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**DIRECTORATE: RESOURCE DIRECTED MEASURES**

# LETABA CATCHMENT

# ECOLOGICAL CONSEQUENCES OF OPERATIONAL FLOW SCENARIOS

## FINAL

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Letaba Catchment Reserve Determination Ecological consequences of flow scenarios i

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**Inception report**
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**Briefing Document**
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DWAF Report No. RDM/B800/00/CON/COMP/1304

**Groundwater Scoping Report**
Haupt C J and Sami, K
DWAF Report No. RDM/B800/02/CON/COMP/0504

**Wetland Scoping Report**
Marneweck, G C
DWAF Report No. RDM/B800/03/CON/COMP/0604

**Resource Units Report**
Heath, R G
DWAF Report No. RDM/B800/00/CON/COMP/0704

→ **Resource Units Report: Appendix 1**
**Habitat Integrity Index**
Fouche, P and Moolman
**Appendix 2: Systems operation report**
Haumann, K.
DWAF Report No.
RDM/B800/00/CON/COMP/0704

**EWR Report: Quality**
Scherman, P
DWAF Report No. RDM/B800/01/CON/COMP/0804

**EWR Report: Quantity**
Heath, R G and Palmer, R W
DWAF Report No. RDM/B800/01/CON/COMP/0904

→ **EWR Report: Quantity:**
**Appendices**
**Specialist reports**
- Fish
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DWAF Report No.
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**Ecological consequences of flow scenarios**
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**Hydrology support & water resource evaluation**
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**Socio–economics flow scenarios**
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**Ecological Data**
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RDM/RB800/00/CON/COMP/1604

# EXECUTIVE SUMMARY

## Background

The Department of Water Affairs and Forestry (DWAF) identified the Letaba River Catchment as a priority catchment for quantifying environmental needs in line with the new legislation. This report forms part of a comprehensive assessment of the Ecological Water Requirements of the Letaba River Catchment.

## Aims

The aims of this report were:

- To describe the various operational flow scenarios that were developed for the Letaba River Catchment;
- To describe the ecological consequences of various flow scenarios at selected sites; and
- To recommend an optimized scenario that minimizes impacts on users and the ecosystem.

## Assumptions and Limitations

The main limitations of this study concerned the following:

- Hydrology only updated to 1995;
- Low level of confidence in the user requirements used in the hydrology modelling; and
- Problems associated with the ecological interpretation of monthly hydrology.

## Study area

The Letaba Catchment is located in Limpopo Province and covers an area of approximately 13 400 km$^2$. The catchment is drained by the Groot Letaba River and its major tributaries the Klein Letaba, Middle Letaba, Letsitele and Molototsi rivers. From the confluence of the Klein and Groot Letaba rivers, the Letaba River flows through the Kruger National Park until it joins with the Olifants River near the border with Mozambique.

## Sites Selected

Seven sites were selected for EWR assessment (Table A).

**Table A. Sites selected and the corresponding Resource Unit.**

| EWR site number | River and site name |
|---|---|
| EWR1 | Groot Letaba - Appel |
| EWR 2 | Letsitele |
| EWR 5 | Klein Letaba |
| EWR 3 | Groot Letaba - Hans Marensky |
| EWR 4 | Groot Letaba - Letaba Ranch |
| EWR 6 | Groot Letaba – Lonely Bull |
| EWR 7 | Groot Letaba - Letaba Bridge |

## METHODS

### *Scenarios*

Several meetings with regional water managers were held to develop appropriate operational flow scenarios. The development of these scenarios was an iterative process in which the severity of impacts, complexity and budget constraints determined the number of iterations needed. The Recommended Ecological Category and alternative categories were used as the basis for developing scenarios, and the EWR were then modified because of system constraints, user demands and impacts on system yield. A summary of the various scenarios considered is shown in Table B.

Table B. Ecological Water Requirements Scenarios developed for the Letaba River Catchment.

| Scenario Number | Description |
|---|---|
| 1 | EWR for PES. |
| 2 | EWR for the alternative categories below the PES were modelled |
| 3 | EWR for the alternative categories above the PES were modelled |
| 4 | **Main river downstream of Tzaneen Dam:**<br>The model provides the REC flow requirements to EWRs 6 and 7 with the following modifications:<br>• High flows are moved to more appropriate months<br>**EWR 1**: The model provides the REC flow requirements but with floods > 8 $m^3/s$ removed.<br>**EWR 2**: (Letsitele) All high flows are removed. Low flows decreased to be equal to the present flows in the dry season. Wet season flows are provided for the REC.<br>**EWR 5** (Klein Letaba): The model provides for the REC flow requirements but with high flows removed to appropriate months.<br>Low flows decreased to be equal to present day in June and July. |
| 5 | **Same as Scenario 4 with the following changes**:<br>**EWR 3:** If EWR 3 is not met with Scenario 4, supply EWR 3 at PES category.<br>**EWR 4**: Decrease August, September and October low flows to present.<br>Move the Nov. floods to Dec. or any other high flow month so that there is no conflict. |
| 6 | **Same as Scenario 4,** but where relevant, the alternative category below the PES are supplied rather than the PES or REC. |
| 7 | **Same as for Scenario 6 with the following changes:**<br>• Delete all floods at EWR 4, 6 and 7<br>• Delete all floods at EWR 5 >than 5 $m^3/s$<br>• Delete all floods at EWR 3 > than 18 $m^3/s$<br>• Supply demand at EWR 3 and 4, according to the changes in requirements set up by the fish specialist, from Tzaneen Dam.<br>• Supply the deficit at EWR 6 and 7 from Middle Letaba Dam (not from Tzaneen Dam) |

## Ecological Implications

A small group of specialists met for a two-day meeting (5 and 6 May 2005) to assess the ecological and water quality implications of the proposed EWR scenarios. Flow duration graphs for the wettest and driest flow months for natural, present day, the EWRs and for each scenario were distributed to specialists prior to the meeting. For the low-flow component, the output of the yield model for the various scenarios was converted to stress duration graphs. The stress duration graphs were then compared to the original low-flow requirements, and an assessment based on the rule-based models for individual ecosystem components was made (i.e. FRAI, MIRAI and VEGRAI). Relationships between flow and stress can be strongly non-linear and so it was not always simple to assess modified flow regimes in terms of their impacts on the ecology. By quantifying, the relationships between flow and stress and specifying the stress regime characteristics for rivers in different ecological conditions (i.e. for different categories), it was possible to estimate the ecological responses to flow scenarios.

For the high-flow components, an assessment of the ecological implications of the various flow scenarios was based on assessing the flow duration graphs, focussing mainly on vegetation and geomorphology. A qualitative description of the likely significance of the ecological and water quality risks of each scenario, based on an assessment of the severity and likely occurrence of expected impacts, was provided.

## CONCLUSIONS

Table C summarises the compliance of the REC at each EWR site and for each scenario.

Scenarios 1, 2 and 7 would meet the REC at all sites. Scenarios 4 and 6 would be problematic at EWR Sites 3 (Prieska) and 4 (Letaba Ranch). The present day situation, even with supposed 0.6 $m^3/s$ releases from the Tzaneen Dam for the KNP, does not meet the recommended EC at EWR sites 3, 4, 6 and 7.

The best comprise scenario is the ecological water requirements for Scenario 7. The overall impact of this scenario is not as significant as for scenario 1.

## Table C: Summary of the number of EWR sites where the REC can be met per scenario

| Site | REC | Sc 1 | Sc 2 | Sc 4 | Sc 6 | Sc 7 | PD |
|---|---|---|---|---|---|---|---|
| EWR 2 | D | ☺ | ☺ | ☺ | ☺ | ☺ | ☺ |
| EWR 3 | C/D | Y+ | Y+ | X | X | ☺ | X |
| EWR 4 | C/D | Y+ | Y+ | X | X | ☺ | X (-) |
| EWR 5 | C | ☺ | ☺ | ☺ | ☺ | ☺ | ☺ (1) |
| EWR 6 | C | ☺ | ☺ | ☺ | ☺ | ☺ | X |
| EWR 7 | C | ☺ | ☺ | ☺ | ☺ | ☺ | X |
| No. EWR sites where ecological objectives are NOT achieved | | 0 | 0 | 2 | 2 | 0 | 4 |

*Where*: ☺ = meet REC, x = did not meet REC, (1) = Riparian vegetation a problem, Y+ = exceeds REC.

# ACRONYMS

| | |
|---|---|
| D: RDM | Directorate: Resource Directed Measures |
| DWAF | Department of Water Affairs & Forestry |
| EC | Ecological Category |
| EQR | Ecological Quality Requirements |
| EMC | Ecological Management Category |
| EWR | Ecological Water Requirements |
| EIS | Ecological Importance and Sensitivity |
| FAII | Fish Assemblage Integrity Index. |
| FD | Fast-Deep |
| FRAI | Fish Response Assessment Index |
| FS | Fast-Shallow |
| HAI | Habitat Assessment Index |
| IFR | Instream Flow Requirement |
| MIRAI | Macro Invertebrates Response Assessment Index |
| nMAR | naturalised Mean Annual Runoff |
| KNP | Kruger National Park |
| PAI | Physico-chemical Driver Assessment Index |
| PD | Present Day |
| PES | Present Ecological State |
| REC | Recommended Ecological Category |
| RDM | Resource Directed Measures |
| RQO | Resource Quality Objective |
| SANP | South African National Parks |
| SASS | South African Scoring System |
| Sc | Scenario |
| SD | Slow-Deep |
| SPATSIM | Spatial and Time Series Information Modelling |
| SS | Slow-Shallow |
| VEGRAI | Riparian Vegetation Response Assessment Index |
| WR2000 | Water Resources 2000 |
| WRYM | Water Resources Yield Model |

## GLOSSARY

| | |
|---|---|
| BIOTA | A collective term for all the organisms (plants, animals, fungi and bacteria) in an ecosystem. |
| BIOTOPE | The place in which a certain assemblage of organisms live. |
| DROUGHT FLOW | The minimum flow required facilitating the survival of the riverine ecosystem in a particular condition and over short, infrequent periods, when users are subject to water restrictions. In the Letaba River System, Drought flows were defined as low-flows that occur less than 10% of the time under natural conditions for each month. |
| ECOLOGICAL CATEGORY | A category indicating the potential management target for a river. Values range from Category A (unmodified, natural) to Category D (largely modified). This term replaces former terms used, namely: Ecological Reserve Category (ERC), Desired Future State (DFS) and Ecological Management Category (EMC). The reasons for these changes are explained in the proceedings of a workshop to clarify the terminology used in Reserve determinations (DWAF 2003). It should be noted that a distinction is made between Management Classes, which form part of the National Classification System, and Ecological Categories, which forms part of the Ecological Water Requirement assessment. |
| ECOSPECS | Clear and measurable specifications of ecological attributes (e.g. water quality, flow, biological integrity) that defines the Ecological Category. The purpose of ecospecs is to establish clear goals relating to resource quality (Kleynhans 2003). |
| ECOSTATUS | An overall assessment of the Ecological Category (A-F), based on rule-based integration of specialist indices (water quality, fish, etc). EcoStatus refers to the totality of the features and characteristics of the river and its riparian areas that bear upon its ability to support an appropriate natural flora and fauna and its capacity to provide a variety of goods and services" (Iversen *et al.* 2000, *In* IWR Environmental 2003). |
| 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. |
| EURYTOPIC | Tolerant. |
| FRESHET | Flow pulse. |
| HABITAT | The place in which a plant or animal lives. (See BIOTOPE.) |

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|---|---|
| HYDRAULICS | The branch of science and technology concerned with the mechanics of fluids, especially liquids. |
| HYDROLOGY | Science dealing with properties, distribution and circulation of water in the biosphere. |
| INSTREAM FLOW REQUIREMENTS (IFR) | The flow patterns (magnitude, timing and duration) needed to maintain a riverine ecosystem in a particular condition. This term is used to refer to the quantity component only of Ecological Water Requirements. |
| INVERTEBRATE | An animal without a backbone - includes insects, snails, sponges, worms, crabs and shrimps. |
| MAINTENANCE FLOW | The flow required to meet the requirements of the riverine ecosystem at a particular site and maintain the resource base in a particular condition during "normal" climatic years. The distinction between "normal" and "drought" was based on an examination of monthly flow duration curves. For the Letaba River System, “normal” low-flows were defined as those that occur at or more than 30% of the time under natural conditions for each month. |
| PRESENT ECOLOGICAL STATE (PES) | The degree to which ecological conditions of an area have been modified from natural (reference) conditions. The measure is based on water quality variables, biotic indicators and habitat information collected 1 to 3 years prior to the assessment. Results are categorised on a 6-point scale, from Category A (*Largely Natural*) to Category F (*Critically Modified*). |
| REFERENCE CONDITION | Natural ecological conditions, prior to human development. |
| REFUGIA | An area where a population is maintained during unfavourable conditions. |
| RESERVE | The quantity and quality of water required (a) to satisfy basic human needs by securing a basic water supply, as prescribed under the Water Services Act, 1997 (Act No. 108 of 1997), for people who are now or who will, in the reasonably near future, be (i) relying upon; (ii) taking water from; or (iii) being supplied from, the relevant water resource; and (b) to protect aquatic ecosystems under the National Water Act, 1998 (Act No. 36 of 1998) in order to secure ecologically sustainable development and use of the relevant water resource. The Reserve refers to the modified EWR, where operational limitations and stakeholder consultation are taken into account. |

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| RESOURCE UNIT | Stretches of river that is sufficiently ecologically distinct to warrant their own specification of Ecological Water Requirements. |
| RHEOPHILIC | Flow-dependent. |
| RIPARIAN | Pertaining to the river bank. |
| RIPARIAN HABITAT | The physical structure and associated vegetation of the areas associated with a watercourse which are commonly characterised by alluvial soils, and which are inundated or flooded to an extent and with a frequency sufficient to support vegetation of species with a composition and physical structure distinct from those of adjacent land areas. |
| TERRACE | Relic floodplain or valley floor deposits above the present river level representing a former floodplain level prior to incision. |

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# 1. INTRODUCTION

The National Water Act (Act No. 36 of 1998) (NWA) is founded on the principle that the National Government has overall responsibility for and authority over water resource management for the benefit of the public without seriously affecting the functioning of the natural environment. In order to achieve this objective, Chapter 3 of the NWA provides for the protection of water resources through the Reserve for water resources.

The Reserve is defined as the quantity and quality of water required (a) to satisfy basic human needs and (b) to protect aquatic ecosystems. The basic human needs component of the Reserve is easy to quantify as it is based on average water consumption per capita and standard drinking water standards. The quantity and quality of water needed to protect aquatic ecosystems is more difficult to quantify and the methods of doing so are under continual development and improvement.

The Directorate: Resource Directed Measures (D: RDM) is tasked with the responsibility of ensuring that the Reserve requirements, which have priority over other uses in terms of the NWA, are determined before license applications are to be processed. There are several stressed catchments where applications for licensing have been received by the D: RDM. The available water resources cannot meet all the water requirements of the users in these catchments, without trade-off among water user sectors. DWAF has identified these stressed catchments where it will be desirable in the near future to undertake compulsory licensing. One of these areas identified, as a priority for compulsory licensing is the Letaba catchment (Water Management Area 2). The full implementation of the Reserve will almost certainly result in curtailment of water allocations once the compulsory licensing process is implemented. Consequently, there is an urgent need for an accurate assessment of the Reserve Requirements of the Letaba River catchment.

The key RDM component, which will be addressed within this study, is to provide a range of flow scenarios (consisting of Environmental Water requirements - EWR scenarios and operational scenarios) and its ecological consequences.

## 1.1 AIMS OF THIS REPORT

The aims of this report were:

- To describe the various operational flow scenarios that were developed for the Letaba River catchment; and
- To describe the ecological consequences of various flow scenarios at selected EWR sites.

## 1.2 OBJECTIVE OF SETTING ECOLOGICAL CONSEQUENCES AND FLOWS

The objective of this phase of the comprehensive Reserve of the Letaba catchment study was the following:

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| To determine the ecological consequences of different flow scenarios at each EWR site. |

## 1.3 ASSUMPTIONS AND LIMITATIONS

The main limitations of this study concerned the following:

- The Letaba hydrology used was last updated in 1994 and this did not include the 2000 floods. An assessment, using the most up to date hydrology was undertaken on two quaternaries (dry and wet, DWAF 2006a). This assessment indicated that the low hydrology was not adversely affected and consequently the readily available hydrology was used in this study;

- No transboundary (international) obligations to supply Mozambique with water from the Letaba and Olifants River were taken into account, as there are no current treaties committing South Africa to supply such water;

- Low level of confidence in the user requirements used in the hydrology modelling; and

- Problems associated with the ecological interpretation of monthly hydrology.

# 2. STUDY AREA

The Letaba Catchment is located in Limpopo Province and covers an area of approximately 13 400 $km^2$. The catchment is drained by the Groot Letaba River and its major tributaries the Klein Letaba, Middle Letaba, Letsitele and Molototsi rivers. From the confluence of the Klein and Groot Letaba rivers, the Letaba River flows through the Kruger National Park until it joins with the Olifants River near the border with Mozambique.

More than 20 major instream dams and weirs have been constructed in the Groot Letaba catchment, which has resulted in this catchment being highly regulated. The existing limited water resources in the Letaba Catchment have been severely overexploited at the expense of the environment in order to meet the commercial (irrigation, afforestation and industry) and rapidly increasing domestic water demands. The dense afforestation that takes place in the upper catchment and the intensive irrigated agriculture, of mainly sub tropical fruits, on the banks of the Groot Letaba outside the KNP, are the major water users in the study area. The instream dams are used for the supply of irrigation water for this intensive irrigated agriculture.

Seven sites were selected for EWR assessment (Table2.1and Figure 2.1).

**Table 2.1: Sites selected and the corresponding Resource Unit.**

| EWR site number | River and site name |
|---|---|
| EWR1 | Groot Letaba - Appel |
| EWR 2 | Letsitele |
| EWR 5 | Klein Letaba |
| EWR 3 | Groot Letaba - Hans Marensky |
| EWR 4 | Groot Letaba - Letaba Ranch |
| EWR 6 | Groot Letaba – Lonely Bull |
| EWR 7 | Groot Letaba - Letaba Bridge |

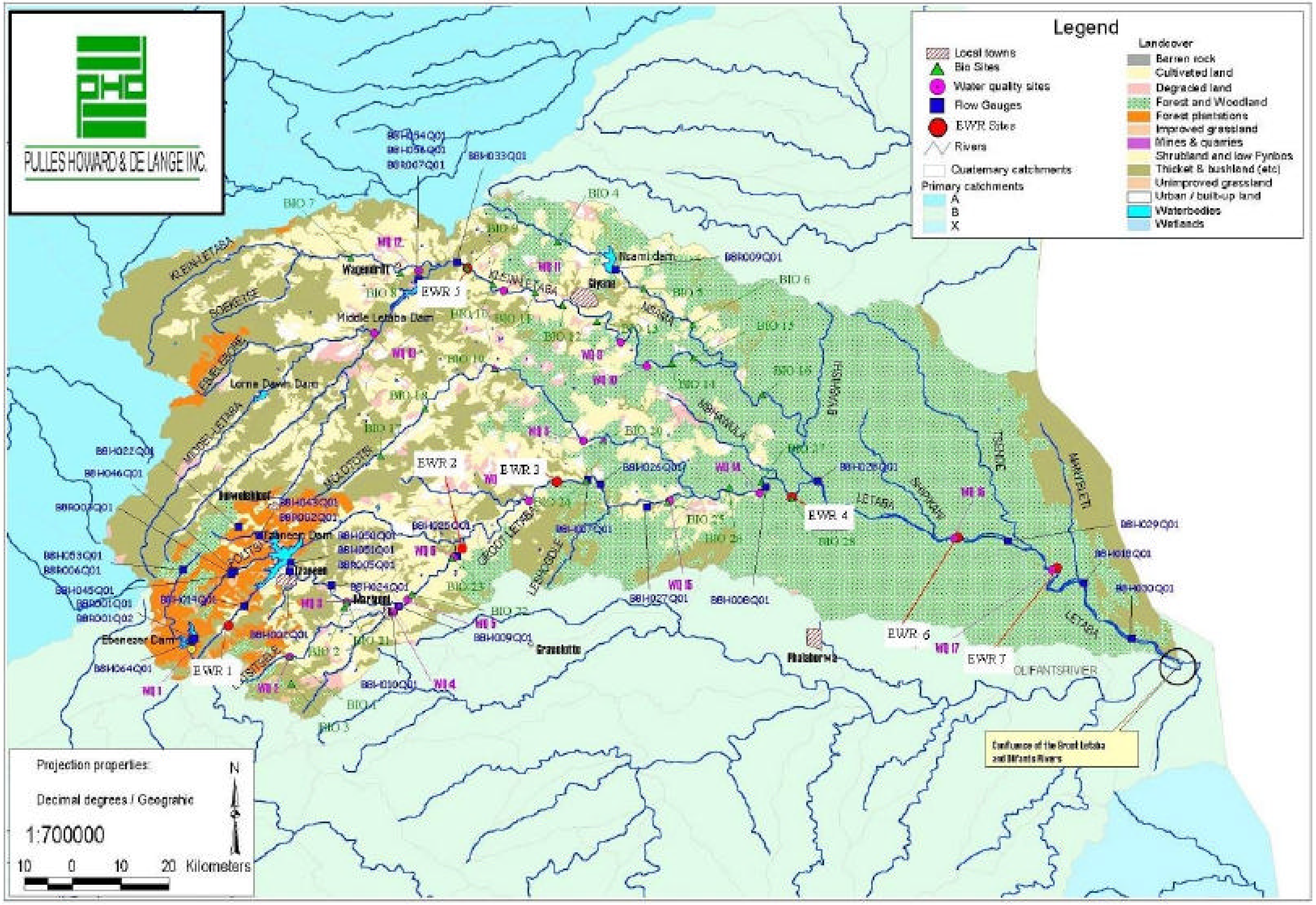



**Figure 2.1: Map of the Letaba River catchment, showing major tributaries, dams, gauging weirs and EWR sites.**

# 3. DESCRIPTION OF OPERATIONAL SCENARIOS

Meetings with regional water managers were held to develop appropriate operational flow scenarios. The development of these scenarios was an iterative process in which the severity of impacts, complexity and budget constraints determined the number of iterations needed. The REC and alternative ECs were used as the basis for developing scenarios, and the EWR were then modified because of system constraints, user demands and impacts on system yield. A summary of the various scenarios considered is shown in Table 3.1 and Figure 3.1 (as developed during an initial meeting held on 22 November 2004 with members of the project team and representatives from DWAF). Additional scenarios were also evaluated but were not sufficiently different to warrant ecological consequences determination. They are document in the DWAF (2006 a) report.

**Table 3.1: Ecological Water Requirements Scenarios developed for the Letaba River catchment.**

| Sc Number | Description |
|---|---|
| 1 | EWR for PES (Sc1) consists of EWR demands for PES as developed with the desktop method. EWRs to be supplied as first priority at the assurances specified in the EWR assurance rules (Table 3.2). |
| 2 | EWR below PES (Sc 2) the alternative categories below the PES were modelled (Table 3.2). |
| 3 | EWR above PES (Sc 3) for alternative categories above the PES were modelled (Table 3.2). |
| 4 | **Main river downstream of Tzaneen Dam:**<br>No other EWR site in the main river downstream of Tzaneen Dam draws from dams. The model provides the REC flow requirements to EWRs 6 and 7 with the following modifications:<br>**EWR 6 and 7:** Move high flows in October to November or any other appropriate months that it can be met<br>**EWR 1**: The model provides the REC flow requirements but with floods > 8 $m^3/s$ removed.<br>**EWR 2**: (Letsitele) All high flows are removed. Low flows decreased to be equal to the present flows in the dry season. Wet season flows are provided for the REC.<br>**EWR 5** (Klein Letaba): The model provides for the REC flow requirements but with high flows in November and April to wet season months where available. High flows removed to appropriate months.<br>Low flows decreased to be equal to present day in June and July. |
| 5 | **Same as Scenario 4 with the following changes**:<br>**EWR 3:** If EWR 3 is not met with Scenario 4, supply EWR 3 at PES category.<br>**EWR 4**: Decrease August, September and October low flows to present.<br>Move the Nov. floods to Dec. or any other high flow month so that there is no conflict. |
| 6 | Use **Scenario 2 as the base line (i.e. all EWR sites at D) with similar rules than Scenario 4**, i.e. Supply/demand EWR at D (with the following changes) for EWR 6 and 7 as highest priority user.<br>No other EWR site in the main river downstream of Tzaneen Dam draws from dams - only checking what happens at the other EWR sites.<br>**EWR 6 and 7**: Move the high flows in October to November or any other month that it can be met.<br>**EWR 1** Same changes as for Scenario 4<br>**Letsitele (EWR 2)**, The same changes as for Scenario 4 |

| Sc Number | Description |
|---|---|
| 7 | **Same as for Scenario 6 with the following changes:**<br>• Delete all floods at EWR 4, 6 and 7<br>• Delete all floods at EWR 5 >than 5 $m^3/s$<br>• Delete all floods at EWR 3 > than 18 $m^3/s$<br>• Supply demand at EWR 3 and 4, according to the changes in requirements set up by the fish specialist, from Tzaneen Dam.<br>• Supply the deficit at EWR 6 and 7 from Middle Letaba Dam (not from Tzaneen Dam) |

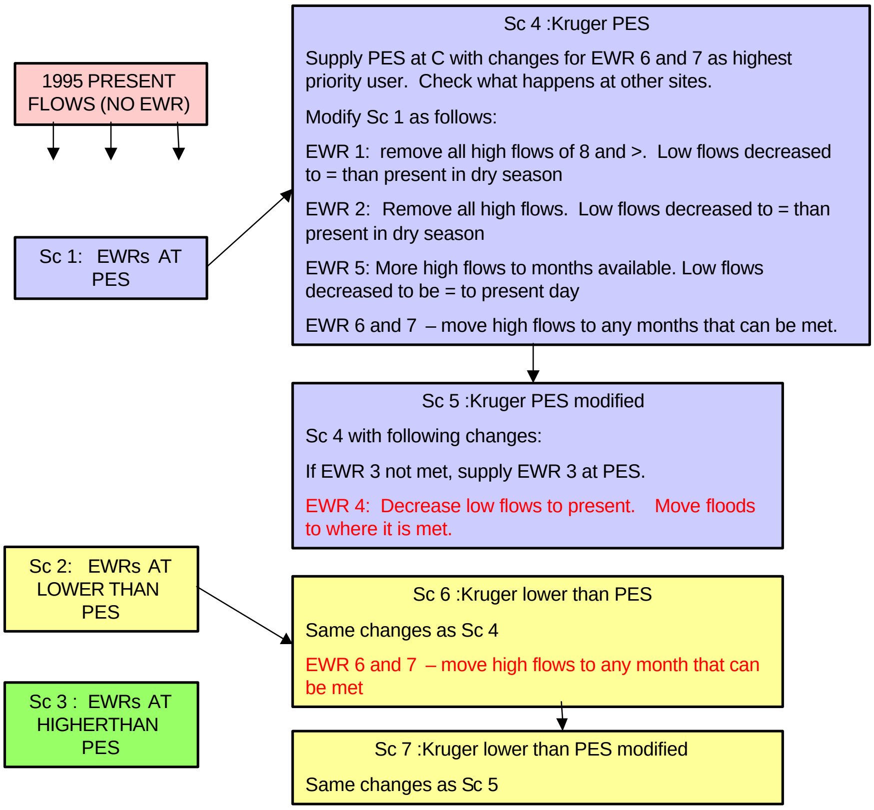



**Figure 3.1: Different scenarios depicted for the Letaba River Comprehensive Reserve.**

## 3.1 ECOLOGICAL CATEGORIES ASSOCIATED WITH SCENARIOS

Table 3.2 gives and indication of the ECs associated with REC (Sc 1), the up scenario (Sc 3) and down scenario (Sc 2) that were modelled for the Letaba Reserve study.

**Table 3.2: Ecological categories associated with the REC, up and down scenarios.**

| EWR Sites | REC (PES) Sc1 | Up (Sc 3) | Down (Sc 2) |
|---|---|---|---|
| 1 | C | C | D |
| 2 | D | D | D |
| 3 | C/D | C | D |
| 4 | C/D | C | D |
| 5 | C | C | D |
| 6 | C | B | D |
| 7 | C | B | D |

# 4. APPROACH TO DETERMING ECOLOGICAL CONSEQUENCES

## 4.1 BACKGROUND

Ecological Water Requirements (EWR) was assessed for various ecological river states, called Ecological Categories (ECs). During this assessment, no consideration is given on whether the EWRs are available, can be managed or supplied. Various alterations of the EWR to achieve the same objective or EC were also not considered. These results are documented in the report on the Ecological Water Resources of the Letaba – Quantity Report (DWAF 2006a). It must be noted that a number of different flow regimes can achieve a specific objective. For practical reasons, one flow regime (EWR) to achieve or maintain various ECs set as benchmarks against which flow regimes can be tested.

The EWR flows for difference ECs were then tested to determine whether they were available, utilising a systems model (Water Resources Yield Model – WRYM, for the Letaba updated by PD Naidoo & Associates, DWAF 2006b). The WRYM models the EWRs as priority so that the impact on the yield and therefore on other users (present and/or future) can be assessed. The model set up is described in DWAF (2006b).

## 4.2 APPROACH

The hydrologist assessed the impacts of the EWRs on the yield. The EWRs considered initially consisted of an EWR to achieve an EC lower than the Recommended EC (REC, Scenario 1), one to achieve the REC (Scenario 2) and one to achieve a higher than REC. Knowing now where potential shortages exist as well as the EWR characteristics that cause the shortages, potential changes to the EWRs are suggested. The operational constraints are also considered in the adjustments to the EWRs. Examples of typical constraints in the Letaba catchment are as follows:

- Existing dams with limited outlet capacity (such as Tzaneen, Middle Letaba and Ebenezer);
- Existing dams far upstream from EWR sites, i.e. released floods could be attenuated (such as Tzaneen, Middle Letaba and Ebenezer);
- Downstream demand, i.e. ecological and irrigation water supply that has to be supplied at high assurance and uses the river as a conduit; and
- International agreements, which could be seen as existing constraints (such as those with Mozambique).

## 4.3 ECOLOGICAL EVALUATION OF DIFFERENT FLOW SCENARIOS

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

The tools used to undertake the evaluation are the following:

- Flow duration graphs for the wettest and driest flow months consisting of graphs for natural flow, present day, the EWRs and each flow scenario to be evaluated;
- Stress duration graphs (stress profiles) of the wet and dry season illustrating the natural, present day and flow scenario stress profiles. (Habitat Flow-Stressor Response - HFSR) method is described IWR Source to Sea (2004); and

- Stress indices for each component providing all the descriptions for stresses ranging from 0 - 10 as well as the motivations for the stress levels at specific durations that were selected to represent the requirements for each component in each category.

The processes normally followed prior to and during the specialist meeting are sequentially described below (IWR Source to Sea, 2004 or Kleynhans *et al.*, 2005):

- The stress duration graphs were provided to the instream specialists, and are attached to this document (Appendix A);
- Specialists compare the stresses associated with each scenario against the required stress point for each of the EWRs for the various categories as provided during the EWR specialist meeting. The original stress requirements are plotted on the stress duration graphs for assessment purposes (Appendix A);
- Specialists determine which category each scenario represents for their components by running the Eco Status models. This would only be necessary if the EC related to the scenario is not obvious. An example of this process would be as follows. Fish required a stress of 5 to occur for 60% of the time to achieve a C category. It was also determined that a stress of 5 that occurs for 50% of the time would represent a D category. The scenario to be evaluated consists of a stress of 5 that occurs for 57% of the time. An evaluation must now be made whether this still represents a C category, a C/D or a D category and the motivation for the decision must be supplied. This is an over-simplified example as a variety of stresses, durations would normally be identified during both the wet, and dry season and the high flows would also be evaluated. The specific stress points recommended are therefore evaluated and the motivations considered. The habitat conditions associated with the changed flows might require different ratings in the applicable EcoStatus models (FRAI and MARAI) and require running them predictably;
- The various component categories for each flow scenario were used to determine the EcoStatus. The EcoStatus model is then run to determine the impact on the EC EcoStatus; and
- An assessment should also be made of how likely it would be that these evaluated states would be achieved when non-flow related issues are taken into account.

## 4.4 CONSTRAINTS

Detailed motivations were not documented due to the limited time available. An evaluation was undertaken to determine how the scenarios impact floods on the Letaba. As the volume for floods (based on the flow duration graphs) and more was achieved for all scenarios, the focus was on the changes in low flows. The assumption was therefore made that the geomorphologic category is maintained for all scenarios and the geomorphologist was not involved. The emphasis of the ecological consequences of the scenario centred on the low flows and instream biological responses. Riparian vegetation with emphasis on the low flows was also investigated.

The focus was on whether ecological objectives were achieved. Were it is possible that the EC could be increased, this was only expressed with the 'more than' symbol. No effort was made to assess the scale of the increase.

## 4.5 FLOW CONCENTRATION MODELLING

The water quality implications of each scenario were assessed based on flow concentration modelling. The results of this exercise were presented in a separate report on water quality (DWAF 2006c). The results of the flow concentration models were used to run the PAI. The water quality consequences was then presented to the ecologists so that they were aware of the driver changes, in this case mostly water quality and hydrology (geomorphology did not change) and could consider this when predicting biological responses. Flow concentration modelling was not possible at all sites (due to either a limited data set or a poor data correlation) and then the PAI was populated using expert judgment (using available water quality data collected as well as knowledge of the river system).

## 4.6 PROCEDURE DURING LETABA SPECIALIST MEETING

To aid the evaluation, the fish and invertebrate points as required were plotted on the stress durations graphs (Appendix A). The impact on category was evaluated separately for low and high flows and the FRAI, MARAI and VEGRAI models were run (if necessary) to determine the impact on the EC. The high flows were checked to determine whether this was likely to impact on the component EcoStatus.

A two-day meeting of a small group of experts (hydrologist and key ecologists) was held to assess the ecological and water quality implications of the proposed EWR scenarios (5 and 6 May 2005). Flow and stress duration graphs for the wettest and driest flow months for natural, present day, the EWRs and for each scenario were distributed to specialists prior to the meeting.

The stress duration graphs were compared to the original stress requirements and an assessment based on the predictive results of the FRAI, MIRAI and VEGRAI was made. Relationships between flow and stress can be strongly non-linear and so it was not always simple to assess modified flow regimes in terms of their impacts on the ecology. By quantifying the relationships between flow and stress and specifying the stress regime characteristics for rivers in different ecological conditions (i.e. for different categories), it was possible to estimate the ecological responses to flow scenarios.

For the high-flow components an assessment of the ecological implications of the various flow scenarios was based on professional judgement, focussing mainly on vegetation and geomorphology. A qualitative description of the likely significance of the ecological and water quality risks of each scenario, based on an assessment of the severity and likely occurrence of expected impacts, was provided.

The various component categories for each flow scenario were then evaluated to determine the EcoStatus, based on the rule-based EcoStatus models. The required fish and aquatic invertebrate points were plotted on the flow and stress durations graphs (Appendix A). The ecological consequences for various flow scenarios were extracted for each site and adjustments were made to the scoring systems for aquatic invertebrates (MIRAI), fish (FRAI) and riparian vegetation (VEGRAI) (Appendix D). The results were used to assess the Instream and EcoStatus tables. Hydrology and Water Quality were revised, adjusting the driver score (Appendix D). The EC for geomorphology remained the same as the REC for each evaluated scenario. Motivations for each component adjustment were provided for each scenario evaluated.

## 4.7 ECOLOGICAL CONSEQUENCES:EWR 1, APPEL

The flows at EWR 1 (Appel), in the Groot Letaba River, are regulated upstream by Ebenezer Dam. Furthermore directly downstream of this site these are an off take canal that dramatically reduces the flow in the river. This off take is used for potable water supply for Tzaneen. This isolated reach of river had very little influence on the flows of the rest of the Letaba River system.

At the site, all the Present Day flows met the reserve without scenarios having to be tested and consequently none of the design of the scenarios had any influence on the ecological flows at this site.

Due to the fact that the ecological flows at this site cannot currently be managed, as the potable water supply to Tzaneen has priority, the ecological consequences of flow were not determined for EWR 1.A dummy site was however created below this site in the WRYM to test consequences of the scenarios on the downstream flows (DWAF 2006b)

# 5. ECOLOGICAL CONSEQUENCES: EWR 2, LETSITELE

The flow scenarios were evaluated to determine whether some are sufficiently similar to be grouped. This resulted in the decision that the following two scenarios were evaluated:

- Sc 6 = Sc 4, Sc 2; and
- Present Day Sc

## 5.1 INVERTEBRATES

***PES D 48.1.7%***

All the scenarios modelled in the MARAI were similar to the PES and all stayed as a D category. Values for Sc's 2 and 6 were 52 % (slight improvement). Value for present day was 44 % (slightly worse then PES).

## 5.2 FISH

***Present Day Scenario (EC D 58.7%)***

The scenario curve(s) lies above, i.e. is worse than the fish PES in the dry season. During dry season drought periods, a stress of 10 is exceeded for 10% of the time. This flow will not provide any fast habitats and there is a serious risk that the flow dependant indicator species will be lost if the situation persist for more than a few weeks. For short periods of low flow, the fish will survive in shallow slow flow, pools and in the main stem of the Letaba River. The flow dependent species will be under severe stress in the dry season in this scenario and population crashes can be expected in drought periods.

In the wet season, this scenario provides higher flows than required for a fish EC of C. The improved flows in the wet season facilitate healthy conditions for breeding, recruitment as well as flushing of the river system.

The dry season is the problem here and the habitat conditions results from PD flows will result in the fish REC dropping from a C to D category.

***Scenario 6 (EC C 71.39%)***

The scenario curve lies below, i.e. is better than the fish PES in the dry season. During dry season drought periods, a stress of 8 is exceeded for 10% of the time and this implies flows of 0.12 $m^3/s$ with a maximum depth of almost 0.3m in the critical section. This flow will provide for moderate fast deep and abundant fast shallow habitat.

In the wet season, the scenario provides higher flows than required for a fish EC of C and a stress of 6 is never exceeded. The improved flows in the wet season facilitate healthy conditions for breeding and recruitment.

## 5.3 VEGETATION

***Scenario 6 (EC D 43 %)***

The main change expected is in terms of cover and abundance in the marginal and lower riparian vegetation zones. On the upper zone, flows will remain reduced and terrestrialisation and alien invasion is likely to continue. The upper and lower riparian zone is unlikely to be affected as the floods remain the same. The riparian vegetation is likely to remain much the same with some deterioration of the marginal zone. The riparian vegetation will be in a low D category that is a slight improvement from the D/E category

***Present day scenario ( EC D/C 37.5%)***

Herbaceous and more drought tolerant vegetation are likely to increase in the marginal zones vegetation zones along the active channel. More non-vegetated sediment is expected with a decrease in riparian vegetation abundance and cover. This is likely to decrease habitat diversity in the long-term. In the upper zone where high flows will remain reduced, terrestrialisation and riparian vegetation loss is likely to continue. The riparian vegetation will deteriorate slightly by remain as a D/E category (D/E – 37.5 %).

## 5.4 ECOSTATUS

The ecological consequences for each component are explained below.

The flows passing EWR 2 for the various scenarios were similar for most of the year except for the dry season, when there were significant differences among the scenarios. There are no upstream dams to capture or regulate flow in the Letsitele catchment. Despite these differences, the flows for all scenarios were well within the recommended stress durations for all categories, excluding the below PES (Sc 2) (Appendix A, Figure 5.1). Scenarios 4 and 6 indicated an improvement in all components, except water quality and geomorphology, with the remainder being the same as the PES category (Figure 5.1).

| Components | PES | REC | SC 6 | present day |
|---|---|---|---|---|
| Hydrology | C | C | D | D |
| Geomorphology | D/E | D | D/E | D/E |
| Water quality | C/D | C/D | C | C |
| **DRIVER** | **C/D** | **C/D** | **D** | **D** |
| Fish | C | C | C | D |
| Invertebrates | D | D | D | D |
| **INSTREAM** | **D** | **D** | **C** | **D** |
| Riparian veg | D/E | D | D | D/E |
| **ECOSTATUS** | **D** | **D** | **D** | **D** |

**Figure 5.1: Summary of ecological consequences of flow scenarios at EWR 2.**

# 6. ECOLOGICAL CONSEQUENCES: EWR 3, DIE EILAND

The flow scenarios were evaluated to determine whether some are sufficiently similar to be grouped. This resulted in the decision that the following four scenarios were evaluated.

- Sc 1;
- Sc 2;
- Sc 4 = Sc 6; and
- Present Day Sc

## 6.1 INVERTEBRATES

***Scenario 1 (C EC 63%)***

Stresses under this scenario are very similar to the recommended invertebrate category of a C.

***Scenario 2 (C EC 64 %)***

The dry season flows for the various scenarios exceed the invertebrate requirements. The ecological stress for the various scenarios for the dry season ranged between 4 and 5, equivalent to a flow of between 0.5 and 1m/s. These flows are likely to improve habitat availability slightly. The MIRAI model was therefore re-run with improved flows for taxa preferring moderate and high flows, and the scores improved slightly, but conditions remained in a C category (MIRAI 64%).

***Scenarios 4 and 6 (D EC 55 %)***

The MIRAI model was re-run with improved flows for taxa preferring moderate and high flows, and the stress scores decreased. There was a slight increase in the EC to a D category (MIRAI 55.4 %).

***Present Day Scenario (EC 44 %)***

The MIRAI model was re-run with improved flows for taxa preferring moderate and high flows, and the scores decreased, but conditions remained in a D category (MIRAI 44.1 %).

## 6.2 FISH

***Present day (EC D/E = 41.9%)***

The scenario curve lies above, i.e. is worse than the fish PES in the dry season. During dry season maintenance periods, a stress of 9 is exceeded for 67% of the time and this implies flows of 0.05 $m^3/s$. This flow will not provide any fast habitats and there is a serious risk that the flow dependant indicator species will be lost if the situation persist for more than a few weeks. For short periods of low flow, this fish will survive in shallow slow flow and in pools.

In the wet season, the scenario provides higher flows than required for a fish EC of C in all but drought periods during which a stress of 9.5 may be exceeded for 2% of the time. In spite of this, the improved flows in the wet season facilitate healthy conditions for breeding and recruitment.

The dry season is the issue and the habitat conditions results from PD flows will result in the fish EC dropping to a D/E category.

***Scenario 1 (EC C = 62.5%)***

The scenario curve lies above, i.e. is worse than the fish PES in the dry season. During dry season maintenance periods, a stress of 4 is exceeded for 5% of the time and this implies flows of 0.24 $m^3/s$. In the critical cross section a discharge of 0.3 $m^3/s$ provides a fast flow of 0.3m/s at 0.3m depth which is considered suitable for the indicator species identified (i.e. between stress 4 and 5). This stress is exceeded for 45 % of the time in the dry season. This flow will not provide any fast habitats and there is a serious risk that the flow dependant indicator species will be lost if the situation persist for more than a few weeks. For short periods of low flow, this fish will survive in shallow slow flow and in pools. There is no fast deep habitat available, but at 0,5 $m^3/s$ fast shallow habitats does to appear. However, depths are very shallow in the critical cross section.

In the wet season, the scenario provides higher flows than required for a fish EC of C/D in all but drought periods during which a stress of 9 may be exceeded for 10% of the time. In spite of this, the improved flows in the wet season facilitate healthy conditions for breeding and recruitment.

The dry season is the issue but despite this Scenario 1 flows will result in the fish EC improving to a C category.

***Scenario 2 (EC = 62.5% C)***

The scenario curve for fish lies between modelled D and C/D EC in the dry season for Sc 2. This flow will not provide all the required fast habitats and there is a risk that the flow dependant indicator species will be lost if the situation persist for more than a few weeks. For short periods of low flow, this fish will survive in shallow slow flow, pools and the pools that the weirs create.

In the wet season, the curve for this scenario indicates that all flows requested for a Category C EC are exceeded. The curve does not extend above a stress of 6 (or $0.17m^3/s$) in the wet season. In the wet season, the scenario provides higher flows than required for a fish EC of C/D in all periods. Improved flows in the wet season facilitate healthy conditions for breeding and recruitment, while in maintenance periods conditions remain satisfactory for the survival of the species, but only limited amounts of fast deep and fast shallow habitats will remain in critical sections.

The fish EC for Scenario 2 is considered to be the same as Sc 1 and will result in an improved fish EC to a C category.

***Scenario 6 (EC D = 50.13%)***

The scenario curve lies above, i.e. is worse than the fish PES in the dry season. During dry season maintenance periods, a stress of 9 is exceeded for 40% of the time and this implies flows of 0.05 $m^3/s$. This flow will not provide any fast habitats and there is a serious risk that the flow dependant indicator species will be lost if the situation persist for more than a few weeks. For short periods of low flow, this fish will survive in shallow slow flow and in pools.

In the wet season, the scenario provides higher flows than required for a fish EC of C in all but drought periods during which a stress of 9.5 may be exceeded for 2% of the time. In spite of this, the improved flows in the wet season facilitate healthy conditions for breeding and recruitment.

The dry season is the problem and the habitat conditions results from Scenario 6 flows will result in the fish EC dropping from a C to D category.

## 6.3 VEGETATION

**Scenario 1 (EC C/D 58.7%)**

The main change as a result of Scenario 1 is expected in terms of cover and abundance improvement in the marginal and lower riparian vegetation zones. On the upper bank flows will remain reduced and terrestrialisation and alien invasion is likely to continue. The lower riparian zone is unlikely to be affected, as the floods remain the same. The riparian vegetation is likely to slightly improve to a C/D (58.7 %) category in Sc 1.

***Scenario 2 (EC D 54.1 %)***

The main change as a result of Scenario 2 is expected is in terms of cover and abundance in the marginal and lower riparian vegetation zones. On the upper bank flows will remain reduced and terrestrialisation and alien invasion is likely to continue. The lower riparian zone is unlikely to be affected, as the floods remain the same. The riparian vegetation is likely to remain in a D (54.06 %) category in Scenario 2.

***Scenarios 4 and 6 (EC D/E 41.6%)***

The effects of Scenarios 4 and 6 will be restricted predominantly to the marginal vegetation and lower riparian zones at the site. Marginal vegetation is likely to decrease in abundance in the active flow areas as flow ceases on a regular basis. The reed beds occurring on the margins of the channel and on the lower banks may be affected by the lower flows, which occur for longer periods. The lower riparian zone is unlikely to be affected, as the floods remain the same. The riparian vegetation is likely to deteriorate from a D to a D/E (41.6 %) category in Sc 4 and 6.

***Present day scenario (EC D/E 40.7%)***

The Present Day scenario will affect the upper riparian zone. Herbaceous and more drought tolerant vegetation are likely to increase in the upper riparian zone as well as in the active channel areas. The extent of reedbeds is likely to decrease. More extensive non-vegetated cobble areas are expected with a decrease in riparian vegetation composition, abundance and cover. This is likely to decrease habitat diversity in the long-term. In the upper zone where high flows will remain reduced, terrestrialisation and riparian vegetation loss is likely to continue. The riparian vegetation category will deteriorate to a D/E (40.74 %) in the PD scenario.

## 6.4 ECOSTATUS

The ecological consequences for each component are explained below.

Upstream dams and weirs seasonally regulate the flows passing EWR 3. There were significant differences among the scenarios (Figure 6.1). Despite these differences the wet season flows for all scenarios were well within the recommended stress durations for all categories. In the dry season scenarios 1, 2 and above PES were the only scenarios within the recommended stress durations for all categories (Appendix A, Figure 6.1). Scenarios 1, 2 and above PES indicated an improvement in all components except geomorphology when compared to the PES category (Figure 6.1).

| Components | PES | AEC up | AEC down | SC1 | SC 2 | SC 6 | present day |
|---|---|---|---|---|---|---|---|
| Hydrology | D | C | D | C | C | D | E |
| Geomorphology | C | B/C | D | C/D | C/D | C/D | C/D |
| Water quality | C | B | D | C | C | C | C |
| **DRIVER** | **C/D** | **C** | **D** | **C** | **C** | **D** | **D** |
| Fish | C/D | B/C | D | C | C | D | D/E |
| Invertebrates | D | C | D | C | C | D | D |
| **INSTREAM** | **C/D** | **C** | **D** | **C** | **C** | **C** | **D** |
| Riparian veg | D | C | D | C/D | D | D/E | D/E |
| **ECOSTATUS** | **C/D** | **C** | **D** | **C** | **C** | **D** | **D** |

**Figure 6.1: Summary of ecological consequences of flow scenarios at EWR 3.**

# 7. ECOLOGICAL CONSEQUENCES: EWR 4, LETABA RANCH

The flow scenarios were evaluated to determine whether some are sufficiently similar to be grouped. This resulted in the decision that the following four scenarios were evaluated.

- Sc 1;
- Sc 2;
- Sc 4 = Sc 6; and
- Present Day Sc.

## 7.1 INVERTEBRATES

***Scenario 1 (EC C)***

The ecological stress for the various scenarios for the dry season ranged between 4 and 5, equivalent to a flow of between 0.5 and 1m/s. These flows are likely to slightly improve habitat availability. The MIRAI model was therefore re-run with improved flows for taxa preferring moderate and high flows, and the scores improved to a C EC.

***Scenario 2 (EC D)***

The EC for the invertebrates in Sc 2 would still be in a D EC with a slight improvement in the dry and maintenance flows.

***Scenarios 4 and 6 (EC D 45.6%)***

The ecological stress for the various scenarios for the dry season ranged between 4 and 5, equivalent to a flow of between 0.5 and 1m/s. These flows are likely to improve habitat availability slightly. The MIRAI model was therefore re-run with improved flows for taxa preferring moderate and high flows, and the scores improved slightly, but conditions remained in a category D (MIRAI 45.6 %). There is an increased presence and abundance of taxa with a preference for very fast, slow and moderate velocities in these scenarios.

***Present Day (EC E 37.9%)***

The ecological stress for the various scenarios for the dry season was 10 for 65% of the low flow months. The MIRAI model was therefore re-run. The scores deteriorated to a lower category E (MIRAI 37.9 %).

The changes as a result of the PD scenario per metric were as follows:

- Flow modification – all metrics had higher values (worse) due to the reduction of taxa with a preference for very fast, slow and moderate velocities;

- Habitat – there would be a loss of available habitat such as mobile columns, vegetation and water column; and

- Water Quality – there would be a loss in the number and abundance of taxa with a high and medium preference for unmodified water quality.

## 7.2 FISH

***Scenario 1 (EC C 71.8%)***

The scenario curve lies below, i.e. is better than the fish PES in the dry season. During dry season maintenance periods, a stress of 5 is exceeded for 10% of the time and this implies flows of 0.22 $m^3$/s. This improvement provides a marginal increase in the availability of fast deep habitat and fast shallow habitat.

In the wet season, the scenario provides higher flows than required for a fish EC of C and seldom exceeds a stress of 1. Higher flows in the wet season contribute to improved breeding and recruitment while improved drought flows provide for better survival.

Scenario 1 leads to a slightly improvement in flow conditions but the EC remains a C.

***Scenario 2 (EC C)***

The scenario curve lies below, i.e. is better than the fish PES in the dry season. During dry season maintenance periods, a stress of 4.5 is exceeded for 10% of the time. This improvement provides a marginal increase in the availability of fast deep habitat and fast shallow habitat.

In the wet season, the scenario provides higher flows than required for a fish EC of C and seldom exceeds a stress of 1. Higher flows in the wet season contribute to improved breeding and recruitment while improved drought flows provide for better survival.

Scenario 2 leads to a slightly improvement in flow conditions but the EC remains a C.

***Scenarios 4 and 6 (EC D)***

The scenario curve follows the category C (PES) fish curve in the dry season.

In the wet season the scenario provides higher flows than required for a fish EC of C in all but drought periods during. There remains a 3% chance of no flow in February. In spite of this, the improved flows in the wet season facilitate healthy conditions for breeding and recruitment.

The dry season is the problem here and the habitat conditions results from Sc's 4 and 6 flows will result in the fish EC dropping from a C to D category.

**Present Day (EC E 35.59 %)**

The scenario curve lies above, i.e. is worse than the fish PES in the dry season. In every month there is a chance of a stress of 10 (0.04 $m^3$/s) being exceeded for 30% of the time. This flow will not provide any fast habitats and there is a serious risk that the flow dependant indicator species will be lost if the situation persist for more than a few weeks. For short periods of low flow, this fish will survive in shallow slow flow and in pools. Ongoing extended low flow period will only affect those species, which already survive in pools, and the impact is not detectable because of the ongoing abundance of slow deep pools at the site.

In the wet season the scenario provides higher flows than required for a fish EC of C but there remains a 2% chance of no flow remains in February. In spite of this, the improved flows in the wet season facilitate healthy conditions for breeding and recruitment.

The dry season is the problem and the habitat conditions resulting from Present Day Scenario flows will cause the fish EC to drop from a C to an E category.

## 7.3 VEGETATION

***Scenarios 1 (EC C/D 62.63%)***

Scenario 1 will lead to no improvement in high flows (floods) and there needs to be higher low flows to assist with the re-establishment of the lower riparian zone vegetation. Given that sedimentation is likely to continue to occur even with increased low flows, reed beds are likely to increase. Increased reed beds will stabilize sediment and direct flow that will assist with scouring in active channels between reed beds. The associated increase in vegetation cover and abundance and localized scouring is likely to maintain or possibly even increase habitat diversity in the medium to long-term. Since the changes relate to increased low flows, the changes in the Vegetation Response model were made in the marginal zones (predominantly cover and abundance) and only slightly in the lower riparian. The lower riparian may be improved slightly if the low flows are increased. Terrestrialisation is likely to continue in the upper riparian zone. The riparian vegetation is likely to improve slightly from a D to a C/D (62.63 %) ecological category.

***Scenario 2 (EC C/D 59.9%)***

Scenario 2 will lead to the continued sedimentation, and the same response as to Scenario 1. Slight improvement will take place (C/D (59.86 %) EC).

***Scenarios 4 and 6 (EC D 47%)***

The effects of Sc 4 and 6 will be restricted predominantly to the marginal vegetation zones although increased stress may be expected in the lower riparian zone. Given that sedimentation is likely to continue to occur, herbaceous and more drought tolerant vegetation is likely to increase. The extent of reed beds is likely to decrease since sections of the river are likely to become drier. More extensive non-vegetated sandy areas are expected with a decrease in riparian vegetation composition, abundance and cover. This is likely to decrease habitat diversity in the long-term. In the upper zone where high flows will remain reduced, terrestrialisation and riparian vegetation loss is likely to continue. The riparian vegetation will decrease but remain in a D category (47.04 %).

***Present day scenario (EC D/E 42.63%)***

The effects of this scenario will be restricted predominantly to the marginal zones although increased stress may be expected in the lower riparian zone from impacts on bank storage. There is likely to be decreased habitat diversity in the long-term. In the upper zone where high flows will remain reduced, terrestrialisation and riparian vegetation loss is likely to continue. The riparian vegetation will decrease to a D/E category (42.63 %).

## 7.4 ECOSTATUS

Upstream dams, weirs and seasonally flows from the Molototsi River regulate the flows passing EWR 4. There were significant differences among the scenarios (Figure 7.1). Despite these differences the wet season flows for all scenarios were well within the recommended stress durations for all categories. Scenarios 6 and Present Day does not meet the ecological objectives and Sc 1 and 2 improve the ecological objectives (Appendix A, Figure 7.1). Scenarios 1 and 2 indicated an improvement in all components except water quality when compared to the PES category (Figure 7.1).

| Components | PES | AEC up | AEC down | SC 1 | SC 2 | SC 6 | present day |
|---|---|---|---|---|---|---|---|
| Hydrology | D | C | D | C | C | D | D/E |
| Geomorphology | C/D | C | D | C/D | C/D | C/D | C/D |
| Water quality | B/C | B | C/D | C | C | C | C |
| **DRIVER** | **C.D** | **C** | **D** | **C** | **C** | **D** | **D** |
| Fish | C | B/C | D | C | C | D | E |
| Invertebrates | D | C | D | C | D | D | E |
| **INSTREAM** | **C/D** | **B/C** | **D** | **C** | **C** | **D** | **E** |
| Riparian veg | D | C/D | D | C/D | C/D | D | D/E |
| **ECOSTATUS** | **C/D** | **C** | **D** | **C** | **C** | **D (LOW** | **D/E** |

**Figure 7.1: Summary of ecological consequences of flow scenarios at EWR 4.**

# 8. ECOLOGICAL CONSEQUENCES: EWR 5, KLEIN LETABA

The flow scenarios were evaluated to determine whether some are sufficiently similar to be grouped. This resulted in the decision that the following two scenarios were evaluated:

- Sc 1, Sc 2, Sc 6 and Present Day Sc; and
- Sc 4 = Sc 6

## 8.1 INVERTEBRATES

***Scenarios 1,2 and 6 and present day (EC C/D 60.4%)***

These scenarios provide slightly higher flows in both the dry and wet season. These flows are likely to improve availability of habitat for organisms with a preference for bedrock/boulders and mobile cobbles). The higher flows will result in improvements of the presence and abundance of taxa with a preference for moderately fast flowing water. Stresses under these scenarios improve half a category from a D to a C/D (MIRAI 60.4%).

***Scenario 4 (EC C 66.9%)***

The dry season flows for the various scenarios exceed the invertebrate requirements. The ecological stress for the various scenarios for the dry season ranged between 3.5 and 5, equivalent to a flow of between 0.3 and 0.8m/s. These flows are likely to improve habitat availability (the abundance of taxa with a preference for bedrock/boulders and mobile cobbles) and flow requirements (improvements if the presence and abundance of taxa with a preference or moderately fast flowing water). The MIRAI model was therefore re-run with improved flows for taxa preferring moderate and high flows, and the scores improved to a category C (MIRAI 66.9%).

## 8.2 FISH

***Scenario 4 (EC B =85.3%)***

The scenario curve lies below, i.e. is better than the fish PES in the dry season. During dry season maintenance periods, a stress of 6 is never exceeded. A stress of 3 is exceeded for 30% of the time.

In the wet season, the scenario provides higher flows than required for a fish EC of C and a stress of 4 is never exceeded. The improved flows in the wet season facilitate healthy conditions for breeding and recruitment.

The scenario therefore provides flows to cater for these demands in both the dry and wet season at a level, which exceeds fish C PES category. This provides for limited fast deep and moderately abundant fast shallow habitat that provides for the above dry season survival requirements. These low stresses occur because of the fact that the indicator species (LMOL) is semi-rheophilic and can survive long periods in pools. The flow scenarios therefore cater for movement and growth in the dry season, recruitment and migration in the wet season.

The improved dry season flows and increased habitat availability in Sc 4 flows will result in the fish EC improving from a C to B (85.29%) category.

***Scenario 1,2, 6 and present day (EC B =82%)***

The scenario curve lies below, i.e. is better than the fish PES in the dry season. During dry season maintenance periods, a stress of 6 is never exceeded and this implies flows of 0.031 $m^3/s$. A stress of 3 is exceeded for 30% of the time. This provides for limited fast deep and moderately abundant fast shallow habitat that provides for the above dry season survival requirements.

In the wet season, the scenario provides higher flows than required for a fish EC of C and a stress of 4 is never exceeded. The improved flows in the wet season facilitate healthy conditions for breeding and recruitment.

The scenario therefore provides flows to cater for these demands in both the dry and wet season at a level, which exceeds fish C PES category. This provides for limited fast deep and moderately abundant fast shallow habitat that provides for the above dry season survival requirements. These low stresses occur because of the fact that the indicator species (LMOL) is semi-rheophilic and can survive long periods in pools. The flow scenarios therefore cater for movement and growth in the dry season recruitment, and migration in the wet season.

The improved dry season flows and increased habitat availability in Sc 6 flows will result in the fish EC improving from a C to B (82.01%) category.

## 8.3 VEGETATION

***Scenario 4 (EC B/C 78.06%)***

The effects will be restricted predominantly to the marginal zone. Given that sedimentation is likely to continue to occur, marginal vegetation is likely to increase. The extent of reed beds is likely to increase. Increased reed beds will stabilize sediment and direct flow that will assist with scouring in active channels between reed beds. The associated increase in vegetation cover and abundance and localized scouring is likely to maintain habitat diversity in the medium to long-term. Since the changes relate to increased low flows, the changes in the PES model were made in the marginal zone (predominantly cover and abundance) predominantly. However, given the expected importance of bank storage in this system, the improved low flows are likely to enhance bank storage. The lower riparian zone may thus also improve slightly. The upper zone is unlikely to be affected due to the lack of floods. The riparian vegetation is likely to slightly improve but remain in a B/C (78.06 %) category.

***Scenario 1,2, 6 and present day (EC C 74.98%)***

The effects will be similar to the above but with a slight reduction in flows with effects on the marginal zone. Given that sedimentation is likely to continue to occur, marginal vegetation is likely to be maintained but unlikely to increase substantially. Reed beds may not increase but their presence will still assist with scouring in active channels between the reed beds. The lower riparian zone is unlikely to be affected, as the floods remain the same. The riparian vegetation falls from a B/C to a C (74.98).

## 8.4 ECOSTATUS

The ecological consequences for each component are explained below.

The Middle Letaba Dams, many small farm dams and irrigation abstraction alter the seasonally flows in the Klein Letaba River at EWR 5. There were significant differences among the scenarios (Figure 8.1). Despite these differences, all the scenarios meet the REC. (Appendix A, Figure 8.1).

| Components | PES | AEC down | SC 4 | SC 6 |
|---|---|---|---|---|
| Hydrology | D | D | D | D |
| Geomorphology | C | D | C | C |
| Water quality | B /C | C | B /C | B /C |
| **DRIVER** | **C /D** | **D** | **C** | **C** |
| Fish | C | C /D | B | B |
| Invertebrates | D | D | C | C /D |
| **INSTREAM** | **C** | **D** | **C** | **C** |
| Riparian veg | B /C | C /D | B /C | C |
| **ECOSTATUS** | **C** | **D** | **C** | **C** |

**Figure 8.1: Summary of ecological consequences of flow scenarios at EWR 5.**

# 9. ECOLOGICAL CONSEQUENCES: EWR 6, LONELY BULL

The flow scenarios were evaluated to determine whether some are sufficiently similar to be grouped. This resulted in the decision that the following three scenarios were evaluated.

- Sc 4 = Sc 1;
- Sc 6 = Sc 2; and
- Present Day Sc

## 9.1 INVERTEBRATES

***Scenario 4 (EC C 74.7%)***

The dry season flows for Scenario 4 will reduce the stress from 7.8 to 5 at 40% exceedance. Subsequent there would also be changes to velocity distributions – with velocities greater than 0.6m/s occurring. Metrics changed included slight improvements in the presence and abundance of taxa with a preference for very fast and moderately fast flowing water. Improvement in the number and abundance of taxa with a preference for mobile cobbles and vegetation slightly improved. The MIRAI model was therefore re-run with improved flows for taxa preferring moderate and high flows, and the scores improved to a category C (MIRAI 74.7%) from a D PES.

***Scenario 6 (EC C)***

Stress curves under this scenario are similar to the EC of a C and therefore did not require the MIRAI to be rerun.

***Present Day (EC C 73.2%)***

The stress under this scenario is similar to Scenario 4. The maintenance flows for the PD scenario will reduce the stress from 7.8 to 5 at 40% exceedance. Metrics changed included slight improvements in the presence and abundance of taxa with a preference for very fast and moderately fast flowing water. Improvement in the number and abundance of taxa with a preference for mobile cobbles and vegetation slightly improved. The MIRAI model was therefore re-run with improved flows for taxa preferring moderate and high flows, and the scores improved to a category C (MIRAI 73.2 %).

## 9.2 FISH

***Scenarios 1 and 4. (Fish A/B 88.9%)***

The scenario curve lies below, i.e. is better than the fish PES in the dry season, and zero stress is exceeded 100% of the time.

In the wet season, the scenario provides higher flows than required for a fish EC of D and zero stress is exceeded 100% of the time.

The improved flows in the dry and wet season facilitate healthy conditions for breeding and recruitment. The higher abundance of deeper habitats and water column cover is also provided for non-indicator species.

The improved dry season flows and increased habitat availability in Sc 4 flows will result in the fish EC improving from a C to A/B (88.9%) category.

***Scenario 2 and 6. (EC C 70.3%)***

The scenario curve lies below, i.e. is better than the fish PES in the dry season. Improvements in dry season flows reflect an improvement in habitat and cover availability for the indicator species.

In the wet season, the scenario provides higher flows than required for a fish EC of D including drought periods during which a stress of 4.5 is never exceeded.

Higher flows will result in more habitats being available (fast sandy habitats) as well as improved water quality (flush out nutrients and reduce high summer temperatures). The higher abundance of deeper habitats and water column cover is also provided for non-indicator species.

The improved dry season flows and increased habitat availability in Sc 6 flows will result in the fish EC remaining in a C (70.3%) category.

***Present day (EC D)***

The scenario curve for the PD scenario very closely approximates the fish PES category D for both wet and dry flows and consequently the FRAI model was not rerun.

Wet season flows provide adequate and even good flow-depth categories for breeding and recruitment. Under present conditions, the dry season flows are adequate for maintenance of the fish requirements. However, during drought periods the surface flow of the Letaba River is lost at this EWR site. Dry season flows will not provide any fast habitats and there is a serious risk that the flow dependant indicator species will be lost if the situation persist for more than a few weeks. For short periods of low flow, this fish will survive in shallow slow flow and in pools.

## 9.3 VEGETATION

***Scenario 4 (EC C 75.5%)***

The effects will be restricted predominantly to the marginal vegetation zones. Given that sedimentation is likely to continue to occur, marginal vegetation is likely to increase. The extent of reed beds is likely to increase. Increased reed beds will stabilize sediment and direct flow that will assist with scouring in active channels between reed beds. The associated increase in vegetation cover and abundance and localized scouring is likely to maintain habitat diversity in the short-term. Since the changes relate to increased low flows, the changes in the PES model were made in the marginal zone (predominantly cover and abundance) only. The lower riparian zone is unlikely to improve while the upper zone will not be affected, as the floods remain the same. The riparian vegetation is likely to improve within the C EC (76.51%).

***Scenario 6 (EC C)***

The response of the vegetation to Scenario 6 is the same as for Sc 4.

***Present day scenario (EC C/D 56.8%)***

It is anticipated that the effects will be restricted predominantly to the marginal vegetation zones although increased stress may be expected in the lower riparian zone. Given that sedimentation is likely to continue to occur, herbaceous and more drought tolerant vegetation is likely to increase. The extent of reed beds is likely to decrease since sections of the river are likely to become drier. More extensive non-vegetated sandy areas are expected with a decrease in riparian vegetation composition, abundance and cover. This is likely to decrease habitat diversity in the long-term. In the upper zone where high flows will remain reduced, terrestrialisation and riparian vegetation loss is likely to continue. The riparian vegetation will decrease to a C/D (56.83 %) EC.

## 9.4 ECOSTATUS

Upstream dams, irrigation weirs and flows from both the Klein and Groot Letaba rivers control the flows within the Kruger National Park at EWR 6. Scenarios 4 and 6 both meet the REC while the Present Day Scenario does not meet the PES (Figure 9.1, Appendix A).

| Components | PES | AEC up | AEC down | SC 4 | SC 6 | present day |
|---|---|---|---|---|---|---|
| Hydrology | D | C | D | C | C | D |
| Geomorphology | C | C | D | C | C | C |
| Water quality | C | B | D | C | C | C |
| **DRIVER** | **C** | **C** | **D** | **C** | **C** | **C/D** |
| Fish | C | B | D | A/B | C | D |
| Invertebrates | D | C | D | C | C | C |
| **INSTREAM** | **C/D** | **B/C** | **D** | **B** | **C** | **C/D** |
| Riparian veg | C | B | D | C | C | C/D |
| **ECOSTATUS** | **C** | **B** | **D** | **C** | **C** | **C/D** |

**Figure 9.1: Summary of ecological consequences of flow scenarios at EWR 6.**

# 10. ECOLOGICAL CONSEQUENCES: EWR SITE 7, LETABA BRIDGE

The flow scenarios were evaluated to determine whether some are sufficiently similar to be grouped. This resulted in the decision that the following three scenarios were evaluated:

- Sc 1 and Sc 4,
- Sc 2 and Sc 6; and
- Present Day Sc.

## 10.1 INVERTEBRATES

***Scenarios 1, 2 and 4 (EC C 55.4%)***

The dry season flows for the various scenarios exceed the invertebrate requirements. The ecological stress for the dry season changed from 7.5 to 5 at a 40% occurrence. Differences in habitat characteristics and biotic response were sufficient to cause a change in the MIRAI score to improve to a C category (55.4 %).

***Scenario 6 (EC C 55.4%)***

The response of the aquatic invertebrates to Sc 6 is the same as for Sc 4.

***Present Day (EC E 32.2%)***

The scenario curves lies above, i.e. worse than the invertebrate PES, in the dry season with an ecological stress of 9.8 occurring of 60 % (as apposed to 5%). The maintenance dry season level of 40% falls within the drought and all stresses are above 5. In the wet season the maintenance stress values ranging from 5 to 4.6 at a 30% occurrence.

In the PD scenario most of the taxa with a preference for very fast and moderately fast flows will be lost. There is a reduction in the number and abundance of taxa with a preference for mobile cobbles and vegetation in the dry months. Taxa with a high or moderate requirement for water quality would be adversely affected. Due to prolonged low flows in the dry months, survival of rheophilic species is minimal.

Differences in habitat characteristics and biotic response were sufficient to cause a change in the MIRAI score to drop to a E category (32.2 %).

## 10.2 FISH

***Scenario 1 and 4. (EC B/C 79.9%)***

The scenario curve lies below, i.e. is better than the fish PES in the dry season, a stress of 3.5 for 100% of the time is never exceeded in September. In dry season flows, fast-deep habitats remain absent but there is an improvement in the availability of the fast-shallow habitats when compared to the fish PES.

In the wet season, the scenario provides higher flows than required for a fish EC of C.

The improved flows in the dry and wet season facilitate healthy conditions for breeding, recruitment and survival. Higher flows will result in more habitats being available (fast sandy and deep habitats) as well as improved water quality (flush out nutrients and reduce high summer temperatures). The higher abundance of deeper habitats and water column cover also provides for non-indicator species.

The improved dry season flows and increased habitat availability in Sc 4 flows will result in the fish EC improving from a C to B/C (79.9%) category.

***Scenario 2 and 6 (EC C 68%).***

The scenario curve lies slightly below, i.e. is better than the fish PES in the dry season with a stress of 3.5 never exceeded. Improvements in dry season flows reflect an improvement in habitat and cover availability for the indicator species.

In the wet season, the scenario provides slightly higher flows than required for a fish EC of C. The higher flows will result in more habitats being available (fast sandy habitats) as well as improved water quality (flush out nutrients and reduce high summer temperatures). The higher abundance of deeper habitats and water column cover is also provided for non-indicator species.

Despite the slightly improved flows Sc 6 fish EC will remain at a C (68.4 %) category.

***Present day scenario. (EC D 49%)***

The scenario curve lies above, i.e. is worse than the fish PES in the dry season. During dry season maintenance periods, a stress of 9.5 is exceeded for 65 % of the time. This flow will not provide any fast habitats and there is a serious risk that the flow dependant indicator species will be lost if the situation persist for more than a few weeks. For short periods of low flow, this fish will survive in shallow slow flow and in pools.

In the wet season, the scenario provides higher flows than required for a fish EC of a C category. The conditions for recruitment of flow dependent species are good in the wet season, but their survival in doubt in the maintenance low flow periods. Currently the flow-dependant indicator species of *Chiloglanis engiops* and *C. pretoriae* are now absent.

The dry season is the problem and the habitat conditions results from the PD scenario flows will result in the fish EC dropping from a C to D (49%) category.

## 10.3 VEGETATION

***Scenario 4 (EC C 73%)***

The effects will be restricted predominantly to the marginal vegetation zones. Given that sedimentation is likely to continue to occur, marginal vegetation is likely to increase. The extent of reed beds is likely to increase. Increased reed beds will stabilize sediment and direct flow that will assist with scouring in active channels between reed beds. The associated increase in vegetation cover and abundance and localized scouring is likely to maintain habitat diversity in the short-term. Since the changes relate to increased low flows, the changes in the PES model were made in the marginal zone (predominantly cover and abundance) only. The lower riparian zone is unlikely to improve while the upper zone will not be affected as the floods remain the same. The riparian vegetation is likely to improve within the same EC.

***Scenario 6 (EC C 70.8%)***

The effects will be similar to the above but with a slight reduction in flows with effects on the marginal zone. The riparian vegetation will remain in a C (70.84 %) category in Sc 6.

***Present scenario (EC 57.27%)***

Effects will be restricted predominantly to the marginal vegetation zones although increased stress may be expected in the lower riparian zone. Given that sedimentation is likely to continue to occur, herbaceous and more drought tolerant vegetation is likely to increase. The extent of reed beds is likely to decrease since sections of the river are likely to become drier. More extensive non-vegetated sandy areas are expected with a decrease in riparian vegetation composition, abundance and cover. This is likely to decrease habitat diversity in the long-term. In the upper zone where high flows will remain reduced, terrestrialisation and riparian vegetation loss is likely to continue. The riparian vegetation will decrease to a C/D (57.27 %) category.

## 10.4 ECOSTATUS

Upstream dams, irrigation weirs and flows from both the Klein and Groot Letaba rivers control the flows within the Kruger National Park at EWR 7. Scenarios 4 and 6 both meet the REC while the Present Day Scenario does not meet the PES (Figure 10.1, Appendix A).

| Components | PES | AEC up | AEC down | SC 4 | SC 6 | present day |
|---|---|---|---|---|---|---|
| Hydrology | D | C | D | C | C | D |
| Geomorphology | C | B | D | C | C | C |
| Water quality | C | B | D | B/C | B/C | C |
| **DRIVER** | **C** | **B** | **D** | **C** | **C** | **C/D** |
| Fish | C | B | D | B/C | C | D |
| Invertebrates | D | C | D | C | C | E |
| **INSTREAM** | **C** | **C** | **D** | **C** | **C** | **D** |
| Riparian veg | C | B | D | C | C | C/D |
| **ECOSTATUS** | **C** | **B** | **D** | **C** | **C** | **D** |

**Figure 10.1: Summary of ecological consequences of flow scenarios at EWR 7.**

# 11. CONCLUSIONS

The results of the comparison of the different ecological consequences of flow scenarios are indicated in Figures 5.1 to 10.1 and summarised in Table 11.1.

Scenario 7 was derived as a result of several iterations of the flow scenarios and was recommended as the most suitable scenario as it meets the REC, i.e. most of the ecological objectives, and has a minimal impact on system yield.

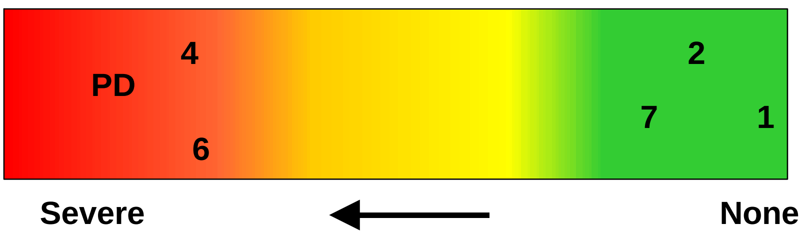
A Traffic Light diagram comparing the ecological effects of the different scenarios is shown in Figure 11.1. The results per EWR site are summarised in Figure 11.1.

**Table 11.1: Summary of the number of EWR sites where the REC can be met per scenario.**

| Site | REC | Sc 1 | Sc 2 | Sc 4 | Sc 6 | Sc 7 | PD |
|---|---|---|---|---|---|---|---|
| EWR 2 | D | ☺ | ☺ | ☺ | ☺ | ☺ | ☺ |
| EWR 3 | C/D | Y+ | Y+ | X | X | ☺ | X |
| EWR 4 | C/D | Y+ | Y+ | X | X | ☺ | X (-) |
| EWR 5 | C | ☺ | ☺ | ☺ | ☺ | ☺ | ☺ (1) |
| EWR 6 | C | ☺ | ☺ | ☺ | ☺ | ☺ | X |
| EWR 7 | C | ☺ | ☺ | ☺ | ☺ | ☺ | X |
| No. EWR sites where ecological objectives are NOT achieved | | 0 | 0 | 2 | 2 | 0 | 4 |

*Where*: ☺ = meet REC, x = did not meet REC, (1) = Riparian vegetation a problem, Y+ = exceeds REC.

The results are summarised in Table 11.1 that illustrates that Scenarios 1, 2 and 7 would meet the recommended Ecological Category at all sites. Scenarios 4 and 6 would be problematic at EWR Sites 3 (Prieska) and 4 (Letaba Ranch). The present day situation with a variable operational procedure releases from the Tzaneen Dam for the downstream irrigation and the KNP, does not meet the recommended EC at EWR's 3, 4, 6 and 7.




**Increased risk of not meeting Ecological Objectives**

**Figure 11.1: Ecological comparison of scenarios. Note that red illustrates an unacceptable situation for ecology and green an acceptable condition.**

During the scenario optimisation process Scenarios 1, 2 and 7 where used to improve the assurance of water to EWR sites 3 and 4 and ultimately to the KNP. These scenarios will therefore not degrade the river at the EWR sites.

After consideration of the flow scenario that were investigated, it is apparent that the EWR flows for **Scenario 7** is the most suitable scenario as it meets the REC, most of the ecological objectives, and has a minimal impact on all the user categories (Table 11.1). Furthermore, Scenario 7 provides the best trade off between the need for protection of the ecological ecosystems in the Letaba catchment with the need to ensure the socio-economic growth is not severely negatively impacted. In the traffic diagrams, it can be seen that Scenario 7 is the only scenario that was lying on the green side (Figure 11.1).

While the present releases to Kruger National Park should be 0.6 $m^3/s$ an annual average of 0.456 $m^3/s$ flow (14.8 million $m^3$/annum) is released to Kruger National Park from Tzaneen Dam (DWAF 2006c). This release includes domestic abstraction to Letsitele users, Ritavi, Naphuno, and Letaba Citrus Processors. The annual demand of these users is estimated to be 6.06 million $m^3$. Thus, the effective release to Kruger National Park is 8.74 million $m^3$/annum (0.277 $m^3/s$).

## 12. REFERENCES

DWAF (2006a). Letaba Catchment Reserve Determination: Environmental Water Requirements report: Quantity. DWAF Report No. RDM/B800/01/CON/COMP/0904.

DWAF (2006b). Letaba Catchment Reserve Determination Hydrological support and water resource evaluation. DWAF Report No. RDM/800/00/COMP/1104.

DWAF (2006c). Letaba Catchment Reserve Determination Environmental Water Requirements report: Quality. DWAF Report No. RDM/800/00/COMP/0804.

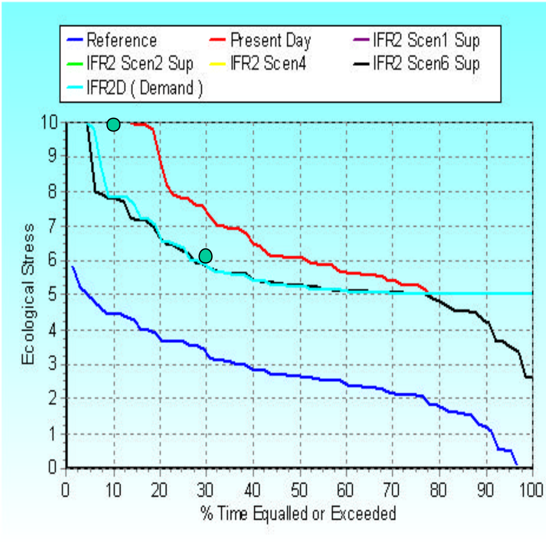
Kleynhans, CJ, Louw, MD, Thirion, C, Rossouw, NJ, and Rowntree, K (2005). River EcoClassification: Manual for EcoStatus determination (Version 1). Joint Water Research Commission and Department of Water Affairs and Forestry report. WRC Report No. KV 168/05

IWR Source to Sea (2004). Editors. A comprehensive Eco Classification and Habitat Flow Stressor Response manual. Prepare for IWQS DWAF, Project No. 2002-148.

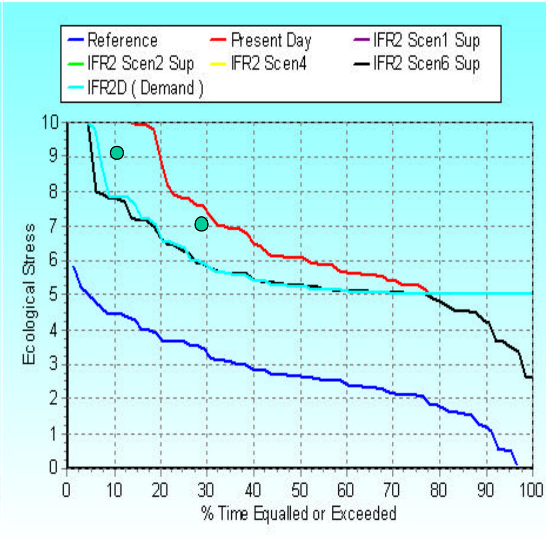
# APPENDIX A:
# STRESS DURATION GRAPHS REPRESENTING THE VARIOUS FLOW SCENARIOS AND THE FISH AND INVERTEBRATE REQUIREMENTS.

## EWR2 Dry season (Letsitele)

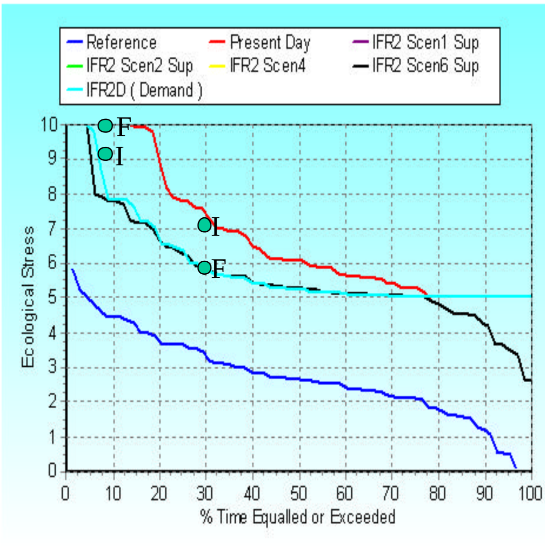
**Stress Response Duration Curve of IFR 2 under various scenarios during the dry season (September)**




Fish




Invertebrates

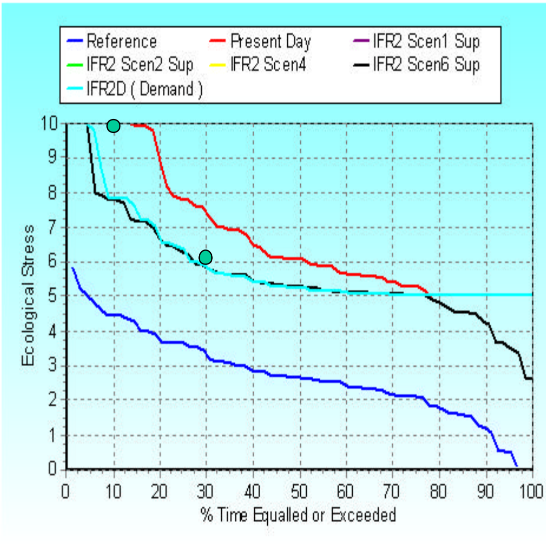


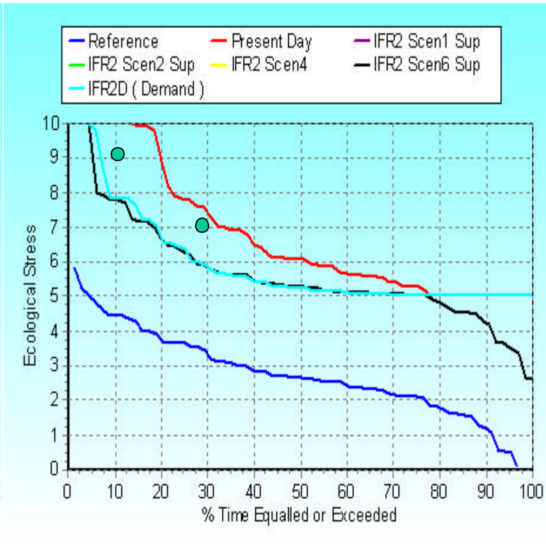

Dark green = D

Fish and Invertebrates

## EWR2 Wet season (Letsitele)

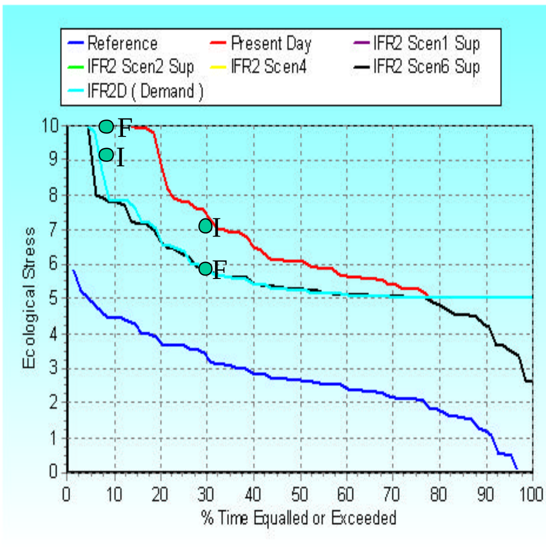
**Stress Response Duration Curve of IFR 2 under various scenarios during the dry season (September)**




Fish

Invertebrates

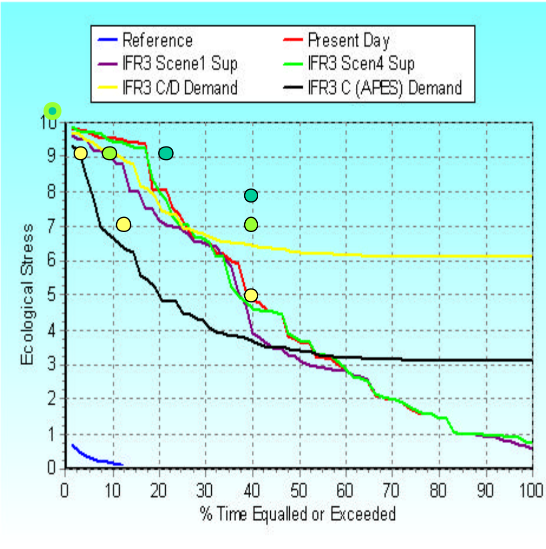


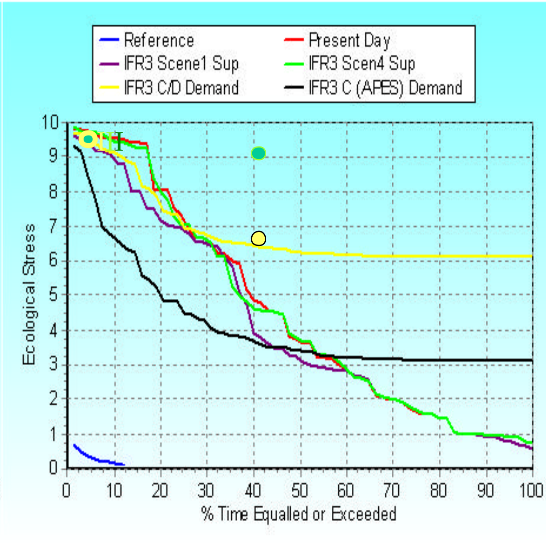

Dark green = D

Fish and Invertebrates

## EWR3 Dry season (Hans Marensky)

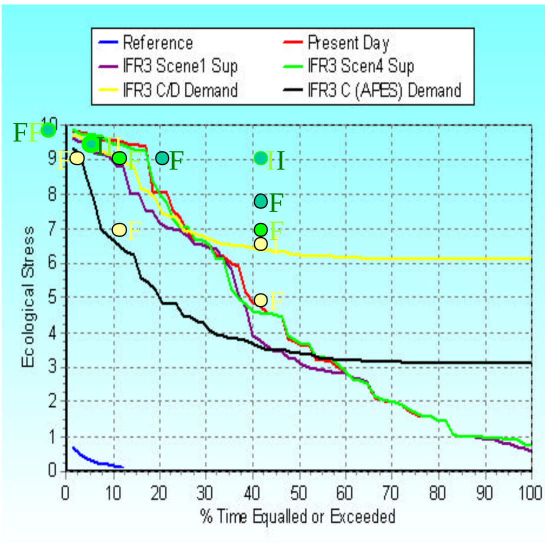
**Stress Response Duration Curve of IFR 3 under scenario 1 and 4 and PES and APES demand for the dry season (July)**




Fish

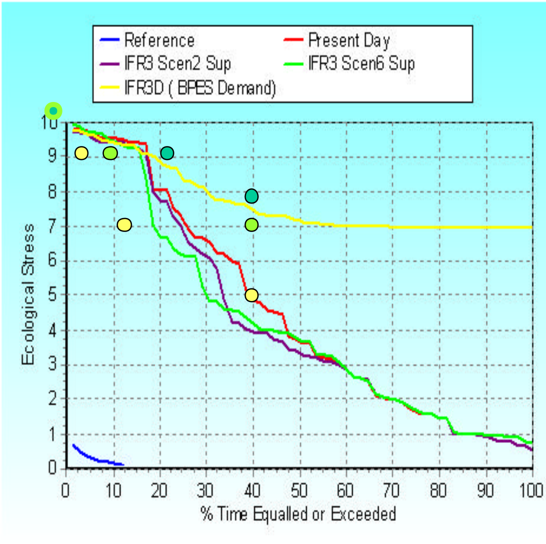
Invertebrates



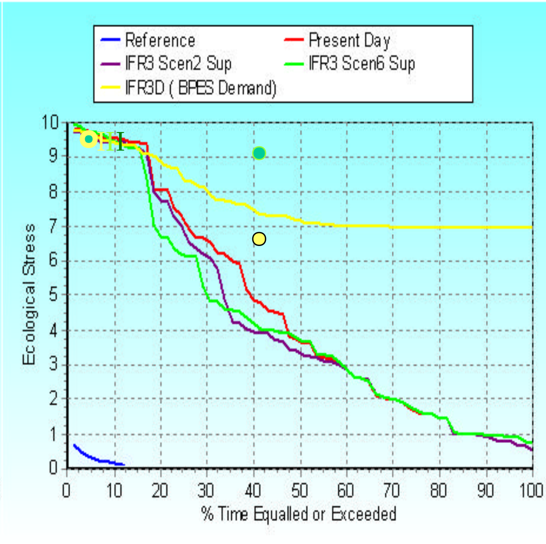

Dark green = D
Light green = C/D
Orange = C

Fish and Invertebrates

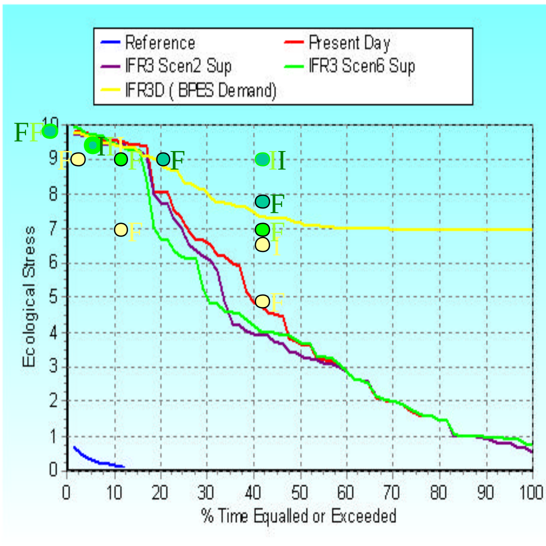
**Stress Response Duration Curve of IFR 3 under scenario 2 and 6 during the dry season (July)**




Fish




Invertebrates

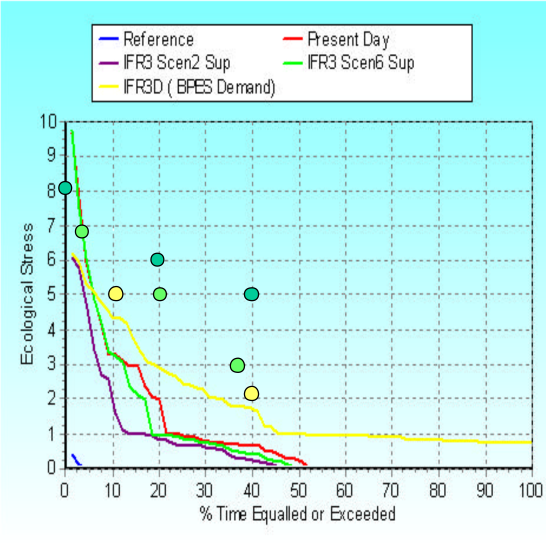



Dark green = D
Light green = C/D
Orange = C

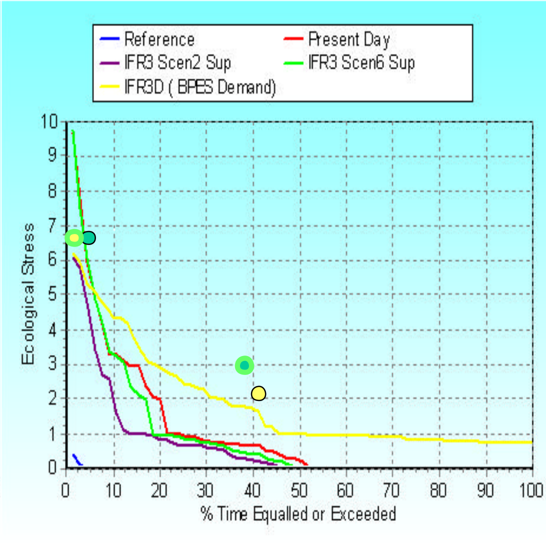
Fish and Invertebrates

## EWR3 Wet season (Hans Marensky)

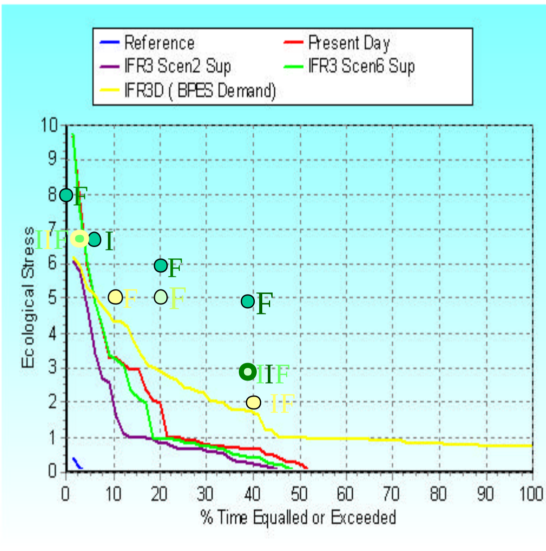
**Stress Response Duration Curve of IFR 3 under scenario 2 and 6 during the wet season (February)**




Fish



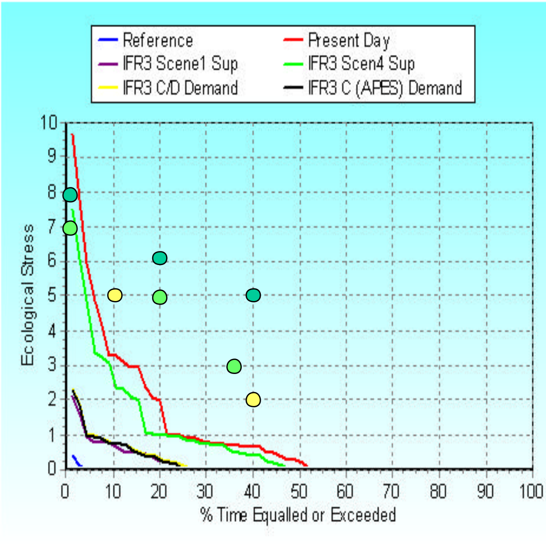

Invertebrates

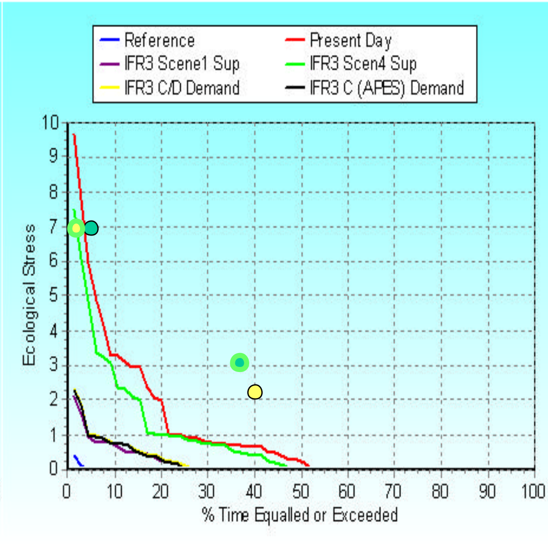



Dark green = D
Light green = C/D
Orange = C

Fish and Invertebrates

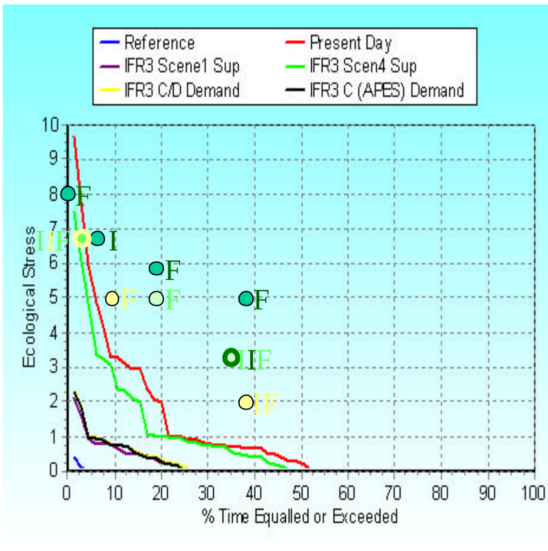
**Stress Response Duration Curve of IFR 3 under scenario 1 and 4 and PES and APES demand for the wet season (February)**




Fish

Invertebrates

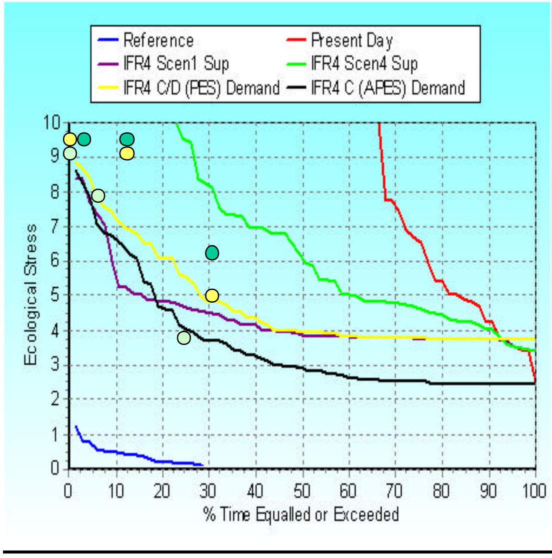



Dark green = D
Light green = C/D
Orange = C

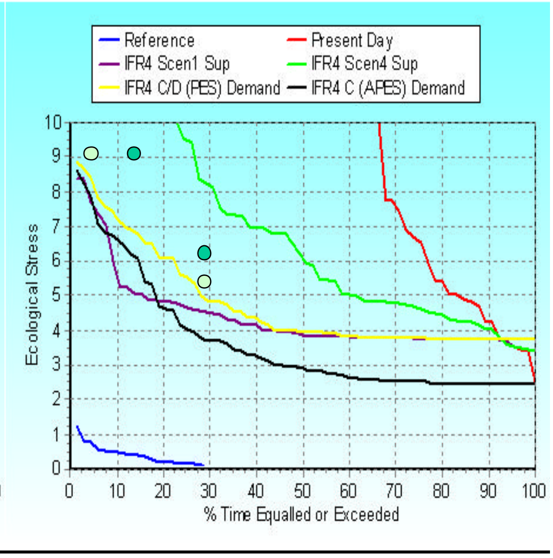
Fish and Invertebrates

## EWR4 Dry season (Letaba Ranch)

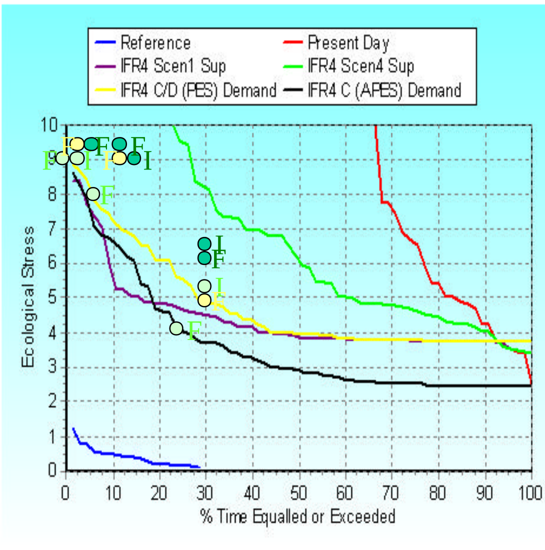
**Stress Response Duration Curve of IFR4 under scenario 1 and 4 and PES and APES Demand during the dry season (September)**




Fish




Invertebrates

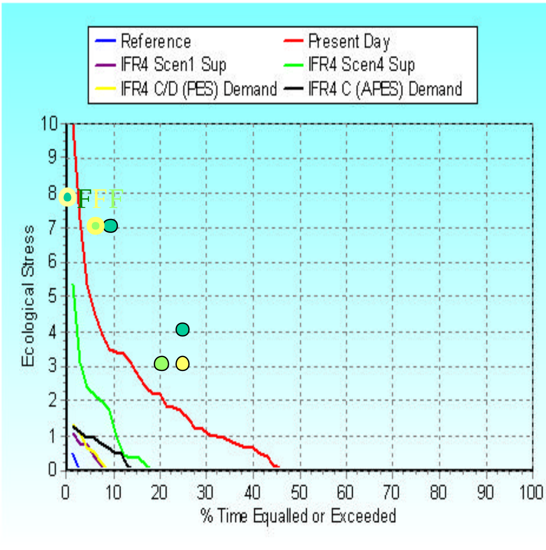



Dark green = D
Light green = C
Orange = C/D

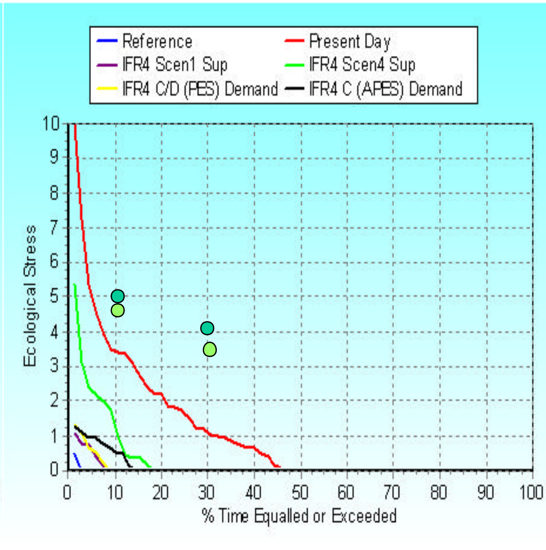
Fish and Invertebrates

## EWR4 Wet season (Letaba Ranch)

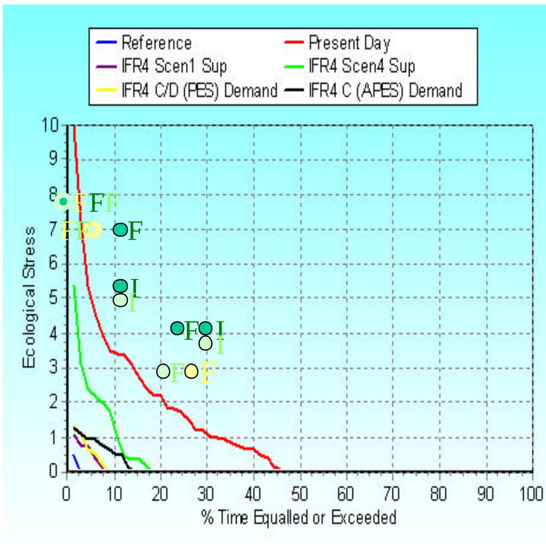
**Stress Response Duration Curve of IFR4 under scenario 1 and 4 and PES and APES Demand during the wet season (February)**




Fish




Invertebrates

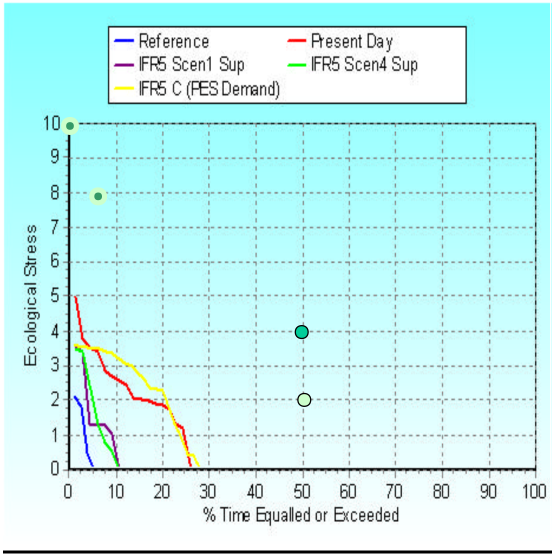


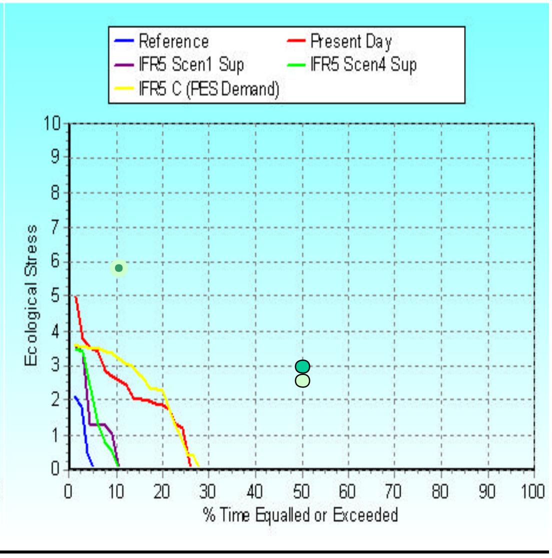

Dark green = D
Light green = C
Orange = C/D

Fish and Invertebrates

## EWR5 Dry season (Klein Letaba)

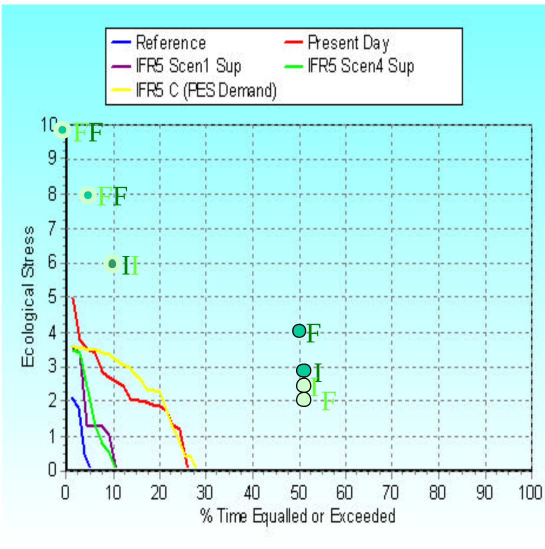
**Stress Response Duration Curve of IFR 5 under scenario 1 and 4 and PES and APES Demand during the wet season (February)**




Fish

Invertebrates

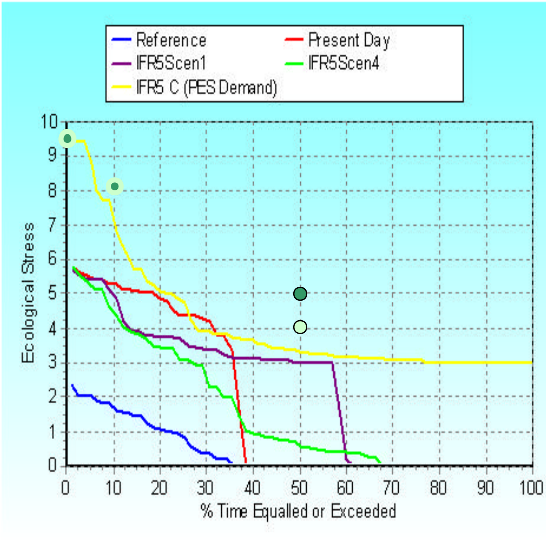



Light green = C
Dark green = D

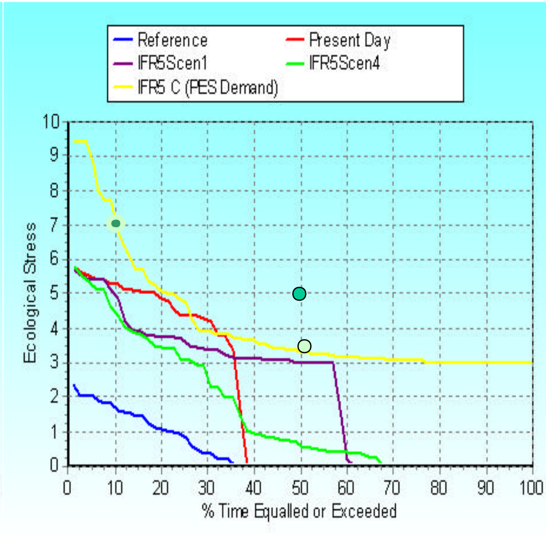
Fish and Invertebrates

## EWR5 Wet season (Klein Letaba)

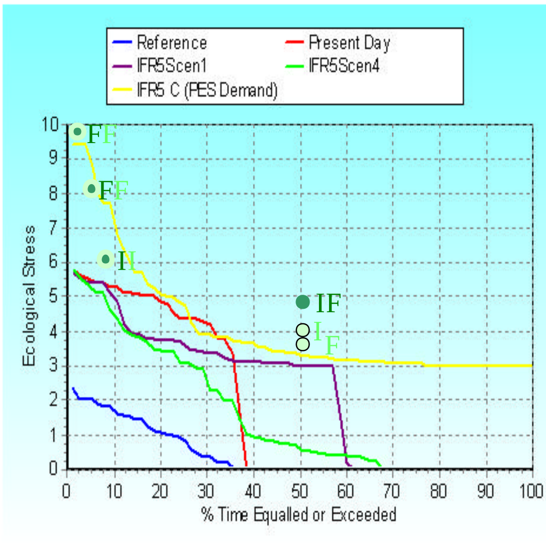
**Stress Response Duration Curve of IFR 5 under scenario 1 and 4 and PES and APES Demand during the dry season (September)**




Fish




Invertebrates

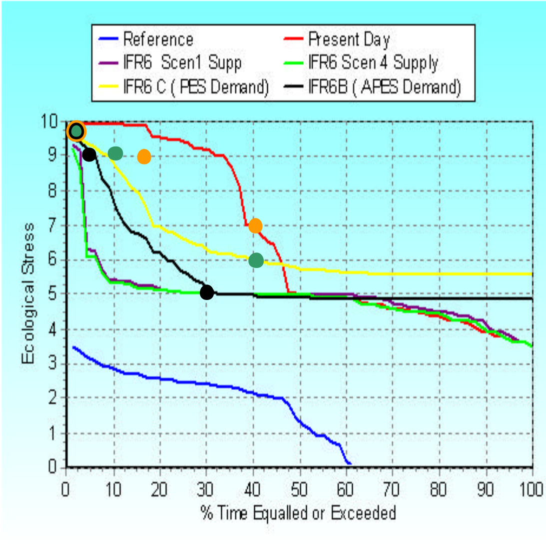



Light green = C
Dark green = D

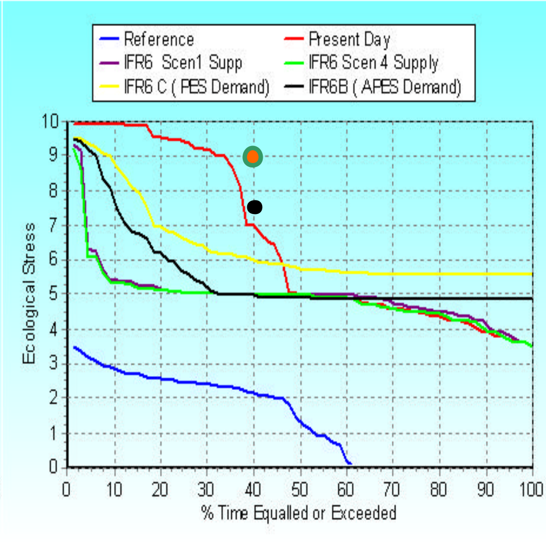
Fish and Invertebrates

## EWR6 Dry season (Lonely Bull)

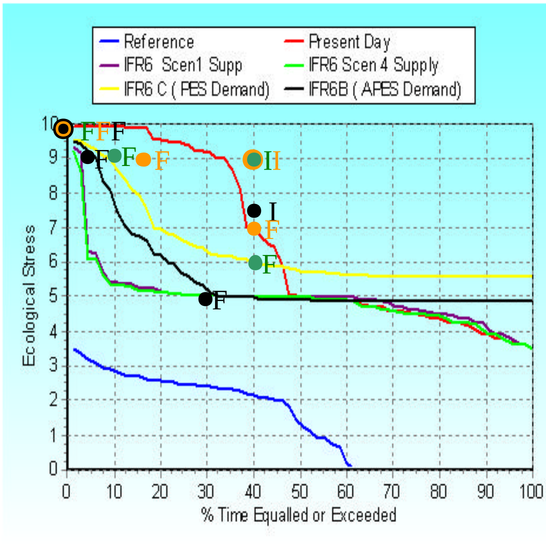
**Stress Response Duration Curve of IFR 6 under scenario 1 and 4 during the dry season (July)**




Fish



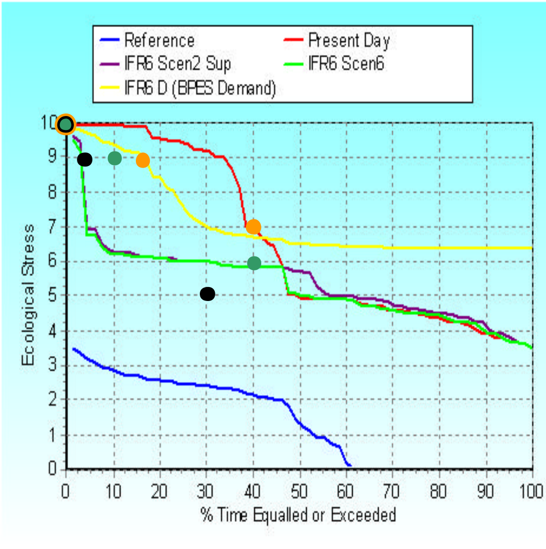

Invertebrates



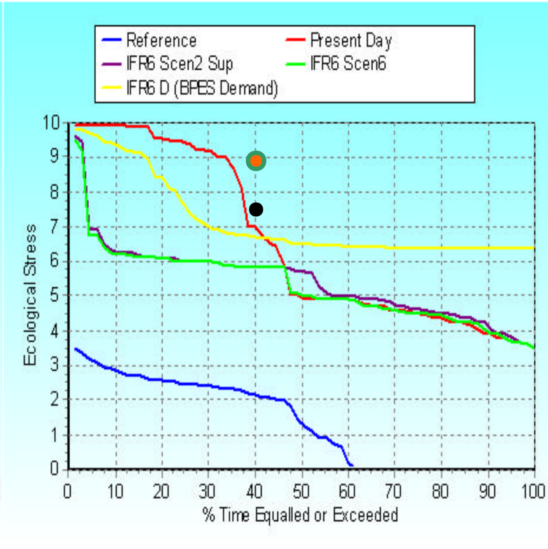

Orange = D
Dark green = C
Black = B

Fish and Invertebrates

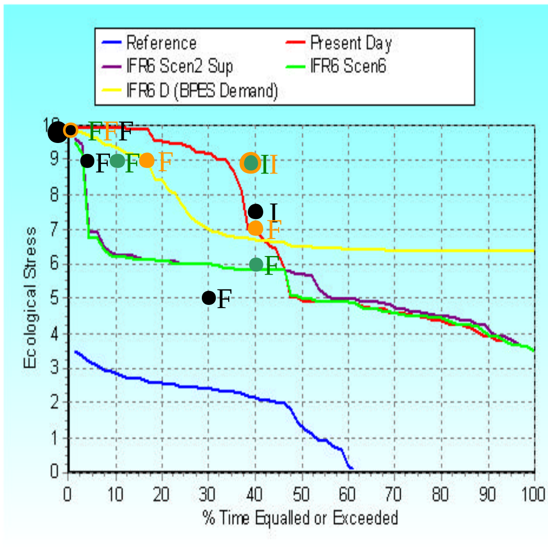
**Stress Response Duration Curve of IFR 6 under scenario 2 and 6 during the dry season (July)**




Fish




Invertebrates

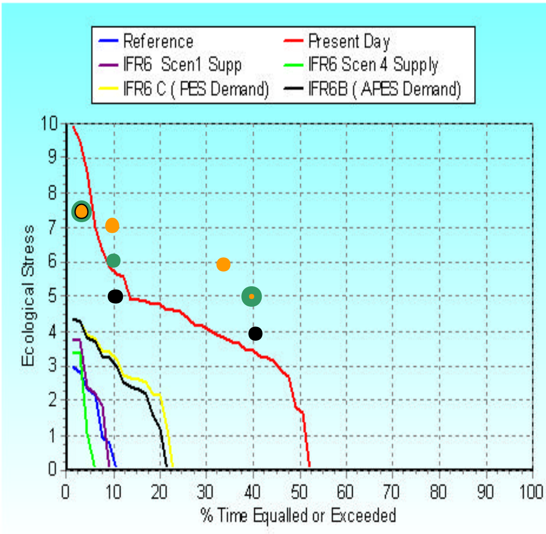


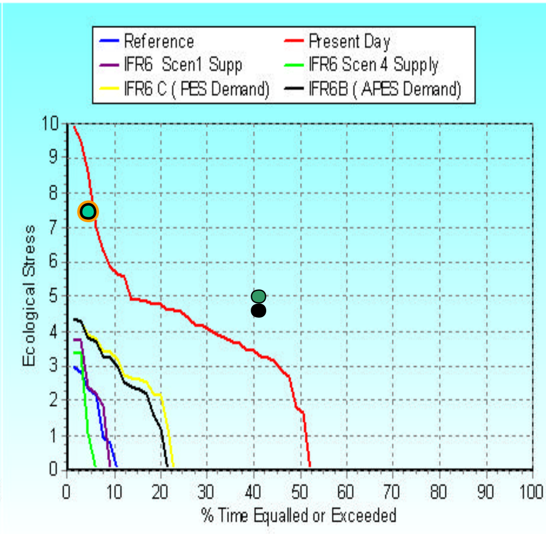

Orange = D
Dark green = C
Black = B

Fish and Invertebrates

## EWR6 Wet season (Lonely Bull)

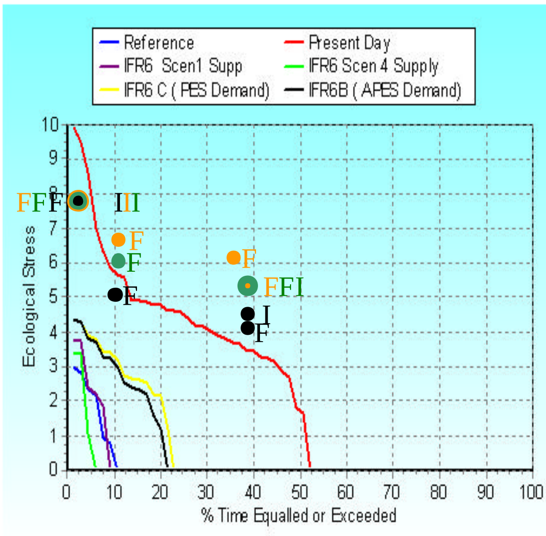
**Stress Response Duration Curve of IFR 6 under scenario 1 and 4 during the wet season (February)**




Fish

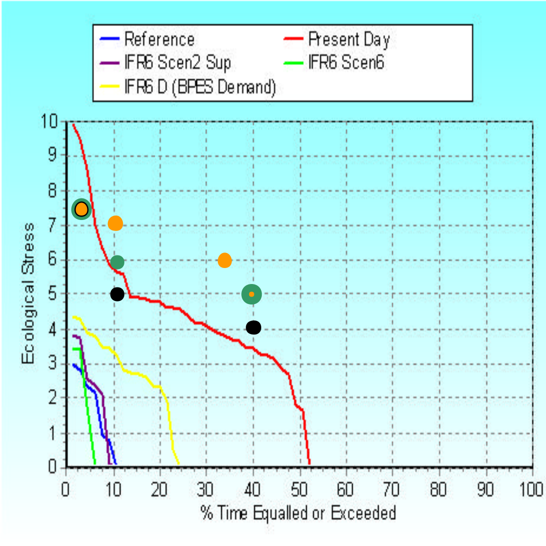
Invertebrates



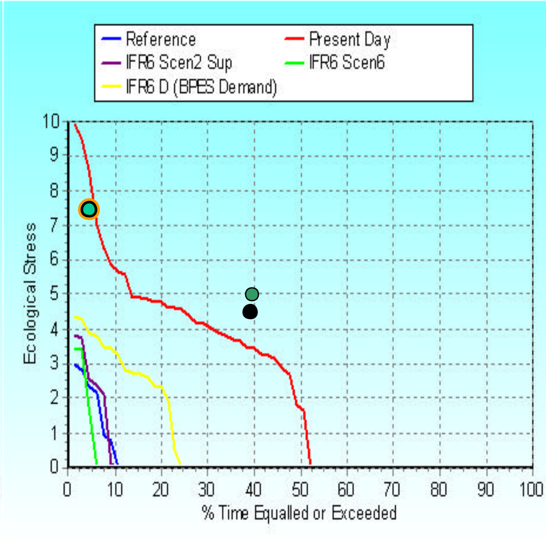

Orange = D
Dark green = C
Black = B

Fish and Invertebrates

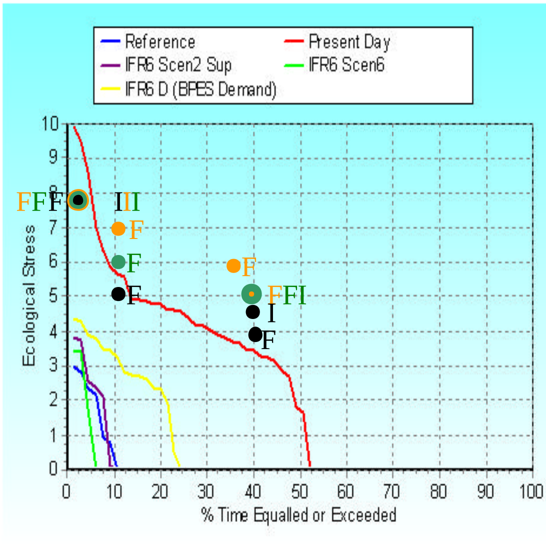
**Stress Response Duration Curve of IFR 6 under scenario 2 and 6 during the wet season (February)**




Fish




Invertebrates

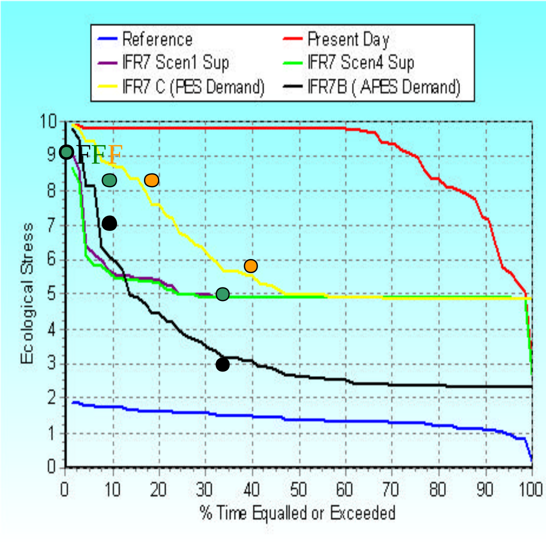



Orange = D
Dark green = C
Black = B

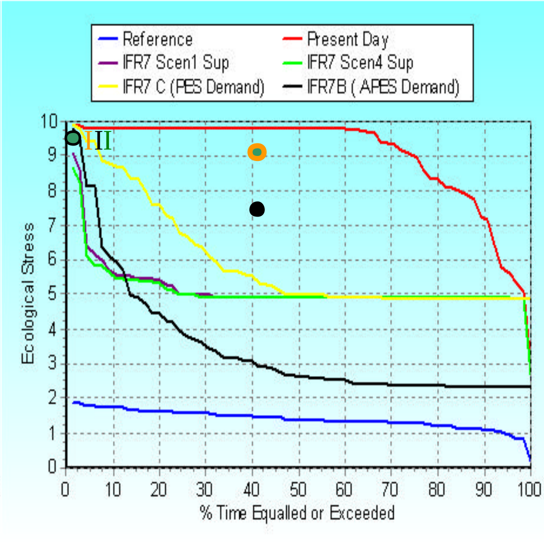
Fish and Invertebrates

## EWR7 Dry season (Letaba Bridge)

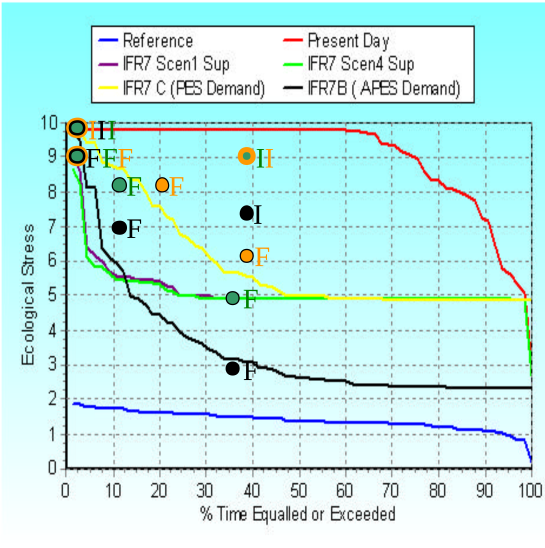
**Stress Response Duration Curve of IFR 7 under scenario 1 and 4 and PES and APES Demand during the dry season (September)**




Fish



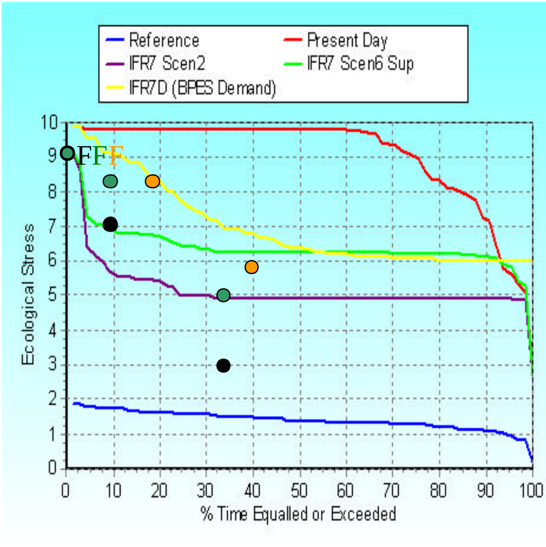

Invertebrates



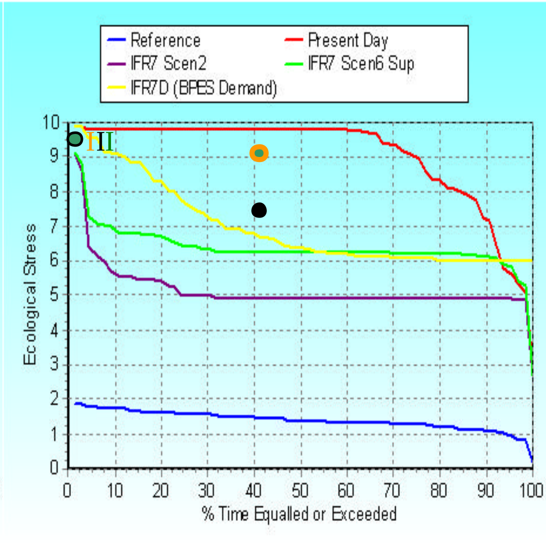

Orange = D
Dark green = C
Black = B

Fish and Invertebrates

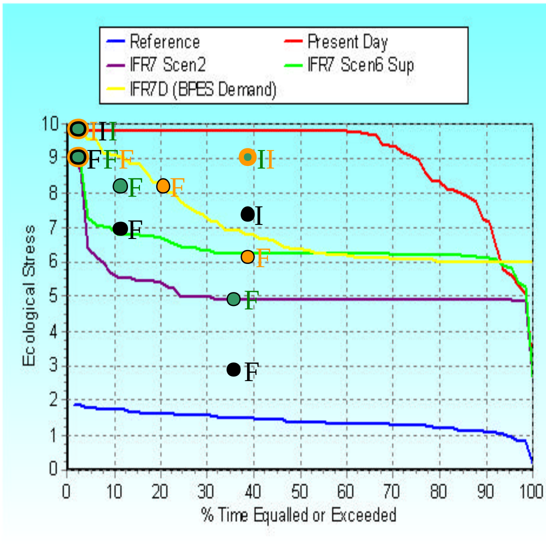
**Stress Response Duration Curve of IFR 7 under scenario 2 and 6 during the dry season (September)**




Fish




Invertebrates

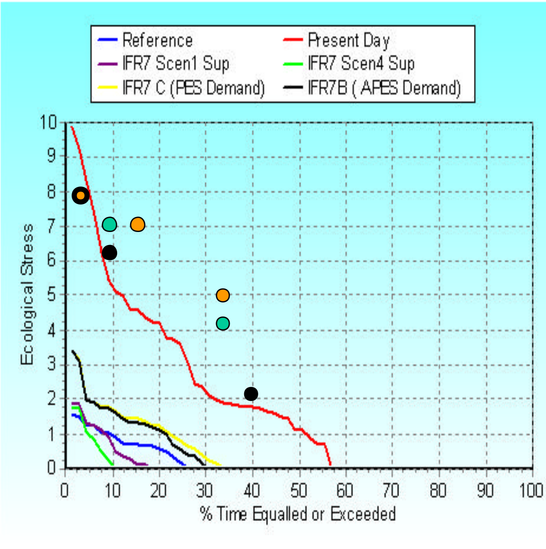



Orange = D
Dark green = C
Black = B

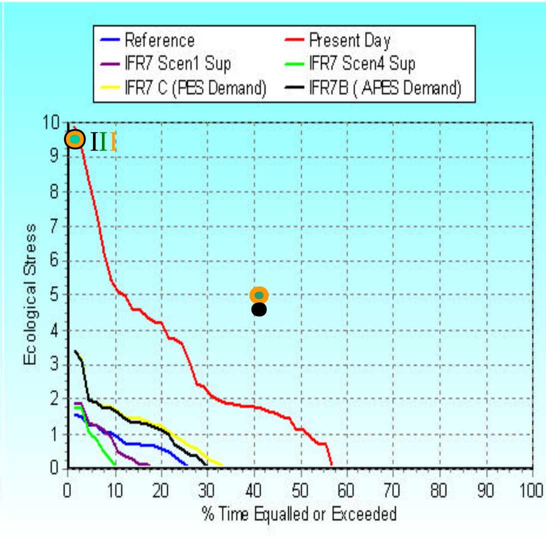
Fish and Invertebrates

## EWR7 Wet season (Letaba Bridge)

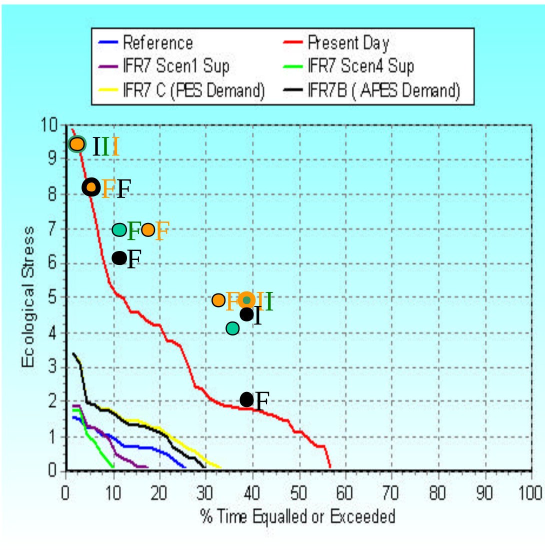
**Stress Response Duration Curve of IFR 7 under scenario 1 and 4 and PES and APES Demand during the wet season (February)**




Fish



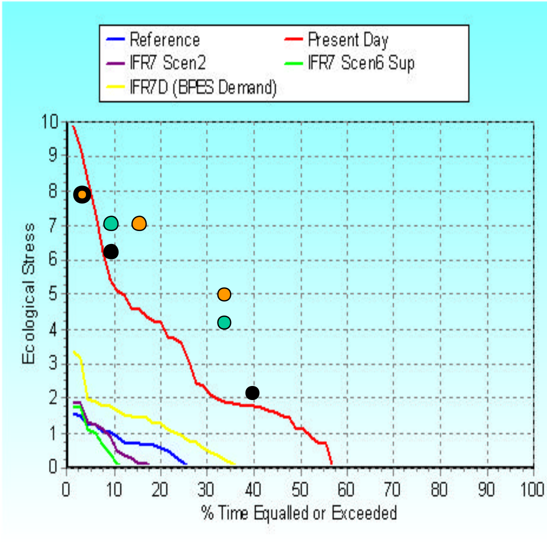

Invertebrates



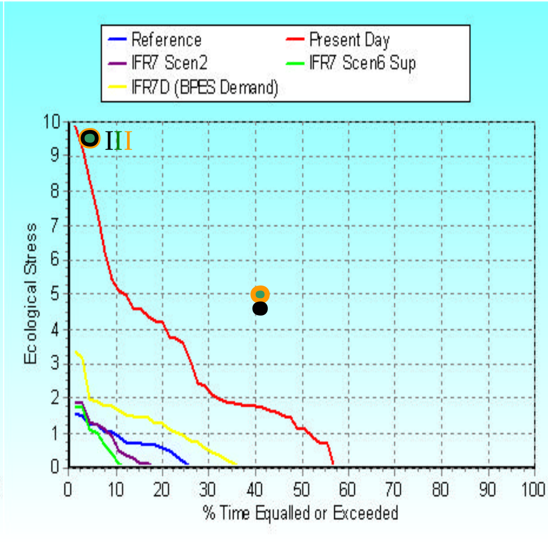

Orange = D
Dark green = C
Black = B

Fish and Invertebrates

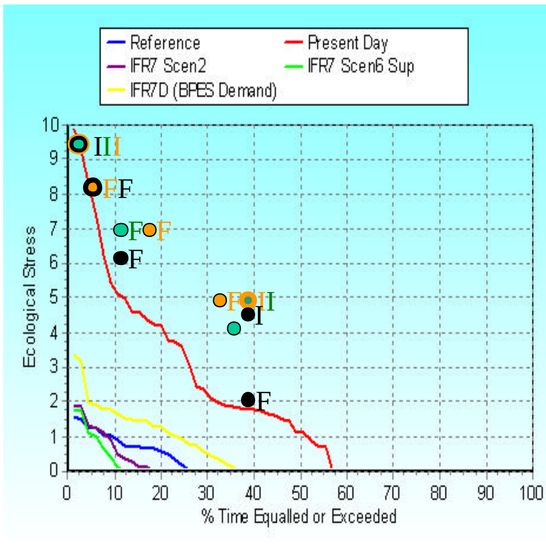
**Stress Response Duration Curve of IFR 7 under scenario 2 and 6 during the wet season (February)**




Fish




Invertebrates




Orange = D
Dark green = C
Black = B

Fish and Invertebrates

# Appendix B

## River Hydraulics: Plots for scenario assessments

**AL Birkhead[1] and A.A. Jordanova[2]**

**[1]Streamflow Solutions CC**
**Berea, East London**

**[2]Centre for Water in the Environment**
**University of the Witwatersrand, Johannesburg**

## GRAPHICAL REPRESENTATION OF RESULTS

The habitat type abundance ratings (final results from the ecological flow assessments - refer to Appendices A1 and A2: of the river hydraulics reports) are plotted as a function of discharge in Figs 1 to 7 for each of the sites, respectively. The average velocity and maximum depth (for the riffle/rapid cross-sections) have also been included to streamline the assessments of changes in these hydraulic parameters.

Four velocity-depth Categories (hydraulic habitat types) showed in Figs 1 to 7 are:

SS Slow (<0.3 m/s) and shallow (<0.5 m): This includes shallow pools and backwaters.
SD Slow (<0.3 m/s) and deep (>0.5m): This includes deep pools and backwaters.
FS Fast (>0.3 m/s) and shallow (<0.3 m): Shallow runs, rapids and riffles fall in this Category
FD Fast (>0.3 m/s) and deep (>0.3 m): Deep runs, rapids and riffles fall under this Category.

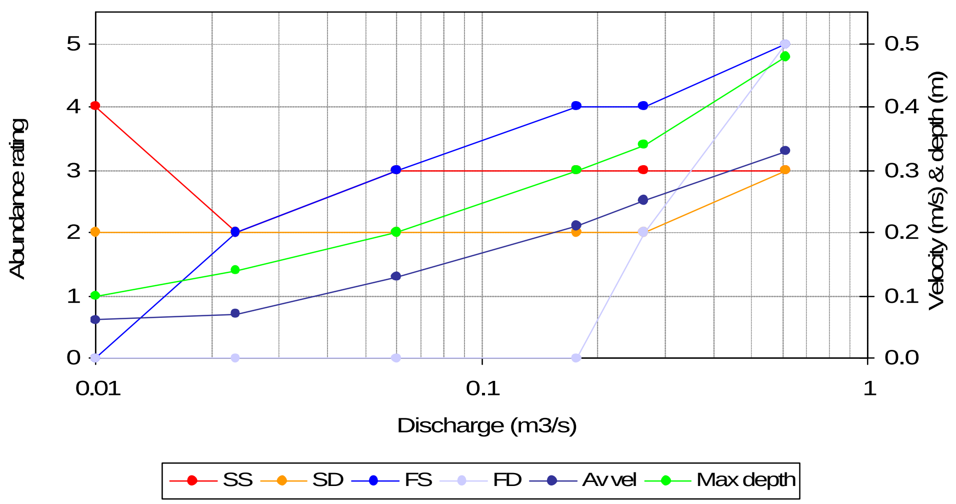



**Figure B:1 Site 1: Habitat-Type Abundance Ratings For Fish As A Function For Discharge.**

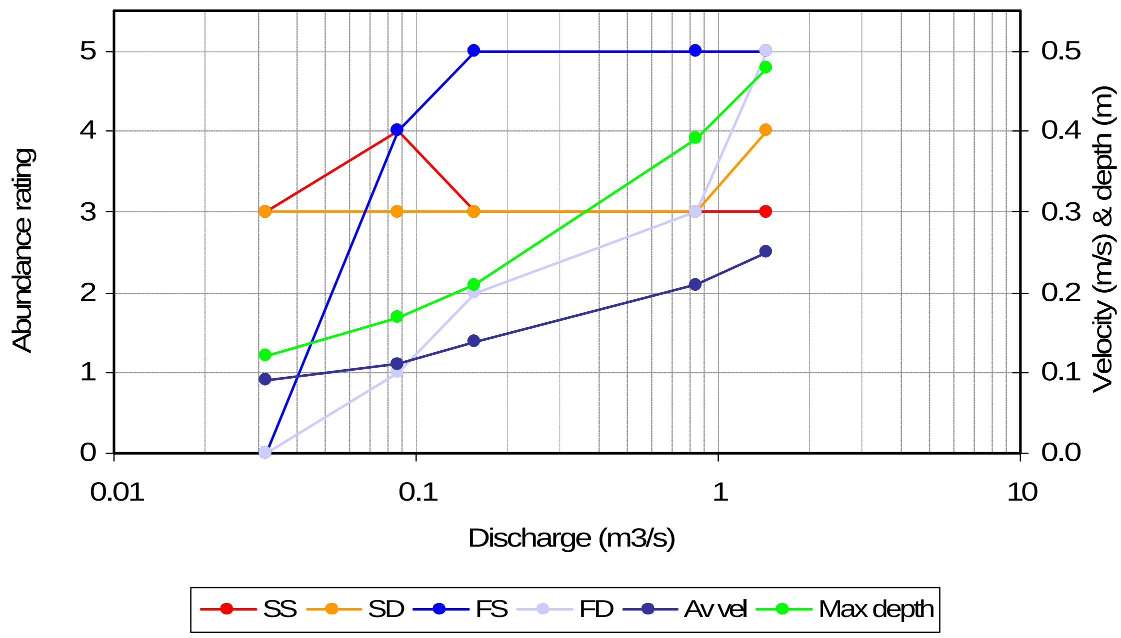



**Figure B:2 Site 2: Habitat-Type Abundance Ratings For Fish As A Function For Discharge.**

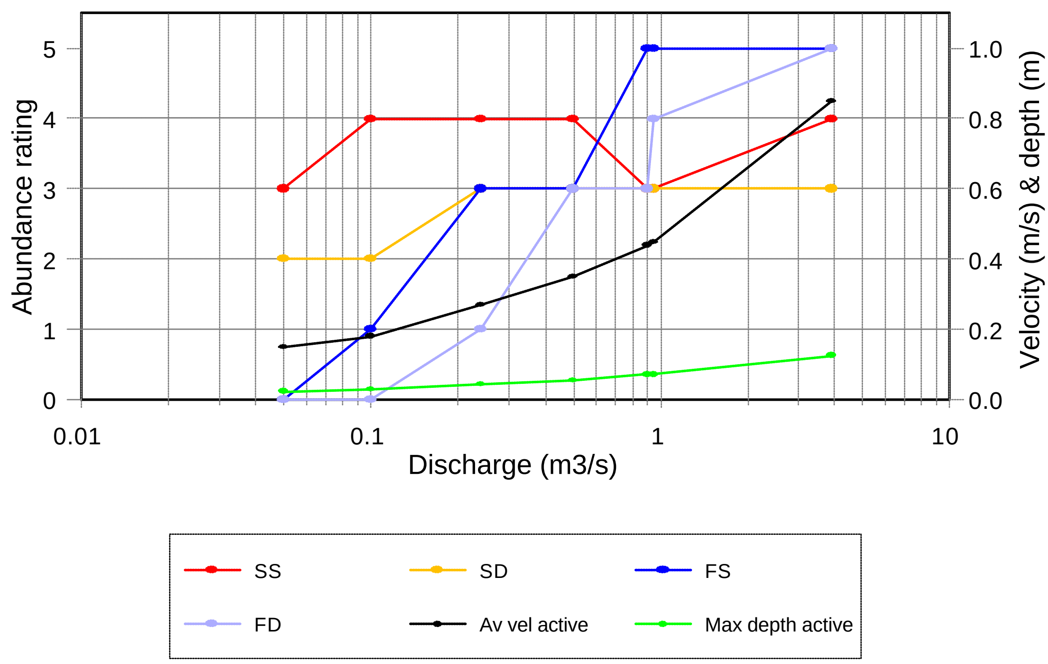



**Figure B:3 Site 3: Habitat-Type Abundance Ratings For Fish As A Function For Discharge.**

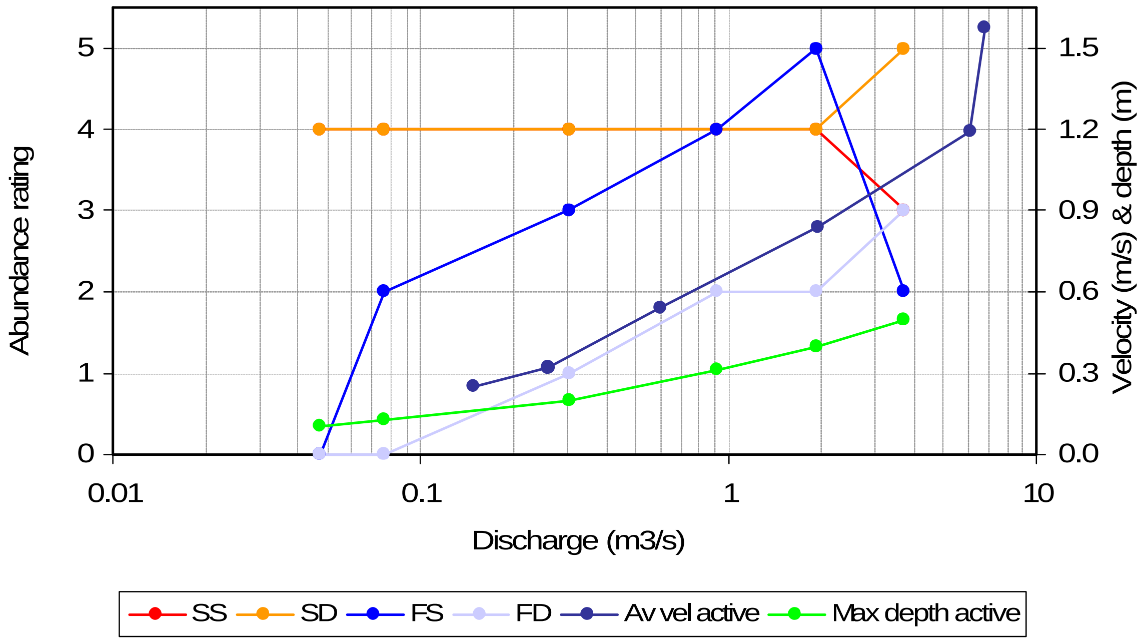



**Figure B:4 Site 4: Habitat-Type Abundance Ratings For Fish As A Function For Discharge.**

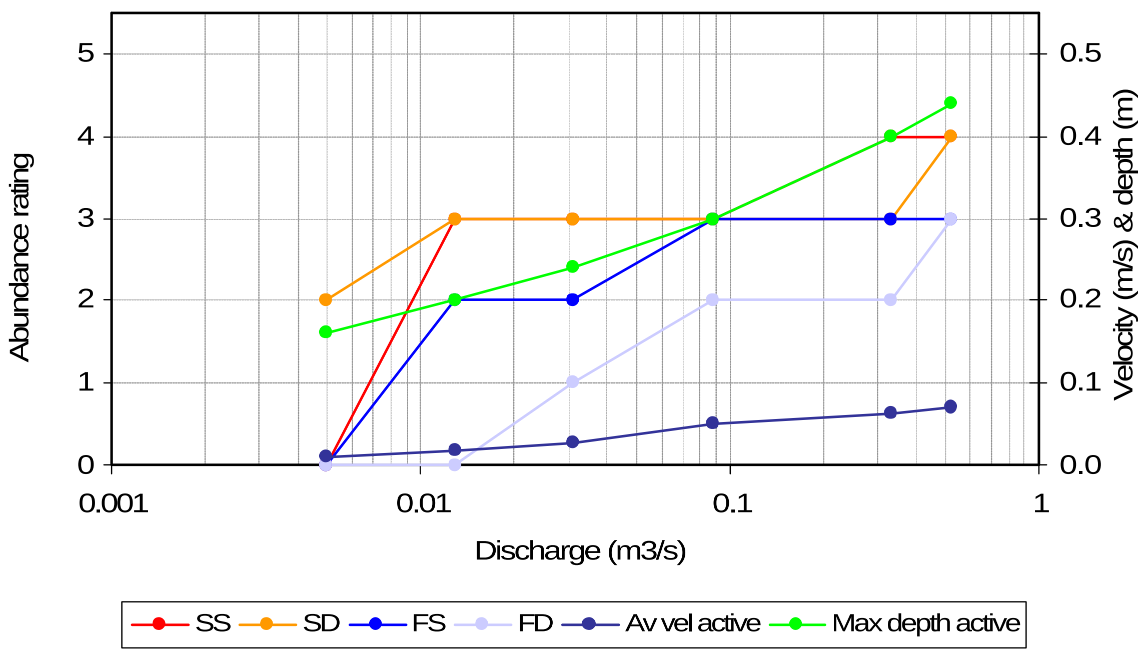



**Figure B: 5 Site 5: Habitat-Type Abundance Ratings For Fish As A Function For Discharge.**

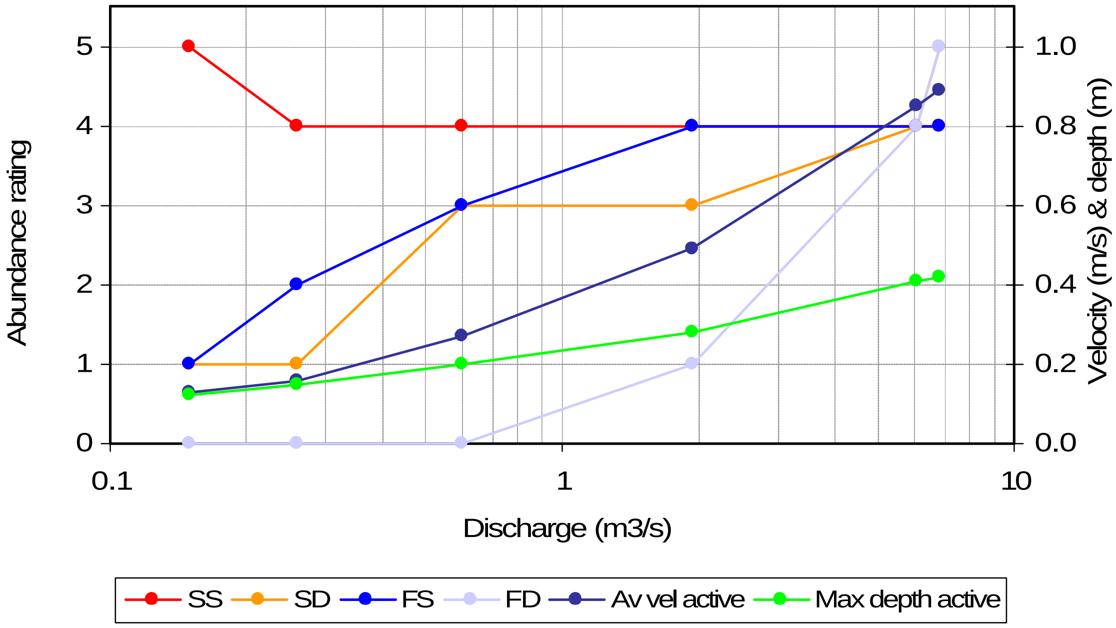



**Figure B:6** **Site 6: Habitat-Type Abundance Ratings For Fish As A Function For Discharge.**

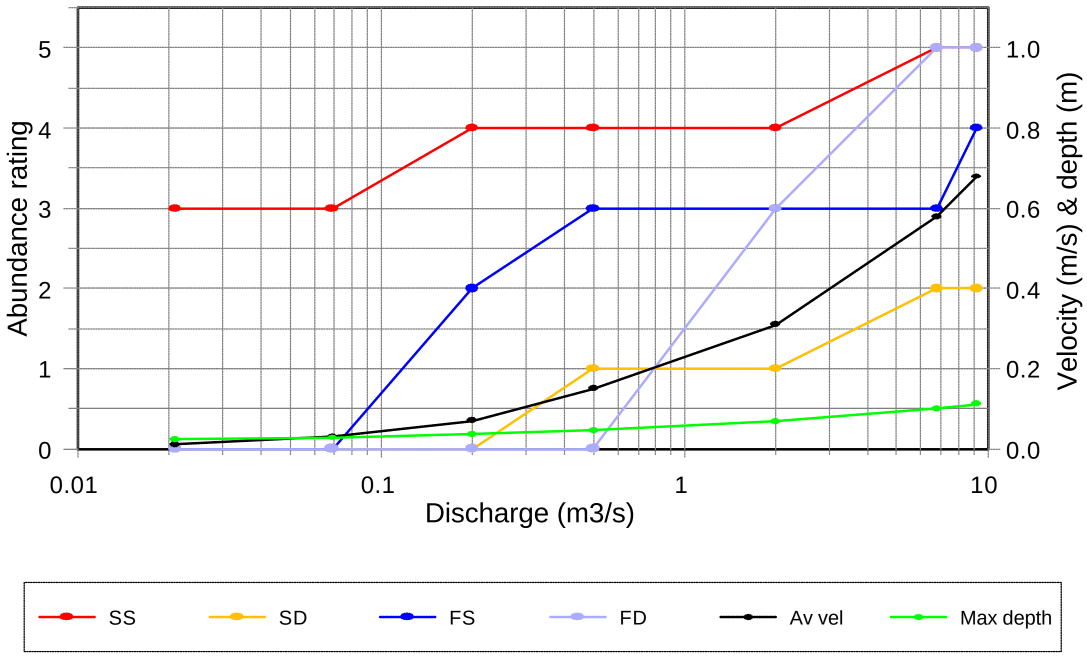
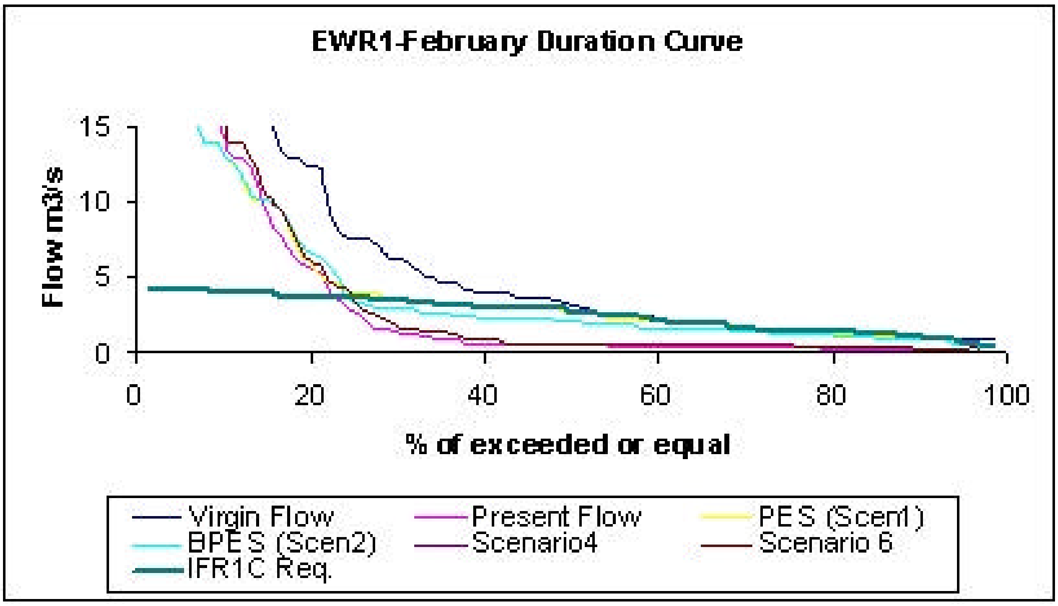
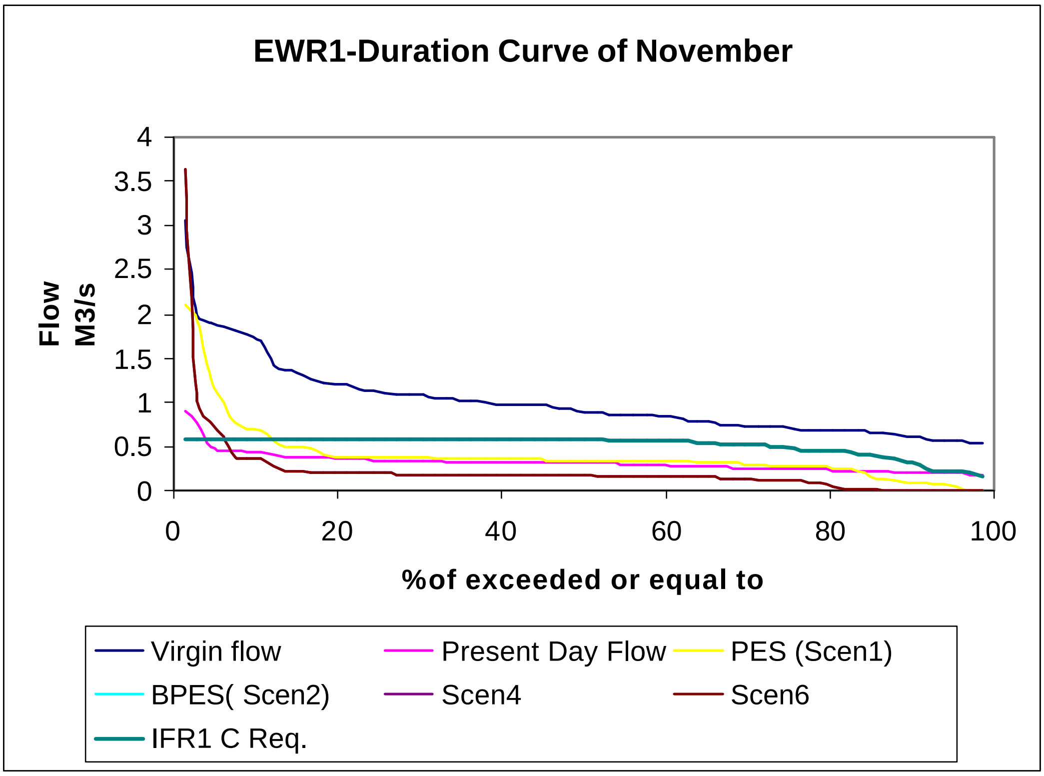



**Figure B:7** **Site 7: Habitat-Type Abundance Ratings For Fish As A Function For Discharge.**

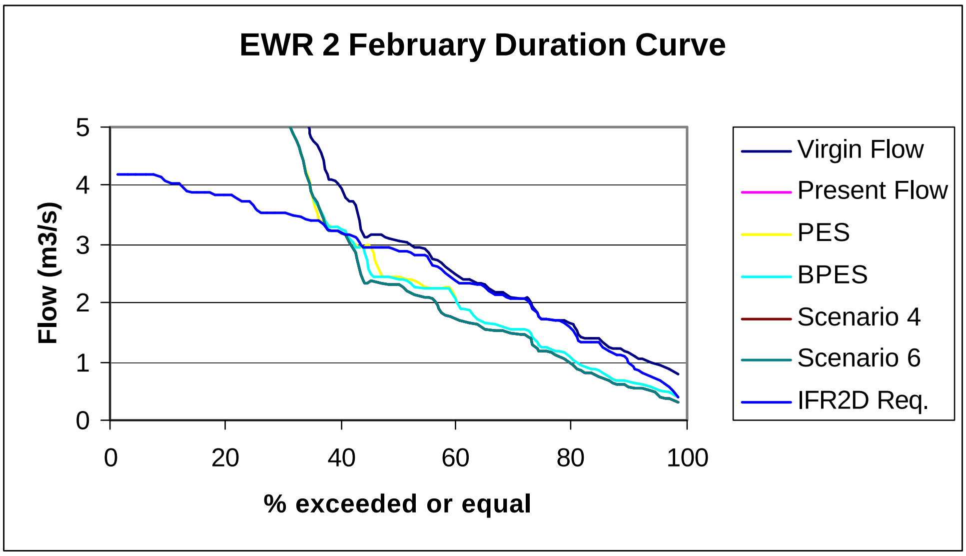
# Appendix C: Flow duration curves

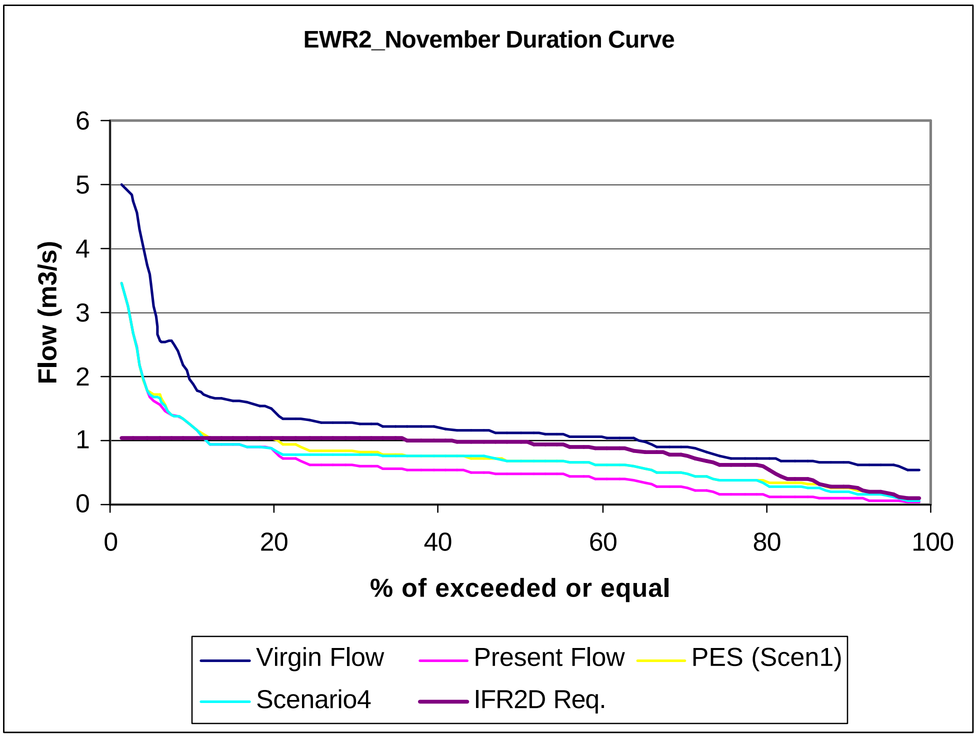
## EWR 1


EWR1-February Duration Curve
Flow m3/s
15
10
5
0
0
20
40
60
80
100
% of exceeded or equal
Virgin Flow
Present Flow
PES (Scen1)
BPES (Scen2)
Scenario4
Scenario 6
IFR1C Req.

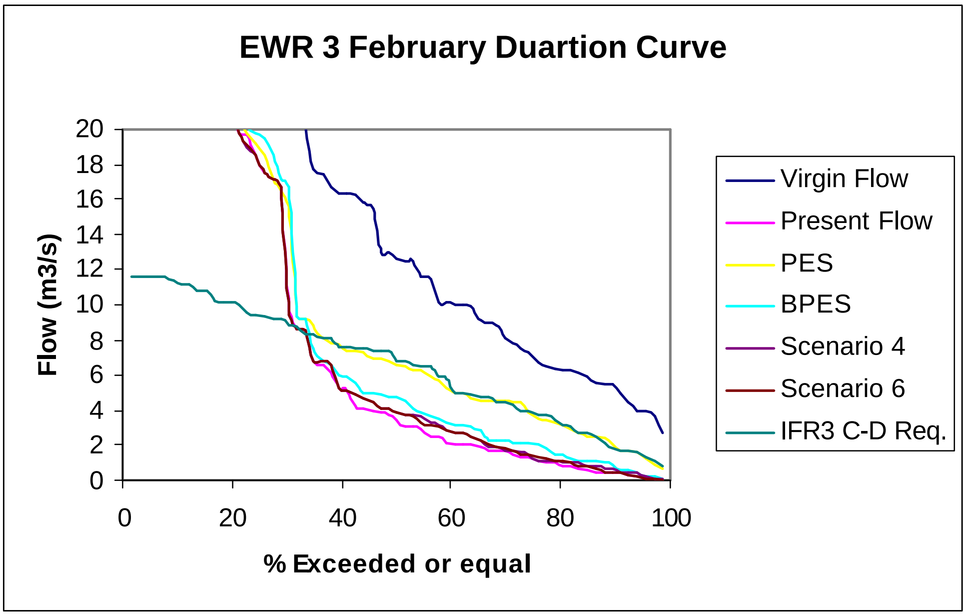

EWR1-Duration Curve of November
Flow M3/s
4
3.5
3
2.5
2
1.5
1
0.5
0
0
20
40
60
80
100
%of exceeded or equal to
Virgin flow
Present Day Flow
PES (Scen1)
BPES( Scen2)
Scen4
Scen6
IFR1 C Req.

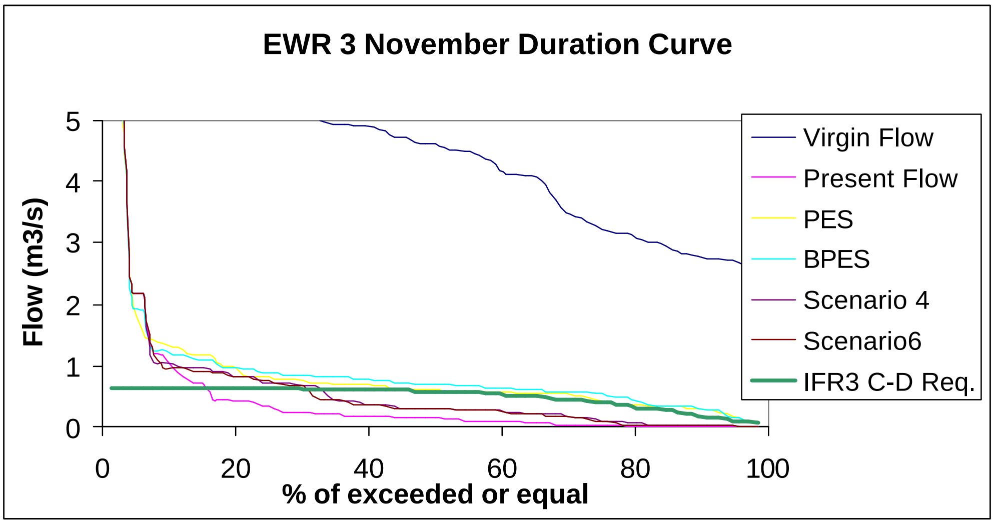
# EWR 2:


EWR 2 February Duration Curve
Flow (m3/s)
0
1
2
3
4
5
0
20
40
60
80
100
% exceeded or equal
Virgin Flow
Present Flow
PES
BPES
Scenario 4
Scenario 6
IFR2D Req.

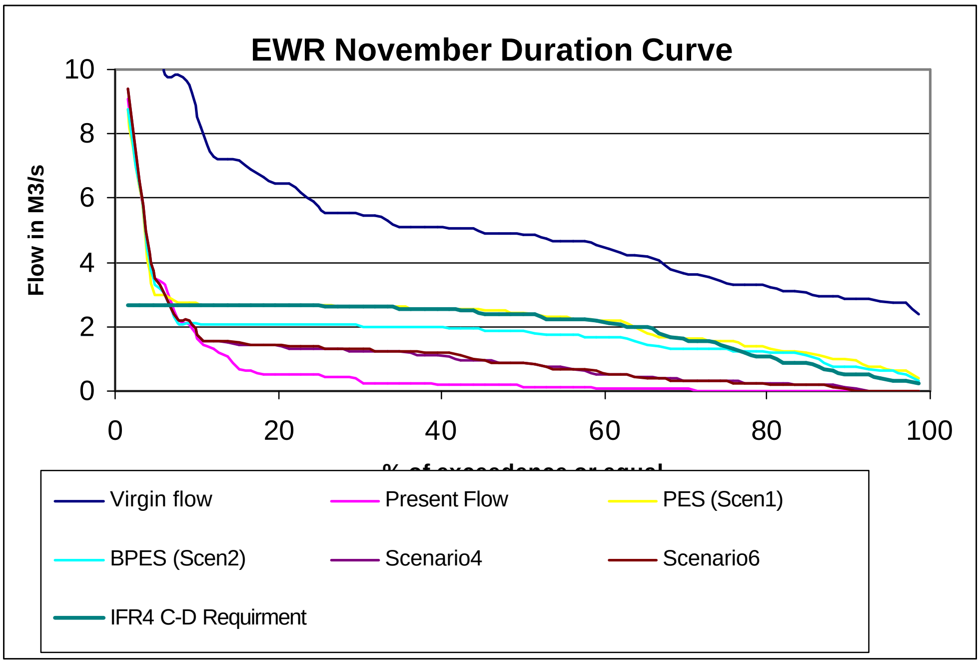

EWR2_November Duration Curve
Flow (m3/s)
0
1
2
3
4
5
6
0
20
40
60
80
100
% of exceeded or equal
Virgin Flow
Present Flow
PES (Scen1)
Scenario4
IFR2D Req.

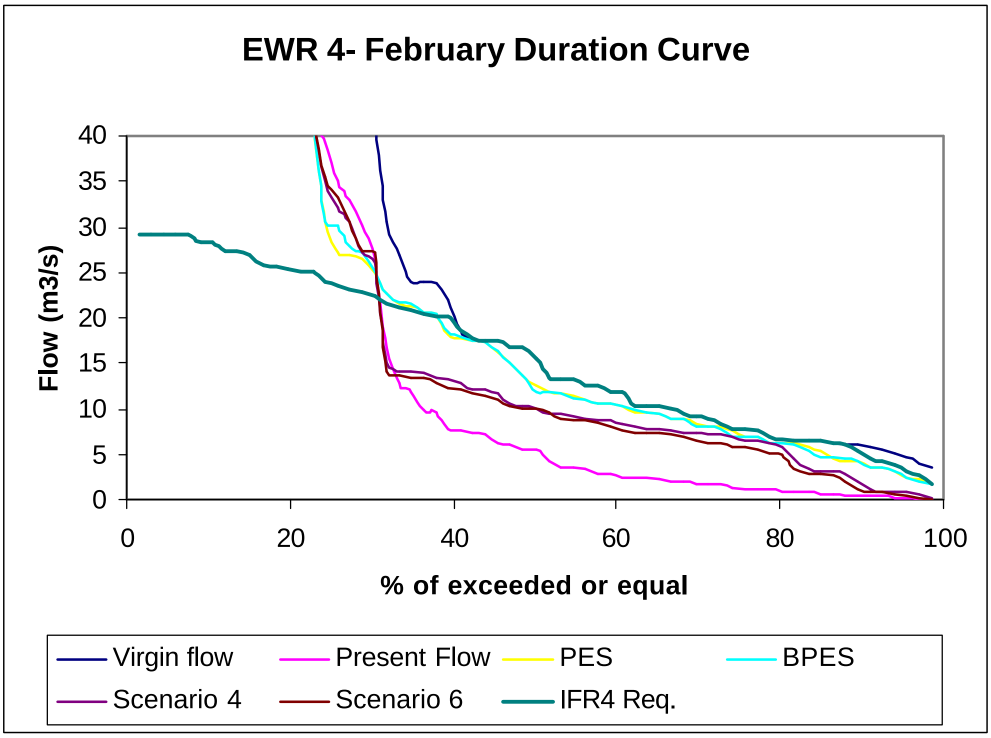
# EWR 3


EWR 3 February Duartion Curve
Flow (m3/s)
20
18
16
14
12
10
8
6
4
2
0
0
20
40
60
80
100
% Exceeded or equal
Virgin Flow
Present Flow
PES
BPES
Scenario 4
Scenario 6
IFR3 C-D Req.

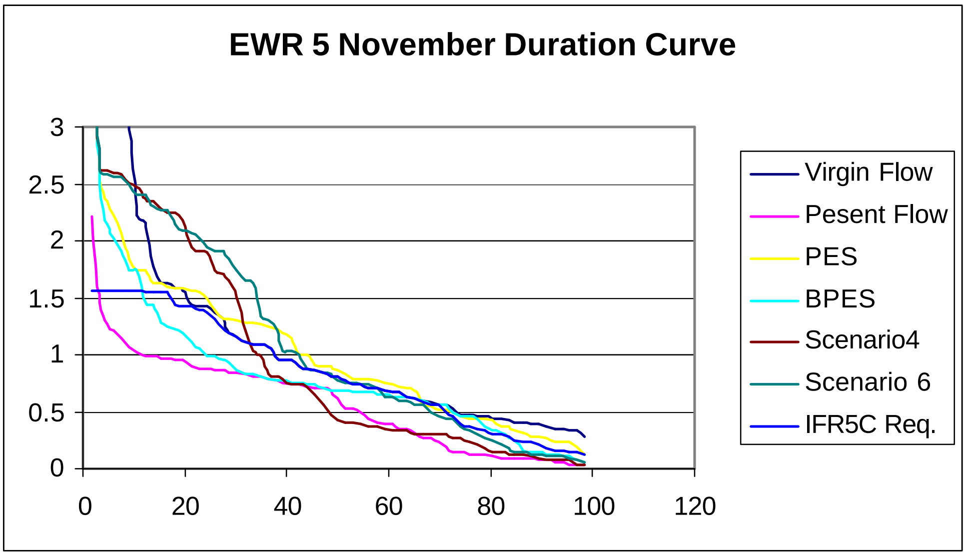

EWR 3 November Duration Curve
Flow (m3/s)
5
4
3
2
1
0
0
20
40
60
80
100
% of exceeded or equal
Virgin Flow
Present Flow
PES
BPES
Scenario 4
Scenario6
IFR3 C-D Req.

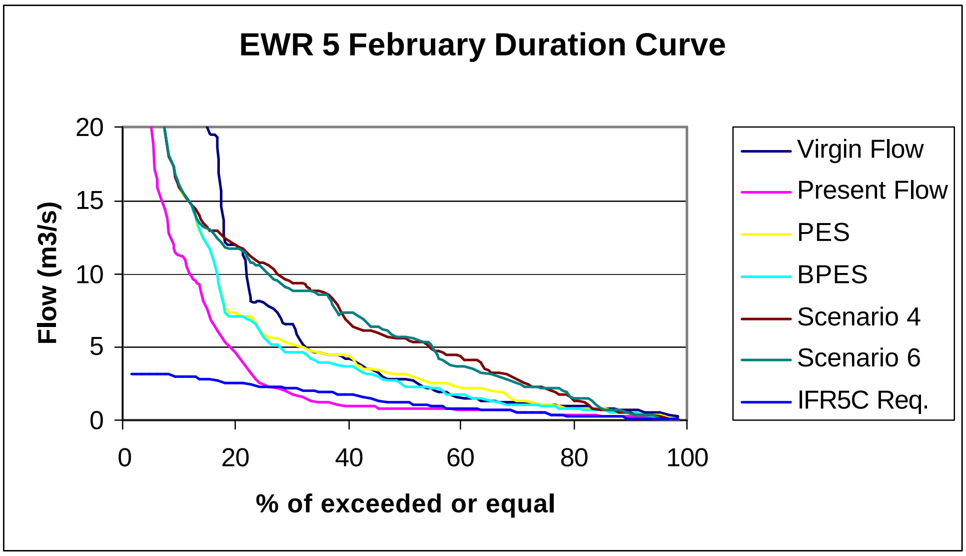
# EWR 4


EWR November Duration Curve
Flow in M3/s
10
8
6
4
2
0
0
20
40
60
80
100
% of exceedence or equal
Virgin flow
Present Flow
PES (Scen1)
BPES (Scen2)
Scenario4
Scenario6
IFR4 C-D Requirment

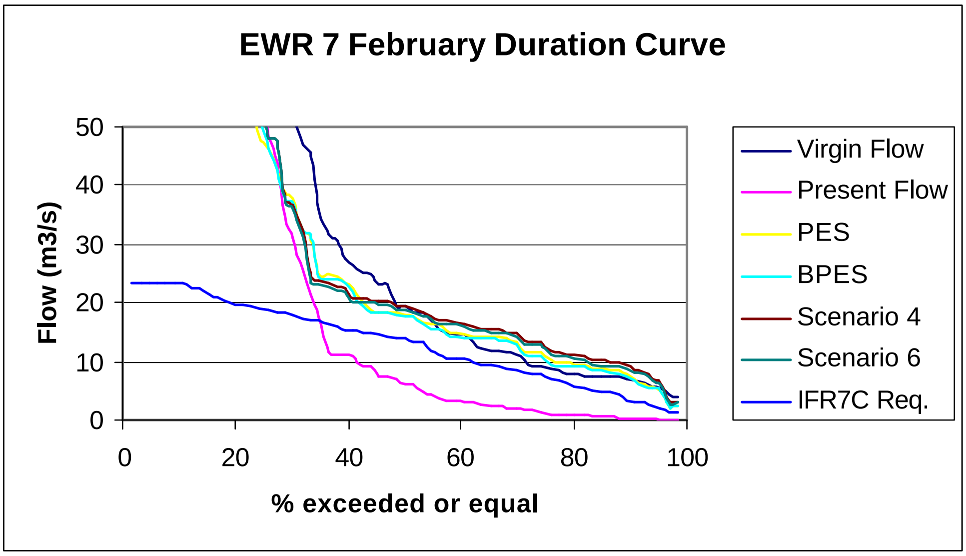

EWR 4- February Duration Curve
Flow (m3/s)
40
35
30
25
20
15
10
5
0
0
20
40
60
80
100
% of exceeded or equal
Virgin flow
Present Flow
PES
BPES
Scenario 4
Scenario 6
IFR4 Req.

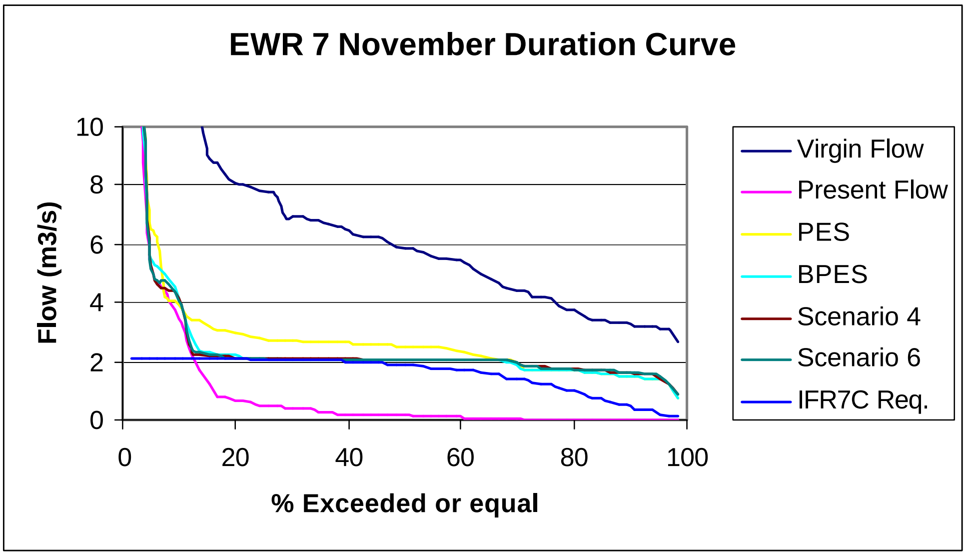
# EWR 5


EWR 5 November Duration Curve
3
2.5
2
1.5
1
0.5
0
0
20
40
60
80
100
120
Virgin Flow
Pesent Flow
PES
BPES
Scenario4
Scenario 6
IFR5C Req.


EWR 5 February Duration Curve
Flow (m3/s)
20
15
10
5
0
0
20
40
60
80
100
% of exceeded or equal
Virgin Flow
Present Flow
PES
BPES
Scenario 4
Scenario 6
IFR5C Req.

# EWR 7


EWR 7 February Duration Curve
Flow (m3/s)
50
40
30
20
10
0
0
20
40
60
80
100
% exceeded or equal
Virgin Flow
Present Flow
PES
BPES
Scenario 4
Scenario 6
IFR7C Req.


EWR 7 November Duration Curve
Flow (m3/s)
10
8
6
4
2
0
0
20
40
60
80
100
% Exceeded or equal
Virgin Flow
Present Flow
PES
BPES
Scenario 4
Scenario 6
IFR7C Req.

# Appendix D

## Driver tables final per scenario (included as an Appendix in Ecological data DWAF Report No. RDM/RB800/00/CON/COMP/1604)

- **Geomorphology**
- **Water quality**
- **Hydrology**
- **MARAI**
- **FRAI**