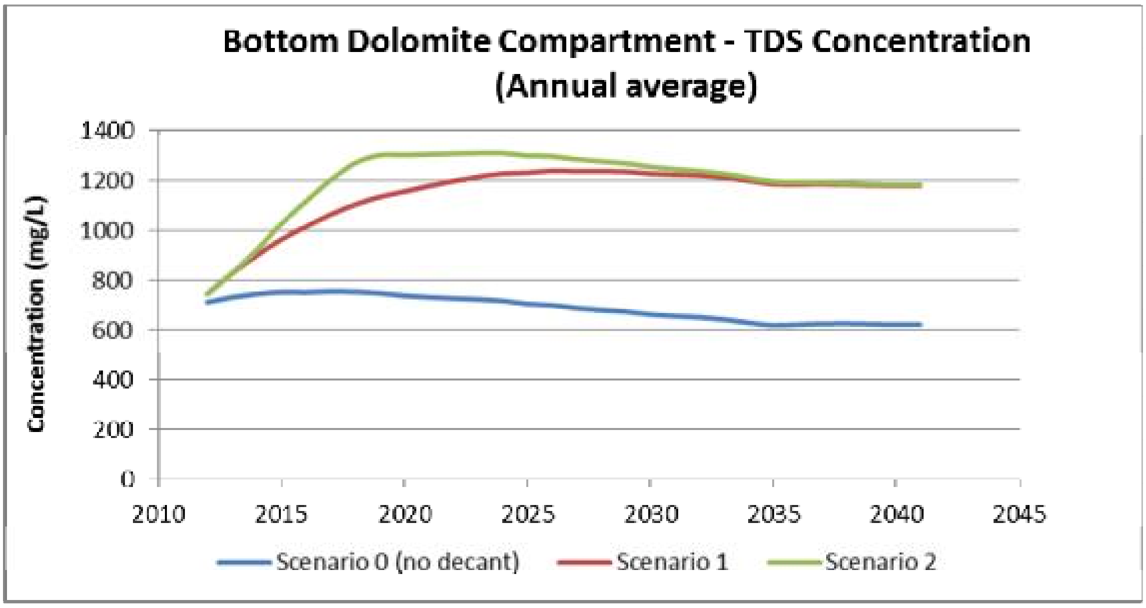
The following conclusions are drawn from the plotted annual results and trends observed:

Upper Tweelopiespruit: Channel number 1155 was chosen to represent the river below the current AMD decant point. Scenarios 1 and 2 show very high TDS of around 2500 mg/L for the river immediately below the current decant point. This is similar to the decant TDS of 2776 mg/L, which suggests limited dilution of the river at this point. The base scenario with no AMD projects an average annual TDS concentration of around 250 to 300 mg/L, although the confidence on this figure is low due to insufficient resolution in the model to capture detailed localized land-use impacts within this small catchment. There is a noticeable difference in the load into the river between scenario 1 and 2 during the short term period with higher volumes associated with the Mintails option. These results are as expected. All other scenarios return AMD downstream of the dolomites.

Dolomites: Before presenting the results, it must be re-iterated that the simulation of the dolomites is at a low confidence level and should be taken as indicative of possible trends, rather than as absolute. The simulated TDS concentrations in the three dolomite compartments for scenarios 1 and 2 is shown together with scenario 0 (no further AMD decant from 2013 as a base reference) in the figures overleaf.

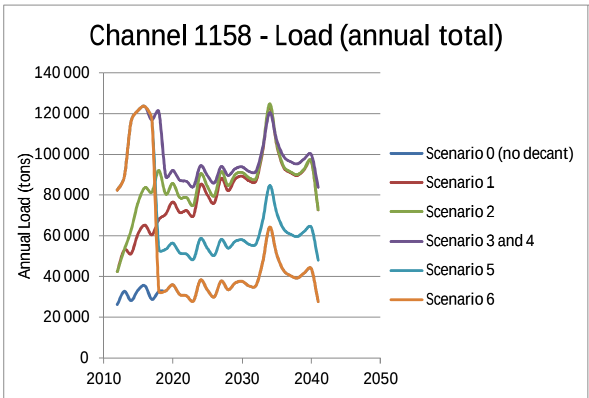

Upstream Dolomite Compartment - TDS Concentration
(Annual average)
Concentration (mg/L)
3 000
2 500
2 000
1 500
1 000
500
0
2010
2015
2020
2025
2030
2035
2040
2045
Scenario 0 (no decant)
Scenario 1
Scenario 2

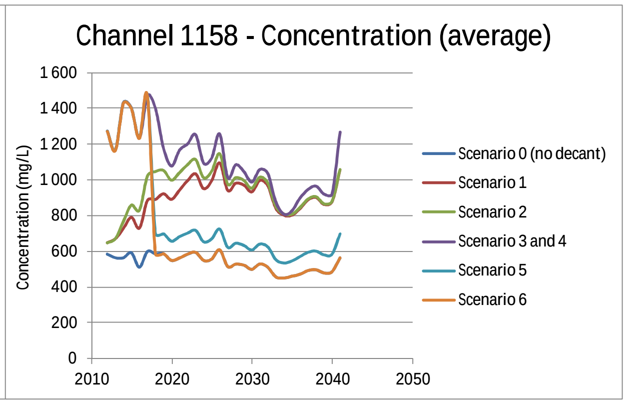

Middle Dolomite Compartment - TDS Concentration
(Annual average)
Concentration (mg/L)
2 000
1 500
1 000
500
0
2010
2015
2020
2025
2030
2035
2040
2045
Scenario 0 (no decant)
Scenario 1
Scenario 2



The results show that the salinity in the dolomites increases significantly over time for scenarios 1 and 2 which continue to return neutralised AMD to the river above the dolomites. The salinity increase is progressively lagged for the downstream aquifers. The simulated salinity in the three dolomite compartments increases up to around 2020, and thereafter appears to stabilise. The longer term TDS concentration flowing out of the lowest dolomite compartment appears to be around 1200 mg/L. Again, this should be only taken as indicative of the trend. Further work in understanding and defining the dolomites, as well as groundwater extraction there from, is suggested if the option of returning neutralized AMD above the dolomites is pursued.

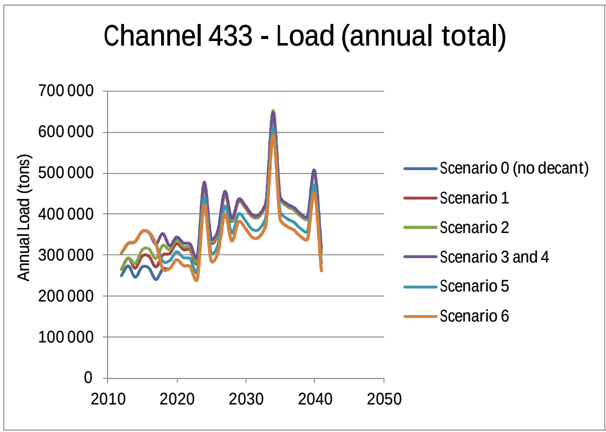
River stretch below the dolomites: The results obtained for all the scenarios for the river stretch below the dolomites to the junction with the first significant tributary are shown in the graphs below.

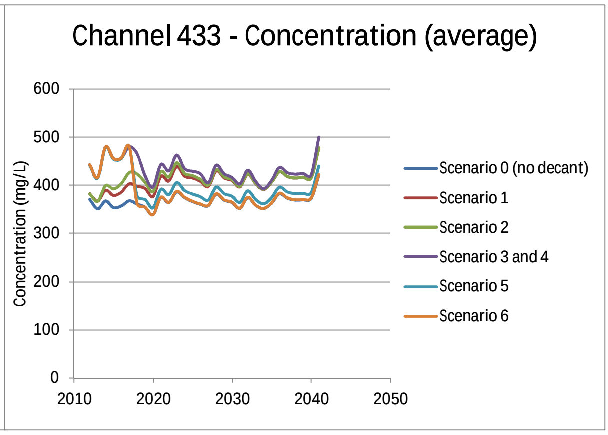




As can be seen there are significant differences in the loads and TDS concentration levels between the scenarios for this stretch of river. Although there are varied short term differences, the six scenarios tend to cluster into three distinct patterns over the long term. The scenarios (1, 2 and 3) that continue to return neutralized AMD of 2776 mg/L, appear to result in a longer term average annual TDS concentration of around 900 to 1000 mg/L. Scenario 5 which entails reducing the AMD decant down to 1000mg/L, results in annual average TDS levels in this stretch of river of around 600 to 650 mg/L. Scenarios 0 and 6 which have zero AMD returned to the river from 2013 and 2018 respectively both resulted in longer term average annual TDS concentrations of around 500 mg/L.

Crocodile River below confluence with the Jukskei and Hennops: The simulated load and TDS concentration results for the river after the confluence with both the Jukskei and Hennops tributaries are shown in the graphs overleaf. These results are also representative of this Crocodile River flowing into Hartbeespoort Dam. The results shown a significant dilution of the Crocodile River with AMD decant, and a narrowing of the range impacts for the different scenarios. Although the average annual TDS values are lower, the trends remain the similar to those observed upstream. Scenarios 1, 2 and 3 having similar average annual TDS concentrations of around 400 to 450 mg/L, and scenario 5, 6 and 0 being around 350 to 400 mg/L. The longer term impact of the scenarios with continued return of neutralized AMD of 2776 mg/L, is an increase of approximately 50 000 tons/a in load and 50 mg/L in TDS concentration. This amounts to about a 15% increase in load and TDS concentration entering Hartbeespoort Dam. The impact of scenario 5 (1000 mg/L long term AMD) is relatively small, and only increases average annual load and TDS concentration by about 4 to 5 %.





Hartbeespoort Dam: The TDS concentrations for Hartbeespoort Dam are very similar to the trends of the inflows into the Dam, as to be expected.

Conclusions and Recommendations

The results show significant increases in salinity load and concentration levels in river stretches immediate downstream of the possible decant/return flow points. These impacts however, decrease with distance downstream with the confluence of tributaries of the Crocodile River. The net impact of the different scenarios shows about a 15 % increase in salinity into Hartbeespoort Dam for scenarios which neutralize the AMD to 2 776 mg/L and only about a 4 to 5% increase in salinity into Hartbeespoort Dam for the scenario with longer term neutralized AMD of 1000 mg/L. As there is currently no specific blending rule or other similar water quality related operating rule in the Crocodile West River catchment, these potential impacts related to the long term solution options are not quantifiable from a water quantity impact. The acceptability of these impacts will need to be confirmed using the resource quality objective guidelines. Further to this, more information on the dolomites is needed to increase the confidence in the results for the scenarios that return AMD above the dolomites, particularly over the short term.

APPENDIX E: Comments received on the Scenarios Report and manner in which they were addressed

Comment received from	Comment	Addressed (Y/N)	How addressed
H Roux	Page: 13 correction Kareespruit, a tributary of the Klein Marico River	Y	Corrections made in report
	Page 25: please provide full reference and not just Kleynhans	Y	Full reference provided
	Page 69: Not Barbus mattozi but rappax, it is correct in the management class report vulnerable IUCN classification	Y	Corrections made in report Included in Table 14 of report
	Page 74: Spelling of Hartbeespoort Dam	Y	
	Page 75: Table 17; <D ? thus EF also check same table in management classes report, same mistake	Y	Table updated to make it easier to read and interpret results
	Page 87: Maloney is not in this area Kromelenboog, spelling	Y	Corrected in report Corrected in report
	Page 91: from, not form	Y	Corrected in report
	Page 121: 17a? (missing1)	Y	Corrected in report to be 17a, not 7a
	Page 142: Kareespruit, a tributary of the Klein Marico River	Y	Corrected in report

	Page 270: replace sampling point *100000763: Rietvlei 03, u/s of WWTW close to bridge*, as not part of same area	Y	Moved to correct area of the table
T Nyamande	Include a table showing the percentage NFEPA coverage	Y	Table included in report
	Include the implications based on the recommended MCs	Y	Table included in report