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Review of Environmental Water Requirements &

Related Information for the Olifants Catchment

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Acronyms

AEC	Alternate Ecological Category
BBM	Building Block Method
CD:RDM	Chief Directorate: Resource Directed Measures
DRIFT	Downstream Response to Imposed Flow Transformation
DSS	Decision support system
EC	Ecological Category
EF	Environmental Flow
EIS	Environmental Importance and Sensitivity
EWR	Ecological Water Requirements
HFSR	Habitat Flow-Stressor Response
MCM	Million cubic metres
HPP	Hydropower Project
MAR	Mean Annual Runoff
MCM	Million Cubic Metres
N/A	Not applicable or Not available
NWA	National Water Act (South African)
PD	Present Day
PES	Present Ecological State
RDM	Resource Directed Measures
REC	Recommended Ecological Category
RESILIM	Resilience in the Limpopo
RESILIM-O	Resilience in the Limpopo – Olifants
RQO	Resource Quality Objectives
S&EWR	Social and Environmental Water Requirements.
WATRES	Water Resources Ecosystem Services
WRCS	Water Resource Classification System

1 Introduction

1.1 The RESILIM-O project

The RESILIM-O project is part of a larger RESILIM project addressing resilience in the Limpopo region. RESILIM-O focusses on the Olifants Basin (see Section 4).

The objectives of RESILIM-O are to (USAID 2013):

- Reduce climate vulnerability by promoting science-based adaptation strategies;
- Enhance water security and integrated water resources management;
- Conserve biodiversity and improve management of high priority ecosystems;
- Develop stakeholder capacities to manage water and ecosystem resources;
- Ensure continuous, reflective and collaborative learning;
- Facilitate exchanges across the Basin and with other Basins

The main themes of the RESILIM-O project are listed in Table 1.1. Information on each of these the themes will be provided by a series of workpackages, each of which will contribute to one or more theme.

TABLE 1.1 RESILIM-O THEMES

Theme 1	Theme 2	Theme 3	Theme 4
Integrated systems and resilience analysis and ensuring pathways to impacts within the Olifants Basin	Support for trans-boundary integrated water resources management (IWRM) for the Olifants Basin	Biodiversity conservation in critical areas of the basin	Learning, capacity development and communication

This report forms part of the deliverables on the Social and Environmental Water Requirements (S&EWR) workpackage (Section 1.2).

1.2 The RELIMI-O, S&EWR workpackage

The RESILIM-O, S&EWR workpackage will contribution to Theme 1: Integrated systems and resilience analysis by describing, modeling and quantifying the links between changes in flow in the river and changes in ecosystem condition and ecosystem services and benefits. However, its main contribution is to Theme 2: Trans-boundary IWRM.

Accordingly, it addresses Objective 2: enhancing water security and integrated water resources management.

1.2.1 RELIMI-O, S&EWR activities

RESILIM-O, S&EWR aims to use existing determinations of Environmental Water Requirements (EWR) and aquatic ecosystem services, plus relevant information from the livelihoods, ecosystem-services and risks assessments to populate and calibrate a DRIFT (Downstream Response to Imposed Flow Transformations) Decision Support System (DSS). The DSS will then be used to predict the likely impacts associated with flow scenarios on the riverine ecosystem, and on people who depend on it for services, livelihoods and other benefits.

The RESILIM-O, S&EWR workpackage comprises three main activities, *viz*:

- Activity 1: Synthesize and review current determinations for Environmental Water Requirements (EWRs) and water resources ecosystem services under different scenarios.
- Activity 2: Contribute to a systemic understanding of the Olifants Basin, practices related to water resource protection and to the resilience analysis for the Olifants Basin.
- Activity 3: Use DRIFT-DSS at the year 1 site(s) to assess scenarios. The scenarios may be related to water resources' Management Classes and other scenarios (such as climate change) as required by the project. Scenarios will be assessed in terms of ecosystem services and well-being as identified by stakeholders in collaboration with the Ecosystem Services and Social Benefits workpackages, and will compare results with those of the Classification study.

The DRIFT-DSS that is populated and used to assess scenarios in Activity 3 will provide the implications of those scenarios for the ecosystems and the people and social structures that are dependent on them. However, the source of the information used to calibrate the two portions of the DSS (biophysical and social) will be supplied through different avenues:

- The hydrological information (daily time-series for the baseline and scenarios) will be provided by the Hydrological team;
- Biophysical information will be supplied by the RESILIM-O, S&EWR team using existing information (see Section 1.2.2) as far as possible;
- The ecosystem services and social benefits information will be supplied by the respective teams, with interactions with the RESILIM-O, S&EWR team, to ensure that the various processes can supply information in the format required for DRIFT.

1.2.2 RESILIM-O, S&EWR approach and data requirements

RESILIM-O, S&EWR: Activity 3 (Section 1.2.1) necessitates the population and calibration of a DRIFT-DSS for a single focus site in the Olifants Basin using, where possible, information generated by previous EWR and EWR-related studies.

Table 1.2 summarises the main steps in the population and calibration of the DRIFT-DSS and the type of information needed to inform each step. The extent to which the information available from previous EWR and EWR-related studies will be useful in populating and calibrating the DSS will be evaluated in the subsequent sections using the information in Table 1.2 as a guide.

TABLE 1.2 STEPS IN THE POPULATION AND CALIBRATION OF THE DRIFT-DSS AND THE TYPE OF INFORMATION NEEDED TO INFORM EACH STEP

	STEP	EXPLANATION	INFORMATION/DATA NEEDED FROM EXISTING STUDIES
1	Site selection	Select a focus site	Evaluation of the type and quality of data needed for Steps 2 – 5 available for sites in the basin (see Section 7).
2	Indicator selection	In the DRIFT-DSS a network of indicators is used to describe the river ecosystem and its human users. Indicators: - are items that can describe changes in the riverine ecosystem as a result of flow change. - must be objects (e.g. sand bars; small-mouth yellowfish, groups of fish) that are directly or through other indicators affected by flow and can be described through changes in their abundance, concentrations (for e.g. water quality), extent/area (for e.g. riffles), or value. - selection is informed by the physical and chemical nature of the river ecosystem, the biota present, and the use made of/value placed on these by people. Typically a DRIFT assessment will use between 50 and 200 indicators across the disciplines of geomorphology, water quality, riparian vegetation, invertebrates, fish, other biota of interest, and ecosystem services / social aspects.	Distributional/community data for vegetation, fish, invertebrates. Life history data for vegetation, fish, invertebrates. Research and monitoring data linking the physical and chemical nature of the river ecosystem, and the biota present, to the flow regime. Human use of or dependency on river resources. Valued/rare river resources/species. Criteria for resource use, such as E. coli concentrations in drinking water.
3	Population of response curves	Response curves form the heart of the DRIFT-DSS, and must be compiled for every indicator selected in Step 2. Each response curve depicts the relationship between a driving indicator and a responding indicator. In RESILIM-O, S&EWR, biophysical response curves will be compiled based on any available relevant knowledge: existing data, national and international literature, global understanding and local knowledge. Ecosystem services response curves will be complied based on input from RESILIM-O teams responsible for that workpackage. Response curves may be extrapolated from and to similar sites.	Thresholds for resource use, such as water quality criteria of drinking water. Motivations of seasonal depths and velocities for maintaining habitat biota. Delineation of lateral zones in riparian vegetation. Lowflow 'stress tables' for indicators used in HFSR[1] studies. Delineation, showing similarly between sites in terms of hydrology, water quality, habitat and biota.
5	Calibration of outputs and response curves	In RESILIM-O, S&EWR, the primary calibration target will be to ensure that the outputs (EWRs and Ecological Categories) of the DRIFT-DSS match those of existing Reserve studies.	EWR volumes linked to ecosystems condition (i.e. Ecological Categories) as a percentage of natural annual and/or monthly volume Estimates of extent of change in indicators linked to percentage of natural annual and/or monthly volume
		Cross check inconsistences in DRIFT-DSS output versus existing studies	Hydrological time-series data used in existing study(ies)

[1] *See Section 2.6.2 for descriptions of the different methods*

1.3 Purpose of this report

This is the RESILIM-O, S&EWR Activity 1 Report. Its purpose is to collate relevant information from Reserve determinations (e.g., DWAF 2001a, b and c), ecosystem services and valuation (e.g., DWAF 2001d, DWA 2010a) and Classification (e.g. DWA 2012) studies undertaken in the Olifants Basin since 2000, and to identify studies and data that will be used to inform later activities in RESILIM-O, S&EWR. Particular consideration is given to biophysical data that will be useful in populating and calibrating the response curves to ensure that the resultant DRIFT predictions of annual volume linked to ecosystem condition are in alignment with those used in the Reserves and Classification process.

The summary of relevant information includes:

- Study rivers
- Location of EWR sites and key habitats
- Assessment methods used
- The length of record and time-step of the hydrological data used
- Present Ecological States (PES)
- Biophysical indicators used, and their relationship to flow
- Ecosystem services identified / social indicators used
- Recommended and alternative ecological condition (REC and AEC respectively)
- EWRs for maintaining different REC and AEC
- Any additional detail pertaining to values for indicators
- Valuation methods applied, and values derived for ecosystem services.

The remaining sections of this report are as follows:

- Section 2, which explains key concepts and terms and provides a description of DWA levels of Reserve assessment and EWR methods used in South Africa.
- Section 3, which describes DRIFT.
- Section 4, which gives an overview of the study area in the context of EWRs.
- Section 5, which lists the applicable studies undertaken in the basin, identifies information of relevance to this study that was generated by them, and summarises the results (with details in Appendix A to Appendix C). It also describes how information from these studies can be used to assist with the population and calibration of the DRIFT-DSS (Table 1.2).
- Section 6, which outlines the proposed procedure for capturing this information in DRIFT, and maximising compatibility between the outcomes for previous studies and the DRIFT assessments.
- Section 7, provides a short-list of possible EWR sites for Activity 3 based on the type and quality of the information available at each.

1.4 General comments

The process of summarising the results of previous studies highlighted several challenges.
Chief among these are:

- Access to full and final documentation. Most of the reports for DWA-funded studies are not available on the DWA website and signed off copies of the Reserves cannot be accessed. This means that even if the relevant reports are obtained, there is uncertainty whether they are the final versions.
- The reports contain errors, such as summary tables that provide highflow maintenance flows that are labelled lowflow, which means that each table must be double checked and/or advice sought on what constitutes the correct information. This is made more difficult by the fact that reports within a study do not contain the same information for different areas. For instance, the Comprehensive Reserve Determination reports for the Middle and Lower Olifants provide the Desktop Model outputs for each site, but the report for Upper Olifants does not. This means that EWR tables within the Upper Olifants report cannot be checked for errors against the Desktop Model output.
- Results/recommendations for the same site vary between documents, without clear explanations for the reasons for the differences.
- The "Status of Aquatic Ecosystems Olifants" report (DWAF and DFID 2007), which looks at all EWRs and the Preliminary Reserves, mentions discrepancies between recommended and signed-off Reserves – only some of these appeared to be actual discrepancies.
- The use of the term 'Present Ecological Status' (PES) in the various Reserve and Classification related documentation can create confusion, as the 'PES' reported in, for example, 2001 is no longer the 'PES' in 2014, and differs from the PES assessed in 2009. Indeed often the 'PES' is out of date before the report is released.
- It is difficult to access the raw data (such as hydrological time-series or stress-tables where HFSR was used). DWA do not house these data, and the only option is to approach the consultant responsible for the collecting/collating the data. Even then, the data are often no longer available – and in some cases the consultant is question has passed away.
- The motivations for particular components of the flow regime are often not helpful. For instance, in DWAF (2001c), IFR Site 13, the motivation of "Mobilise sediments and prevent excessive sediment deposition" is provided for discharges of 6, 8, 18, 30 and 50 m3/s.

The challenges are not confined to Reserve and related reports. Summary statistics from other fields, such as water-resources and hydrology also vary widely. For instance, values for the 'water deficit' in the Olifants Basin are provided in several sources, but seldom agree, due to differences in data, assumptions, dates of the studies (and consequent changes in supply and demand). These differences make it difficult to interpret the information. Similarly, several lists of functioning and defunct gauges exist, but these do not agree with one another. In this regard, the list from *http://www.dwaf.gov.za/iwqs/wms/data/000key.asp* was used for this report.

2 Key processes, methods and concepts

2.1 Environmental Water Requirements

Environmental Water Requirements (EWRs)[2] describe the quantity, timing and quality of water flows required to sustain freshwater and estuarine ecosystems at a given level of health (*sensu* Hirji and Davis 2009).

In South Africa, once a future level of health has been chosen for a river or river reach, the associated EWR becomes the Ecological Reserve (see Section 2.2.4) for that river or river reach (DWAF 1998).

2.2 Water resource protection in South Africa

Activities to protect and manage water resources, as envisaged in the National Water Act of South Africa (NWA; DWAF 1998), are divided into:

- Resource-Directed Measures (RDM), which focus on the protection and management of the water resources of the country. These include processes such as Classification and Reserve determination, and;
- Source-Directed Controls", which focus on the management and control of water users and include processes such as issuing of water-use and waste-water licenses.

RDM activities are the responsibility of the Department of Waters Affairs' Chief Directorate: Resource Directed Measures (CD:RDM).

2.2.1 Classification

In accordance with the NWA (DWAF 1998), a Water Resource Classification System (WRCS) was developed in 2007 (DWAF 2007), and the summary steps published in Government Gazette (Government Gazette, 17 September 2010 No. R. 810 and No. 33S41).

The WRCS is a set of technical guidelines and procedures for determining the different classes of water resources, and their associated ecological condition. The WRCS was designed for use in a consultative process (Classification Process) to classify water resources across the country. The outcome of the Classification Process will be a Management Class, Resource Quality Objectives (RQOs; Section 2.2.3) and the Reserve (Section 2.2.4) for every significant water resource (river, estuary, wetland and aquifer). Together, these will determine the level of protection afforded freshwater ecosystems, and the amount of water available for off-stream use.

[2] *Synonymous terms include Instream Flow Requirements (IFRs), Environmental Flows (EFs), and EFlows.*

The WRCS comprises the following seven steps:

- **Step 1:** Delineate the units of analysis and describe the status quo of the water resources or water resources;
- **Step 2:** Link the socio-economic and ecological value and condition of the water resource or water resources
- **Step 3:** Quantify the ecological water requirements and changes in non-water quality[3] ecosystem goods, services and attributes;
- **Step 4:** Determine an ecologically sustainable base configuration scenario;
- **Step 5:** Evaluate scenarios within the integrated water resource management process;
- **Step 6:** Evaluate the scenarios with stakeholders; and
- **Step 7:** Gazette and implement the class configuration.

2.2.2 Management Class

Management Classes are set different parts (sub-basins) or a river basin depending on the level of use that will be made of the water resources in each sub-basin in the future (Table 2.1). The Management Class is defined by a set of quantity and quality attributes that DWA and society agree on for the water resources in sub-basin.

TABLE 2.1 REQUIREMENTS FOR ECOLOGICAL CONDITION FOR THE THREE MANAGEMENT CLASSES (DOLLAR *ET AL*. 2006)

MANAGEMENT CLASS	DESCRIPTION	CONFIGURATION GUIDELINES
Class 1: Minimally used	The configuration of water resources within an IUA results in an overall water resource condition that is minimally altered from its pre-development condition.	At least 60% of the freshwater ecosystems in a sub-basin are A or B category.
Class 2: Moderately used	The configuration of water resources within an IUA results in an overall water resource condition that is moderately altered from its pre-development condition.	At least 40% of the freshwater ecosystems in a sub-basin are A or B category.
Class 3: Heavily used	The configuration of water resources within an IUA results in an overall water resource condition that is significantly altered from its pre-development condition.	No requirement for A or B cat

[3] *The wording of this section is misleading: water quality is dealt with in Step 3 (e.g. Step 3c may consider water-quality characteristics for which a change in 'fitness for use' for a particular activity might arise under different scenarios).*

2.2.3 Resource Quality Objectives

The NWA (DWA 1998) defines 'resource quality' as the 'quality' of all aspects of a water resource including:

- The quantity, pattern, timing, water level and assurance of instream flow;
- The water quality including the physical, chemical, and biological characteristics of the water;
- The character and condition of the instream and riparian habitat; and
- The characteristics, condition and distribution of the aquatic biota.

It also states that the purpose of RQOs is to 'establish clear goals relating to the quality of the relevant water resources' and stipulates that in determining RQOs a balance must be sought between the need to protect and sustain water resources and the need to use them. The Act also binds authorities and institutions to uphold the RQOs that have been set.

RQOs are intended to provide targets that can be measured/audited. These encompass the objectives for both resource protection and users requirements, for instance, the water quality for a processing plant. RQOs for the freshwater ecosystems typically comprise a descriptor, which forms the RQO, and a description of the threshold beyond which change would constitute a deviation from the agreed objective for that descriptor, the so called Threshold of Potential Concern (TPCs).

The Reserve requirements, which form part of the RQOs, are usually in the form of exceedance curves, although monthly lowflow requirements are also often provided for monitoring.

2.2.4 The Reserve

The Reserve is defined as the "quantity and quality of water required to satisfy basic human needs … and to protect aquatic ecosystems in order to secure ecologically sustainable development and use of the relevant water resource" (DWAF 1998). These are referred to as the Basic Human Needs (BHN) Reserve and the Ecological Reserve, respectively. The NWA (DWAF 1998) further specifies that:

- A Reserve must "be in accordance with the class of the water resource as determined …" during Classification (Section 2.2.1 and "…ensure that adequate allowance is made for each component of the Reserve", and
- "Until …. a class of a water resource has been determined, the Minister …. must, before authorising the use of water under section 22(5), make a preliminary determination of the Reserve."

Preliminary Reserves will be superseded by any Reserve agreed on as a result of Classification.

2.3 Water resource protection in Mozambique[4]

In Mozambique, water resources protection is dealt with in the National Water Policy (PNA, 1995, amended in 2007 and becoming the PA), the 1990 Constitution and Water Law (16/91) and through the SADC Protocol on Shared Watercourses. There is an advisory National Water Council and five regional water administrations (ARA-Sul, ARA-Centro, ARA-Norte, ARA-Zambezi, and ARA-Centro Norte). ARA-Sul (Regional Administration of Waters in the South), falls under the Ministério das Obras Públicas e Habitação and Direção Nacional de Águas (DNA) and is responsible for the Olifants-Limpopo river. Priority of use is given to human water supply, sanitation and common uses, followed by water for environmental sustainability. Conflicts may be resolved through socio-economic cost-benefit analyses performed by the ARAs (Barros 2009, quoted on Limpopo River Awareness Kit website).

2.4 Present Ecological Status

Present Ecological Status (PES) describes the ecological condition, at the time of the assessment, of the aquatic ecosystem (river, wetland or estuary) in terms of its ability to support and maintain a balanced, integrated composition of physico-chemical, habitat and biotic characteristics on a temporal and spatial scale relative to the natural characteristics of ecosystems of the region. The PES assessments are used to place the ecosystem in an Ecological Category as indicated in Table 2.2.

TABLE 2.2 DEFINITIONS OF THE PRESENT ECOLOGICAL STATUS (PES) AND ECOLOGICAL CATEGORIES (AFTER KLEYNHANS 1996).

ECOLOGICAL CATEGORY	PES % SCORE	DESCRIPTION OF THE HABITAT
A	90-100%	Still in a Reference Condition.
B	80-90%	Slightly modified from the Reference Condition. A small change in natural habitats and biota has taken place but the ecosystem functions are essentially unchanged.
C	60-80%	Moderately modified from the Reference Condition. Loss and change of natural habitat and biota has occurred, but the basic ecosystem functions are still predominantly unchanged.
D	40-60%	Largely modified from the Reference Condition. A large loss of natural habitat, biota and basic ecosystem functions has occurred.
E	20-40%	Seriously modified from the Reference Condition. The loss of natural habitat, biota and basic ecosystem functions is extensive.
F	0-20%	Critically / Extremely modified from the Reference Condition. The system has been critically modified with an almost complete loss of natural habitat and biota. In the worst instances, basic ecosystem functions have been destroyed and the changes are irreversible.

[4] *Corrections and additions to this section will be made once information is available from the relevant workpackes on the RESILIM-O project.*

2.5 Indicators

Indicators are the basic building blocks of monitoring and evaluation systems (Global Water Partnership 2010). In IWRM work, indicators are part of a hierarchy of terms used, to assess progress toward some goal (GWP 2010). From the highest to lowest level these terms are:

Goals: Broad qualitative statements about what is to be achieved or what problem is to be solved.
Objectives: The means identified to achieve the goals.
Actions: The specific activities identified to accomplish the objectives.
Targets: Defined and measurable levels at which it can be deduced that goals and objectives have been achieved.
Indicators: Measures selected to assess progress.

Thus, in the context of the Reserve, indicators are used to represent ecosystem attributes that are likely to respond to changes in flow and for which predictions of change are made, linked to each EWR. Once Classification has been undertaken, the indicators are translated into RQOs.

2.6 EWR methods used in South Africa

The development of methods for EWR assessments in South Africa is comprehensively reviewed in King and Pienaar (2011).

2.6.1 Assessment levels

Methods vary in terms of their level of detail (Box2.1)

Box 2.1
DWA levels of Reserve determination

Desktop:	No fieldwork. Monthly hydrological data.
Rapid-1:	Limited field work (c. 1 hour per site) to do a PES assessment. Uses monthly hydrological data. No specialist input. Uses the Desktop Model (see 2.6.2) based on PES.
Rapid-2:	Limited field work (c. 2 hours per site) to do a PES assessment, a discharge measurement and basic biological sampling. Specialist input for fish and invertebrates. No hydraulics. Desktop Model verified and adjusted using biotic information.
Rapid-3:	Limited field work (c. 6 hours per site) to do a PES assessment, basic hydraulics and biological sampling. Specialist input for hydraulics, fish and invertebrates. Desktop Model verified and adjusted using hydraulics and biotic information.
Intermediate:	One full field visit to collect biophysical data. Full hydraulics and biological sampling. Uses daily hydrological data. Considers socio-economic impacts.
Comprehensive:	Sampling over one year. Two full field visits to collect biophysical data. Full hydraulics and biological sampling. Uses daily hydrological data. Considers socio-economic impacts.

2.6.2 EWR assessment methods for rivers

In South Africa, EWR assessment methods must be ratified by the Department of Water Affairs (DWA) before they can be used for EWR determinations. The methods currently ratified for use for rivers are:

- The Desktop Model (Hughes and Hannart 2003);
- The Building Block Methodology (BBM; King et al. 2000);
- The Habitat Flow Stressor Response (HFSR) method (Hughes and Louw 2010); and
- DRIFT(1) (Brown *et al*. 2008) and DRIFT(2) (Brown *et al*. 2013)[5].

The level of assessment affects the EWR methods used. In general, the Desktop Model is used in Desktop and Rapid Reserve determinations, and BBM, HFSR and DRIFT are used in Intermediate and Comprehensive assessments. The BBM is an old method and has been replaced by HFSR and DRIFT. DRIFT has not been applied in the Olifants Basin, but is included here, as it is intended for use in RESILIM-O, S&EWR.

A comparative summary of the methods is given in Table 2.3.

HFSR and DRIFT differ in the way ecological information is used to evaluate the implications of different flows for the riverine ecosystem: DRIFT developing response curves, and HFSR developing stress duration curves. It is unclear whether the results of the two methods are comparable in terms of their predicted impacts associated with flow change because there are no studies where they have been applied simultaneously. However, broad level evaluations suggest that they produce comparable outputs (Brown 2013).

TABLE 2.3 COMPARATIVE SUMMARY EWR METHODOLOGIES USED FOR THE RIVERS.

Considerations	Desktop and Rapid level	Intermediate and Comprehensive level			
	Desktop	**BBM**	**HFSR**	**DRIFT(1)**	**DRIFT(2)**
Software	Desktop Model within SPATSIM	None	Habitat Flow Stressor Response model within SPATSIM[6]	VBA and Excel databases	Delphi coded software with links to GoogleMaps
Hydrology	Monthly data in WR90 format	Daily data	Daily data	Daily data	As for DRIFT(1)
Lowflows	Pro-rata distribution of MAR in accordance with results of detailed EWR assessments at similar sites	Motivations for flows to meet requirements of biophysical indicators	Stress indices set for fish and macroinvertebrates	Response curves linking biophysical indicators to flow indicator change	As for DRIFT(1), but links to changes in flow or any other indicator
Highflows	Monthly volumes for maintenance and drought	Motivations for number and timing of floods to meet requirements of biophysical indicators	Predictions of change in indicators linked to occurrence of floods of different magnitude		

[5] *DRIFT(1) has evolved substantially to the DRIFT(2) version proposed for use in RESILIM-O, EWRS, which has been applied elsewhere in Africa, South America and Asia, but not as yet in South Africa.*
[6] *Spatial and Time Series Modelling (Hughes and Forsythe 2006).*

Considerations	Desktop and Rapid level	Intermediate and Comprehensive level			
	Desktop	BBM	HFSR	DRIFT(1)	DRIFT(2)
Output	Ecological categories	Recommended flow of an EC	Ecological categories	Ecological categories, predicted changes in abundance of indicators	As for DRIFT(1) + time-series of changes + summaries of Integrity
	Annual volume of EWR	Annual volume of EWR	Annual volume of EWRs	Annual volume of EWRs	The same as DRIFT(1)
	Monthly lowflows for maintenance and drought	Monthly lowflows for maintenance and drought	Monthly lowflows for maintenance and drought	Monthly lowflows for maintenance and drought	
	Monthly volume for intra-annual floods	Timing, duration, peak and volume of intra-annual floods	Timing, duration, peak and volume of intra-annual floods	Timing, duration, peak and volume for intra-annual and inter-annual floods	
Can evaluate flow scenarios?	Limited	No (prescriptive)	Yes	Yes	Yes

In both HFSR and DRIFT, relationships are developed between different aspects of the riverine ecosystem and flow. HFSR links ecological stress with flow duration curves, while DRIFT links abundance, area, concentration or other measure with flow indicators (such as wet season peak flow, or dry season duration) as well as to any other indicator. Both can thus be used to assess the impact of alternative flow scenarios on ecological condition at each site (Brown 2013).

The Desktop Model cannot be used for assessing scenarios directly, but once calibrated, can provide summary flow regimes to meet a range of ecological conditions. These can, in turn, be checked against scenario flow regimes to see which comes closest. The Desktop Model also has the “IFR Edit” module that allows it to be calibrated using data from comprehensive or intermediate environmental flow assessments at similar sites in the basin. This makes the Desktop Model invaluable for extrapolating environmental flow data from one part of the river system to another (Brown 2013).

There are several key differences between the methods that have been applied in the basin (BBM and HFSR) and DRIFT. A crucial issue is the extent to which the information generated by these studies can be used to inform a DRIFT assessment for the purposes envisaged in RESILIM-O, S&EWR.

3 DRIFT

DRIFT (King *et al*. 2003) is a holistic, interactive EWR assessment method, which provides the biophysical consequences for rivers of changing their flow regimes. It is a published method (King *et al*. 2003), with a detailed User Manual (Brown *et al*., 2008 and 2013), and as such is has been extensively peer reviewed.

DRIFT has been widely applied: Angola and Botswana (King and Brown 2007), Lesotho (King *et al*. 2003), Mozambique (Beilfuss and Brown 2010; Southern Waters 2011a), Namibia (Southern Waters 2010), Peru (Norconsult and Southern Waters 2011), South Africa (e.g. Brown *et al*., 2006), Pakistan/Kashmir (Southern Waters 2013; Southern Waters 2014), Sudan (Southern Waters 2009), Tanzania (PBWO/IUCN 2008) and Zimbabwe (Brown 2007).

DRIFT is based on response curves (Section 3.1.3) constructed from all relevant knowledge, including expert opinion and local wisdom, and as such is suitable for use in regions where there are few biophysical data available on the flow-related aspects of the rivers. It aims to provide an objective and transparent assessment of the effects of changes in flow on the downstream environment and the people who depend on it.

DRIFT is a data-management tool, allowing data and knowledge to be used to their best advantage in a structured way. Within DRIFT, each specialist uses discipline-specific methods to derive the links between river flow and river condition. The central rationale of DRIFT is that different aspects of the flow regime of a river elicit different responses from the riverine ecosystem. Thus, removal of part or all of a particular element of the flow regime will affect the riverine ecosystem differently than will removal of some other element.

In DRIFT, the long-term daily-flow time-series is partitioned into parts of the flow regime that are thought to play different roles in sculpting and maintaining the river ecosystem, such as the onset of flow seasons, which may affect breeding cycles, or the magnitude of the annual flood, which may inundate a floodplain. This makes it easier for ecologists to predict how changes in the flow regime could affect the ecosystem. The ‘parts’ of the flow regime used in DRIFT are called flow indicators.

These generally include:

- Seasonal/daily variations
- Mean annual runoff
- Dry season onset
- Dry season minimum 5-day discharge
- Dry season duration
- Dry season average daily volume
- Wet season onset
- Wet season minimum 5-day discharge
- Wet season duration
- Wet season flood volume
- Transition 1 average daily volume
- Transition 2 average daily volume
- Transition 2 recession shape

The variability of the flow regime in timing and magnitude, both in its natural state and in any future scenario, is captured automatically through instructions within the hydrological module of the DSS that identify the flow indicators year-by-year and translate the daily (or sub-daily) flow regimes to a time-series of flow indicators.

The result is an annual time-series of seasonal flow indicators. This means the response of the river ecosystem is assessed for a particular time-step (season) rather than an averaged response over several years. This provides far greater scope for using monitoring and other data from a particular year or season to calibrate the time-series responses.

3.1 Summary of the DRIFT Process

The basic sequence of activities in the DRIFT DSS can be summarised as follows:

1. Collect/collate data for the study at a site(s) along the river.

2. Augment with expert knowledge for similar river systems and a global understanding of river functioning.

3. Obtain a daily time-series to reflect current or baseline conditions, which are translated to flow indicators.

4. Construct relationships (response curves; Section 3.1.3) for the expected response of individual ecosystem/social indicators (Section 3.1.1) to changes in linked indicators (Section 3.1.2)). Response curves are constructed using severity ratings which are directly translated as percentage changes in abundance, concentration, value or other relevant measure.

5. The response curves allow the response to the time-series of flow indicators to be sequentially calculated to produce a time-series of abundance (or other relevant measure) for each indicator.

6. Adjust the severity ratings to integrity ratings by assigning a negative sign for a move away from the natural ecosystem condition and a positive for a move towards natural.

7. Model future changes in basin hydrology, and calculate the annual flow indicator time-series (i.e. repeat step 3 for each scenario).

8. Using the flow indicators and response curves a time-series of change in abundance (or other measure) is calculated for each indicator.

9. Convert the resulting time-series to Integrity Scores to predict overall ecological condition.

In RESLIM-O, however, rather than starting from scratch, Steps 1 and 2 will use the information generated by the previous EWR studies in the Olifants Basin.

3.1.1 Indicators

The indicators are biophysical and or social aspects of the riverine ecosystem that are expected to change with a change in flow. They comprise both flow indicators and other indicators. Indicators are objects (e.g. sand bars; fish) rather than processes (e.g. nutrient cycling), and are described through changes in their abundance, concentrations (for e.g. water quality), extent/area (for e.g. riffles), or value (e.g. income from fishing). Some examples of indicators are provided in Table 3.1. In total 50-70 or more indicators could be used.

TABLE 3.1 EXAMPLES OF INDICATORS USED IN THE OKAVANGO STUDY TO PREDICT THE BIOPHYSICAL AND SOCIAL IMPACTS OF DEVELOPMENT-DRIVEN FLOW CHANGES (KING AND BROWN 2009)

DISCIPLINE	EXAMPLE INDICATOR
Geomorphology	Sand bars
Water quality	Conductivity
Vegetation - river	Upper Wet Bank (trees and shrubs)
Vegetation - delta	Lower Floodplain
Macroinvertebrates	Channel – submerged vegetation habitat
Fish	Large fish that migrate onto floodplains
Birds	Specialists using floodplain pools and water lilies (jacanas)
Wildlife	Outer floodplain grazers
Social - economic	Household income from reeds
Social - lifestyle	Wellbeing from intangible river attributes

3.1.2 Linked indicators

The traditional approach to EWR assessments is based on using links between individual indicators and individual flow categories. DRIFT, however, uses an ecosystem approach, with links between individual indicators and a range of influencing flow categories and other so-called linked indicators. These links and relationships provide a more transparent, and easily monitored breakdown of the expected response of the river ecosystem.

For instance, instead of having to integrate the effects of habitat change, temperature and cover into a single response to change in dry season low flows (Figure 3.1), the linked-indicator approach allows a specialist to consider habitat change, temperature and cover individually.

3.1.3 Response curves[7]

Response curves (Figure 3.2) depict the relationship between a biophysical or socio-economic indicator and a linked indicator (e.g., flow, food supply). In RESILIM-O, S&EWR, response curves will be constructed between an indicator and all the linked indicators deemed to be driving change. The aim is not to include every conceivable, but rather to restrict the linkages to those that are most meaningful and can be used to predict the bulk of the likely responses to a change in the flow or sediment regimes of the river. In modelling or mathematical terms, the linked indicators should be ‘necessary and sufficient’.

[7] *The bulk of this section is taken from Joubert et al., 2009.*

Response curves are constructed using severity ratings (Section 3.1.4).

Response curves are used to evaluate scenarios by taking the value of the linked (driver) indicator for any one scenario and reading off the resultant value for the response indicators from their respective response curves. Once this had been done the database combines these values to predict the overall change in each indicator (and in the overall ecosystem) under each scenario.

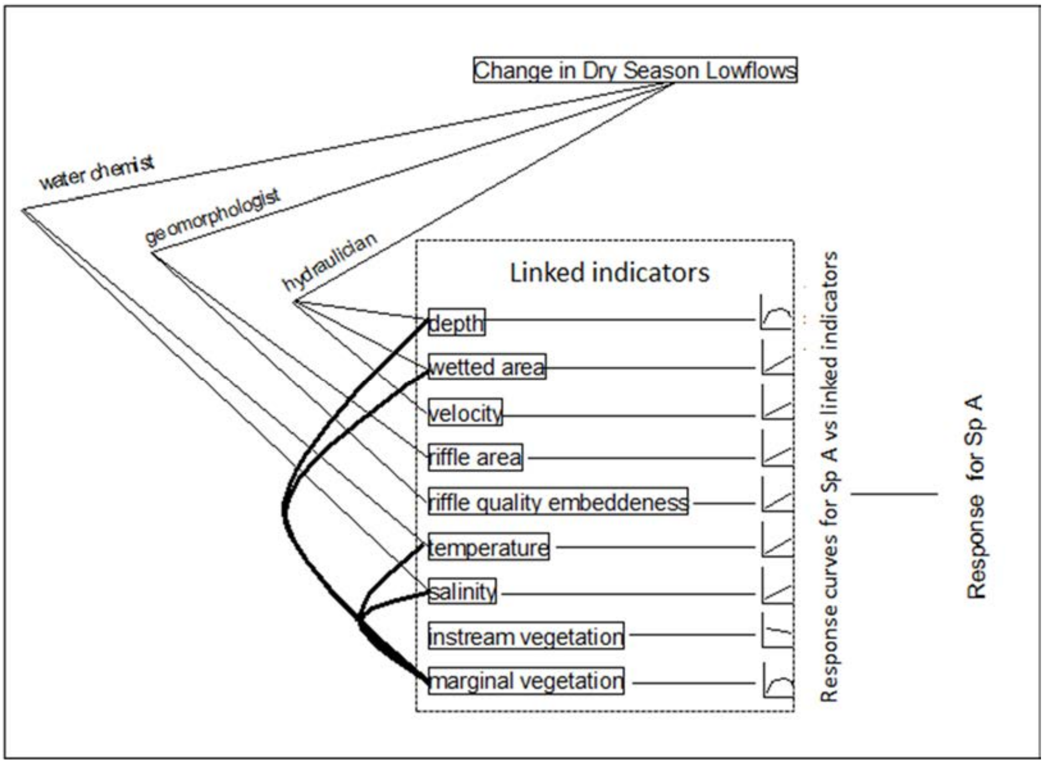


Figure 3.1 Schematic giving hypothetical example of linked indicators for Fish Sp A. Responses curves are required for each linked indicators. These are combined to derive the response for Fish Sp A for a change in dry-season low-flows.

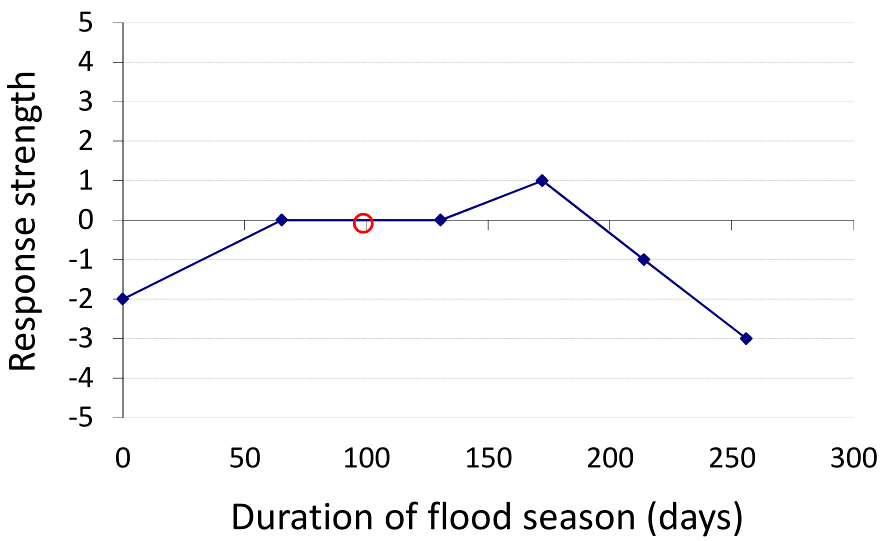


Figure3.2 Example of a response curve – in this case of the relationship between duration of the flood season and the abundance of fish that are resident in the river. The circle indicates median baseline (current) duration of the flood season and the line describes how fish abundance would increase or decrease in years with longer or shorter flood seasons relative to the baseline. Fish abundances - response strength – is relative to baseline, with baseline abundance shown as zero change from baseline, or 100% of baseline (King et al. 2014).

3.1.4 Scoring system used

Into the foreseeable future, predictions of river change will be based on limited knowledge. Most river scientists, are reasonably comfortable predicting the nature and direction of ecosystem change, but find it more difficult to predict its timing and intensity. To calculate the implications of loss of resources to subsistence and other users in order to facilitate discussion and trade-offs, it is nevertheless necessary to quantify these predictions as accurately as possible.

Three types of information are elicited for each biophysical indicator, *viz*.:

- Severity ratings, which describe increase/decreases for an indicator in response to changes in the flow indicators,
- Abundance (or other relevant measure such as concentration, area, value) of each indicator in response to change in flow, and;
- Integrity ratings, which indicate whether the predicted change is a move towards or away from natural, i.e., how the change influences overall ecosystem condition.

The severity ratings are used to construct the response curves. The Integrity ratings are used to describe overall ecosystem condition/health.

3.1.4.1 Severity ratings

The severity ratings comprise 11-point scale of -5 (large reduction) to +5 (very large change; Brown et al., 2008; Table 3.2), where the + or – denotes an increase or decrease in abundance or extent. These ratings are converted to percentages using the relationships provided in Table 3.2. The scale accommodates uncertainty, as each rating encompasses a range of percentages; however, greater uncertainty can also be expressed through providing a range of severity ratings for any one predicted change (after King et al., 2003). For example, a severity score of -1 indicates that a range from 80-100% of baseline abundance is retained, but a range of severity scores from -1 to -2 could be used, indicating that 60-100% of baseline abundance is retained.

TABLE 3.2 DRIFT SEVERITY RATINGS AND THEIR ASSOCIATED ABUNDANCES AND LOSSES – A NEGATIVE SCORE MEANS A LOSS IN ABUNDANCE RELATIVE TO BASELINE, A POSITIVE MEANS A GAIN.

SEVERITY RATING	SEVERITY	% ABUNDANCE CHANGE
5	Critically severe	501% gain to ∞ up to pest proportions
4	Severe	251-500% gain
3	Moderate	68-250% gain
2	Low	26-67% gain
1	Negligible	1-25% gain
0	None	no change
-1	Negligible	80-100% retained
-2	Low	60-79% retained
-3	Moderate	40-59% retained
-4	Severe	20-39% retained
-5	Critically severe	0-19% retained includes local extinction

Note that the percentages applied to severity ratings associated with gains in abundance are strongly non-linear and that negative and positive percentage changes are not symmetrical (Figure 3.3; King et al. 2003).

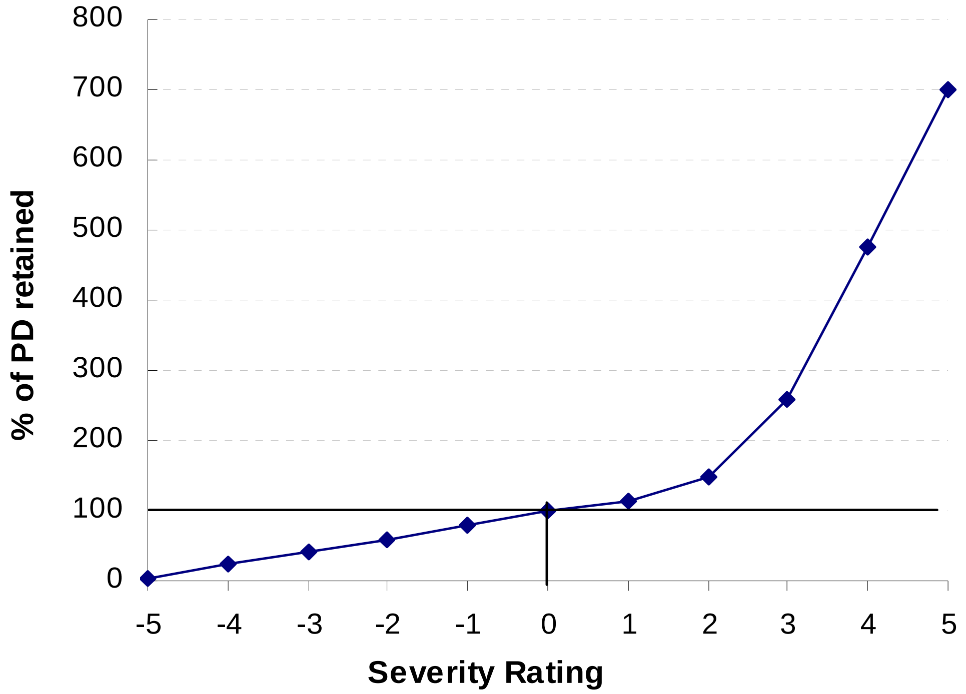


Figure 3.3 The relationship between severity ratings (and severity scores) and percentage of baseline as used in DRIFT and adopted for the DSS. (PD=present day or baseline, and = 100%).

For each year of hydrological record, and for each indicator, the severity rating corresponding to the value of a flow indicator is read off its Response Curve. The severity ratings for each flow indicator are then combined to produce a severity score, which provides an indication of how abundance, area or concentration of an indicator is expected to change under the given flow conditions in each year, relative to the changes that would have been expected under baseline conditions in the basin.

3.1.4.2 Integrity ratings

Integrity ratings use the absolute value of between 0 and 5 provided for the severity scores but include a negative or positive sign, depending on whether the change in abundance predicted by the severity score represents a shift to/away from naturalness, *viz*. (Brown and Joubert 2003):

- Toward natural ecosystem condition is represented by a positive integrity rating; and
- Away *from natural* ecosystem condition is represented by a negative integrity rating.

The integrity ratings are calculated using the average abundance (concentration, area, value) for each ecosystem indicator over the entire response time-series. The integrity ratings for each indicator are then combined to provide an Overall Integrity Score, which is used to place the river ecosystem results for a particular flow scenario within a classification of overall river condition, using the South African eco-classification categories A to F (Table 3.3; Kleynhans 1996; Kleynhans 1999; Brown and Joubert 2003).

The ecological condition of a river is defined as its ability to support and maintain a balanced, integrated composition of physico-chemical and habitat characteristics, as well as biotic components on a temporal and spatial scale that are comparable to the natural characteristics of ecosystems of the region.
For instance, if the present ecological status (PES) of a river is a B-category, a scenario that yields a negative Integrity Score would represent movement in the direction of a category C-F, whilst one with a positive score would indicate movement toward a category A, as follows:

TABLE 3.3 DEFINITIONS OF THE PRESENT ECOLOGICAL STATE (PES) CATEGORIES (AFTER KLEYNHANS 1996).

ECOLOGICAL CATEGORY	DESCRIPTION OF THE HABITAT
A	Unmodified. Still in a natural condition.
B	Slightly modified. A small change in natural habitats and biota has taken place but the ecosystem functions are essentially unchanged.
C	Moderately modified. Loss and change of natural habitat and biota has occurred, but the basic ecosystem functions are still predominantly unchanged.
D	Largely modified. A large loss of natural habitat, biota and basic ecosystem functions has occurred.
E	Seriously modified. The loss of natural habitat, biota and basic ecosystem functions is extensive.
F	Critically / Extremely modified. The system has been critically modified with an almost complete loss of natural habitat and biota. In the worst instances, basic ecosystem functions have been destroyed and the changes are irreversible.

If the Overall Integrity Score is positive, this denotes a move toward natural, i.e. restoration initiatives:

- ≤1 or ≥-1, the ecological condition will remain within the same category as present day/baseline;
- >1 and ≤2, the ecological condition will move one category closer to natural;
- >2 and ≤3, the ecological condition will move two categories closer to natural;
- Etc.

If the Overall Integrity Score is negative, this denotes a move away from natural:

- ≥-1, the ecological condition will remain within the same category as present day;
- <1 and ≥ 2, the ecological condition will move one category further away from natural;
- <2 and ≥ 3, the ecological condition will move two categories further away from natural;
- Etc.

Overall Integrity Scores are calculated for the ecosystem as a whole, i.e., the combined effect of changes in the indicators. The results can be plotted as Overall Integrity Score (y-axis) vs. percentage or volume of MAR (x-axis) or, where there are relatively few points as in this project, simply as a plot of Overall Integrity Scores per site, which allows for easy comparison between sites.

The categories represent points along a continuum, thus the 'divisions' between the categories are only guides as to the general position at which the ecological condition might be expected to shift from one category to the next. They provide an indication of the relative categories associated with each scenario and should not be viewed as an absolute prediction of future condition.

3.2 The DRIFT-DSS

The DRIFT-DSS is programmed using Delphi XE and uses a NexusDB v3 database. The software is designed for use in all computers running Windows XP and upwards, and the DSS supports both single-user and multi-user modes. The DSS makes use of Google Earth (standard version) in the delineation module: if the images from this module are used in reports, a Google Earth Pro licence is required.

The DRIFT-DSS is divided into three sections, each dealing with a different stage in the EWR determination process. These are (Brown *et al*. 2013; Figure 3.4).

1. Set-up
2. Knowledge Capture
3. Analysis.

The first two sections deal with the population of the DSS and the calibration of the relationships that will be used to predict the ecosystem response to changes in flows. The third section is used to generate results once the first two sections have been populated, and to produce the reports and graphics detailing the predictions for the scenarios under consideration.

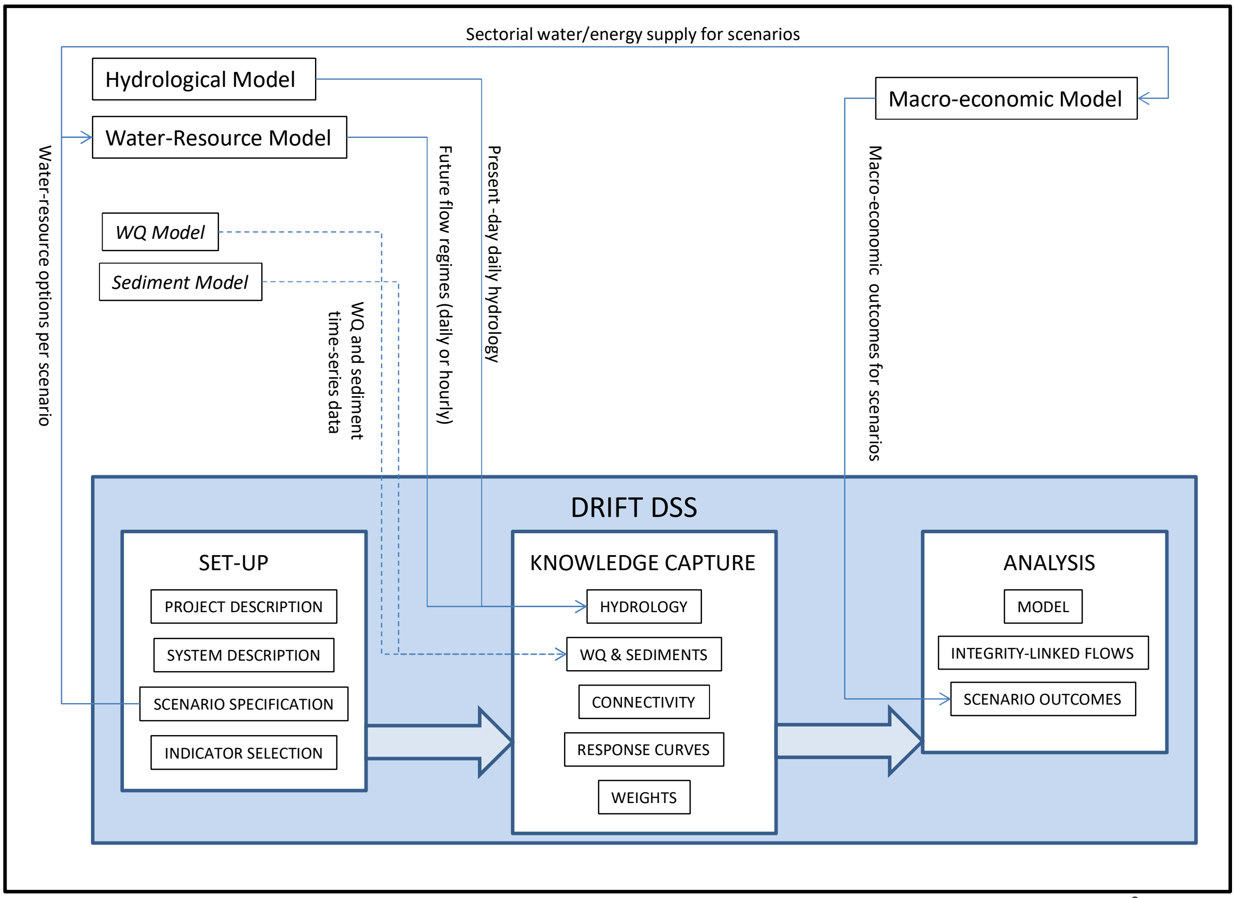


Figure 3.4 Arrangement of modules in the DRIFT-DSS and inputs required from external models[8].

[8] *Note: outputs of macro-economic modules can currently not be imported into the DSS, but this will be included in later versions.*

All hydrological modelling is done outside of the DSS. The DSS is dependent on the outputs of a hydrological model to provide baseline basin hydrology and a water resource model used to predict the changes in the flow regime associated with the proposed water-resource developments under the various scenarios.

Additional detail on the DSS, including a User Manual, is available in Brown *et al*. (2013).

4 Overview of the study area

The study area for RESILIM-O is the Olifants Basin in South Africa and Mozambique (Figure 4.1).

The Olifants River rises in the west in the highly-developed and densely-populated province of Gauteng. It flows through the South African provinces of Limpopo and Mpumalanga, then through the Kruger National Park before it enters the Gaza province of Mozambique, and becomes the Rio das Elephantes. The river reaches the sea near Xai-Xai on the east coast of Mozambique about 300 km north of Maputo. The main tributaries, from west to east, are Bronkhorstspruit (Gauteng Province), Elands River (Mpumalanga Province), Steelpoort River (Mpumalanga Province), Blyde River (Limpopo Province), Letaba River (Kruger National Park), Singuedzi /Shingwidzi River (Gaza) and, finally, the Limpopo (Gaza). The Olifants- Elefantes River, until the confluence with the Limpopo, is *c*. 955 km long (*c*. 831 km in South Africa), with the final Limpopo reach to the sea being c. 303 km long (source: DWA 1:500 000 rivers coverage). Within South Africa the Olifants basin covers about 54 570 km^2 (RHP, 2001) with a runoff of approximately 2400 MCM / a.

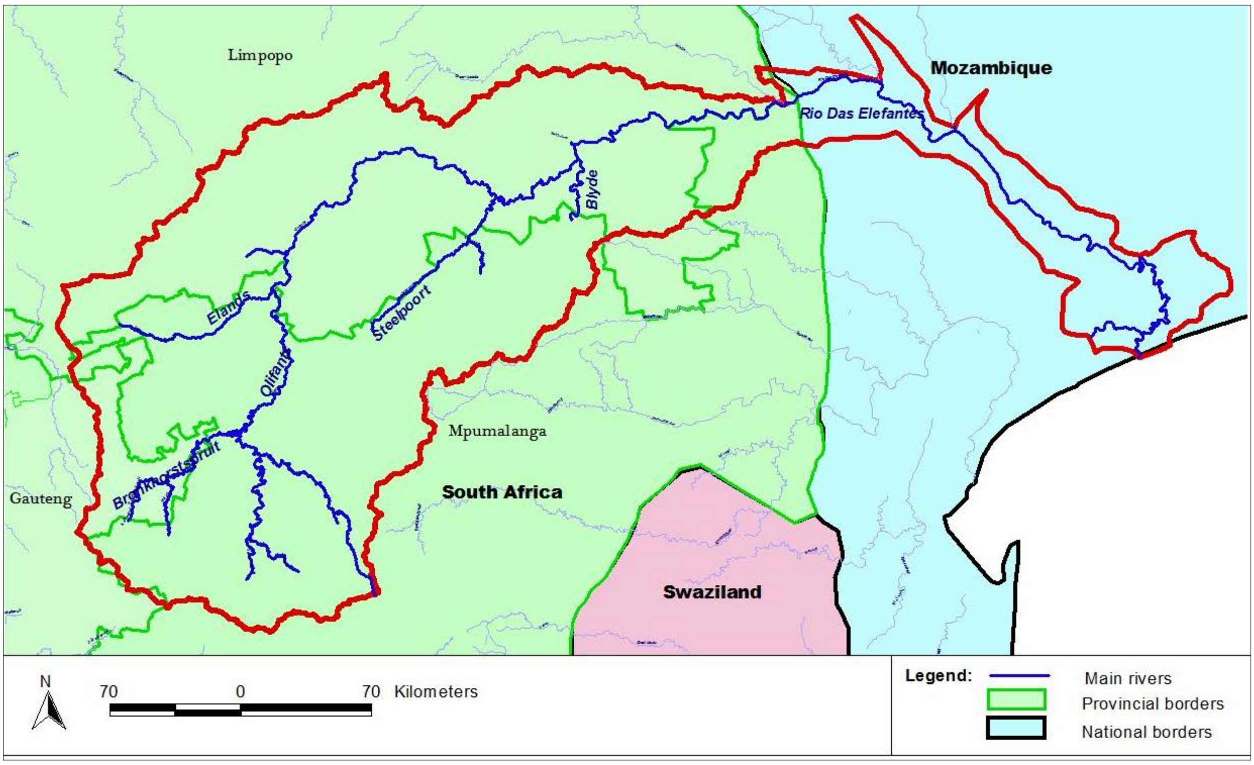


Figure 4.1 The Olifants River Basin and RESILIM-O study area

The South African portion of the basin was referred to as the Olifants Water Management Area (WMA) (Table 4.1) and was divided into sub-WMAs called: the Upper Olifants, Middle Olifants, Steelpoort and Lower Olifants. In terms of the proposed new WMAs boundaries (to reduce the number from 19 to 9) in the second National Water Resources Strategy, the Olifants WMA remains but will now include the Letaba river (i.e. the remaining B quaternaries from the B primary drainage region) (DWA 2013).

TABLE 4.1 MEAN ANNUAL RUNOFF (MAR) FOR THE FOUR WMA SUB-AREAS IN THE SOUTH AFRICAN PORTION OF THE OLIFANTS BASIN AND FOR MOZAMBIQUE

AREA	SUB-AREAS OF THE OLIFANTS WMA	NATURAL MAR
OLIFANTS WMA (SOUTH AFRICA) (DWA 2010B)	Upper Olifants	465
	Middle Olifants	481
	Steelpoort	396
	Lower Olifants	698
	Total for SA portion	2 040
	Location	
LIMPOPO MOZAMBIQUE AT CHOKWE	At Chokwe (range from different studies)	3707-4087

There are around 140 gauging stations[9] listed with DWA for the South African portion, but most of these are no longer functional. There are also *c.* 119 DWA water quality monitoring points. There are three gauging weirs on the Elefantes section in Mozambique and three on the Limpopo section. None of them appear to be currently active.

The rivers and wetlands in the Olifants Basin are subject to severe impacts including pollution from sewage, mining and other sources. Water quality in the Loskop Dam is extremely poor with constant cyanobacteria blooms since 2008. Filamentous algae also cause problems in the irrigation system arising from this dam. There have been significant fish and crocodile deaths both in Loskop Dam and in the Lower Olifants within Kruger National Park, which appear to be linked to water quality issues arising from pollution, as well as high levels of flow regulation, abstraction, sediment from releases from Phalaborwa barrage, and sedimentation up into the Olifants Gorge from the Massingir Dam. These factors have contributed to a decline in ecosystem condition throughout the basin.

The once perennial flow in the Olifants River is now seasonal, and flow through the Kruger National Park has ceased several times in the last five years, despite legal provisions for the Reserve (King and Pienaar 2011; Pollard and du Toit 2011). Flow into Mozambique is significantly reduced from natural levels and there is no cross-border flow for three to four months in a year. Salination in the lower sections of the river, may be due to reduced freshwater flows and consequent seawater intrusion.

For additional details refer to DWA (2010b (EGSA); 2011a-c (Reconciliation); 2012a, b and 2013 (Classification)), Pollard and du Toit (2011), the Internal Strategic Perspective (DWAF, 2004), and other reports mentioned in this Section.

[9] *This number varies between sources.*

4.1 Industry and demographics

4.1.1 South Africa

About 10% of South Africa's population resides in the Olifants Basin (IWMI 2008), with about 67% of the population being rural and the remaining 33% urban. The majority of people live in the middle Olifants area. Access to water for productive, domestic and recreation use is inequitably distributed, with a "water poverty index" from 2001 ranking the Olifants Basin water poverty at nearly twice the national average (Magagula *et al*. 2006, cited in IWMI 2008). The main economic activities are agriculture, mining and power generation.

Since 1994, the Olifants Basin in South Africa has been characterised by a rapid expansion of mining, in particular of platinum and coal, and electricity generation. The basin produces *c*. 55% of South Africa's electricity and c. 90% of its coal is mined there (Water Wheel 2010). There are currently eight major coal-fired electricity power stations in the basin (van Vuuren *et al*. 2003, cited in IWMI 2008), and decant of water from collieries is estimated to be around 170-200 million litres annually (Mining Weekly 2009). This has led to a precipitous increase in the pollution threats to the river ecosystem. This is illustrated by the cumulative capacity over time of various slimes, tailings and other pollution control dams in the South African section of the basin (Figure 4.2) shows the structures listed on www.dwa.gov.za, but may exclude some of the dams as designations are not always given. Nonetheless, the rapid in increase in capacity over the last 15 or so years is clear.

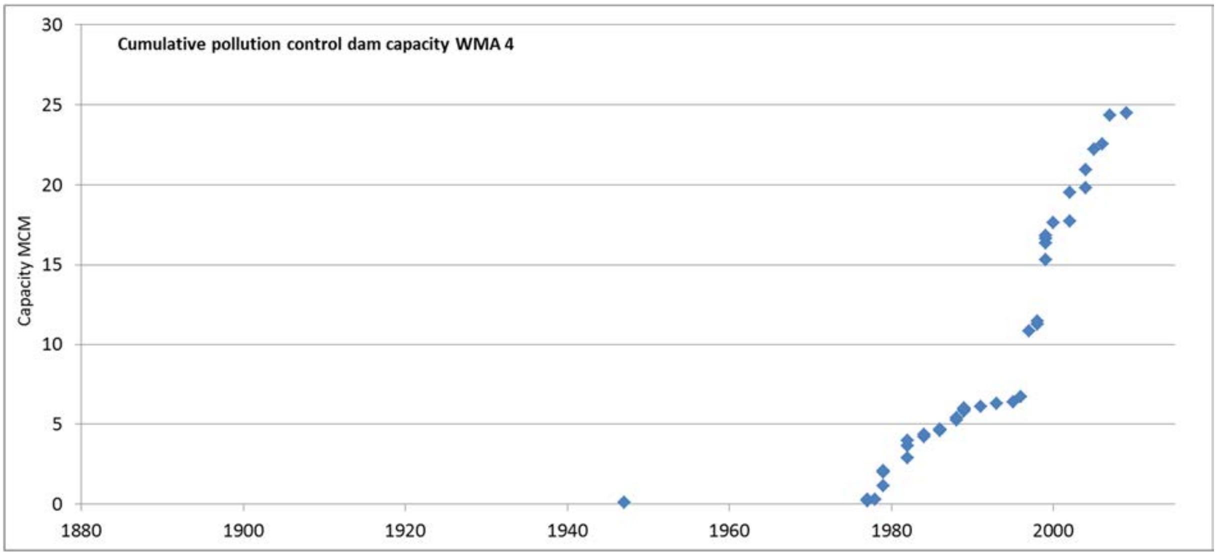


Figure 4.2 The cumulative capacity over time of slimes, tailings and other pollution control dams in the Olifants WMA.

4.1.2 Mozambique

In Mozambique, the main centre in the basin is Xai-Xai (population 127 000) but there are smaller settlements at Chokwe (c. 62 000), Massingir (all three have airports), Guija, Barrio, Nwanhapale, and Duma amongst others. Chokwe is the location of a large irrigation scheme, most of which is currently used by subsistence farmers, and there are small schemes near Massingir Dam. Small-scale agriculture is the main source of food and income along the Elefantes-Limpopo, while fishing can supplement food supplies, but is economically important to a relatively few fishers in Massingir Dam and in the river.

The Chokwe scheme consists of about 34 000 ha, around 10 000 ha of which is currently unusable due to salinization and flood damage from the 2000 and 2012 floods, and about 7 000 ha is currently utilised. Of the utilised area, the bulk is used by subsistence farmers.

The Limpopo National Park (LNP), which is part of the Great Limpopo Transfrontier Park created in 2001, is bounded by the Olifants River in the south and the Limpopo River in the north and east. There is a "voluntary resettlement programme" in place which offers incentives for villages to move to the buffer zone (which currently has about 4000 residents). Some villagers may have had to move (or change the location of the grazing and crop-growing activities) two or three times due to the initial building of the dam, the civil war, the raising of the dam wall, the declaration and zoning of the Park, the demarcation of land for a biofuels project (land was already in use by communities, and land earmarked for LNP resettlement was then also earmarked for the biofuels project), and for other rehabilitation efforts on the dam. Various LNP initiatives exist, such as irrigation projects (benefiting about 3 240 community members), tree nurseries (to supply trees to the Park and firewood to the community) and the upgrading of roads. A 56-km long barrier fence, from Massingir Gate in the west to the confluence with the Limpopo River, has been completed to separate the buffer zone from the wildlife areas and thus reduce human-wildlife conflict (http://www.peaceparks.co.za/programme. php?pid=25&mid=1009).

4.2 Water use and related infrastructure

4.2.1 South Africa

Total water use in the Olifants Basin within South Africa is estimated at c. 1016 million m3/a, i.e., 95.6% of the available water resources (DWA 2011a). Irrigated agriculture is the largest user and accounts for about 48% of total water use in the basin. Thereafter, mining and power generation use about 30%, with other industrial and domestic use making up the remaining 22% (DWA 2011a).

Provision of storage capacity to meet water demand in the basin has followed a steady increasing trend over the last 70 years, with a period of rapid expansion in the late 1980s-early 1990s (Figure 4.3). As was the case for Figure 4.2, Figure 4.3 shows only those structures with clear designations as listed on www.dwa.gov.za.

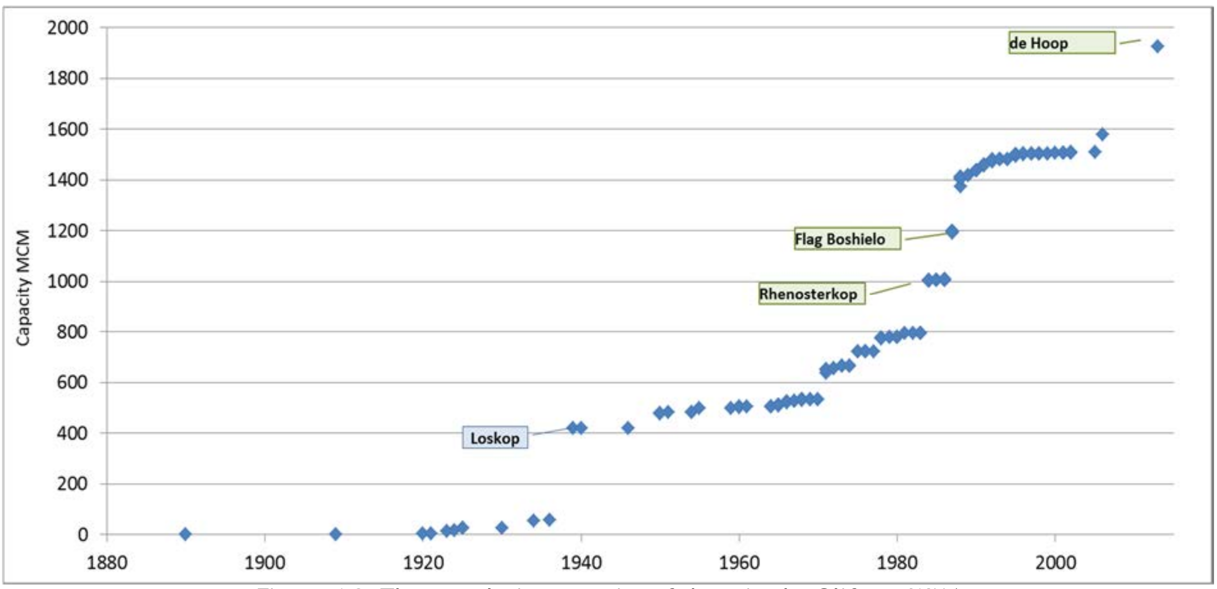


Figure 4.3 The cumulative capacity of dams in the Olifants WMA

Some of the larger storage dams in the South African portion of the basin are: Loskop Dam, Rhenosterkop Dam, Flag Boshielo Dam, Witbank Dam, Kettingspruit Dam, Bronkhorstspruit Dam, Blyderivierspoort Dam, Middelburg Dam, and Rust de Winter Dam. The de Hoop Dam, with a capacity of 347.4 MCM, has recently been completed. The Record of Decision (RoD) makes provision for Reserve releases of approximately 31.6 MCM per annum (32% of the historical firm yield), and the outlet works were designed to facilitate variable releases of high and low flows (DWAF 2006 cited in DWA 2010b). There are three Water Court orders pending clarification which require releases from Witbank, Middelburg and Loskop Dams.

Water is transferred into the basin from the Inkomati, Usutu and the Vaal basins, and used for cooling power stations, and from the Vaal and Levuvu basins to augment domestic, municipal and mining supply. A small amount of water is also transferred out of the basin to the Limpopo and Crocodile (West) basins.

4.2.2 Mozambique

The Massingir Dam (capacity 2 800 MCM), which was built in 1977, is the main impoundment on the river in Mozambique. It is situated about 30 km downstream of the South African border, with the inundation area extending into the Olifants Gorge just after the confluence with the Letaba River in the Kruger National Park. The dam sprung a leak just after completion, which prevented the reservoir from holding more than 40 percent of its capacity. This, together with the civil war, delayed a plan to build a 40-MW hydropower plant. Various rehabilitation projects have been proposed or undertaken since 1993, but the main work began in the 2003 with African Development Bank funding the Massingir Dam and Smallholder Agricultural Rehabilitation Project (MDSARP), with the intention of improving safety and yield from irrigated areas. The dam wall was also raised. The EWR study in Section 5.5 formed part of the EIA for this work. In 2007-08, further dam rehabilitation was undertaken and an additional spillway was constructed (the work also included installing pumps at Chilaulen, downstream of Xai Xai to prevent salt intrusion). Thereafter, the bottom outlet pipes ruptured in 2008, and were repaired in 2009-11 and an auxiliary spillway was constructed in 2011-12.

A biofuel project was initiated with ProCana to irrigate over 30 000 hectares of cane at Massingir, but the ProCana contract was cancelled after two years, and awarded to Massingir Agro-Industrial (a partnership including SIAL of Mozambique and TSB of South Africa (Milgroom 2013). The project involves estmiblishment of around 37 000 ha of sugar cane and the building of a processing plant (for sugar, ethanol and the production of electricity) at Massingir Dam. It appears that the contract includes direct abstraction from Massingir Dam (Engineering News, Apr 26, 2013).

There is a barrage, the Macarretane barrage, just downstream of the confluence between the Elefantes and Limpopo Rivers, which supplies water to the Chokwe irrigation scheme.

There is currently no information available regarding the envisaged allocations to the Massingir community irrigation schemes, the biofuels / sugar project, Chokwe irrigation or the EWRs.

5 Previous EWR-related studies in the Olifants Basin

This chapter summarises the previous studies in the basin that generated information pertaining to the objectives of RESILIM-O, S&EWR. The studies included in the review are listed in Table 5.1 and include, *inter alia*: EWR/Reserve determinations, Classification and valuation of ecosystem services.

TABLE 5.1 STUDIES INCLUDED IN THIS REPORT. SHADING DENOTE STUDIES THAT OFFER THE MOST RELEVANT AND USEFUL DATA IN TERMS OF RESILIM-O, S&EWR (EXT=EXTRAPOLATED).

Type	Reference	Focus Area	Rivers/wetlands	EWR Sites	Quat	Level	Method
Comprehensive Reserve	DWAF (2001a; 2001b; 2001c)	Upper Olifants	Olifants	IFR1	B11J	Ext from IFR2	BBM
			Olifants	IFR2	B32A	Comprehensive	BBM
			Klein Olifants	IFR3	B12E	Comprehensive	BBM
			Wilge	IFR4	B20J	Comprehensive	BBM
		Middle Olifants	Olifants	IFR5	B32D	Comprehensive	BBM
			Lower Elands	IFR6	B31G	Comprehensive	BBM
			Middle Elands	IFR6b	B31D, Quat outlet	Ext from IFR6	BBM
			Upper Elands	IFR6c	B31C, Quat outlet	Ext from IFR6	BBM
			Olifants	IFR7	B51G	Comprehensive	BBM
			Olifants	IFR8	B71B	Comprehensive	BBM
		Lower Olifants	Steelpoort	IFR9	B41J	Comprehensive	BBM
			Steelpoort	IFR10	B41K	Ext from IFR9	BBM
			Olifants	IFR11	B71J	Ext from IFR 13	BBM
			Blyde	IFR12	B60J	Comprehensive	HFSR
			Olifants	IFR 13	B72D	Comprehensive	BBM
			Selati	IFR14a	B72H	?	BBM
			Selati	IFR14b	B72K	Ext from IFR14a	BBM
			Olifants	IFR16 /17	B73H	Comprehensive	BBM
Intermediate Reserve	Salomon (2007a)	Mozambique	Elefantes	MOZ-1	Y30C	Intermediate	HFSR
			Limpopo	MOZ-2	Y30F	Intermediate	HFSR
Intermediate Reserve	Stassen (2008)	Lower Olifants	Dwars	DWA-EWR1	B41H	Comprehensive	HFSR
Rapid Reserve	Kleynhans (2007)	Lower Olifants	Blyde River	n/a	B60B	Desktop level	Desktop Model
Rapid Reserve	Singh (2007)	Lower Olifants	Ohrigstad River	n/a	B60E, B60F	Desktop level	Desktop Model
Rapid Reserve	Oryx Environ-mental. (2006)	Upper Olifants	Steenkoolspruit River and trib	n/a	B11C, B11D, B11E	Desktop level	Desktop Model
Rapid Reserve	-	Upper Olifants	Noupoortspruit	NOU-EWR1	B11G		
Rapid Reserve	-	Lower Olifants	Treur	TRE-EWR1	B60C		
Rapid Reserve	Ncapayi (2001)	Middle Olifants	Mapochs/ Masala	-	B41C	Desktop level	Desktop Model
Rapid Reserve	Grant et al. (2006)	Upper Olifants	Rietspruit River (with B11E wetlands)		B11E	Desktop level	Desktop Model
RHP	See Section 5.2	Whole basin		RHP sites	Various	Not applicable	
Updated PES	DWA (2014b)	Whole basin		Not applicable	All	Sub-quaternaries, desktop	Habitat Integrity
EGSA	DWA (2010a)	Whole basin		No sites-but higher confidence nodes available	All	Not applicable	
Classification	DWA (2012, 2014a)	Upper Olifants	Upper Klein Olifants	OLI-EWR1	B12C	Rapid 3	Rapid 3
		Middle Olifants	Upper Steelpoort	OLI-EWR2	B41B	Rapid 3	Rapid 3
			Kranspoortspruit	OLI-EWR3	B32A	Rapid 3	Rapid 3
			Klip	OLI-EWR4	B41F	Rapid 1	Rapid 1
			Watervals	OLI-EWR5	B42G	Rapid 3	Rapid 3
			Upper Spekboom	OLI-EWR6	B42D	Rapid 3	Rapid 3
		Lower Olifants	Klaserie	OLI-EWR7	B73A	Rapid 3	Rapid 3
			Ohrigstad	OLI-EWR8	B60H	Rapid 2	Rapid 2
			Dorpspruit	OLI-EWR9	B42B	Rapid 1	Rapid 1

Studies on dams, groundwater and wetlands are excluded from this review as they are beyond the scope of the current workpackage. Water quality is dealt with as part of another workpackage, but is included to the extent that it was part of the studies mentioned in Table 5.1.

The review focussed on those studies that offered the most relevant data for the population and calibration of the DRIFT DSS (shaded in Table 5.1). Results presented in this section are summaries intended to convey overall impressions. More detailed results are provided in Appendix B and Appendix C. The locations of the EWR sites listed in Table 5.1 are illustrated in Figure 5.1.

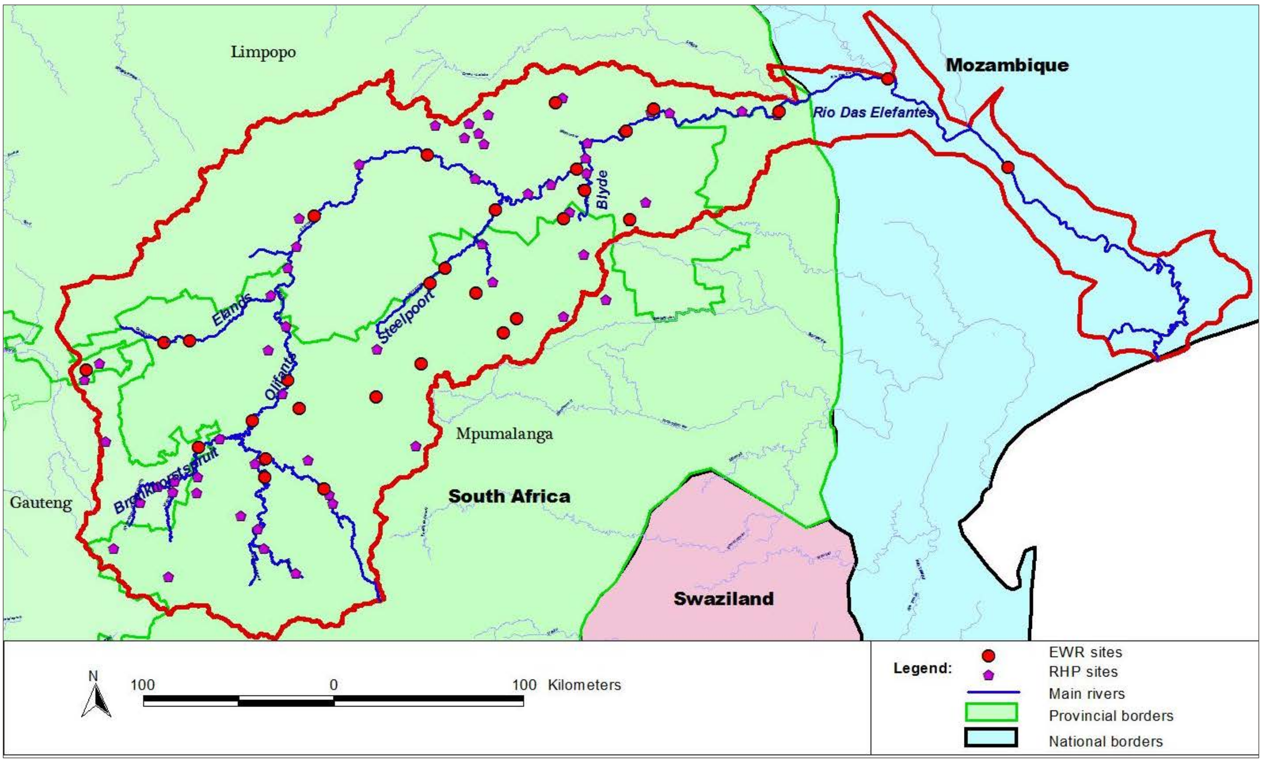


Figure 5.1 The Olifants River Basin and RESILIM-O study area showing the EWR Sites mentioned in Table 5.1 and the RHP sites (not all of which are necessarily active).

5.1 Desktop assessments of Present Ecological State (PES; 2000, 2014)

In 1999, desktop assessments (based on expert opinion) of PES and Ecological Importance and Sensitivity (EIS) were done for the whole of South Africa at a quaternary catchment scale (Kleynhans 2000). This was repeated, starting in 2010, at a sub-quaternary (quinary or tributary level). The updated PES for the Olifants WMA began in 2011 and the final reports should be available in 2014 (DWA 2014b, in prep.).

The PES-EIS database is used in the eco-classification process, in the River Health Programme (RHP), in EWR determinations (if site visits are not undertaken), and in setting conservation priorities and biodiversity targets.

These studies generated the following data of potential use in RESILIM-O, S&EWR:

- Updated, relatively fine-scaled PES assessments for the whole basin[10]. Where information from the Reserves or Classification is unavailable, the updated PES information could be used to calibrate the outputs of the DRIFT-DSS.
- Comparable data on ecosystem condition in 1999 and 2011 that could be used to trace trends, and evaluate response to flow and other anthropogenic changes in the basin;

5.1.1 Results

A comparison between the results for the Olifants Basin of the 1999 and 2011 assessments indicate that most quaternaries (54%) are the same ecological category, while 25% are worse and 21% are better. *Note that this is based on aggregating the sub-quaternary ecological categories of 2011 to quaternary level, using a length-weighted average.*

Given the general narrative of a catchment with a rapid increase in mining, energy and other polluting activities, it may seem surprising that there was not a more obvious decline in river health. However, this may be because the quaternary level assessments of 1999 concentrated on mainstem rivers, whereas the quinary-level assessments in 2011 gave tributaries more consideration. Since, tributaries tend to be in better condition that mainstems, this may have resulted in a higher score when combined for the quaternary.

In general, desktop assessments are less reliable than field based assessments. Studies where site visits were undertaken and whose PESs are therefore probably more reliable are the:

- 2001 Reserve study (DWAF 2001a-c);
- 2010 Reconciliation Study (11 of the 19 sites done in 2001; DWA 2011b); and
- 2011 Classification Study (9 new sites; DWA 2011d).

Table 5.2 lists those quaternaries whose ecological category changed according to the 1999 and 2011 desktop PES assessments, plus information from the Reserve, Reconciliation and Classification studies. If relevant, comment from DWAF/DfID (2007) is provided: this was a desktop assessment of the state of aquatic ecosystems in the Olifants basin undertaken in 2006 with specialist input.

TABLE 5.2 QUATERNARY CATCHMENTS WHOSE EC CHANGED ACCORDING TO 1999 AND 2011 DESKTOP, WITH ECS AND COMMENTS FROM OTHER STUDIES FOR COMPARISON.

Quat	River	Desktop PES		Change	EWR Sites	EWR Site visits EC			Comments
		1999	2011	2011 vs. 1999		Reserve 2001	Recon 2010/1	Classifi-cation 2011	
B11A	Olifants	C	D	worse					DWA/DfID (2007); B11A, D-G = E
B11F	Olifants	D	E	worse					B11B and C = D/E
B11J	Olifants	D	C	better	IFR1	D	D	D	DWA/DfID (2007) quat = C DWA (2011b): Deterioration because of water quality problems - inadequate wastewater treatment (Real degradation not reflected in EC due to change in methods)
B11K	Klipspruit	D	E	worse					
B12B	Klein-Olifants	D	E	worse					
B12C	Klein-Olifants	C	D	worse					

[10] *The Classification study used the updated PES/EIS estimates or those from the Reconciliation study where these were available.*

Quat	River	Desktop PES 1999	Desktop PES 2011	Change 2011 vs. 1999	EWR Sites	EWR Site visits EC Reserve 2001	EWR Site visits EC Recon 2010/1	EWR Site visits EC Classifi-cation 2011	Comments
B12E	Klein-Olifants*	C	C	no change	IFR3	D	D	C***	DWA (2011b): Deterioration due to water quality problems - inadequate wastewater treatment
B20A	Bronkhorstspruit	C	D	worse					
B20C	Bronkhorstspruit	C	D	worse					
B20G	Saalboomspruit**	D	C	better					DWA/DfID (2007) quat = D
B20J	Wilge*	C	C	no change	IFR4	B	C	C	DWA (2011b): Marked degradation in instream condition (possible main cause being mining along Saalboomspruit)
B31D	Middle Elands and Enkeldoringspruit	D	C	better	IFR6b	E	n/a	C	DWA/DfID (2007) quat = D
B31E	Gotwane	C	D	worse					
B31G	Elands *	D	D	no change	IFR6	E	C/D	D	DWA (2011b): Instream improvement may be due to changed operation of Rhenosterkop Dam ****
B31H	Elands	D	E	worse					
B31J	Elands	D	E	worse					DWA/DfID (2007) quat = E
B32B	Selons	D	C	better					DWA/DfID (2007) quat = B/C
B32D	Olifants	D	C	better	IFR5	C	C	C	DWA/DfID (2007) quat = C
B32F	Bloed	D	C	better					DWA/DfID (2007) quat = C
B32G	Moses	C	D	worse					
B32H	Moses	C	D	worse					
B41A	Grootspruit	C	D	worse					
B41B	Steelpoort	C	D	worse	OLI-EWR2	n/a	n/a	C	DWA/DfID (2007) quat = D
B41D	Steelpoort	B	C	worse					
B41G	Groot-Dwars	B	D	worse					
B41H	Steelpoort & Dwars	C	D	worse	DWA-EWR1	n/a B/C:2008	n/a	B/C	
B41J	Steelpoort	C	E	worse	IFR9	D	C/D	D	
B42B	Dorpspruit & Doringbergspruit	D	C	better	OLI-EWR9	n/a	n/a	C/D	DWA/DfID (2007) quat = C/D
B42D	Spekboom	B	D	worse	OLI-EWR6	n/a	n/a	C	
B42E	Spekboom	B	C	worse					
B51A	Motsephiri	C	D	worse					
B51B	Olifants	E	C	better					Not in DWA/DfID (2007)
B51E	Olifants	E	C	better					DWA/DfID (2007):Endorheic pans
B51F	Nkumpi	D	C	better					DWA/DfID (2007) quat = C
B51H	Ngwaritsi	D	E	worse					
B52J	Mphogodima	D	C	better					
B60B	Blyde	C	B	better					DWA/DfID (2007) quat = B/C
B60C	Treur	A	B	worse					
B60E	Ohrigstad	B	C	worse					
B60F	Ohrigstad	D	C	better					DWA/DfID (2007) quat = C
B60J	Blyde	B	C	worse	IFR12	B	B/C	B/C	DWA/DfID (2007) quat = B
B71A	Olifants	D	C	better					DWA/DfID (2007) quat = D
B71B	Olifants	D	C	better	IFR8	D	C/D	D	DWA/DfID (2007) quat = D
B71C	Mohlapitse	A	B	worse					
B71E	Motse	C	E	worse					
B71G	Olifants	D	C	better					DWA/DfID (2007) quat = D
B72B	Makhutswi	D	B	better					DWA/DfID (2007) quat = C/D
B72E	Ngwabitsi	C	D	worse					
B72H	Ga-Selati	D	C	better	IFR14a	C	n/a	C	DWA/DfID (2007) quat = D
B72J	Molatle	D	C	better					Not in DWA/DfID (2007)
B72K	Ga-Selati	D	E	worse	IFR14b	E	n/a	E	
B73B	Klaserie	D	C	better					DWA/DfID (2007) quat = B/C
B73F	Timbavati	C	B	better					DWA/DfID (2007) quat = A
B73G	Olifants	C	B	better					DWA/DfID (2007) quat = C
B73J	Olifants	C	A	better	IFR16/17	C C	C		DWA/DfID (2007) quat = C

* Included because of changes recorded in Reconciliation Study (DWA 2011b).
** But see comments for B20J-IFR4.
*** No explanation provided for the change.
**** Also known as “Mkhombo Dam”. Incorrectly as “Rhenosterpoort” in some Reconciliation reports. See: http://www.dwaf.gov.za/DSO/Documents/Cat%201,%202%20and%203%20Dams%20Jan%202014.kmz).

5.2 River Health Programme (RHP)

The objective of RHP is to collect information regarding the ecological state of river ecosystems in South Africa. A State-of-the-River Report for the Crocodile, Sabi-Sand and Olifants River Systems was compiled in 2001. Since then, it is unclear to what extent that RHP monitoring has been on-going in the Olifants Basin.

Refer to: http://www.dwaf.gov.za/iwqs/rhp/state_of_rivers/crocsabieolif_01_toc.html

5.2.1 Results

The 2001 RHP information was used in the various studies described here, but as far as we are aware has not yet been updated.

5.3 Olifants Basin Comprehensive Reserve determination (DWAF 2001a, b, c, and d)

The objectives of the Olifants Comprehensive Reserve determination study were to comply with the requirements of the NWA and to provide DWA (and other stakeholder) with information regarding the consequences of different ecological categories along different reaches of the ecosystem.

The study generated the following data of relevance to RESILIM-O, S&EWR:

- Summary data that could be useful for calibrating the outputs of the DRIFT assessment, including:
  - Basin delineation;
  - Discipline specific PES (as at 1999-2000) assessments from site visits to 19 EWR sites;
  - Volume and distribution of water (EWRs) required to maintain up to three ecological conditions (PES, REC and AEC) at 18 sites;

- Discipline-specific summaries for geomorphology, water quality, riparian vegetation, invertebrates and fish that could be used to inform the selection of DRIFT indicators;
- Discipline-specific data that could be used to inform the development of response curves in the DRIFT-DSS, such as:
  - Motivations for depth and velocity requirements for biotic indicators;
  - Lowflow stress assessments for IFR 12 for a range of biotic indicators;

- An evaluation of people's direct dependence on ecosystems for (DWAF 2001d; see Section 5.3.2) that could be used to inform the social indicators and response curves in the DSS.

5.3.1 Environmental Water Requirements

The most reliable EWR data for the Olifants WMA are available from the Comprehensive Reserve determinations conducted between 1999 and 2001 (DWAF 2001a-c), notwithstanding the fact that these were among the earliest such assessments in South Africa and many of the methods used were still under development. The BBM was used for all sites, except for IFR 12, which used HFSR. Much of the subsequent work, such as the calibration of the Desktop Model, and the EGSA and Classification Process, was based on these data.

5.3.1.1 Results

A summary of the EWRs from the Comprehensive Reserve determination (DWAF 2001a-c) is given in Table 5.3.

TABLE 5.3 SUMMARISED EWR REQUIREMENTS FROM THE COMPREHENSIVE RESERVE (DWAF 2001A TO C).

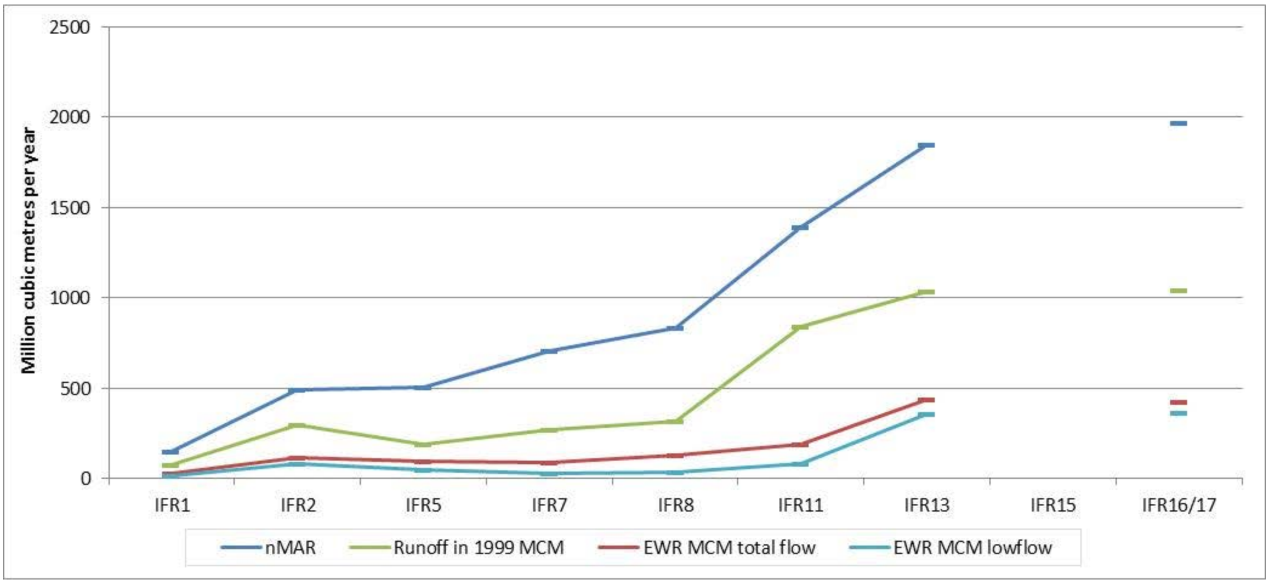
Quat	River	Site	nMAR, 1999 MCM*	Runoff as in 1999 MCM	PES	REC	EWR for REC			
							% nMAR**	MCM per annum***	% nMAR-lowflow only	MCM lowflow only*
B11J	Olifants	IFR1	148.094	74.33	D	C	18.63	27.59	9.980	14.8
B32A	Olifants	IFR2	489.731	298.89	C	B	23.77	116.41	16.288	79.8
B12E	Klein Olifants	IFR3	73.675	40.8	D	C	27.01	19.90	13.243	9.8
B20J	Wilge	IFR4	192.857	126.39	B	B	29.94	57.74	16.319	31.5
B32D	Olifants	IFR5	502.596	190	C	C	19.01	95.54	9.996	50.2
B31C	Upper Elands	IFR6c	31.327	26.32	C	B	31.19	9.76	19.705	6.2
B31D	Middle Elands	IFR6b	42.351	34.39	E	C	23.11	9.78	11.591	4.9
B31G	Lower Elands	IFR6	63.417	4.3	E	D	17.86	11.33	6.318	4.0
B51G	Olifants	IFR7	704.793	266.8	E	D	12.68	89.37	3.841	27.1
B71B	Olifants	IFR8	834.533	318.9	D	D	15.22	127.02	4.296	35.9
B41J	Steelpoort	IFR9	171.580	161.2	D	D	15.17	26.03	7.964	13.7
B41K	Steelpoort	IFR10	406.231	311.89	D	D	12.1	49.15	7.429	30.2
B71J	Olifants	IFR11	1393.158	843	E	D	13.7	190.84	5.986	83.4
B60J	Blyde	IFR12	383.703	275.8	B	B	34.49	132.44	27.956	107.4
B72D	Olifants	IFR13	1845.375	1035	C	B	23.57	434.87	19.425	358.4
B72H	Selati	IFR14a	54.93	40.5	C	C	31.17	17.11	19.587	10.8
B72K	Selati	IFR14b	64.97	48.5	E	D	24.80	16.11	not given	not given
B73C	Olifants	IFR15	not given		C	B	not given			
B73H	Olifants	IFR16/17	1968.007	1043	C	B	21.63	425.68	18.344	361

* Taken from the DWA excel file nMAR if different to that given in the Reserve reports

** Taken from the REC and % signed off and in .tab files (where latter currently available – Middle and Lower only)

*** Calculated

The annual volumes for the mainstem Olifants are presented in Figure 5.3. Detailed EWRs (.tab files and flood requirements) are provided in Appendix A.5, with node level details in Appendix C.



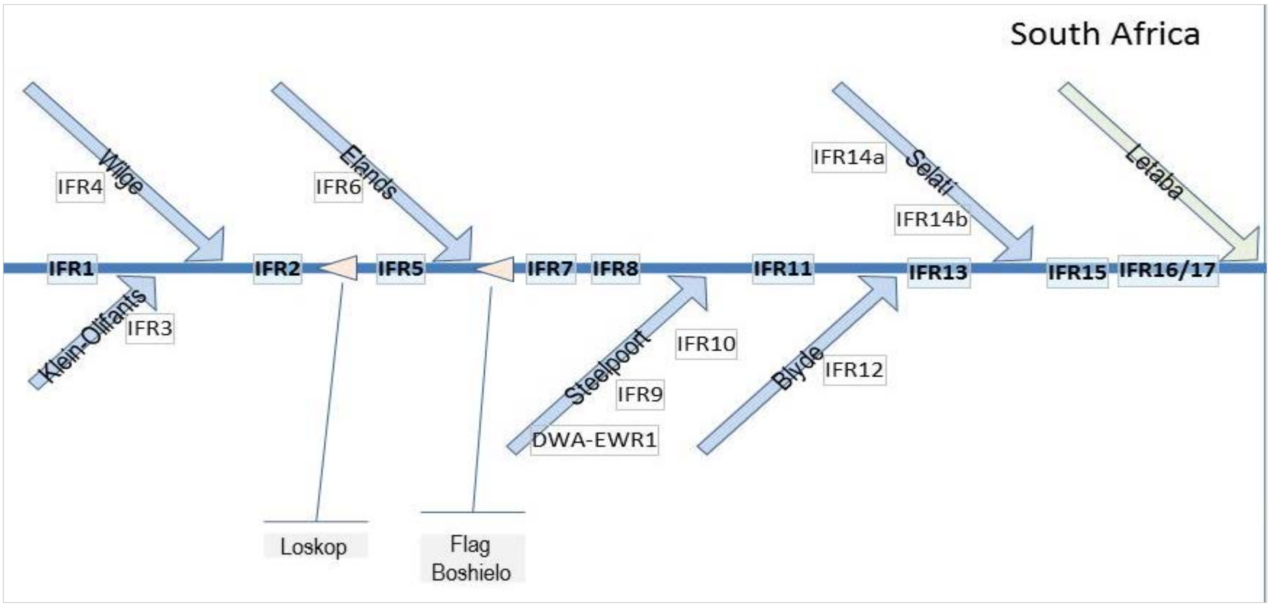


Figure 5.3 Olifants mainstem natural runoff, 1999 runoff and EWR requirements as MCM per year, plus a schematic showing the position of the EWR sites (not to scale)

5.3.2 Dependence on ecosystems[11]

The level of use of, or dependence on, five different aspects of the riverine ecosystem (DWAF 2001d), including:

1. As a source of potable water;
2. As a source of water for domestic animals;
3. Occurrence and utilization of fish;
4. Occurrence and utilization of plants; and
5. Utilisation of water for irrigation.

A qualitative scoring method was applied based on interviews key stakeholders or communities along each reach or within each similar zone. Overall reliance was evaluated using a combination of: extent / locality, duration and magnitude.

Levels of reliance for each of the sources of use / dependencies were rated as:

- **High:** If any one, or more, of the following situations occur:

  a] The locality of resource is the river channel,
  b] Duration of reliance on resource is permanent or
  c] The magnitude of reliance on the resource is critical.

- **Moderate:** if one of the following situations occurs:

  a] The locality of resource is the bank of the river or area further away,
  b] The duration of reliance on resource is not permanent, or
  c] The magnitude is not critical;

- **Low:** if one of the following situations occur:

  a] The locality of resource is on the streams flowing into the Olifants River or its major tributaries or is further away,
  b] The duration of reliance on resource is short term, or
  c] The magnitude is medium to low;

- **Very low** reliance or no reliance if one of the following situations occur:

  a] The locality of resource is not close to the Olifants River or its tributaries,
  b] The duration of reliance on resource is temporary, or
  c] The magnitude is very low.

- No reliance.

Information on timing of use, as well as plant species used was also provided in this study.

[11] *More details are provided for ecosystem services and social assessments methods than for EWRs as these are well described elsewhere.*

An overall evaluation was also given across all the different levels of dependency, as follows:

- **Reliance Class i**: stakeholders rely absolutely on the river for their livelihood and should the resource quality of the river deteriorate, it will adversely influence communities.
- **Reliance Class ii:** stakeholders rely on the river but alternatives exist for them for the specific resource utilisation
- **Reliance Class iii:** stakeholders only marginally rely on the river for their well-being.
- **Reliance Class iv**: stakeholders do not rely on the river at all.

The approach adopted was simple and consistent and lends itself to conversion to a numeric scoring system comparable with PES or EC. As such, the information generated could be used to translate the data into DRIFT response curves provided:

- The qualitative scores were converted to numeric scores (see Results section for an example)
- It will be possible to specify whether an increase was 'good' or 'not good', i.e., whether 'more' of something is a 'good' or 'bad'.
- Thresholds or tipping points of depletion (assuming 'less' is 'bad') can be identified that would lead to critically low availability or accessibility.
- The results of the dependence / use of the five different aspects of the ecosystem, can be aggregated to site level.

5.3.2.1 Results

As an illustration, and in the interest of comparison with other results, we have assigned simple, evenly spaced (i.e. linear) scores to the valuations as follows[12]:

- No reliance 0
- Very Low reliance 1
- Low reliance 2
- Moderate reliance 3
- High reliance 4
- Very High reliance 5

Similarly, for overall reliance across all resources, the following rating were applied:

- Reliance Class iv (none) 0
- Reliance Class iii 1
- Reliance Class ii 2
- Reliance Class I (high) 3

Overall reliance is taken as the median of the scores for each component. On the basis of this approach, results per sector of the Olifants mainstem are presented in Table 5.4

[12] *Note that conversions from qualitative to numeric scores, should ideally take place with discussion with the specialist and / or stakeholders themselves, to ensure that non-linearities are captured.*

TABLE 5.4 RELIANCE ON THE UPPER AND MIDDLE OLIFANTS RIVERINE ECOSYSTEM, ADJUSTED TO NUMERIC SCORES AND MEDIANS FROM DWAF (2001D) FOR ILLUSTRATIVE PURPOSES.

See text for scoring. The scores in the last row of each section "Reliance Class Of River" (0-3) are directly from DWAF (2001d), while the score in the shaded top corner of each section under the heading "Median" are calculated from the numeric scores used in this example (0-3). "Sectors" are the kilometres along the river (e.g. km 1 - 18). Scores for each aspect are 0-5.

Resource and River Sectors (km)	Communities					Median
UPPER						
Sectors 1 to 18	Middelkraal	Roodekop	Driehoek	Klijnkopje		**2**
Source of potable water	2	2	2	2		2
Source of water for domestic animals, game	1	1	1	1		1
Occurrence and utilisation of fish	3	3	3	3		3
Occurrence and utilisation of plants	3	2	2	2		2
Utilisation of water for irrigation	1	1	1	1		1
Reliance Class of river	1	1	1	1		
Sectors 18 to 38 (Confluence of Wilge =S 29)	Loskop Dam Nature Reserve					**2**
Source of potable water	2					2
Source of water for domestic animals, game	1					1
Occurrence and utilisation of fish	3					3
Occurrence and utilisation of plants	2					2
Utilisation of water for irrigation	1					1
Reliance Class of river	1					
MIDDLE						
Sectors 39 to 57 (Loskop Dam=S 39, Stokkiesdraai =S 57)	Hartman	Pretorius	Pieterse			**2**
Source of potable water	2	2	2			2
Source of water for domestic animals, game	1	1	1			1
Occurrence and utilisation of fish	3	3	3			3
Occurrence and utilisation of plants	2	2	2			2
Utilisation of water for irrigation	4	4	4			4
Reliance Class of river	3	3	3			
Sectors 57 to 65 (Tiekiedraai farm= S 65)	Elandskraal	Tiekiedraai				**2**
Source of potable water	3	2				2.5
Source of water for domestic animals, game	1	1				1
Occurrence and utilisation of fish	3	3				3
Occurrence and utilisation of plants	2	2				2
Utilisation of water for irrigation	2	2				2
Reliance Class of river	1	1				
Sectors 65 to 88 (Rooipoort Dam =S 79, Confluence of Steelpoort =S 88)	Bloublomkloof	Diamand	Scheiding	Rostock	Dublin	**3**
Source of potable water	4	3	2	4	4	4
Source of water for domestic animals, game	1	1	1	1	1	1
Occurrence and utilisation of fish	3	3	3	3	3	3
Occurrence and utilisation of plants	3	3	3	2	2	3
Utilisation of water for irrigation	2	2	2	2	1	2
Reliance Class of river	3	2	2	3		

DWAF (2001d) produced similar results for the Lower Olifants, Klein Olifants, Bronkhorstspruit, Elands, Steelpoort, Blyde and Selati (see also Dippenaar et al. 2005) Rivers. The overall results using the numeric conversion described (and medians in shaded right-hand cells in Table 5.4) are given for the whole basin in Table 5.5. Note that these are given for river sectors (kilometres), a coverage for which is not currently available.

TABLE 5.5 SUMMARY OF RELIANCE (USING EXAMPLE OF QUANTIFICATION OF RATINGS FROM TABLE 5.4 (S=SECTOR (=KM), KNP=KRUGER NATIONAL PARK).

Zone	Sectors (km)	Communities					Reliance	Approx. location of EWR sites	
OLIFANTS									
Upper	S 1 to 18	Middelkraal	Roodekop	Driehoek	Klijnkopje		**2**	IFR1	S 18
	S 18 to 38	Loskop Dam Nature Reserve					**2**	IFR2	S 34
Middle	S 39 to 57	Hartman	Pretorius	Pieterse			**2**	IFR5	S 43
	S 57 to 65	Elandskraal	Tiekiedraai				**2**	IFR7	S 63
	S 65 to 88	Bloublom-Kloof	Diamand	Scheiding	Rostock	Dublin	**3**	IFR8	S 78
Lower Olifants Weir below Strydom Tunnel ~S 94 KNP start ~S 112	S 88 to 94	Riverside	Gamametsa	Anlaagte	The Oaks	The Elms	**3**		
	S 94 to 112	Oxford	Excellence				**2.5**	IFR11 IFR13	S 98 S 104
	S 112 to 132	KNP					**2**	IFR15 IFR16/17	S 113 S 128
KLEIN OLIFANTS									
Upper	S 1 to 9	Vaalbank	Boesman-laagte				**2**	OLI-EWR1	S 3
Lower	S 9 to 12	This sector is mountainous - no communities were identified						IFR3	S 12
BRONKHORSTSPRUIT-WILGE									
	S 1 to 16	Witklip	Spitskop	Strehla			**2**	IFR4	S 15
ELANDS									
Upper	S 1 to 19	Vaalbank	Thabak-wibidu				**2**	IFR6	S 19
Lower	S 19 to 27	Matlala					**2**		
STEELPOORT									
	S 1 to 10	Gamalekane	Boschkloof	Apiesboom	Tswetlane		**3**	IFR9 IFR10	S 3? S 8?
BLYDE									
	S 1 to 8	Otters Dam	Jonkmans-spruit				**3**	IFR12	S 4
SELATI									
	S 1 to 18	Danie/Willie	Selati Reserve	Bosbok			**2**	IFR14b IFR14a	S 18 S 5?

5.4 Dwars River Intermediate Reserve assessment (Stassen 2008a, b; CIC 2008)

The Dwars River Reserve assessment (Stassen 2008) was undertaken at the Intermediate level using the HFSR approach for low flows, and inspection of the measured flow at B4H009, upstream of the EWR site for freshets and floods at one site (DWA-EWR1). The study also included a rapid-level cost-benefit analysis. The main reason for the study was to support the evaluation of the water use licence application for the building of the Richmond Dam and the abstraction of surface- and ground-water.

The study generated the following data of relevance to RESILIM-O, S&EWR:

- Summary data that could be used for calibrating the outputs of the DRIFT assessment, including:
  - Discipline-specific PES assessments (as at 2008) for the EWR site;
  - Volume and distribution of water (EWRs) required to maintain up to three ecological conditions (PES, REC and AEC) at the site;
- Discipline-specific summaries for geomorphology, water quality, riparian vegetation, invertebrates and fish that could be used to inform the selection of DRIFT indicators;
- Lowflow stress assessments for biotic indicators at the site that could be used to inform the response curves in the DRIFT-DSS;
- A cost-benefit analysis which could inform indicators or response curves for use in the DRIFT-DSS.

5.4.1 Environmental water requirements

Three ecological categories were assessed (B, B/C [PES], and C). The REC was B/C. In addition, six scenarios were assessed to establish the impact of proposed new developments on the Dwars and Steelpoort Rivers. Scenario 5, a 2.5 MAR dam with a 1.91 million m^3 yield, was proposed as the scenario that would maintain a B/C ecological condition at the EWR site.

5.4.1.1 Results

A summary of the EWRs is given in Table 5.6, with details in Appendix A.6 and flood requirement in App Table 31.

TABLE 5.6 SUMMARY EWRS FOR DWA-EWR1 OF THE DWARS RESERVE ASSESSMENT.

Quat	River	Site	nMAR, 2008 MCM*	Runoff as in 1999 MCM	PES	REC	EWR for REC			
							% nMAR	MCM per annum	% nMAR-lowflow only	MCM lowflow only
B41H*	Dwars River	DWA-EWR1	31.429		B/C	B/C	25.91	8.142	19.41	6.099

* Naturalised mean annual runoff (nMAR) based on the total flow from quaternary catchment B41G and 18% of B41H. Flow record scaled from the Steelpoort River flow record as determined during the high confidence Reserve determination study for the Olifants River.

** REC determined during the intermediate III Reserve determination study on the Dwars River at EWR site (S24° 50' 38.1"; E30° 05' 30.8") in quaternary catchment B41H.

5.4.1.2 Characteristics of the dams in the Upper Dwars River

DWA (2008a) provided an assessment of the outlet capabilities of the dams on the Dwars / Steelpoort (Table 5.7).

- The proposed Richmond Dam, which was being evaluated by the Reserve study, had no outlet constraints.
- Der Brochen Dam[13] had some release constraints but was capable of releasing the required freshets.
- Inyoni[14] Dam had considerable constraints but did have some release capabilities.

This has relevance in terms of the decision of both the Reconciliation and the Classification studies to exclude floods from their yield modelling and evaluation of delivery of EWRs because they "*most dams do not have the ability to release freshets, and floods will spill* (see Section 5.7)". As a consequence of this decision, it is likely that only the lowflows will be included in licences, which means many river sections will not receive their required EWRs, as there would be no requirement to release freshets, even where they could be. The only freshets most reaches would receive would be what is supplied by the immediate catchment.

TABLE 5.7 CHARACTERISTICS OF THE DAMS IN THE UPPER DWARS RIVER (FROM STASSEN 2008A)

Dam	Incremental MAR	Gross Full Supply Capacity	Dead Storage	Net Full Supply Capacity	Physical constraints on outlets
	10^6m^3	10^6m^3	10^6m^3	10^6m^3	m^3/s
Richmond 2.5*MAR	5.36	13.50	0.60	12.90	None
Inyoni	0.69	0.48	0.03	0.45	Only 0.02 m^3/s below FSC
Kafferskraal	11.39	0.74	0.00	0.74	None
Der Brochen	0.00	7.29	0.05	7.29	0.82 m^3/s below 13.06m 1.84 m^3/s below 17.06m 2.28 m^3/s below 20.06m 2.70 m^3/s below 25.06m
Farm Dams	6.91	0.08	0.00	0.08	None – Always spilling

5.4.2 Cost benefit analysis

A "rapid cost-benefit analysis" was undertaken as part of the Dwars Reserve determination study. This looked at the direct costs and benefits associated with the "Der Brochen Platinum Project" of Anglo Platinum and Khumama Platinum, and the associated Richmond Dam, namely:

- Financial benefits to Anglo Platinum and its stakeholders (shareholders, employees and government);
- Cost of water provisioning (construction cost of the dam and operational cost); and
- Costs of ecosystem services lost as a result of construction of the dam.

[13] *This was spelt der Bruchen in ORRS, but der Brochen appears to be the correct spelling.*
[14] *The Inyoni Dam belongs to the Two Rivers mine (consortium of Impala Platinum and African Rainbow Minerals). The dam wall has been raised and a new overflow has been built. The Richmond Dam is upstream of Inyoni Dam.*

5.4.2.1 Results

The direct and indirect benefits (including multiplier effects) are given in Table 5.8. Ecosystem services were considered in terms of provisioning and cultural services, and the report summary provided in Table 5.9.

TABLE 5.8 THE COMBINED DIRECT AND INDIRECT BENEFITS OF THE DER BROCHEN PROJECT TO THE NATIONAL ECONOMY EXPRESSED IN TERMS OF WATER USE. (FROM CIC 2008)

COMPONENT	UNITS	DIRECT	COMBINED WITH INDIRECT (MULTIPLIER) EFFECTS
DER BROCHEN WATER USE	Megalitres / day	2.1	
	Cubic metres per year	766 500	
VALUE ADDED VALUE OF WATER	R mill per year	2 498	3 365
EMPLOYMENT VALUE OF WATER	R mill per year	874	1 177

TABLE 5.9 SUMMARY OF ECONOMIC EFFECTS RESULTING FROM THE PROPOSED RICHMOND DAM IN TERMS OF DIRECT AND INDIRECT ECONOMIC EFFECTS AND AQUATIC ECOSYSTEM SERVICES. (From CIC 2008). 'Highly likely' effects have been shaded.

BENEFITS AND COSTS	CATEGORY	LIKELIHOOD OF EFFECT	CONSEQUENCE
DIRECT FINANCIAL BENEFITS	Value added through Anglo Platinum operations	Highly likely	R2 498 million per year
INDIRECT FINANCIAL BENEFITS	Value added through Anglo Platinum suppliers and customers	Highly likely	R867 million per year
SUPPORTING AND REGULATING SERVICES	Various	Unlikely	A category B/C river is maintained
PROVISIONING ECOSYSTEM SERVICES (COSTS)	Food, Wood and fibre Biochemical and pharmaceutical products	Highly likely	Not quantified, relevant for a small portion of the Ga Mawela community, Anglo Platinum possibly to compensate
	Fresh water	Highly unlikely	Water provisioning to towns would be increased
	Genetic resources	Highly unlikely	No threatened or scarce species in the affected area

CULTURAL	Cultural diversity	Highly likely	Not quantified, relevant to the whole Ga Mawela community, Anglo Platinum possibly to compensate
	Spiritual and religious values		
	Knowledge systems		
	Educational values		
	Inspiration		
	Aesthetic values		
	Social relations		
	Sense of place		
	Cultural heritage values		
	Recreation and ecotourism	Unlikely	R0.00

Provisioning services included the provision of freshwater, the availability / collectability of wild food, fibre, and medical products, and the presence of threatened resources. None were quantified.

The dam would inundate approximately 30 hectares[15] of the GaMawela communities' St George's farm. However, the report concluded that although the dam and inundation might affect collection of food, wood and fibre, there was no information available regarding this use. In addition to supplying the platinum mine, the water would also supply towns in the area, but the community would not be able to access irrigation water from the dam (Business Day Live, May 17 2013). The land itself, while 'highly significant but not irreplaceable' in the Mpumalanga Biodiversity Conservation Plan, was in a poor state due to overgrazing and frequent fires, and thus threatened genetic resources would be highly unlikely to be affected. The report concluded that it was likely that the communities would need compensation for reduced provision of ecosystem services (food, fibre, and medical).

The report concluded that it was likely that the GaMawela community would need to be compensated for the loss of cultural services but that there were no recreational and tourism activities in the area, nor any future possibility of such.

5.5 Rio dos Elefantes assessment (Salomon 2007a-i)

The Rio dos Elefantes EWR assessment was undertaken as part of the "Massingir Dam and Smallholder Agricultural Rehabilitation" (MDSAR) project, which included rehabilitation of the Massingir Dam to improve dam safety, allow for increased irrigation downstream, and for environmental releases.

The EWR assessment (Salomon 2007a-i) was done at an Intermediate level using the HFSR approach at two sites and a social assessment of reliance on ecosystem services. Sixteen scenarios were assessed which differed in the releases made from Massingir to meet different priorities downstream.

[15] *Or 50 hectares, depending on the source.*

The study generated the following data of relevance to RESILIM-O, S&EWR:

- Summary data that could be used for calibrating the outputs of the DRIFT assessment, including:
  - discipline-specific PES (as at 2007) assessments for two EWR sites;
  - volume and distribution of water (EWRs) required to maintain up to three ecological conditions (PES, REC and AEC) at the two sites.
- Discipline-specific summaries for geomorphology, water quality, riparian vegetation, invertebrates and fish that could be used to inform the selection of DRIFT indicators.
- Lowflow stress assessments for biotic indicators at two sites that could be used to inform the response curves in the DRIFT-DSS (thus far, the stress tables are unavailable to us).
- A social study that included assessments of use and dependence on natural riverine resources and that could inform DRIFT response curves.

5.5.1 EWR assessment results

The HFSR method was used to develop the overall lowflow requirements (based on fish and invertebrates). For the freshets and floods each specialist motivated for particular events (as per BBM). For both sites, the critical month for the dry season was October and for the wet season, February. Both sites had a PES of C/D (Salomon 2007g) and a REC of C (however, both PES and REC are given as C in Salomon (2007a)). None of the reports provide the nMAR, but for the purposes of this review the nMAR was calculated from the Desktop Model outputs, giving MARs of 2819.0 and 7618.4 MCM respectively (see App Table 32, App Table 33). The total EWR as a % of these nMARs and the Desktop Model results was 14.90 and 14.18 respectively (App Table 32, App Table 33). These are slightly different to those provided in Salomon (2007a, as shown in Table 5.10). A summary of the EWRs is given in in Table 5.10, with details (.tab files and flood requirements) in Appendix A.7.

TABLE 5.10 MEAN ANNUAL REQUIREMENTS AS A PERCENTAGE OF MAR AND AS MCM FOR CATEGORY C (Salomon 2007a).

Site	Category	EWR as % of MAR			Long term mean as % of nMAR			
		Total % MAR	Maint. % MAR	Drought % MAR	Low Flow MCM	% MAR	Total Flow MCM	% MAR
EWR1	C	14.77	10.39	4.26	317.684	11.34	444.402	15.87
EWR2	C	14.05	5.27	2.03	450.849	5.99	1138.159	15.11

5.5.2 Social assessment

The social assessment (Salomon 2007h) identified:

- Key stakeholders;
- Their livelihoods and natural, physical, financial, human and social assets, and the policies, institutions and processes which may affect resilience and vulnerability;
- Their relationships with the river in terms of its provision of goods and services;
- The socio-cultural importance of the goods and services to those directly dependent for their livelihoods on the health of the river; and
- The sensitivity of the relationships to changes in quantity and quality of the water in the river (e.g. Floods, flow reductions, increases in salinity).

The primary stakeholders were traditional users, who were directly dependent on the river. Secondary stakeholders who may have an influence on the relationship of the primary users to the rivers were also identified.

Scores were given to the qualitative assessments of these relationships and their importance, according to the criteria given in Table 5.11.

TABLE 5.11 TYPES OF IMPORTANCE THAT WERE SCORED IN THE SOCIAL ASSESSMENT (Salomon 2007)

A) SOCIO-ECONOMIC IMPORTANCE
1. People directly dependent on a healthy flowing river for water supplies
2. People dependent on riparian plants for building, thatching and medicinal plants
3. People dependent on the river for subsistence fishing
4. People using the river for recreational purposes that requires ecologically healthy river
5. People using the river water for subsistence agriculture
B) CULTURAL/HISTORICAL VALUES
1. Sacred places on the river, and religous cultural events associated with the river
2. Historical/archaeological sites on the river
3. Special features and beauty spots
4. General aesthetic value of the river
5. Sense of place of those living proximate to the river
C) CONSERVATION ASPECTS IN A SOCIAL CONTEXT
1. Potential for ecotourism
2. Present recreation, and potential for recreation

5.5.2.1 Results

An example of the detailed results for two of the resource units are given in Table 5.12. Table 5.13 summarises results for all resource units.

TABLE 5.12 DETAILED RESULTS FOR TWO OF THE RESOURCE UNITS.
Importance of goods and services provided and sensitivity to changes in their quantity and quality (from Salomon 2007h). (i)= importance of goods & service provided,
(ii) = sensitivity to quantity / quality changes, (iii) = importance and sensitivity synthesis,
(iv) = confidence. All scores from 0 to 4.

DETERMINANTS	(i)	(ii)	(iii)	(iv)	COMMENTS
RU A: Elefantes River, Border to Massingir Dam					
A) SOCIO-ECONOMIC IMPORTANCE					
1. People directly dependent on a healthy flowing river for water supplies	2	3	2.5	4	Adjacent hand-dug wells
2. People dependent on riparian plants for building, thatching and medicinal plants	3	4	3.5	4	
3. People dependent on the river for subsistence fishing	3	3	3	4	
4. People using the river for recreational purposes that requires ecologically healthy river	0	2	1	4	
5. People using the river water for subsistence agriculture	0	0	0	4	
B) CULTURAL/HISTORICAL VALUES					
1. Sacred places on the river, and religous cultural events associated with the river	3	1	2	1	Rock formations of the gorge propitious
2. Historical/archaeological sites on the river	2	1	1.5	1	
3. Special features and beauty spots	4	4	4	4	
4. General aesthetic value of the river	4	4	4	4	
5. Sense of place of those living proximate to the river	3	1	2	3	
C) CONSERVATION ASPECTS IN A SOCIAL CONTEXT					
1. Potential for ecotourism	4	4	4	4	
2. Present recreation, and potential for recreation	2	3	2.5	4	Part of ecotourism
MEDIAN OF DETERMINANTS	**3**	**3**	**2.5**		
ECOLOGICAL IMPORTANCE AND SENSITIVITY CATEGORY (EISC)	High	High	High		
RU B: Massingir Dam					
A) SOCIO-ECONOMIC IMPORTANCE					
1. People directly dependent on a healthy flowing river for water supplies	1	4	2.5	4	Adjacent hand-dug wells
2. People dependent on riparian plants for building, thatching and medicinal plants	1	1	1	4	
3. People dependent on the river for subsistence fishing	4	3	3.5	4	
4. People using the river for recreational purposes that requires ecologically healthy river	0	3	1.5	4	
5. People using the river water for subsistence agriculture	4	4	4	4	Recessive agriculture
B) CULTURAL/HISTORICAL VALUES					
1. Sacred places on the river, and religous cultural events associated with the river	2	3	2.5	1	
2. Historical/archaeological sites on the river	2	2	2	2	
3. Special features and beauty spots	4	3	3.5	4	
4. General aesthetic value of the river	4	3	3.5	4	
5. Sense of place of those living proximate to the river	4	4	4	4	
C) CONSERVATION ASPECTS IN A SOCIAL CONTEXT					
1. Potential for ecotourism	4	4	4	4	
2. Present recreation, and potential for recreation	4	4	4	4	
MEDIAN OF DETERMINANTS	**4**	**3**	**3.5**		
ECOLOGICAL IMPORTANCE AND SENSITIVITY CATEGORY (EISC)	Very high	High	Very high		

TABLE 5.13 SUMMARY OF IMPORTANCE OF GOODS AND SERVICES PROVIDED AND SENSITIVITY TO CHANGES IN THEIR QUANTITY AND QUALITY (FROM SALOMON 2007H) FOR ALL RUS.
(I)= importance of goods & service provided, (ii) = sensitivity to quantity / quality changes, (iii) = importance and sensitivity synthesis, (iv) = confidence. All scores from 0 to 4.

RIVER REACH	RU	(I)	(II)	(II)
ELEFANTES : BORDER TO MASSINGIR DAM	RU A	3	3	2.5
ELEFANTES : MASSINGIR DAM	RU B	4	3	3.5
ELEFANTES : MASSINGIR TO SHINGUEDZI RIVER	RU C	3	2.5	2.75
ELEFANTES : SHINGUEDZI RIVER TO LIMPOPO RIVER	RU D	2	3	2.5
LIMPOPO : LIMPOPO RIVER TO MACARRETANE	RU E	2	2.5	2.25
LIMPOPO : MACARRATANE TO MEANDER STARTS	RU F	3	3	2.25
LIMPOPO : MEANDERING TO XAI XAI	RU G	2	3	2.5
LIMPOPO : ESTUARY	RU H	1.5	3	2.25

5.5.3 Scenarios

Four main scenarios were analysed, each with four sub-scenarios:

- Scenario 1: To evaluate if the EWR can be supplied by only supplying other demand sectors in the catchment for different levels of development. Four sub-scenarios were used to represent the various levels of irrigation expansion in the catchment.
- Scenario 2: To consider the supply of hydropower. It assess whether the environmental requirement can be supplied when water is released for hydropower and irrigation. Hydropower gets precedence over irrigation supply.
- Scenario 3: Higher priority was given to irrigation supply than hydropower. The amount and level of assurance of hydropower that can be generated was assessed while the driving force is irrigation.
- Scenario 4: After evaluating the first scenario, the fourth was required, because, in most cases the EWRs were not met. This scenario therefore considers specific environmental releases.

A maximum of 5000 ha of irrigation was modelled on the Elefantes portion of the river, which suggests that the irrigation demands did not include those for the potential sugar and biofuels project at Massingir (see Section 4.1.2 4.1.2). The ProCana project and subsequent projects probably only arose after Salomon (2007i) was complete.

TABLE 5.14 SCENARIOS MODELLED IN SALOMON (2007I)

SCENARIO	DESCRIPTION	OUTCOME
SCENARIO 1A	Inflow to Massingir dam from upstream catchment on the basis of; - No EWR releases in Elefantes Catchment - Flag Boshielo Dam raised to 822m amsl In Elefantes and Limpopo catchment; - Domestic water from Massingir dam gets highest priority - Water release to meet Irrigation downstream of the dam - Irrigation in Chokwe get water first from Limpopo and the remaining balance from Massingir dam - Irrigation in Xai- Xai area abstract from Limpopo downstream of Chokwe - 5% river loss between Chokwe and Xai-Xai irrigation - Because the flow generated by Ninham Shand already considered river losses, these losses were not separately included in Limpopo catchment upstream of Chokwe. - No flow release for hydropower - No EWR release in the catchment - Irrigation and Domestic demand for the current development condition as provided by Salomon - All irrigation demands simulated as min-max channel - Domestic supply simulated as specific demand channel - Full supply level (FSL) of Massingir Dam 125m amsl.	The failure is significant under Scenario 1a and 1b. No major difference was observed at EWR2. Scenario 1d performs best, but in Sep and Oct the supply far exceeds the EWR. In general, under Scenario 1 the environmental requirements could not be met. The dry and wet month stress curve is higher than the current riparian ecosystem can handle Thus, releasing for irrigation alone cannot meet the environmental flow requirements.
SCENARIO 1B	As for 1a, but with irrigation demand that takes into account current planned level of investment.	
SCENARIO 1C	As for 1a, but with irrigation demand that takes into account current level of investment and medium term potential investment as a result of improved water supply assurance	
SCENARIO 1D	Takes into account the long-term development vision: Elefantes irrigation is developed to its full potential irrigable area and Chokwe and Xai-Xai are rehabilitated to their original equipped condition	
SCENARIO 2 AND ITS SUB-SCENARIOS	The same as each of the sub-scenarios under Scenario 1 modified as follows: - Hydropower supply to generate a design capacity of 28MW electric power. - Minimum required electric power = 25MW - FSL of Massingir dam raised to be 125m amsl. However, because the dam also functions by attenuating peak flows during rainy season, a different initial level was used for each month in a year depending on the expected flow in that specific month - Highest priority to hydroelectric power demand next to domestic demand.	Unlike Scenario1, in this scenario the irrigation demand cannot be supplied 100% of the time. In all of the four sub-scenarios irrigation demands could only be supplied about 40% of the time. In few cases the flow at both EWR sites under Scenario 2a failed to meet the low flow requirements, but in most cases it was higher than the EWR. The uniform flow release to meet the hydropower requirement also affected the seasonality by reducing the variability of flow from month to month.

SCENARIO 3 AND ITS SUB-SCENARIOS	To test how much energy could be generated while supplying irrigation requirements (i.e. letting irrigation demand determine the generation of hydropower). The difference between Scenario 2a and Scenario 3a is the level of priority given to hydropower. Under Scenario 2a highest priority was given to hydropower next to domestic demand (water released from Massingir dam is dictated by the hydropower requirement irrespective of irrigation demand). Thus there is a possibility of releasing water above the irrigation demand downstream. Under Scenario 3a water released is mainly dictated by irrigation water demand.	Scenario 3a like Scenario 1a can supply the demand 100% of the time without failure. An energy supply comparison of Scenario 2a and Scenario 3a showed both scenarios did not meet the energy requirement. However more energy can be supplied under Scenario 2a than Scenario 3a.
SCENARIO 4	Under Scenario 1 the environmental requirements could not be met. Scenario 4 was the same as Scenario 1a, but with environmental flow requirements at the two sites imposed into the system and EWR1 having highest priority next to domestic water supply.	The requirements at EWR1 were met in both the dry and wet seasons.

5.6 Ecosystem Goods and Services (EGSA) project (DWA 2010a)

In DWA (2010a) the values of ecosystem goods and services, in relation to riverine and wetland attributes and condition, were estimated at a coarse level for the Olifants, Inkomati and Usutu/ Mhlatuze WMAs.

The main objective of the study, commissioned by DWA, was to provide information and/or an approach for the evaluation of ecosystem goods and services, in relation to riverine and wetland attributes and condition in the later Classification processes in the three WMAs. The information included spatially-explicit descriptions of aquatic ecosystem goods, services and attributes, their estimated value for significant water resources, and their relationship to ecosystem characteristics and health in the WMAs. The project explored methods to determine and extrapolate values. Changes in ecosystem services could thus be linked to changes in river and wetland attributes as a result of different scenarios.

The steps in the EGSA valuation process (with reference only to the Olifants WMA) were:

1] Delineation of the WMA using the methods established for the WRCS, i.e. nodes were established along the river to denote locations where natural conditions (e.g. ecoregion, geomorphic zones), ecosystem health (e.g. PES), degree of use and infrastructure (presence of dams), change from upstream to downstream or where information exists (EWR sites, flow gauging stations).

2] Quantification of physical attributes or characteristics of the rivers at each node using various sources (see Table 5.15) e.g. Google Earth, data from the field visits, input from specialists with particular knowledge of the area, from the resource use survey (see below), and EWR studies.

3] Rapid characterisation of 24 river and wetland sites (in terms of e.g. channel width, riparian zone width, percentage cover of different groupings of plants, etc.) was undertaken during a field visit.

4] Estimation of resource availability or supply using information from Steps 1, 2, and 4, and in some cases also from Step 5.

5] Elicitation of services and values: A resource use survey was undertaken in four villages in three quaternary catchments, by means of village head interviews and household questionnaires / interviews. These provided:

- Descriptions (quantitative and qualitative) of aquatic resource use;
- Perceptions of resource quality (e.g. water quality) and abundance (e.g. availability of fish);
- Relationships between household characteristics and demand;
- Relationships between abundance and proximity of resources (supply); and,
- The importance of the resources in local livelihoods;

6] Data augmentation: The resource use survey data were augmented with other data, such as census data, and were used to establish the relationships between use and household characteristics and between use and value.

7] Linking of use, value and availability (demand and supply): This information could in turn be linked to ecosystem condition, and the physical attributes of the relevant river (i.e. resource availability or supply), and both could be extrapolated to similar reaches and social zones.

8] Estimation of regulating services such as carbon sequestration, water purification and provision of refugia.

9] Estimation of recreation, tourism, spiritual, aesthetic and cultural values.

A summary of the physical attributes and services identified in the study, and the data and approaches used to estimate their value is given in Table 5.15.

For each resource, an equation was developed describing the relationship between level of use, type of river and household characteristics. For example, the relationship for fish catch was:

$$\text{Catch (kg)} = 14.186 * \%\ \text{traditional houses} - 2.0439.$$

This formula could be used to estimate the total fish catch (in kg) for representative river reaches and households across the study area.

TABLE 5.15 MEASURES AND SOURCES OF INFORMATION USED IN THE EGSA STUDY (DWA 2010A).

MEASURE	DATA SOURCE
"RUN OF RIVER YIELD"	WSAM
CHANNEL AND RIPARIAN ZONE WIDTH AND AREA	EWR information, Google Earth and field visits
WATER QUALITY FITNESS FOR DOMESTIC AND RECREATIONAL USE	DWA gauging station records
RIPARIAN AND CHANNEL SEDIMENT TYPES AND COVER	EWR information, Google Earth and specialist input (M Rountree);
RIPARIAN VEGETATION TYPE AND COVER	EWR information, field visits
AQUATIC VEGETATION	Field data
CRUSTACEANS (E.G. PRAWNS)	Not included as insufficient information available
PESTS AND PATHOGENS	Resource use survey: occurrence of bilharzia or other water related diseases
FISH	FROC (frequency of occurrence database), SAIAB distributional data, together with published flow and habitat preference data and expert knowledge: converted to abundance and biomass estimates
WILDLIFE:	Resource use survey: presence of hippopotamus and crocodiles
NATURAL, BEAUTY AND SUITABILITY FOR RECREATION AND SPIRITUAL USE WERE	Assumed to be directly related to river health, sensitivity and importance as provided by PES and EIS estimates (note that details of the components of PES/EIS also provide information about important attributes such as presence of alien fish such as bass (reducing PES, but increasing recreational fishing value, or presence of rare species);

5.6.1 Results

Information is available regarding the abundance of ecosystem goods (riparian vegetation, sand) per node. At a more summarised level, the values estimated per sub-WMA are provided in Table 5.16.

TABLE 5.16 SUMMARY OF RIVER VALUES PER CATCHMENT IN R MILLIONS, INCLUDING FIRST ORDER RIVERS (FROM DWA2010A)

		UPPER OLIFANTS	MIDDLE OLIFANTS	STEEL POORT	LOWER OLIFANTS	TOTALS
LENGTH OF RIVERS (KMS)		1697	3007	1106	1890	
PROVISIONING	River water for domestic use	16.5	232.1	85	54.5	388.1
	Livestock	0	45.1	10.1	10.7	65.9
	Harvested natural resources	11	28.2	10.2	17.5	66.9
	Total	27.5	305.5	105.3	82.7	521
REGULATING	Water treatment	4.5	3.1	1.4	3.8	12.8
	Carbon sequestration	0.1	1	0.2	1.4	2.7
	Total	4.6	4.2	1.5	5.2	15.5
CULTURAL	Recreation / tourism	37.4	38.4	38.8	249.6	364.2
	Property	0	0	0	5.7	5.7
	Scientific	0.1	0.2	0.1	0.1	0.5
	Total	37.5	38.5	38.9	255.4	370.3
	TOTAL	69.5	348.2	145.7	343.3	906.7

5.7 Reconciliation study (DWA 2010b, DWA 2011a-c)

The “Development of a reconciliation strategy for the Olifants River water supply system” is included here as the Classification Study made use of information from this study. For example, the updated PESs (for 11 sites from the 2001 Reserve) were used, as was the yield model developed. Given the stressed state of the Olifants River, the study investigated potential strategies (“reconciliation strategies”) to ensure a “sustainable water supply” up to 2035. Available water resources, likely future water demands, and possible interventions (dam operating rules, demand management, water transfers, dam construction, waste water re-use etc.) were investigated.

Note that according to the study: “The rule tables that were developed for the Reserve as part of the 1999 study make provision to release small floods (called freshets) from the dams during the spawning season for fish. The existing dams do not have sufficient release capacity to release these small floods, and in most cases they can be generated downstream of the dams from the tributaries and the catchment below the dam. These small floods were therefore removed from the rule tables. Provision has therefore only been made for that portion of the Reserve that is practically implementable. This will reduce the available yield of the whole system by 157 million m^3/a in order to maintain the ecological categories at their recommended levels. The full Reserve with the flood component would have reduced the available yield by 221 million m^3/a.” This is important when evaluating the Reconciliation and Classification results (see Section 5.4.1.2).

5.7.1 Results

The options for reducing water requirements and for increasing water supply considered in the reconciliation study are given in Table , together with some of the associated yield and cost information.

The study found that implementing the (lowflow) Reserve (simulated to happen in 2016 after De Hoop Dam has filled) would reduce the available yield of the whole system by 157 million m^3/a, whereas the full Reserve with floods included would reduce yield 221 million m^3/a.

TABLE 5.17 OPTIONS FOR REDUCING WATER REQUIREMENTS AND FOR INCREASING WATER SUPPLY (DWA 2011C)

Options	Yield/Saving (million m^3/a)	Cost as NPV (R million)	Capital Cost (R million)	URV (R/m^3)
Options for reducing water requirements:				
1. Eliminating unlawful Irrigation use	8.7	12	not provided	0.12
2. WC/WDM: Urban	20	285	not provided	1.48
3. Compulsory licensing	35	32	not provided	0.07
4. Water trading	35	175	not provided	0.35
Options for increasing water supply:				
5. Removal of alien Invasive Plants	15	not provided	120	0.76
6. Dam construction, adjustment:		not provided		
New dam at Rooipoort	59	not provided	1 140	2.14
Dam in Olifants Gorge: Godwinton Chedle	 100 100	not provided	 132 200	 0.14 0.20
Dam in Lower Olifants: Epsom Madrid	 286 440	not provided	 4 820 8 800	 1.58 1.71
Raising of Blyderivierspoort Dam	110	not provided	2 977	2.99
7. Water transfers:		not provided		
Transfer from East Rand (ERWAT)*	38.3	not provided	1 123	7.31
Transfer from Vaal Dam *	160	not provided	3 500	3.60
Transfer from Crocodile (West): Pienaars - Flag Boshielo Dam Crocodile - Flag Boshielo Dam Crocodile - Mogalakwena**	 30 60 25	not provided	 1 268 3 926 3 728	 3.82 6.43 14.51
Transfer from Massingir Dam	50	not provided	2 000	4.85
8. Treat and reuse sewage effluent in mines, at Mokopane and Polokwane	11			
9. Desalination and transfer of seawater	100	not provided	12 970	44.45
10. Using treated acid mine drainage (AMD) in Upper Olifants	21	not provided	not provided	not provided
11. Development and use of groundwater	not provided	not provided	not provided	not provided
12. Refinements to system operating rules	not provided	not provided	not provided	not provided
13. Use of groundwater resources	35			

* Excludes cost of early augmentation of the Vaal System. (LHFP2 (URV R6.14/m^3))

** This option could replace the currently planned ORWRDP-Phase 2B

All cost estimates based on 2010 prices.

5.8 Classification (WRCS) 2011-2014

The purpose of the Classification of the Olifants Basin was to determine the Management Classes for the various sub-basins (see Section 2.2.2), and the underlying configuration of ecological conditions for each reach within each sub-basin. The Classification study used the WRCS (DWAF 2007): The basin was delineated and nodes and IUAs were established for which key information such as EWRs and ecosystem services were provided, and various scenarios were modelled.

The Classification study made use of the information from the Comprehensive and Intermediate EWR assessment (Table 5.1) as a basis for the EWRs for the PESs, RECs and scenarios. EWRs were estimated for an additional nine sites, for the most part at a Rapid 3 level (Table 5.1). The additional sites were necessary in order to allow for extrapolation of EWRs to the nodes established through the WRCS. Initial EWR estimates for the new sites were obtained from the Desktop Model, translated to depths using stage-discharge relationships, examined and adjusted by the specialists. Updated hydrology from the 2009 Olifants River Water Resources development Project (ORWDP), Phase 1 and 2 (DWA, Directorate National Water Resource Planning, 2009) and the Reconciliation study was used. All sites considered are displayed in Figure 5.4.

The Classification made use of the EGSA project (DWA 2011e) as a basis for the estimation of the value of ecosystem services but expanded and adjusted these as required.

The study analysed six scenarios, which included the reconciliations strategies (Section 5.7) in terms of;

1] Achieving the PES or REC,
2] Effects on GDP and other economic measures, and
3] Effect on ecosystem services.

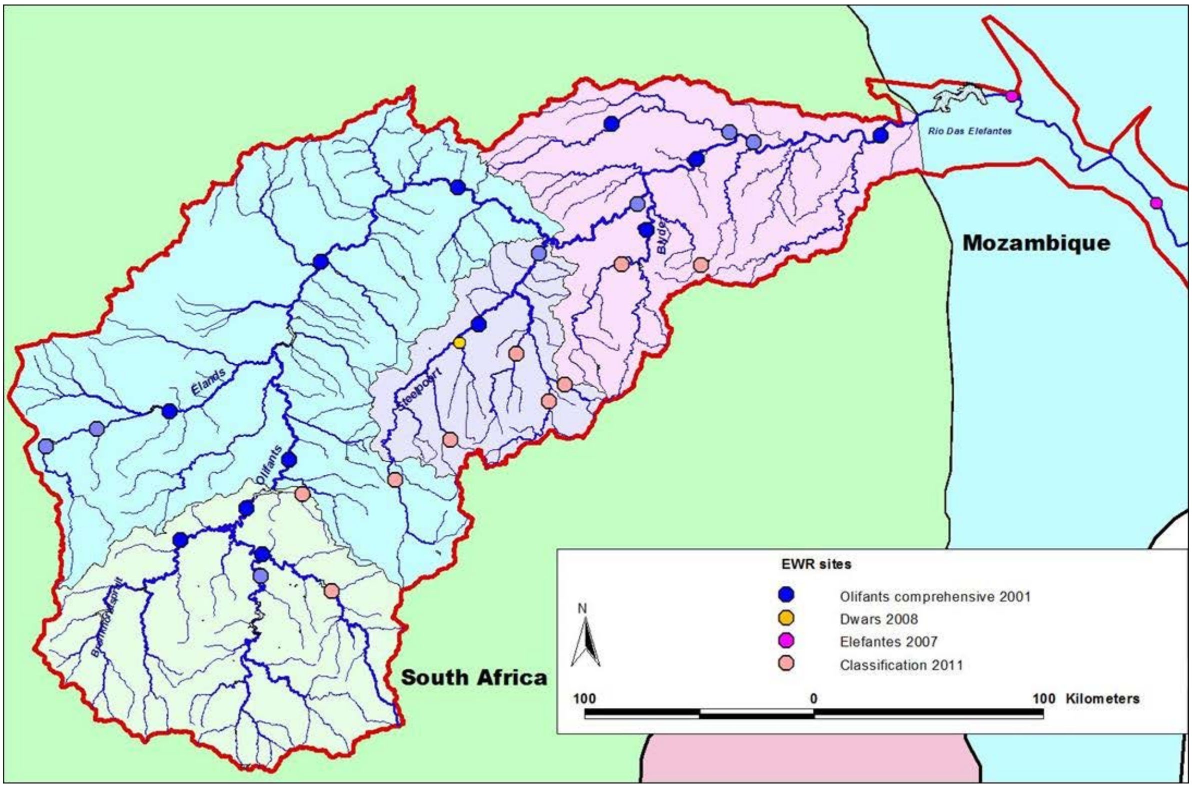


Figure 5.4 Comprehensive EWR sites (blue), the Dwars EWR (orange), the Elefantes EWR study (dark pink), and those added for Classification (pink) in 2011.

5.8.1 Environmental Water Requirements

The EWR requirements for all sites as provided by the Classification study are given in Table 5.18. Note that the yield modelling to see if the PES / REC and other system requirements could be met in the various scenarios, did not includes freshets and floods.

The two scenarios proposed (see Section 5.8.3) could only provide the PES, and so in Table 5.18, the lowflow requirement is given for the PES, rather than the REC. These numbers were checked as far as possible with the original Reserve figures, but not all ecological categories were available. EWRs at each node are provided in Appendix C.

5.8.1.1 Results

TABLE 5.18 RECOMMENDED EWRS FROM CLASSIFICATION STUDY[16].

Total EWR for REC is given, while for the maintenance lowflows only, the EWR for PES is given (as the two proposed scenarios used PES). (n/a=not available). Sorted in alphabetic quaternary catchment (quat) order.

Quat	River	Site	PES 2011	REC 2011	EWRs					
						REC		PES		
					nMAR 2011	Total EWR % nMAR	Total EWR MCM (calc)	Lowflow EWR % nMAR	Lowflow EWR MCM (calc)	ML* m^3/s
B11J	Olifants	IFR1	D	D	184.52	18.63**	34.38	4.70	8.67	0.448
B12C	Klein Olifants	OLI-EWR1	C	C	44.46	28.86	12.83	18.85	8.38	
B12E	Klein Olifants	IFR3	C	C	81.54	27.00	22.02	12.72	10.37	0.229
B20J	Wilge	IFR4	C	B	175.50	29.90	52.47	12.16	21.34	0.918
B31C	Upper Elands	IFR6c	C	-	33.50	31.2	10.45	12.34	4.13	
B31D	Middle Elands	IFR6b	C	-	42.30	23.1	9.78	n/a		
B31G	Lower Elands	IFR6	D	D	60.30	17.90	10.79	6.32	3.81	0.204
B32A	Olifants	IFR2	C	B	500.63	23.80	119.15	12.53	62.73	1.643
B32A	Kranspoortspruit	OLI-EWR3	B	A/B	4.71	46.01	2.17	30.81	1.45	
B32D	Olifants	IFR5	C	C	570.98	19.10	109.06	9.96	56.87	2.039
B41B	Steelpoort	OLI-EWR2	C	C	63.46	29.78	18.90	20.78	13.19	0.830
B41F	Klip	OLI-EWR4	C	B/C	5.20	27.49	1.43	17.18	0.89	
B41H	Dwars	DWA-EWR1	B/C	B/C	31.43	25.91	8.14	19.41	6.10	0.190
B41J	Steelpoort	IFR9	D	D	120.17	15.20	18.27	7.97	9.58	0.720
B41K	Steelpoort	IFR10	D	D	336.63	12.10	40.73	7.43	25.01	1.579
B42B	Dorpspruit	OLI-EWR9	C/D	C/D	63.19	19.28	12.18	11.99	7.58	
B42D	Upper Spekboom	OLI-EWR6	C	B/C	28.04	33.52	9.40	23.67	6.64	
B42G	Watervals	OLI-EWR5	C	C	36.39	23.48	8.54	15.47	5.63	0.765
B51G	Olifants	IFR7	E	D	726.52	12.70	92.27	3.84	27.90	1.447
B60H	Ohrigstad	OLI-EWR8	C	C	65.49	26.35	17.26	16.59	10.86	0.238
B60J	Blyde	IFR12	B/C	B	383.70	34.50	132.38	27.90	107.05	3.270
B71B	Olifants	IFR8	D	D	813.04	15.20	123.58	4.30	34.96	1.852
B71J	Olifants	IFR11	E	D	1321.80	13.70	181.09	11.20***	148.04	7.424
B72D	Olifants	IFR13	C	C	1760.70	23.60	415.53	11.36	200.02	7.144
B72H	Selati	IFR14a	C	C	52.20	31.20	16.29	19.59	10.23	0.264
B72K	Selati	IFR14b	E	C	72.74	24.80	18.04	11.99	8.72	0.302
B73A	Klaserie	OLI-EWR7	B/C	B	25.54	38.95	9.95	27.69	7.07	
B73C	Olifants	IFR15	C	-	n/a					
B73H	Olifants	IFR16/17	C	B	1916.90	21.60	414.05	10.75	206.07	7.474

* Awaiting clarification as to "ML" and the numbers provided.
** The original 2001 EWR was 26%, but this was reduced to 18.63 in the original DWAF 2001 signing off process.
*** This differs fairly substantially from 2001 EWR which was approximately was 6.309.

[16] *Sites prefixed with "IFR" are from the 2001 comprehensive Reserve study, with "OLI-EWR" are additional sites from the Classification study, with "M-EWR" are those from the Elefantes intermediate study and the Dwars intermediate site is named DWA-EWR1.*

5.8.2 Ecosystem services

5.8.2.1 Results

Initial results of levels of ecosystem services provision in the Upper, Middle, Lower Olifants and Steelpoort sub-WMAs are provided in Table 5.19, with aggregate values per IUA and scenario in Table 5.21.

TABLE 5.19 DETAILS OF ECOSYSTEM SERVICES VALUES IN THE OLIFANTS SUB-WMAS
(from Prime Africa, 2011)

	ECOSYSTEM SERVICE	UPPER OLIFANTS	MIDDLE OLIFANTS	STEELPOORT	LOWER OLIFANTS	WMA	TOTAL**	TOTAL***
	Water shadow price					280	280	280.0
PROVISIONING	Domestic water use*	16.5	232.1	85	54.5		388	388.1
	Grazing	-	31.3	10.1	12.8		72	54.2
	Livestock watering*	0	45.1	10.1	10.7		66	65.9
	Harvested products*	11	28.2	10.2	17.5		67	66.9
	Total	**27.5**	**336.7**	**115.4**	**95.5**		**575**	575.1
REGULATING	Water regulation*	4.5	3.1	1.4	3.8		13	12.8
	Carbon Sequestration*	0.1	1	0.2	1.4		3	2.7
	Total	**4.6**	**4.1**	**1.6**	**5.2**		**16**	15.5
CULTURAL	Tourism*	37.4	38.4	38.8	249.6		364	364.2
	Recreation	5.1	5.3	5.3	34.3		50	50.0
	Aesthetic value	0	0	0	5.7		6	5.7
	Aesthetic value					22	22	22.0
	Education*	0.1	0.2	0.1	0.1		1	0.5
	Total	**42.65**	**43.88**	**44.24**	**289.75**		**421**	442.4
	Grand Total	**74.75**	**384.68**	**161.24**	**390.45**		**1 319**	**1 313.0**

* The same as EGSA results.
** Total as in Prime Africa (2011)
** Calculated total

5.8.3 Scenarios

5.8.3.1 Results

The proposed management classes for the WMA are provided in Table 5.20. These would be provided for by either of the possible future scenarios 4 and 6. Details of the node / reach level configuration and EWRs for these management classes are provided in Appendix C.

TABLE 5.20 PROPOSED MANAGEMENT CLASSES FOR THE OLIFANTS WMA
(from DWA 2014)

	INTEGRATED UNIT OF ANALYSIS (IUA)	PROPOSED MANAGEMENT CLASS
1	Upper Olifants River catchment	III
2	Wilge River catchment area	II
3	Selons River area including Loskop Dam	II
4	Elands River catchment area	III
5	Middle Olifants up to Flag Boshielo Dam	III
6	Steelpoort River catchment	III
7	Middle Olifants below Flag Boshielo Dam to upstream of Steelpoort River	III
8	Spekboom catchment	II
9	Ohrigstad River catchment area	III
10	Lower Olifants	II
11	Ga-Selati River area	III
12	Lower Olifants within Kruger National Park	II
13	Blyde River catchment area	I

The overall conclusion of the Classification was that two (Scenarios 4 and 6) of the six scenarios considered could be recommended for consideration by the Minister. The two scenarios are identical except from the fact that one (Scenario 6) requires that additional water be made available through the treatment of mine effluents that are then released into the Upper Olifants River. According to DWA (2012a), these flows could increase the ecological categories at IFR5 and IFR7, provided the treatment is successful.

Both Scenario 4 and 6 meet the EWR to maintain the 2010/2011 PES (apart from where PES is below D, in which case a D was applied instead). The scenarios that met the requirements for REC were considered too expensive and /or unrealistic to implement. However, even under Scenario 4 and 6, not all flow requirements could be met at all times, particularly at IFR4 (Wilge River) and IFR16/17 (Olifants in Kruger National Park):

- EWR4: The best ecological category that could be achieved was a **D** (PES 1999= B, PES 2010= C, REC = B);
- EWR16/17: The best ecological category that could be achieved was a **B/C**, (PES 1999= B, PES 2010= C, REC = B).

Under both Scenario 4 and 6, ecosystem service benefits and contribution to GDP were estimated to increase from current levels. Overall results for the WMA are shown in Figure 5.5. Note that the cost of yield augmentation in both scenarios is expected to be reflected in the price of water.

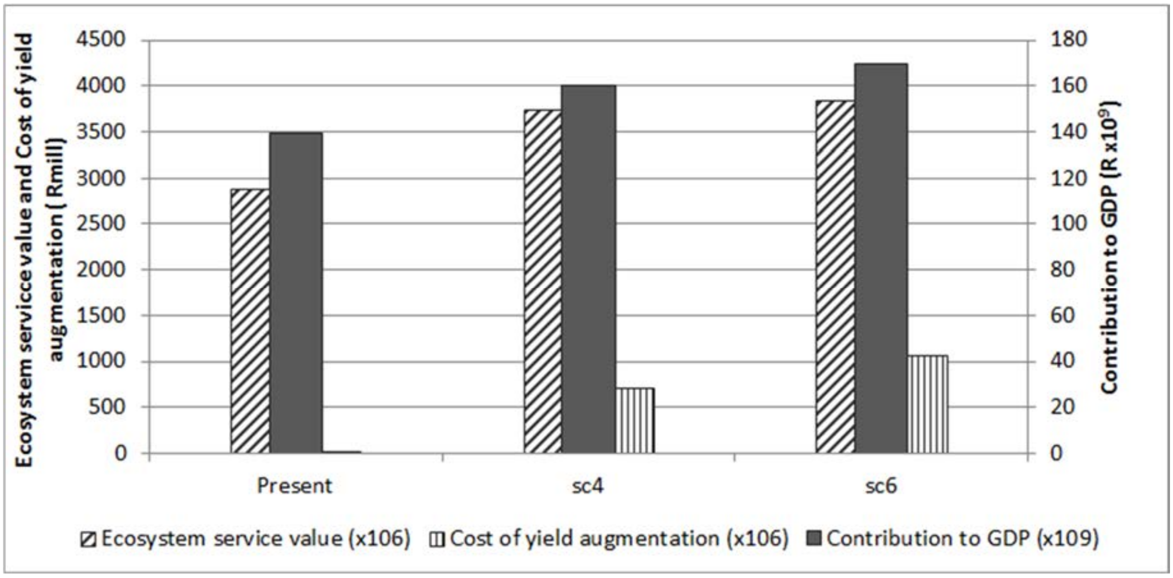


Figure 5.5 Summarised economic values for the two preferred scenarios from the Classification study. (from DWA, 2012a)

TABLE 5.21 DISTRIBUTION OF CHANGES IN ECOSYSTEM SERVICES PER IUA AND SCENARIO, AND IN ECOSYSTEM SERVICES ADJUSTED GDP IN R MILLION PER YEAR (FROM DWA, 2012A)

	CHANGE IN ECOSYSTEM SERVICES		ECOSYSTEM-SERVICES ADJUSTED GDP	
IUA	Scenario4	Scenario6	Scenario4	Scenario6
IUA1	70	79	10652	10596
IUA2	25	28	4110	4088
IUA3	61	70	1104	1098
IUA4	78	89	1956	1946
IUA5	127	144	2553	2540
IUA6	80	91	718	715
IUA7	83	95	2343	2331
IUA8	38	44	591	588
IUA9	27	31	482	480
IUA10	77	87	283	281
IUA11	37	43	2302	2289
IUA12	112	127	947	942
IUA13	25	28	307	306
"POLOKWANE ZONE"[17]			2644	2630

[17] *No definition for this zone nor any reason for its creation could be found in the documentation sourced for this review.*

5.9 Overall summaries

The natural MAR (nMAR) and the PES from the time of the study (or from the 1999 desktop study and the 2011 PES update where unavailable) are provided for each of the EWR sites in the Olifants Basin (Table 5.18). The REC and the associated EWRs are also provided. The location of the sites is given in Figure 4.1.

Note:

As per current Reserve template formats, these percentages EXCLUDE the volume of water contained in floods with a return period of 2 years or greater, which can represent up to 40% nMAR.

The EWRs range extensively across sites: 22 to 39 % nMAR to maintain a B-category river, 19 to 31 % nMAR to maintain a C-category river, and 12 to 19% nMAR to maintain a D-category river (Figure 5.6). The three highest EWRs, in terms of %vMAR, are:

- For the Kranspoortspruit (46%; A/B-category from Classification);
- The Klaserie (39%; B-category from Classification);
- The Blyde (35%; B-category from Classification).

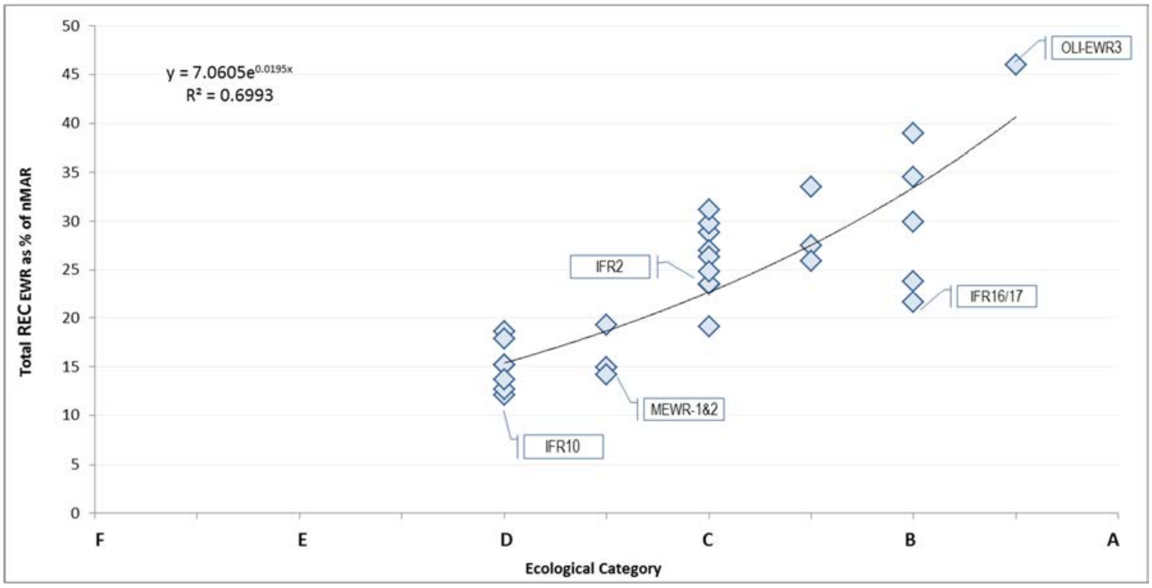


Figure 5.6 Relationship between the recommended Ecological Category and the EWR as a percentage of natural MAR, for the Olifants / Elefantes Reserves.

The relative percentages of nMAR across the basin help to identify the reaches that are important for maintaining condition in downstream sections. For example, the Klaserie River's confluence with the mainstem Olifants River is just upstream of where the Olifants River enters the Kruger National Park, and presumably the Klaserie River is an important contributor to the flow through the park and into Mozambique. The Blyde River is important for maintaining the condition of the Lower Olifants River both in terms of it contribution to total flow but also as a refuge and reseeding area.

TABLE 5.22 EWRS FOR THE DRIEST MONTH FROM THE OLIFANTS BASIN (DWAF 2001A-C).

ZONE	RIVER	SITE	MONTH	EC	RECOMMENDED MCM	NMAR OF DRIEST MONTH	% OF NMAR OF DRIEST MONTH	TOTAL EWR AS % OF TOTAL NMAR
UPPER	Olifants	IFR1	Sep	C	0.540	Monthly natural flow not available		26.00
	Olifants	IFR2	Sep	B	2.460			23.77
	Klein Olifants	IFR3	Sep	C	0.470			27.01
	Wilge	IFR4	Sep	B	1.300			29.94
MIDDLE	Olifants	IFR5	Sep	C	3.630	11.07	32.81	24.65
	Elands	IFR6	Sep	D	0.181	1.38	13.15	17.86
	Elands	IFR6b	Sep	C	0.171	0.67	25.56	23.11
	Elands	IFR6c	Sep	B	0.120	0.46	26.03	31.19
	Olifants	IFR7	Sep	D	1.750	14.61	11.98	12.68
	Olifants	IFR8	Sep	D	1.814	15.28	19.77	15.22
LOWER	Steelpoort	IFR9	Sep	D	0.674	2.45	27.47	15.17
	Steelpoort	IFR10	Sep	D	1.555	6.59	23.61	12.10
	Olifants	IFR11	Sep	D	3.240	18.51	17.51	13.70
	Blyde	IFR12	Oct	B	5.625	12.11	46.45	34.49
	Olifants	IFR 13	Sep	B	20.740	39.38	52.67	23.57
	Selati	IFR14a	Nov	C	0.337	1.17	28.83	17.12
	Selati	IFR14b	Nov	D	0.259	n/a		24.82
	Olifants	IFR15	n/a					
	Olifants	IFR16/17	Sep	B	18.140	41.80	43.40	21.63
LOWER	Dwars	DWA-EWR1	Sep	B/C	0.280	0.6334	44.21	25.92
MOZAM-BIQUE	Elefantes	M-EWR-1	Sep	C	19.107	57.30	33.35	14.90
	Limpopo	M-EWR-2	Sep	C	21.724	93.54	23.22	14.18

TABLE 5.23 EWRS FOR THE DRIEST MONTH FROM ASSESSMENTS DONE IN SOUTHERN AND EASTERN AFRICA

(from King and Brown 2013).

RIVER	CONDITION	NATURAL	MONTH	EFLOW	UNITS	% NATURAL MONTHLY	REFERENCE
OKAVANGO (ANGOLA, NAMIBIA, BOTSWANA)	B	114	Dry season	101	MCM	88.59	King and Brown. (2009)
	C	114	Dry season	93	MCM	81.57	
	D	114	Dry season	21	MCM	18.42	
	B	35	Dry season	20	MCM	57.14	
	C	35	Dry season	15	MCM	42.85	
	C	35	Dry season	19	MCM	54.28	
	B	114	Dry season	101	MCM	88.59	
	D	114	Dry season	21	MCM	18.42	
RUAHA (TANZANIA)	C/D	10.8	November	1.87	m^3/s	17.31	WWF (2010)
ELEPHANTES (MOZAMBIQUE)	C	21.89	September	7.3	m^3/s	33.34	Weiler (2007)
	C	35.71	September	8.3	m^3/s	23.24	
WAMI (TANZANIA)	B	4.2	October	4.3	m^3/s	102.38	Sarmett and Anderson (2008)
	B	15	October	10	m^3/s	66.66	
	B	13.3	October	13.3	m^3/s	100.00	
	B	13.9	September	6.6	m^3/s	47.48	

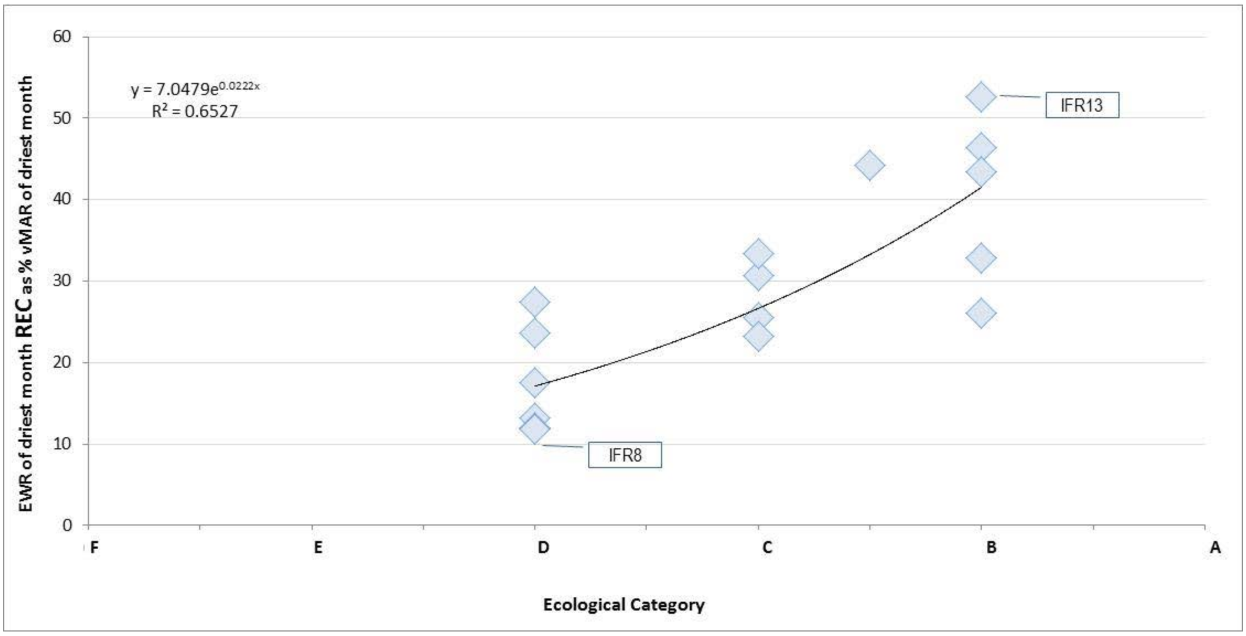


Figure 5.7 Lowflow for the lowest flow month as a percentage of naturalized monthly flow the lowest flow month (for Olifants sites in Table 5.22)

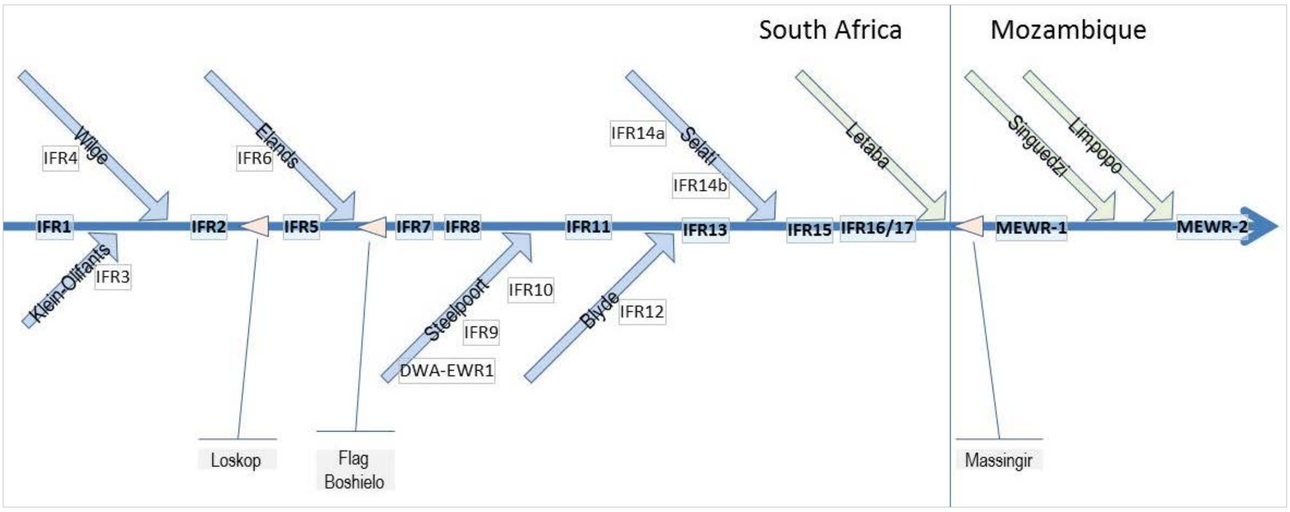


Figure 5.8 Mainstem flow (MCM) for the Olifants and Elefantes, together with schematic of the river with main tributaries and EWR sites.

5.10 Reports that will be used to generate the information listed in Table 1.2

Table 5.24 lists the data requirements presented in Table 1.2, and indicates which (if any) of the existing studies could potentially be used to provide each set of data. Table 5.24 also list whether or not the RESILIM-O, S&EWR team have the reports or information/data in hand.

TABLE 5.24 SOURCES OF INFORMATION FOR THE POPULATION AND CALIBRATION OF THE DRIFT-DSS

INFORMATION REQUIRED	SOURCE	IN HAND?
DELINEATION, SHOWING SIMILARLY BETWEEN SITES IN TERMS OF HYDROLOGY, WATER QUALITY, HABITAT AND BIOTA.	DWAF (2001a-c) Reserve reports	Yes
	DWA (2010b, 2011a-c) reconciliation study reports	Yes
HYDROLOGICAL TIME-SERIES DATA USED IN EXISTING STUDY(IES)	DWAF (2001a-c) Reserve reports	No
	Salomon (2007a-i) Elefantes EWR reports	No
	Stassen (2008a,b) Dwars Reserve reports	No
EWR VOLUMES LINKED TO ECOSYSTEMS CONDITION AS A PERCENTAGE OF NATURAL ANNUAL AND/OR MONTHLY VOLUME	DWAF (2001a-c) Reserve reports	Yes
	Salomon (2007a) Elefantes EWR reports	Yes
	Stassen (2008a) Dwars Reserve reports	Yes
ESTIMATES OF EXTENT OF CHANGE IN INDICATORS LINKED TO PERCENTAGE OF NATURAL ANNUAL AND/OR MONTHLY VOLUME	RQO project	No
	River Health Programme	No
DISTRIBUTIONAL/COMMUNITY DATA FOR VEGETATION, FISH, INVERTEBRATES	DWAF (2001a-c) Reserve reports	Yes
	Desktop PES Update (2014b)	Yes
LIFE HISTORY DATA FOR VEGETATION, FISH, INVERTEBRATES	DWAF (2001a-c) specialist reports	Yes
	Salomon (2007a-i) Elefantes specialist reports	Yes
	Stassen (2008) Dwars specialist reports	Yes
MONITORING DATA LINKING THE PHYSICAL AND CHEMICAL NATURE OF THE RIVER ECOSYSTEM, AND THE BIOTA PRESENT, TO FLOW	River Health Programme (DWAF 2001)	Old data
MOTIVATIONS OF SEASONAL DEPTHS AND VELOCITIES FOR MAINTAINING HABITAT BIOTA	DWAF (2001a-c) Reserve and specialist reports	Yes
DELINEATION OF LATERAL ZONES IN RIPARIAN VEGETATION	DWAF (2001a-c) Reserve reports	Yes
LOWFLOW 'STRESS TABLES' FOR INDICATORS USED IN HFSR STUDIES	DWAF (2001c): IFR 12 stress tables	Yes
	Salomon (2007?) Elefantes stress tables	No
	Stassen (2008?) Dwars stress tables	No
HUMAN DEPENDENCY ON RIVER RESOURCES	DWAF (2001d) (Social Report)	Yes
	DWA (2010a) EGSA report	Yes
VALUED/RARE RIVER RESOURCES/SPECIES	DWA (2010a) EGSA report	Yes
CRITERIA FOR RESOURCE USE, SUCH AS E. COLI CONCENTRATIONS IN DRINKING WATER	Water Quality Guidelines: SANS 241: 2011	Yes
THRESHOLDS FOR RESOURCE USE, SUCH AS WATER QUALITY CRITERIA OF DRINKING WATER	Water Quality Guidelines: SANS 241: 2011	Yes

6 Approach to Activity 3

The approach to Activity 13 has two distinct phases.

Phase 1: Population and calibration of the biophysical component of the DRIFT DSS using existing studies/reports

Phase 2: Capture Water Resource Ecosystem Services (WATRES) and analyse scenarios.

Phase 1 aims to populate and calibrate the DRIFT-DSS for one site using the data from existing studies/reports. This phase is not about validation or verification of the Reserve information already provided for that site, but rather about ensuring that the DRIFT-DSS generates comparable outcomes in terms of flow regimes and overall river condition, and if possible in terms of expected outcomes for individual indicators.

Phase 2 aims to augment the DRIFT-DSS with new information, generated by ecosystem services workpackage, which captures a more comprehensive suite of ecosystem services concerns than was the case in the past. In this phase the main aim is to evaluate the extent to which ecosystem services (as captured using a WatRES type of approach) can be incorporated into Reserve-type determinations in order to provide outputs that are more meaningful in terms of the uses and values that society places on riverine ecosystems. This information is not intended to 'replace' the existing Reserve information for the site.

6.1 Phase 1: Population and calibration of the DRIFT-DSS using existing EWRs

The activities envisaged for Phase 1 of the RESILIM-O-EWRS are presented in Figure 6.1.

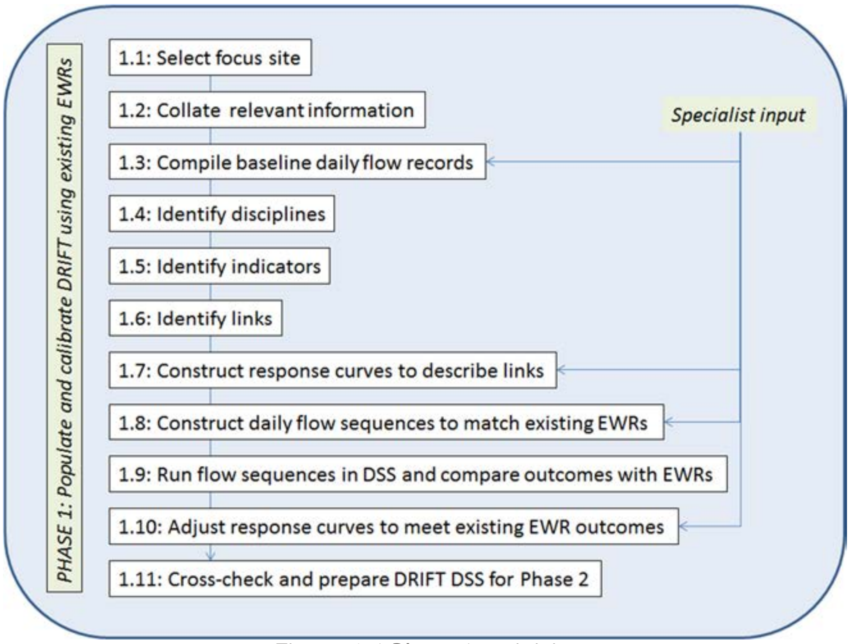


Figure 6.1 Phase 1 activities

6.1.1 Select focus site

In year 1, the RESLIM-O, S&EWR will focus on one site in the Olifants Basin. The aims of RESLIM-O, S&EWR require that this site is located where previous EWR work was undertaken. However, the focus site will be selected in conjunction with other RESILIM-O work packages, and will thus include wider considerations than those for RESLIM-O, S&EWR alone. Section 7 evaluates existing EWR sites in the basin using criteria of relevance to the RESLIM-O, S&EWR and provides a short-list of recommended sites for discussion with the other work packages.

6.1.2 Collate all relevant information

Existing information of relevance to the calibration of DRIFT for the focus site, including raw data, will be collated. This includes the sorts of information discussed in this report (Table 5.24) plus:

- Scientific papers on the study river or on a river(s) with similar characteristics
- DRIFT response curves for river(s) with similar characteristics
- Life history information for fauna and flora found at the site.

6.1.3 Compile baseline daily flow records

The DRIFT-DSS requires daily data (≥30 years) that describe a baseline situation. Typically, baseline is represented by the time at which the study takes place, i.e., “present day”, but it can be any time provided there are sufficient data/memories to allow for the population of the DSS based on that time.

These data will be compiled in the Hydrology work package.

6.1.4 Identify disciplines

In Phase 1, only biophysical disciplines will be considered. These will conform to the disciplines included in previous EWR studies.

6.1.5 Identify indicators

Indicators that describe the characteristics of the focus site will be identified for each of the disciplines selected in Section 6.1.4 from the information provided for previous EWR studies.
An example of this information is provided in Appendix A.

6.1.6 Identify linked indicators

The information in the previous EWR studies will be interrogated to determine to which ‘driver’ indicators each ‘response’ indicator is linked. These are known as ‘linked indicators’. In many cases, this is possible, particularly for links to flow indicators (see Appendix A0) for an example. However, additional linked indicators may or may not be identified based on other literature, such as life-history studies.

6.1.7 Construct response curves to describe links

This is the most difficult activity in Phase 1. Response curves will need to be constructed for the link between each response indicator and its driver indicators. In this regard the method used in the previous EWR studies is an important consideration. HFSR studies provide considerably more information that can assist in the construction of response curves than do BBM or Desktop studies. In order to construct the curves, it is highly likely that information from previous studies will need to be augmented with information from other sources, the scientific literature, EWR studies on similar rivers, and databases, such as FRAI (Kleynhans 2007) and Fishbase (Froese and Pauly 2014, www.fishbase.org).

6.1.8 Construct daily flow sequences to match existing EWRs

In order to compare the outcomes from the DRIFT-DSS to those from the EWR studies, the flow sequences used must match, as far as possible, those used in the EWR studies. For the most part, these are monthly flow sequences, so once constructed they will need to be disaggregated into daily format before being used in the DSS.

These data will be compiled by the Hydrology work package.

6.1.9 Run flow sequences in DSS and compare with existing EWRs

The DRIFT-DSS results for the focus site will be compared with the existing EWR in terms of:

- Ecosystem condition and annual volume, and monthly distribution of flows
- Ecosystem condition and values for individual indicators.
- Expected changes in individual biotic indicators, where possible.

Examples of the relationships between ecosystem condition and annual volume are provided in Section 5.8.

They will also be checked for coherency and consistency, which is a routine part of DRIFT-DSS calibration.

6.1.10 Adjust response curves to meet existing EWR outcomes

Depending on the outcome of Step 1.9, individual response curves may require some adjustment to align with the EWR results at the focus site.

6.1.11 Cross-check and prepare DRIFT-DSS for Phase 2

The outputs will be cross-checked and a user-friendly summary prepared for presentation to the ecosystem services team.

6.2 Phase 2: Capture WATRESs and analyse scenarios

The activities envisaged for Phase 2 of the RESILIM-O-EWRS are presented in Figure 6.2.

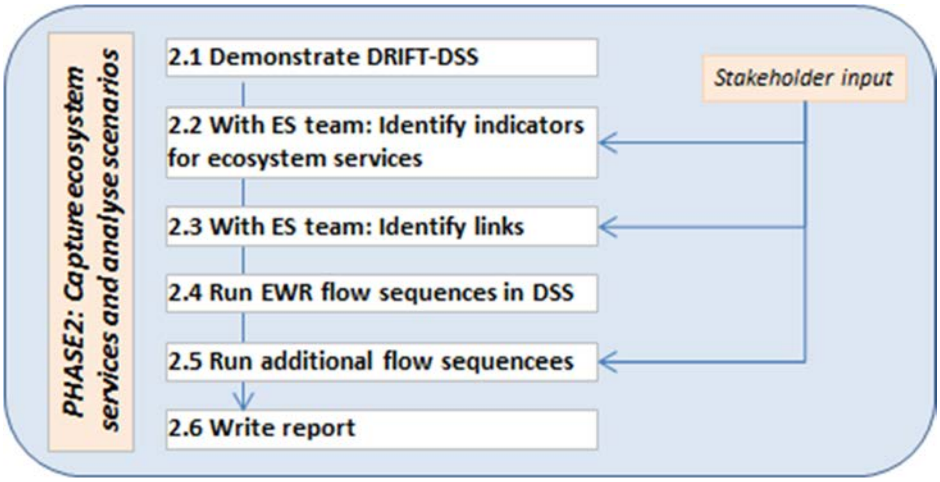


Figure 6.2 Phase 2 activities

6.2.1 Demonstrate DRIFT-DSS to WATRES workpackage

The DRIFT-DSS populated and calibrated in Phase 1 will be demonstrated to the team members involved with the ecosystem services workpackage. The aim of this exercise is to increase understanding of the process of DRIFT, the mechanics of the DSS, the aspects of the ecosystem (indicators) for which predictions can be made based in existing information, and to facilitate an analysis of the gaps between existing information and the outputs required for RESILIM-O.

6.2.2 Identify additional indicators to represent WATRESs

The process of eliciting the ecosystem services will be undertaken by the ecosystem services workpackage. The SW team should have some input into this process, in order to ensure that indicators can be reasonably seamlessly included in DRIFT. Thereafter, in consultation with the ecosystem services team, the ecosystem services indicators will be finalised and entered into the DSS.

6.2.3 Identify linked indicators

Together with the ecosystem services team, links to biophysical (and / or other ecosystem services) indicators will be established for each ecosystem services indicator. For instance:

- A WATRES indicator such as "Sand-mining" may be linked to geomorphological indicators that describe the quantity, condition and location of sand deposits in the river, such as "Sandbars" and the amount of "Clay and mud".
- A WATRES indicator such as "Potable Water Supply" may be linked to water quality variables that describe the suitability of the water for human consumption, such as concentration of "E. Coli" or "Heavy Metals".
- A WATRES indicator such as "Fish Catch" may be linked to fish indicators that represent palatable fish that are targeted by fishermen/women, such as abundance of "Trout".

If additional biophysical indicators are required (in addition to those from existing EWR studies) are required in order to adequately manage the ecosystem services indicator links, these will be added.[18]

6.2.4 Construct response curves

Response curves will need to be constructed for the link between each WATRES indicator and its linked indicators. These curves will be constructed by the ecosystem services team, in collaboration with the RESILIM-O, S&EWR team.

6.2.5 Run EWR flow sequences in DSS

The DRIFT-DSS will be re-run using the flow sequences from the EWR studies (Section 6.1.9), in order to evaluate the outcomes for the ecosystem services indicators and make adjustments if necessary.

6.2.6 Run flow sequences for additional scenarios in DSS

The DRIFT-DSS can then be used to explore additional scenarios related to *inter alia*, climate change.

[18] *If specialist input is needed to compile these curves, there may be budget implications, as the current budget only covers for specialist input on existing indicators.*

7 Recommendations for RESILIM-O, S&EWR focus site(s)

This Section ranks the existing EWR sites in the basin in terms of their suitability for use in RESILIM-O, S&EWR, and provides a short-list of sites recommended for use as the focus site in Activity 3.

The focus site will be selected after consideration of the recommendations from several RESILIM workpackages.

7.1 Summary of information available at EWR sites

The sites and the information used are listed in Table 7.1. Only EWR sites from the Olifants Comprehensive Reserve determination studies (DWAF 2001a-c), the Dwars Intermediate Reserve determination study (Stassen 2008), and the Elefantes Intermediate Reserve determination studies are included (Salomon 2007a), as sites where Desktop and Rapid level Reserves were undertaken do not provide sufficient information for DRIFT-DSS.

Table 7.1 also indicates the 2001 sites that could no longer be accessed in 2010 (during the reconciliation study; DWA 2011b).

7.2 Ranking of EWR sites

Table 7.2 provides a ranking of the sites from the perspective of using the data at these sites to populate and calibrate the DRIFT-DSS. Sites where the results were extrapolated from another site were excluded from the ranking. The sites in Mozambique were also excluded from consideration as focus sites for year 1, as it is envisaged that the daily hydrology will not be available within year 1.

The criteria used to rank the remaining sites were:

- The level of Reserve assessment. Generally, comprehensive studies yield more detailed information than do intermediate studies.
- The EWR method used. The type and detail of the information provided for studies that used the HFSR method is superior to that where BBM was used. The type and detail of information provided in each is illustrated in Appendix A.
- The number of disciplines included in the study. At minimum, these should include: hydrology[19], hydraulics, water quality, geomorphology, riparian vegetation, macroinvertebrates and fish.
- The confidence in the hydrological data used as these are the basis for any EWR study.

[19] *The confidence ranking for hydrology given at the time of the study is reported but the original hydrological data are not available for any of the sites.*

TABLE 7.1 INFORMATION USED / AVAILABLE FOR ASSESSMENT OF EWRS FOR EACH SITE.

*Confidence indications under each discipline are given where available (L=lowflow, H=highflow / floods, 0-very low, 5=very high), otherwise * indicates that the information was used and is available in specialists reports.*

Sites	Quat	Rivers	Level	Method	Hydro	Hydraulics	Geo-morphology	Water Quality	Riparian Vegetation	Aquatic invertebrates	Fish	Access issues (2010; DWA 2011b)
IFR1	B11J	Olifants	Ext from IFR2	BBM	L: 3 H:3	L: 4 H:2	L: 2 H:3	L: 2 H:1	L: 3 H:2	L: 4 H:4	L: 4 H:4	
IFR2	B32A	Olifants	Comprehensive	BBM	L: 3 H:3	L: 4 H:3	L: 2 H:4	L: 0 H:0	L: 2 H:2	L: 4 H:4	L: 4 H:4	X
IFR3	B12E	Klein Olifants	Comprehensive	BBM	L: 3 H:3	L: 4 H:2	L: 2 H:2	L: 2 H:2	L: 2 H:3	L: 3 H:1	L: 3 H:3	
IFR4	B20J	Wilge	Comprehensive	BBM	L: 3 H:3	L: 4 H:2	L: 2 H:4	L: 0 H:0	L: 2 H:4	L: 4 H:3	L: 4 H:4	X
IFR5	B32D	Olifants	Comprehensive	BBM	L: 2 H:2	L: 5 H:5	L:-- H:2	L: 3 H:4	L: 2 H:2	L: 4 H:3	L: 4 H:3	
IFR6	B31G	Lower Elands	Comprehensive	BBM	L: 2 H:2	L: 4 H:2	L: - H:4	L: 3 H:4	L: 2 H:4	L: 4 H:2	L: 4 H:3	
IFR6b	B31D	Middle Elands	Ext from IFR6	BBM	-	-	-	-	-	-	-	
IFR6c	B31C	Upper Elands	Ext from IFR6	BBM	-	-	-	-	-	-	-	
IFR7	B51G	Olifants	Comprehensive	BBM	L: 2 H:2	L: 3 H:4	L: - H:4	L: 2 H:2	L: 2 H:4	L: 3 H:2	L: 4 H:3	X
IFR8	B71B	Olifants	Comprehensive	BBM	L: 2 H:2	L: 4 H:3	L: - H:4	L: 2 H:2	L: - H:3	L: 4 H:4	L: 4 H:3	
IFR9	B41J	Steelpoort	Comprehensive	BBM	L: 2 H:2	L: 4 H:3	L: 2 H:3	L: 1 H:1	L: 2 H:4	L: 4 H:3	L: 4 H:4	X
IFR10	B41K	Steelpoort	Ext from IFR9	BBM	L: 2 H:2	L: 4 H:3	L: 2 H:2	L: 4 H:4	L: 2 H:4	L: 4 H:3	L: 3 H:3	X
IFR11	B71J	Olifants	Ext from IFR 13	BBM	L: 2 H:2	L: 4 H:4	L: 3 H:3	L: 4 H:4	L: 2 H:3	L: 3 H:2	L: 3 H:3	X
IFR12	B60J	Blyde	Comprehensive	HFSR	L: ?4 H:?4	L: ?4 H:?4	L: ?3 H:?4	L: 3 H:3	L: ?3 H:?4	L: 3 H:4	L: ?4 H:?4	
IFR 13	B72D	Olifants	Comprehensive	BBM	L: 2 H:2	L: 4 H:4	L: 3 H:3	L: 2 H:2	L: 2 H:4	L: 5 H:3	L: 4 H:4	
IFR14a	B72H	Selati	Unknown	BBM	L: 2 H:2	L: 2 H:3	L: 2 H:3	L: 1 H:1	L: - H:3	L: 1 H:1	L: 3 H:3	X
IFR14b	B72K	Selati	Ext from IFR14a	BBM	-	-	-	-	-	-	-	X
IFR15		Olifants	Comprehensive		L: 2 H:2	L: 4 H:5	L: - H:-	L: 3 H:3	L: - H:-	L: 2 H:1	L: 3 H:3	
IFR16 /17	B73H	Olifants	Comprehensive	BBM	L: 2 H:2	L: 3 H:5	L: 4* H:3*	L: 3 H:3	L: 1 H:3	L: 4 H:4	L: 4 H:4	
MOZ-1	Y30C	Elefantes	Intermediate	L: HFSR H: BBM/ DRIFT	L: Monthly H: Daily	*	*	*	*	*	*	
MOZ-2	Y30F	Limpopo	Intermediate			*	*	*	*	*	*	
DWA-EWR1	B41H	Dwars	Comprehensive	HFSR	*	* (low conf)	*	*	*	*	*	

TABLE 7.2 RANKING OF EWR SITES FOR USE IN RELIMI-O, S&EWR.

Sites	Rivers	A. Average confidence in results (from Table)							B	C	D	E	F	Weighted average "A"-"F"
		Hydrology	Hydraulics	Geomorph	WQ	Riparian Vegetation	Macro-inverts	Fish	Method	Level	Study date	Considered in DWA (2011b)	Access	
IFR12	Blyde	4	4	3.5	3	3.5	3.5	4	3	3	1	3	3	3.42
IFR16 /17	Olifants	2	4	3.5	3	2	4	4	2	3	1	3	3	3.01
IFR5	Olifants	2	5	2	3.5	2	3.5	3.5	2	3	1	3	3	2.96
IFR13	Olifants	2	4	3	2	3	4	4	2	3	1	3	2	2.92
IFR8	Olifants	2	3.5	4	2	3	4	3.5	2	3	1	3	3	2.92
IFR6	Elands	2	3	4	3.5	3	3	3.5	2	3	1	3	3	2.89
DWA-EWR1	Dwars	3.5	3.5	3		3	3	4	3	2	3	0	3	2.81
IFR4	Wilge	3	3	3	0	3	3.5	4	2	3	1	3	3	2.77
IFR1	Olifants	3	3	2.5	1.5	2.5	4	4	2	1	1	3	3	2.74
IFR9	Steelpoort	2	3.5	2.5	1	3	3.5	4	2	3	1	3	3	2.74
IFR11	Olifants	2	4	3	4	2.5	2.5	3	2	1	1	0	3	2.57
IFR3	Klein lifants	3	3	2	2	2.5	2	3	2	3	1	3	2	2.50
IFR2	Olifants	3	3.5	3	0	2	4	4	2	3	1	0	0	2.47
IFR7	Olifants	2	3.5	4	2	3	2.5	3.5	2	3	1	0	0	2.47
IFR10	Steelpoort	2	3.5	2	4	3	3.5	3	2	1	1	0	0	2.38
IFR15	Olifants	2	4.5		3		1.5	3	2	1	1	3	3	2.19
IFR14a	Selati	2	2.5	2.5	1	3	1	3	2	1	1	0	0	1.84
IFR14b	Selati								2	1	1	0	0	0.22

- The level of confidence in each of the discipline studies. Of these, hydraulics and fish are considered the most important because:
  - Hydraulics provides the translation from discharge to ecologically relevant measures of flow, such as depth, velocity and wetted perimeter, for all the other disciplines;
  - The response for fish typically reflects an integration of the effects of flow on habitat and water quality, environmental cues (such as small floods that trigger spawning) and food supply, such as macroinvertebrates.
- The date at which studies were completed at each site. This is important as lessons learnt over the years are applied in more recent EWR assessments. In this regard, the DWAF (2001) PES, EIS and REC results for several of the sites were revisited, and partially updated, as part of the reconciliation studies in the basin. Eco-classification using updated methods (Kleynhans and Singh 2011) were redone for these sites at that time (DWA 2011b), which offers a slight benefit in terms of understanding the site response to historic changes in anthropogenic influences.

The Reserve studies used scores from 0-5 (0-very low, 5=very high) for confidence in the discipline evaluations (Table 7.1). These scores were retained in the ranking, and additional criteria were added using the same range of scores.

7.3 Recommended focus site(s)

The short-list of recommended sites from the perspective of RESILIM-O, S&EWR is (in order of preference; see Table 7.2

IFR 12: Blyde River
IFR 16/17: Olifants River
IFR 5: Olifants River
IFR 8: Olifants River
IFR 13: Olifants River
IFR 6: Elands River
DWA-EWR1: Dwars River.

8 References

Beilfuss, R. and Brown, C. 2010. Assessing environmental flow requirements and trade-offs for the Lower Zambezi River and Delta, Mozambique. International Journal of River Basin Management, Volume 8. Issue 2: 127 – 138.

Brown, C.A. 2007. Mzingwane Environmental Flows Process: DRIFT Output. Unpublished Report to IUCN-ROSA. 30 pp.

Brown, C.A. and Joubert, A. 2003. Using multicriteria analysis to develop environmental flow scenarios for rivers targeted for water resource development. *Water SA* 29(4): 365-374.

Brown, C.A. Pemberton, C., Birkhead, A., Bok, A., Boucher, C., Dollar, E., Harding, W., Kamish, W., King, J., Paxton, B. and Ractliffe, S. 2006. In Support of Water-resources planning – highlighting key management issues using DRIFT: A Case study. *Water SA* Vol. 32 No. 2. Pg 181-191.

Brown, C. 2013. Project concept note for 'Development and implementation of basin-wide environmental flow regime" in the Orange Senqu River Basin. DRAFT. Southern Waters Ecological Research and Consulting CC

Brown, C.A., Joubert, A.R., Beuster, J., Greyling A. and King, J.M. 2013. DRIFT: DSS software development for Integrated Flow Assessments. Final report. February 2013. Report to the Water Research Commission. WRC project No.: K5/1873. Project Leader: C.A. Brown.

Brown, C.A., Joubert, A.R., Pemberton, C.W., Greyling A. and King, J.M. 2008. DRIFT User Manual, V2.0.: Biophysical module for predicting overall river condition in small to medium sized rivers with relatively predictable flow regimes – Incorporating updates to the DRIFT database. Report to the Water Research Commission. WRC project No.: XX. Project Leader: C.A. Brown

Brown, C.A., Joubert, A.R., Beuster, J. Greyling, A. and King, J.M. 2013. DRIFT: DSS software development for Integrated Flow Assessments. FINAL REPORT to the South African Water Research Commission. February 2013.

CIC International. 2008. Rapid socio-economic assessment of the Richmond Dam. Draft Report. Submitted to: Ms Retha Stassen. Compiled by CIC International, 19 May 2008.

DWAF/DfID. Department of Water Affairs and Forestry (DWAF) and Department for International Development (DFID). 2007. *State of the aquatic ecosystems in the Olifants WMA*. CONTRACT NO. WFSP/WRM/CON2006. Prepared by: Water for Africa in association with Conningarth Economists and Pegasus. January 2007.

Department of Water Affairs and Forestry (DWAF). 2001a. Olifants River Ecological Water Requirements Assessment: Upper Olifants Comprehensive Ecological reserve (Water Quantity). DWAF Report PB 000-00-5699. Author: R. Palmer.

Department of Water Affairs and Forestry (DWAF). 2001b. Olifants River Ecological Water Requirements Assessment: Middle Olifants Comprehensive Ecological reserve (Water Quantity). DWAF Report PB 000-00-5799. Author: R. Palmer.

Department of Water Affairs and Forestry (DWAF). 2001c. Olifants River Ecological Water Requirements Assessment: Lower Olifants Comprehensive Ecological reserve (Water Quantity). DWAF

Report PB 000-00-5899. Author: R. Palmer.

Department of Water Affairs and Forestry (DWAF). 2001d. Olifants River Ecological Water Requirements Assessment: Social utilisation of the Olifants River. DWAF report no: PB 000-00-6099. Author: C. Joubert, Naledi Development.

Department of Water Affairs and Forestry (DWAF). 2001e. State of the rivers report: Crocodile, Sabie-Sand and Olifants River systems. http://www.dwa.gov.za/iwqs/rhp/state_of_rivers/crocsabieolif_01_toc.html.

Department: Water Affairs and Forestry (DWAF). 2007. Development of the Water Resource Classification System (WRCS). By: Chief Directorate: Resource Directed Measures.

Department of Water Affairs (DWA). 2010a . The nature, distribution and value of aquatic ecosystem services of the Olifants, Inkomati and Usutu to Mhlatuze Water Management Areas. Contract Report by Anchor Environmental Consultants for Department: Water Affairs, 362pp.

Department of Water Affairs (DWA). 2010b. Development of a reconciliation strategy for the Olifants River Water Supply System (WP 10197): *Yield analysis of the de Hoop and Flag Boshielo Dams*. Authors: S Mallory. Prepared by Aurecon, in association with others, for DWA. Report No.: P WMA 04/B50/00/8310/16, Nov 2010.

Department of Water Affairs (DWA). 2011a. Development of a reconciliation strategy for the Olifants River Water Supply System (WP 10197): *Water requirements and water resources report*. Authors: J Beumer and S Mallory. Prepared by Aurecon, in association with others, for DWA. Report No.: P WMA 04/B50/00/8310/6, Dec 2011.

Department of Water Affairs (DWA). 2011b. Development of a reconciliation strategy for the Olifants River Water Supply System (WP 10197): *Ecoclassification of the 1999 assessment at EWR sites in the Olifants River* (WMA 4). Authors: D Louw, P Kotze, A Deacon. Prepared by Aurecon, in association with others, for DWA. Report No.: P WMA 04/B50/00/8310/18, Sep 2011.

Department of Water Affairs (DWA). 2011c. Development of a reconciliation strategy for the Olifants River Water Supply System: *Final Reconciliation Strategy Report* (WP 10197). Authors: Beumer, J., Van Veelen, M., Mallory, S., Timm, D., Levin, M. and Team. 2011 J Beumer, Prepared by Aurecon, in association with others, for DWA. Report No.: P WMA 04/B50/00/8310/14. December 2011.

Department of Water Affairs (DWA). 2011d. Classification of significant water resources in the Olifants Water Management Area (WMA-4): *Ecological Water Requirements Report* (Appendix 1: Rapid ecological Reserve determination studies for the Olifants catchment). Report No: RDM/WMA04/00/CON/CLA/0511. Prepared for: Directorate Water Resource Classification. Department of Water Affairs, South Africa. Prepared by: Retha Stassen, Golder Associates Africa, Zitholele Consulting and Prime Africa. September 2011

Department of Water Affairs (DWA). 2011e. Classification of significant water resources in the Olifants Water Management Area (WMA-4): Preliminary background information document: Methodology and data sources in support of the economic analyses for the Classification. Prepared by Prime Africa Consultants. December 2011.

Department of Water Affairs (DWA). 2012a. Classification of significant water resources in the Olifants Water Management Area (WMA-4): *Evaluation of Scenarios Report*, Report No: RDM/WMA04/00/CON/ CLA/0212. Prepared by: Golder Associates Africa, Prime Africa and Retha Stassen.

Department of Water Affairs (DWA). 2013. NWRS: National Water Resource Strategy: Water for an Equitable and Sustainable Future, Second Edition, June 2013.

Department of Water Affairs (DWA). 2014a. Classification of significant water resources in the Olifants Water Management Area (WMA-4): *Management Classes of the Olifants Water Management Area Report*, Report No: RDM/WMA04/00/CON/CLA/0213. Prepared by: Golder Associates Africa, Prime Africa and Retha Stassen.

Department of Water Affairs (DWA). 2014b. Assessment of the Present Ecological State (PES), Ecological Importance (EI) and Ecological Sensitivity (ES) per sub-quartenary reach in the Primary Catchment: B. Draft electronic version. Compiled by the Directorate Resource Quality Services. (Excel tables and Google (.kml) files). DRAFT.

Dippenaar, S., N. Moilwa, S. Olorunju and Visser, A. E. 2005. *An analysis of the livelihoods of communities of the upper Selati catchment*, South Africa. Center for Scientific and Industrial Research (CSIR), Pretoria, South Africa and International Institute for Environment and Development, London, UK.

Froese, R. and Pauly, D. Editors. 2014. FishBase. World Wide Web electronic publication. www.fishbase.org, version (02/2014).

Grant B., Jacobsen, N.H.J. and Viljoen & Associates. 2006. Ecological Wetland Assessment - Matla. Prepared by Ecosun cc for Golder Associates (Pty) Ltd for Matla Colliery (Exxaro) EMPR and Water Use License Application. April 2006. Reference from DWAF-RDM office file: *WMA 4 Database_May 2008.xls*. Document not obtained.

GWP. 2010. IWRM indicators: a GWP Perspective. *Water Country Briefs Project Diagnostic Workshop, Geneva, December 2010*. http://www.unwater.org/downloads/WCB/GWP_IWRM.pdf.

Hirji, R. and Davies, R. 2009. Environmental Flows in water resources policies, plans and projects: Finding and recommendations. World Bank Environment and Development Series. Washington D.C.

Hughes, DA and Hannart, P. 2003. A desktop model used to provide an initial estimate of the ecological instream flow requirements of rivers in South Africa. *Journ. Hydrol*. 270 (3-4), 167-181.

Hughes, D.A. and Louw, D. 2010. Integrating hydrology, hydraulics and ecological response into a flexible approach to the determination of environmental water requirements for rivers. *Environmental Modelling and Software* 25: 910-918

International Water Management Institute (IWMI). 2008. A contribution to the Challenge Program Project 17: Integrated Water Resource Management for Improved Rural Livelihoods: Managing risk, mitigating drought and improving water productivity in the water scarce Limpopo Basin. Baseline Report. Olifants River Basin in South Africa.

Joubert, C. 2001. Olifants River Ecological Water Requirements Assessment. Social Utilisation of the Olifants River. Department of Water Affairs and Forestry. Report PB 000-00-6099.

King, J.M., R.E. Tharme and M.S. De Villiers (eds). 2000. Environmental Flow Assessments for Rivers: Manual for the Building Block Methodology. Report No. TT 131/00. Water Research Commission, Pretoria.

King, J.M. and Brown, C.A. 2009. Environment protection and sustainable management of the Okavango River Basin: Preliminary Environmental Flows Assessment. Scenario Report: Ecological and social predictions. Project No. UNTS/RAF/010/GEF. Report No. 07/2009. Four Volumes.

King, J.M., Brown, C.A. and Sabet, H. 2003. A scenario-based holistic approach to environmental flow assessments for regulated rivers. *Rivers Research and Application*s 19 (5-6). Pg 619-640.

King, J., Beuster, H., Brown, C. and Joubert, A. 2014. Proactive management: the role of environmental flows in transboundary cooperative planning for the Okavango River system. Journal of Hydrological Sciences.

King, J. and Pienaar, H. (eds) 2011. Sustainable use of South Africa's inland waters. Water Research Commission, Pretoria.

Kleynhans, C.J. 1999. A procedure for the determination of the ecological reserve for the purposes of the national water balance model for South African Rivers. Institute for Water Quality Studies. Department of Water Affairs and Forestry, Pretoria, South Africa.

Kleynhans, C.J. 2000. Desktop estimates of the ecological importance and sensitivity categories (EISC), default ecological management classes (DEMC), present ecological status categories (PESC), present attainable ecological management classes (present AEMC), and best attainable ecological management class (best AEMC) for quaternary catchments in South Africa. DWAF report, Institute for Water Quality Studies, Pretoria, South Africa.

Kleynhans, C.J. 2007. Reference from DWAF-RDM office file: *WMA 4 Database_May 2008.xls*. Document not obtained.

Kleynhans, C.J. 2007. Module D: Fish Response Assessment Index. In: *River EcoClassification: Manual for EcoStatus Determination* (version 2). Joint Water Research Commission and Department of Water Affairs and Forestry report.

Limpopo River Awareness Kit website. http://www.limpoporak.com/en/management/value+of+water/economic+value/mozambique.aspx. Accessed Feb 2014.

Milgroom J. 2013. *Policy processes of a land grab: Enactment, context and misalignment in Massingir, Mozambique*. LDPI Working Paper 34. Published by: The Land Deal Politics Initiative in collaboration with the Institute for Development Studies, Initiatives in Critical Agrarian Studies and International Institute of Social Studies, the Institute for Poverty, Land and Agrarian Studies (PLAAS) and the Polson Institute for Global Development with support from the UK Department for International Development (DfID), Atlantic Philanthropies, Inter-Church Organization for Development Cooperation (ICCO), Ford Foundation and Miserior. 26 pp.

Mining Weekly: www.miningweekly.com. 2009. Olifants river basin collieries must join forces to control water decant – Xstrata. Article by Loni Prinsloo. 18th September 2009. Accessed online: http://www.miningweekly.com/print-version/water-management-strategies-for-coal-mines-into-the-future-2009-09-18 on 27 Nov 2013.

Ncapayi, M. 2001. Mapochs Ecological Water Quality Reserve: B41C. Report by DWAF, Institute Water Quality Studies. Author: Ncapayi M, June 2001. DWAF, Institute Water Quality Studies 2001. Reference from DWAF-RDM office file: *WMA 4 Database_May 2008.xls*. Document not obtained.

Norconsult and Southern Waters (2012) Cheves Hydropower Project. Ecological Flow Management Plan. EF Assessment Report. Lima, Peru.

Oryx Environmental. 2006. Scoping and Environmental Impact Report for a Dragline Walkway from Rietspruit Colliery to the proposed Elders Colliery near Bethal. Job No. OE 71 Dragline Walkway. For DWAF, Institute Water Quality Studies 2001. Reference from DWAF-RDM office file: *WMA 4 Database_May 2008.xls*. Document not obtained.

PBWO/IUCN. 2008 Final Scenario Report: Report 4: Pangani River Basin Flow Assessment, Moshi, 23pp.

Pollard, S. and du Toit, D. 2011. The Shared River Initiative Phase I: Towards the sustainability of freshwater systems in South Africa: An exploration of factors that enable or constrain meeting the Ecological Reserve within the context of Integrated Water Resources Management in the catchments of the lowveld. Report to the Water Research Commission. Compiled by Stacey Gouws. Association for Water and Rural Development (AWARD). WRC Report No. TT 477/10.

Prime Africa. 2011. Classification of significant water resources in the Olifants Water Management Area (WMA-4): *Preliminary background information document: Methodology and data sources in support of the economic analyses for the classification of significant water resources in the Olifants Water Management Area (WMA*. Prepared by: Prime Africa Consultants. 19 December 2011

Salomon Lda. 2007a. Determination of Environmental Flow Requirements for the Elefantes River, Moçambique: *Main report*. For the Massingir Dam and Smallholder Agricultural Rehabilitation Project. Prepared by Salomon L da in association with PD Naidoo and Associates for Direcção Nacional de Águas, (DNA), Administração Regional de Águas do Sul (ARA-Sul) and Project Implementation Unit, PIMU.

Salomon Lda. 2007g. Determination of Environmental Flow Requirements for the Elefantes River, Moçambique: *Draft EFR Report*. For the Massingir Dam and Smallholder Agricultural Rehabilitation Project. Prepared by Salomon L da in association with PD Naidoo and Associates for Direcção Nacional de Águas, (DNA), Administração Regional de Águas do Sul (ARA-Sul) and Project Implementation Unit, PIMU.

Salomon Lda. 2007h. Determination of Environmental Flow Requirements for the Elefantes River, Moçambique: *Socio Importance Report*. For the Massingir Dam and Smallholder Agricultural Rehabilitation Project. Prepared by Salomon L da in association with PD Naidoo and Associates for Direcção Nacional de Águas, (DNA), Administração Regional de Águas do Sul (ARA-Sul) and Project Implementation Unit, PIMU.

Salomon Lda. 2007i. Determination of Environmental Flow Requirements for the Elefantes River, Moçambique: *Scenario Report*. For the Massingir Dam and Smallholder Agricultural Rehabilitation Project. Prepared by Salomon L da in association with PD Naidoo and Associates for Direcção Nacional de Águas, (DNA), Administração Regional de Águas do Sul (ARA-Sul) and Project Implementation Unit, PIMU. August, 2007.

Singh, A. 2007. Reference from DWAF-RDM office file: *WMA 4 Database_May 2008.xls*. Document not obtained.

Southern Waters. 2009. Environmental Flow Assessment. Volume 1: Main Report. ESIA for the Saboloka, Dagash and Mograt Hydropower Projects on the Nile River, Northern Sudan. Unpublished project report for SMEC and Sudanese Dams Implementation Unit. 74 pp.

Southern Waters. 2010. Environmental Flow Assessment. Volume 1: Main Report. ESIA for the Baynes Hydropower Project on the Cunene River on the border between Angola and Namibia. Unpublished project report for ERM, and NamPower.

Southern Waters. 2011a. Environmental Flow Assessment Volume 2: Specialist Reports (FIRST Report). ESHIA for the Riversdale Coal Barging Project Phase 2, Zambezi River, Mozambique. Unpublished project report for ERM. 198 pp.

Southern Waters. 2011b. FINAL. Environmental Flow Assessment: Neelum/Kishenganga River, Kashmir (New Hydrology_All scenarios). Unpublished project report for National Engineering Services Pakistan (Pvt.) Limited. 58 pp.

Hagler-Bailey, Water Matters, Southern Waters and Beuster Clarke and Associates. 2011. Kishenganga/Neelum River Water Diversion. Environmental Assessment. Final Report. May 2011. Pakistan

Stassen, R. 2008a. Intermediate ecological Reserve determination for the Dwars River catchment (quaternary catchments B41G and B41H), tributary of the Steelpoort River, Mpumalanga. FINAL REPORT. April, 2008. Report prepared by BKS (Pty) Ltd for DWAF.

Stassen, R. 2008b. Intermediate ecological Reserve determination for the Dwars River catchment (quaternary catchments B41G and B41H), tributary of the Steelpoort River, Mpumalanga. APPENDIX I: Reserve Template. April, 2008. Report prepared by BKS (Pty) Ltd for DWAF.

USAID. 2013. Resilience in the Limpopo Basin Program (RESILIM): Olifants Catchment. USAID Fact Sheet: http://www.usaid.gov/documents/1860/fact-sheet-resilience-limpopo-basin-program-resilim-olifants-catchment-june-2013, Accessed 05 Feb 2014.

Water Wheel. 2010. River ecosystems: All eyes on Olifants as experts search for answers. The Water Wheel May/Jun 2010. p14-18. Accessed online on 30 Jan 2014: http://www.wrc.org.za/Pages/KH_WaterWheel.aspx?dt=4&ms=55;

Appendix A:
Illustrative example for stages 1, and 4-6 of Activity 3

Please note that the example below is an illustrative example only for Steps 1.1, 1.4, 1.5 and 1.6 of the process for Activity 3 (Section 6). The other steps can only be demonstrated by populating the DSS.

A.1 Example EWR site

IFR 13 on the lower Olifants River was selected for this illustrative example (DWAF 2001c). The advantages and disadvantages of the site as provided by specialists at the time of the EWR study (DWAF 2001c) are summarised in App Table 1.

APP TABLE 1: SUMMARY FROM DWAF (2001C) SITE APPENDIX (APPENDIX A) OF ADVANTAGES AND DISADVANTAGES OF IFR 13.

Discipline	Advantages	Disadvantages
Hydraulics	-	Complex site from hydraulics perspective, dominated by rapidly varied flow over a large bedrock control located across the width of the macro-channel floor. Five linked cross-sections were positioned at the site extending to approximately 200 m upstream and downstream of the bedrock control to allow adequate characterisation of the hydraulic behaviour.
Geomorphology	Good hydraulic diversity Some evidence of annual flood level on LB. Representative for this type of reach, i.e. bedrock rapids.	Not complimentary evidence of annual flood on RB. Lot of flood damage, so system has been “re-set”, therefore difficult to talk about an ‘ideal’ condition.
Riparian vegetation	*Ficus* & *Bridelia* present on both banks. Good flood terrace present on lower transect for medium / high flows. Good root zone present on RB - *Breonardia* which can be used to ID low flows despite poor vertical sensitivity.	Poor vertical sensitivity due to width of channel, therefore to identify and specify level requirements for low flows. Main transect difficult for medium/high flows - lower transect will be required for these. Very highly incised channel with many old riparian zones present whose requirements cannot be described.
Macroinvertebrates	Biotope diversity high - large range of substrate sizes, including sand, gravel, cobbles and boulders. Sampling of cobbles possible under a range of flows. Highly representative of river. Profile sensitive to changes in flow	-
Fish	Variety of slow and fast habitats Channel stable. Good marginal and undercut banks and root matts. Submerged aquatic plants present in cross-section (*Potamogeton crispes* & *Chara* spp). Back waters and nursery areas present can be related to present level to determine level where active. Habitat for a diversity of fish.	Hydraulics may be difficult.

A.2 Ecological status

IFR13 is on the Olifants River downstream of confluence with the Blyde River in quaternary catchment B72D (segment 100), and ecoregion 5.06. The closest river health program site is B7OLIF-HOEDS which is about 30km upstream, and about 2 km below the Blyde River confluence. The overall PES in in DWAF (2001c) was C, but because of the EIS given to this reach, the REC was B. The site is strongly affected by the Blyde River, which influences water temperatures, the availability of habitats and the reliability of flow. Blydepoort Dam releases also appear to cause sedimentation at this site, impacting on habitat diversity. Ecological Conditions for each discipline and overall are summarised in App Table 2.

The main reasons provided for the conditions were the altered sediment regime, upstream dams and abstraction, sediment and vegetation loss (due to land-use practices, deforestation, etc.), nutrient inputs (from agriculture, overgrazing, browsing, irrigation), TDS inputs and barriers to fish migration.

APP TABLE 2 SUMMARY FROM DWAF (2001C) OF ECOLOGICAL CATEGORIES FOR EACH DISCIPLINE FOR IFR 13.

COMPONENT	COMMENT	ECOLOGICAL CATEGORY
HYDROLOGY	Score: 8.3	C/D
GEOMORPHOLOGY	The D class reach is defined as being largely modified, with significant changes in geomorphology and in-stream habitat. Geomorphic thresholds appear to have been crossed with the river moving towards a new equilibrium. This is demonstrated by an over-widened channel with numerous sand bars and extensive chokes of large woody debris. (Modifying determinants: Extensive agriculture, riparian zone mismanagement, bridges and weirs).	D
OVERALL WATER QUALITY (WQ)	The improved WQ in this reach is dependent on good quality water from the Blyde River. WQ conditions in the Blyde river are following a trajectory of deterioration, and careful WQ management will be required in the Blyde River, and in this reach of the Olifants River. No instream toxicity testing was undertaken. The invertebrates, fish and WQ were all Category C, with invertebrates tending to improve just downstream of the Blyde River confluence. TDS concentrations measured below the Blyde River confluence were lower than upstream of the confluence, especially during the low flow months	C
RIPARIAN VEGETATION	Reduced cover, loss of large trees with changes in population structure and species composition. (Modifying determinants: Scouring and flooding, reduced flows and water level fluctuations, overgrazing and resulting erosion).	C
AQUATIC INVERTEBRATES	ASPT 4.98, SASS 103	C
FISH	Diversity of fish species present, several sensitive fish present; species missing from reference condition (Modifying determinants: improved water quality and quantity. Cold water pulses which are a problem for some species. Sporadic sedimentation of habitat.). RC: 29 species, PES: 24 species	C
ECOSTATUS	**Trajectory: C (short), D/E (long)**	**C**
INSTREAM HABITAT INTEGRITY	Serious bed modification expected due to upstream activities. The inflow of the Blyde River provides some initial ameliorating affect.	C
RIPARIAN HABITAT INTEGRITY	Large impact of bank erosion due to overgrazing and flow modification expected.	C

A.3 Possible indicators

The site descriptions given in each specialist report provide an indication of indicators for each discipline, while comments from other specialists provide a guide for linked indicators. For example, the abundances of algae and diatom[20]s are important to invertebrate abundance, as they may reduce habitat availability.

A.3.1 Flow indicators

In the BBM approach, flow was divided into components made up of the lowflow (baseflow) in the dry and wet seasons, the intra-annual floods (freshets), and the inter-annual floods. These remain useful ways of considering the biologically relevant part of the flow regime, but suffer from a number of shortcomings if they are the only considerations regarding flow patterns. For example, the average dry season lowflow component does not provide information as to whether the season will start earlier or later, or whether the season lasts longer or shorter than the natural or present day dry season.

DRIFT has a wide-ranging set of flow indicators, including some that are the equivalent, or provide alternatives, to the original BBM indicators (App Table 3). App Table 4 lists the BBM flow indicators for IFR 13, and the DRIFT equivalents/alternatives.

APP TABLE 3: FULL LIST OF DRIFT FLOW INDICATORS

Indicator	Units
Mean annual runoff	m^3/s
Dry season onset	cal week
Dry season relative onset	weeks
Dry season duration	days
Dry season Min 5d Q	m^3/s
Wet season onset	cal week
Wet season relative onset	weeks
Wet season Max 5d Q	m^3/s
Flood volume	MCM
Flood type	Type
Wet season duration	days
T2 recession slope	m^3/s
Dry season ave daily vol	MCM /d
T1 ave daily vol	MCM /d
Wet season ave daily vol	MCM /d
T2 ave daily vol	MCM /d
Dry season min instantaneous Q	m^3/s
Dry season max instantaneous Q	m^3/s
Dry season max rate of change	$m^3/s/min$
T1 min instantaneous Q	m^3/s
T1 max instantaneous Q	m^3/s
T1 max rate of change	$m^3/s/min$
Wet season min instantaneous Q	m^3/s
Wet season max instantaneous Q	m^3/s
Wet season max rate of change	$m^3/s/min$
T2 min instantaneous Q	m^3/s
T2 max instantaneous Q	m^3/s
T2 max rate of change	$m^3/s/min$
Dry season Min 5d Velocity	m/s
Dry season Min 5d WetPerim	m
Dry season Min 5d Depth	m

Indicator	Units
Flood season Max 5d Velocity	m/s
Flood season Max 5d WetPerim	m
Flood season Max 5d Depth	m
Flood season Min 5d Velocity	m/s
Flood season Min 5d WetPerim	m
Flood season Min 5d Depth	m
Dry within day range	m^3/s
T1 within day range	m^3/s
Wet within day range	m^3/s
T2 within day range	m^3/s
Dry Class1	Number
Dry Class2	Number
Dry Class3	Number
Dry Class4	Number
Wet Class1	Number
Wet Class2	Number
Wet Class3	Number
Wet Class4	Number
T1 Class1	Number
T1 Class2	Number
T1 Class3	Number
T1 Class4	Number
T2 Class1	Number
T2 Class2	Number
T2 Class3	Number
T2 Class4	Number
1:2 Class5	Number
1:5 Class6	Number
1:10 Class7	Number
1:20 Class8	Number

[20] *For the purposes of this example, algae and diatoms have been added to water quality (rather than adding a new discipline).*

APP TABLE 4: BBM FLOW INDICATORS FOR IFR 13, AND THE DRIFT EQUIVALENTS/ALTERNATIVES

Flow	BBM flow indicator	DRIFT flow indicators		
Category		Primary	Alternatives	Additional
Low flow / baseflow	Lowflow-dry season	Dry season: minimum 5 day average discharge	- Dry season average daily volume	- Dry season duration - Dry season onset
	Lowflow-wet season	-	- Wet season flood volume - Wet season average daily volume	- Wet season duration - Wet season onset
Intra-annual floods	Freshet-spring	T1 season: minimum 5 day average discharge	- Numbers of intra-annual floods of various classes.	
	Freshet-summer	T1 season: minimum 5 day average discharge	- Numbers of intra-annual floods of various classes.	
	Freshet-autumn	T2 season: minimum 5 day average discharge	- Numbers of intra-annual floods of various classes.	
Inter-annual floods	Floods-wet season	Wet season: maximum 5 day average discharge	- Numbers of inter-annual floods of various classes.	

A.3.2 Biotic indicators

The BBM study did not specify indicators, but particular features of the ecosystem are discussed and mentioned in the motivations for specific flows. These discussion can be used to identify indicators (App Table 5).

APP TABLE 5: INDICATORS EXTRACTED FROM DWAF (2001C)

DISCIPLINE AND INDICATORS	DESCRIPTION / REASONS	SPECIES
GEOMORPHOLOGY		
CHANNEL WIDTH	A basic indicator of geomorphic change	n/a
EMBEDDEDNESS / SEDIMENTATION	Important for invertebrate habitat availability	n/a
FLOOD TERRACE CONDITION	Important for maintenance of the flood terrace / mature tree zone for riparian vegetation	n/a
AREA OF BACKWATERS?	Important for a number of fish species	n/a
BIOTOPE DIVERSITY ?	Important for invertebrate and fish habitat availability (site includes sand bars, cobble, bedrock, undercutting, marginal vegetation, backwaters, riffles and pools)	n/a
WATER QUALITY		
TDS / SALINITY	TDS concentrations measured affected by the relative contribution of Blyde and Olifants River flows.	n/a
FILAMENTOUS LGAE AND DIATOMS	Filamentous algae and diatoms affect invertebrate habitat availability	n/a
NUTRIENTS	Nutrients were moderately high, but were not mentioned as IFR motivations	n/a
HEAVY METALS	Concerns have been expressed about potential heavy metal pollution from the Palaborwa mining complex, but measurements were not made and these were not mentioned as IFR motivations	n/a

VEGETATION		
MARGINAL ZONE	An important habitat for invertebrate and fish species	n/a
MATURE TREE AND FLOOD TERRACE ZONE	Stands of mature trees occur on the channel margins and flood terrace. Changes in flow and sediment have caused undercutting	Ficus sycomorus, Breonadia salicina
AQUATIC INVERTEBRATES		
MAYFLY DIVERSITY	These taxa provide useful indicators for monitoring IFR recommendations at this site	Flat headed mayflies (Afronurus sp.), large carnivorous mayfly Centroptiloides bifasciata
CRUSTACEAN ABUNDANCE	No crustacea were recorded at this site, but should be present	Not provided
OLIGOCHAETE ABUNDANCE	No crustacea were recorded at this site, but should be present	Not provided
MOLLUSC ABUNDANCE	No crustacea were recorded at this site, but should be present	Not provided
SIMULIUM DAMNOSUM ABUNDANCE	The blackfly is a pest species and has been recorded here	Simulium damnosum
FISH		
DEEP, POOL OR STILL WATER SPECIES	Some deeper habitats and pools are available in this Fish Habitat Segment and are important to create some cover, in terms of depth and/or other structures, to sustain adult populations of the larger fish and those preferring pool habitats.	Labeo molybdinus, Labeo ruddi, Oreochromis mossambicus, Schilbe intermedius, Clarias gariepinus
RIFFLE DWELLING AND BREEDING SPECIES	Some species are dependent on riffle habitat (therefore on permanent flow) Others depend on riffles for spawning and juvenile development	Opsaridium peringueyi, Chiloglanis pretoriae, Labeobarbus marequensis, Labeo cylindricus, Labeo rosae
MARGINAL ZONE AND BACKWATER DWELLING SPECIES	Marginal zone habitats serve as refuge areas and spawning grounds for smaller species and backwaters act as nurseries for juveniles. Marginal zone and undercut banks provide cover for certain species	Micralestes acutidens, Barbus paludinosus, Barbus trimaculatus, Barbus unitaeniatus, Barbus annectens, Barbus viviparous, Tilapia rendalli

A.4 Linked indicators

The motivations given for specific flows provide guidance on links between the other biophysical indicators and the flow indicators (App Table 6) and in some cases also the links to other biophysical indicators. However, many of the links will need to be established using relevant specialists.

APP TABLE 6: MOTIVATIONS GIVEN IN DWAF (2001C) FOR EACH FLOW COMPONENT AT IFR13, REARRANGED PER DISCIPLINE, TOGETHER WITH THE SPECIFIC RECOMMENDED FLOWS.

BBM flow category	Maintenance Flows Reasons: IFR motivations	Requirement	Drought Flows Reasons: IFR motivations	Requirement
GEOMORPHOLOGY				
Lowflow-dry season	- Mobilises gravels and sands. Lower flows will lead to embedding of cobbles and complete cover of sand in the river channel.	8 m^3/s		
Lowflow-wet season	- Mobilise sediments and prevent excessive sediment deposition	18 m^3/s	- Mobilises sediments and prevent excessive sediment deposition	6 m^3/s
Freshet-spring+ summer	- 30-50 m^3/s will flush sediments and accumulated organic debris - 60 m^3/s will ensure some flow throughout active channel and inundate all channels	30 m^3/s x 2 Dec 50 m^3/s x 1 Nov 60 m^3/s x 2 Jan, Mar	- Ensures flow throughout the active channel and reworking of sediments, inundate all channels - March freshet reworks sediments mobilised during flood	30 m^3/s x 1, Jan 60 m^3/s x 1, Feb 30 m^3/s x 1, Mar
Floods-wet season	- Mobilises bed material (bankfull), and mobilise sediments on the bed and terraces - Deposits sediments and nutrients on the terraces. 180 m3/s flood will place water on the terrace on the left bank Smaller floods will lead to long-term narrowing of channel, & vegetation encroachment.	180 m^3/s x 1, Feb 250 m^3/s x 1, Feb		
WATER QUALITY				
Lowflow-wet season	- Provides sufficient velocity to prevent proliferation of filamentous algae, flush benthic algae and diatoms	18 m^3/s		
Freshet-spring+ summer	- Provides sufficient flow velocity to dilute salts - Provides sufficient current velocity to prevent proliferation of filamentous algae, flush benthic algae and diatoms that cover rocks, and limit habitat availability for invertebrates	15 m^3/s x 2 Oct 30 m^3/s x 2 Dec 50 m^3/s x 1 Nov 60 m^3/s x 2 Jan, Mar	- Flushes fine organic flocculent, benthic diatoms and algae away	10 m^3/s x 1, Nov 20 m^3/s x 1, Dec
Freshet-autumn	- Provides sufficient flow velocity to dilute salts - Washes away benthic algae and diatoms that cover rocks, and limit habitat availability for invertebrates	20 m^3/s x 1, Apr	- Mobilises fine sediments, increase biotope availability by flushing fine organic flocculant, diatoms, algae.	8 m^3/s x 1, Oct

BBM flow category	Maintenance Flows		Drought Flows	
	Reasons: IFR motivations	Requirement	Reasons: IFR motivations	Requirement
VEGETATION				
Lowflow-dry season	- Provides water to marginal zone on right bank. - Provides water to the rooting zones of Breonardia salicina and Ficus sycomorus on the banks of the active channel. (Breonardia need constant contact with water to ensure survival, growth and reproduction). Lower flows will detrimentally affect marginal zone during hot, dry conditions due to shortage of water for temperature control and transpiration	8 m^3/s	- Ensures depth enough for survival of juvenile stand of Breonarida downstream of the transect on the right bank	2.2 m^3/s
Lowflow-wet season	- Mobilises sediment and prevents encroachment of vegetation into channel	18 m^3/s	-	
Freshet-spring+ summer	- Provides low flows and freshets which will encourage germination and growth of riparian species on newly deposited sediments. - 60 m^3/s saturates rooting zone of *Ficus sycomorus* to provide water for growth and survival of trees on banks of active channel	30 m^3/s x 2, Dec 50 m^3/s x 1, Nov 60 m^3/s x 2, Jan, Mar	- Provides water to encourage growth & survival of marginal zone - Saturates riparian zone of active channel and ensures maintenance of trees, and reduction of stress during hot dry periods	10 m^3/s x 1, Nov 60 m^3/s x 1, Feb 30 m^3/s x 1, Mar 60 m^3/s x 1, Feb 30 m^3/s x 1, Mar
Floods-wet season	- Encourages further deposition of sediments on exposed roots of large *Ficus sycomorus* individuals on left bank. - Deposits sediments and nutrients on terraces, providing nursery conditions for germination and establishment of *Ficus sycamorus* that will ensure the perpetuation of Ficus gallery forest on banks of active channel. Smaller flows may result in gradual depletion of Ficus gallery forest on active channel banks and accumulation of debris.	180 m^3/s x 1, Feb 250 m^3/s x 1, Feb		
INVERTEBRATES				
Lowflow-dry season	- Provides a reasonable diversity of hydraulic conditions and aquatic biotopes to maintain flow-sensitive invertebrates through the dry season. - Provides sufficient depth and velocities to protect invertebrate fauna against high temperatures and low oxygen concentrations that may develop.	8 m^3/s	- Ensures survival of the invertebrate assemblage during drought - Ensures sufficient velocities for flow sensitive mayfly species in this section of river	2.2 m^3/s
Lowflow-wet season	- -	-	- Provides sufficient habitat for many invertebrate species - Provides adequate conditions for flow sensitive mayfly species in this section of river	6 m^3/s

BBM flow category	Maintenance Flows		Drought Flows	
	Reasons: IFR motivations	Requirement	Reasons: IFR motivations	Requirement
Freshet-spring+ summer	- Flushes sediments and accumulated organic debris and improves habitat availability for aquatic invertebrates	30 m^3/s x 2, Dec 50 m^3/s x 1, Nov	- Mobilise fines and debris, thereby improve habitat availability for aquatic invertebrates	5 m^3/s x 1, Oct 20 m^3/s x 1, Dec
Freshet-autumn	- Provides sufficient flow velocity to dilute salts and wash away benthic algae and diatoms that cover rocks & limit habitat availability for invertebrates	20 m^3/s x 1, Apr	- Mobilises fine sediments, increase biotope availability by flushing fine organic flocculant, diatoms, algae.	8 m^3/s x 1, Oct
FISH				
Lowflow-dry season	- Provides a reasonable diversity of hydraulic conditions and aquatic biotopes to maintain flow-sensitive fish	8 m^3/s	- Provides sufficient depth in critical habitat (riffle area in left channel) to ensure survival of flow-dependant fish species. - Provides sufficient habitat (cover & depth) for all fish species recorded here. - Provides adequate depth to provide cooler pools for temperature-sensitive fish species	2.2 m^3/s
Lowflow-wet season	- Optimises biotope availability for all fish species present - Provides an abundant supply of marginal habitats to ensure spawning and recruitment of all species recorded in this segment. - Provides suitable depth (0.99 m) and marginal habitat. Lower flows will reduce availability of marginal cover, and reduce breeding success. Surface area available for flow-dependent species will be reduced.	18 m^3/s	- Provides sufficient depth in fast-flowing habitats to sustain healthy populations of flow-dependant fish species (Class B objectives). - Provides adequate cover in downstream multiple channels.	6 m^3/s
Freshet-spring+ summer	- Provides cues for fish breeding, - Provides flows over spawning beds and clean these habitats, and - Inundates some margins and backwaters that provide refuge for juvenile fish in growing stages. Smaller changes in water levels are unlikely to provide sufficient cues for migration and will reduce habitat diversity and therefore species diversity	50 m^3/s x 1, Nov 30 m^3/s x 2, Dec 60 m^3/s x 2, Jan, Mar	Provides sufficient flow velocity to trigger fish spawning and spawning migrations	10 m^3/s x 1, Nov 20 m^3/s x 1, Dec 60 m^3/s x 1, Feb 30 m^3/s x 1, Mar
Floods-wet season	Same reasons given in report as for intra-annual floods	180 m^3/s x 1, Feb 250 m^3/s x 1, Feb		

Appendix B:

EWR results (.tab files and flood requirements) (Reserve studies)

A.5 Olifants Comprehensive Reserve (DWAF 2001a-c)

Note: *For Sites 5-16/17 these are the ".tab files" from the "Desktop Model". These were unavailable for Sites 1-4, so the tables from the reports (DWAF 2001a) are provided below.*
Where two ECs were provided, they are included.
*The MAR in DWAF (2001a) and the DWA excel sheet are both provided, unless they are exactly the same. That marked with * is from DWAF 2001a, with ** from the DWA Excel file*
The .tab files in some cases differ from the tables within the Reserve report text.

A.5.1 IFR1 IFR estimate: PES = D, REC=C

Note: *There is a discrepancy in the DWAF (2001a) table below and the % MAR as provided in the DWA excel file (which gives 18.63%). It is unknown which is correct. The figure of 18.63 is the one that has been taken forward in later studies (e.g. Classification).*

APP TABLE 1: SUMMARY OF IFR ESTIMATE FOR IFR1 (CLASS C).

	Monthly volume ($10^6 m^3$) Low-Flows		High-flows		Total Flows
	Maint.	Drought	Maint.	Drought	Maint.
Oct	0.86	0.24	0.230	0.17	1.090
Nov	1.46	0.54	0.840	0.33	2.300
Dec	1.95	0.72	1.440	0.32	3.390
Jan	1.95	0.83	5.950	3.84	7.900
Feb	2.13	0.75	14.520	0.32	16.650
Mar	1.74	0.7	1.450		3.190
Apr	1.3	0.6		0.105	1.300
May	0.91	0.54			0.910
Jun	0.7	0.44			0.700
Jul	0.67	0.4			0.670
Aug	0.62	0.32			0.620
Sep	0.54	0.23			0.540
Total Vol	14.83	6.31	10.15	5.085	24.98
% of MAR (MAR=148.6*)	9.980	4.246	16.440	3.417	26.420
% of MAR (MAR=148.094**)	10.014	4.261	16.496	3.429	26.510

A.5.2 IFR2 IFR estimate: PES = C, REC=B

APP TABLE 8: SUMMARY OF IFR ESTIMATE FOR IFR2 (CLASS B).

	Monthly volume ($10^6 m^3$) Low-Flows		High-flows		Total Flows
	Maint.	Drought	Maint.	Drought	Maint.
Oct	2.68	0.8	0.48	0.23	3.160
Nov	6.22	1.76	2.99	0.64	9.210
Dec	11.3	2.36	2.89	0.62	14.190
Jan	13.4	2.68	6.71	2.95	20.110
Feb	12.1	2.42	21.5	0.61	33.600
Mar	9.91	2.28	1.76		11.670
Apr	6.74	1.94	0.29	0.19	7.030
May	4.82	1.74			4.820
Jun	3.63	1.43			3.630
Jul	3.48	1.29			3.480
Aug	3.08	1.07			3.080
Sep	2.46	0.78			2.460
Total Vol	79.820	20.550	36.620	5.240	116.440
% of MAR (MAR=489.7*)	16.300	4.196	7.478	1.070	23.778
% of MAR (MAR=489.731**)	16.299	4.196	7.478	1.070	23.776

A.5.3 IFR3 IFR estimate: PES = D, REC=C

APP TABLE 9: SUMMARY OF IFR ESTIMATE FOR IFR3 (CLASS C).

	Monthly volume ($10^6 m^3$) Low-Flows		High-flows		Total Flows
	Maint.	Drought	Maint.	Drought	Maint.
Oct	0.54	0.268	0.58	0.59	1.120
Nov	0.78	0.311	0.47	0.59	1.250
Dec	1.07	0.348	2.08		3.150
Jan	1.34	0.402	2.25	0.58	3.590
Feb	1.21	0.484	3.54		4.750
Mar	1.13	0.482	0.67	0.24	1.800
Apr	0.91	0.415	0.56		1.470
May	0.67	0.402			0.670
Jun	0.57	0.337			0.570
Jul	0.56	0.321			0.560
Aug	0.51	0.295			0.510
Sep	0.47	0.259			0.470
Total Vol	9.760	4.324	10.150	2.000	19.910
% of MAR (MAR=73.7*)	13.243	5.867	13.772	2.714	27.015
% of MAR (MAR=73.675**)	13.247	5.869	13.777	2.715	27.024

A.5.4 IFR4 IFR estimate: PES = B, REC=B

APP TABLE 10: SUMMARY OF IFR ESTIMATE FOR IFR4 (CLASS B).

	Monthly volume ($10^6 m^3$) Low-Flows		High-flows		Total Flows
	Maint.	Drought	Maint.	Drought	Maint.
Oct	1.74	0.38	0.53		2.270
Nov	2.33	0.52	2.05	0.58	4.380
Dec	3.21	0.62	1.99	0.94	5.200
Jan	3.48	1.02	5.09		8.570
Feb	3.63	1.11	7.89	0.91	11.520
Mar	4.02	1.23	8.17		12.190
Apr	3.1	1.04	0.58		3.680
May	2.7	0.96			2.700
Jun	2.3	0.78			2.300
Jul	2.01	0.7			2.010
Aug	1.61	0.51			1.610
Sep	1.3	0.36			1.300
Total Vol	31.430	9.230	26.300	2.430	57.730
% of MAR (MAR=192.6*)	16.319	4.792	13.655	1.262	29.974
% of MAR (MAR=192.857**)	16.297	4.786	13.637	1.260	29.934

A.5.5 IFR5 IFR estimate: PES = C, REC=B (but signed off REC=C)

APP TABLE 11: SUMMARY OF IFR ESTIMATE FOR IFR5 (CLASS B).

```
Total Runoff : REGION I  B32D
Annual Flows (Mill. cu. m or index values):
MAR                 =  502.596
S.Dev.              =  329.727,
CV                  =    0.656
Q75                 =   12.295
Q75/MMF             =    0.294
BFI Index           =    0.481
CV(JJA+JFM) Index =    1.881
IFR Management Class = B
Total IFR           =  124.031 (24.68 %MAR)
Maint. Lowflow      =   78.557 (15.63 %MAR)
Drought Lowflow     =   27.713 ( 5.51 %MAR)
Maint. Highflow     =   45.474 ( 9.05 %MAR)
Monthly Distributions (Mill. cu. m.)
Distribution Type : Olifants
```

Month	Natural Flows			Modified Flows (IFR)			
				Low flows		High Flows	Total Flows
	Mean	SD	CV	Maint.	Drought	Maint.	Maint.
Oct	22.122	42.762	1.933	4.146	1.471	0.417	4.562
Nov	61.154	83.674	1.368	6.859	2.459	0.831	7.690
Dec	60.793	68.597	1.128	6.820	2.407	4.068	10.888
Jan	87.022	114.792	1.319	9.361	3.343	17.688	27.049
Feb	84.753	134.700	1.589	9.663	3.382	17.585	27.249
Mar	61.915	74.764	1.208	8.960	3.076	3.923	12.883
Apr	39.342	35.321	0.898	7.247	2.588	0.963	8.210
May	27.559	26.248	0.952	7.222	2.541	0.000	7.222
Jun	19.383	12.588	0.649	5.694	1.941	0.000	5.694
Jul	15.092	6.712	0.445	4.814	1.739	0.000	4.814
Aug	12.393	5.349	0.432	4.146	1.471	0.000	4.146
Sep	11.065	6.608	0.597	3.624	1.294	0.000	3.624

APP TABLE 12: SUMMARY OF IFR ESTIMATE FOR IFR5 (CLASS C).

```
Annual Flows (Mill. cu. m or index values):
MAR                 =  502.596
S.Dev.              =  329.727
CV                  =    0.656
Q75                 =   12.295
Q75/MMF             =    0.294
BFI Index           =    0.481
CV(JJA+JFM) Index =    1.881
IFR Management Class = C
Total IFR           =   95.910 (19.08 %MAR)
Maint. Lowflow      =   50.236 (10.00 %MAR)
Drought Lowflow     =   27.809 ( 5.53 %MAR)
Maint. Highflow     =   45.674 ( 9.09 %MAR)
Monthly Distributions (Mill. cu. m.)
Distribution Type : Olifants
```

Month	Natural Flows			Modified Flows (IFR)			
				Low flows		High Flows	Total Flows
	Mean	SD	CV	Maint.	Drought	Maint.	Maint.
Oct	22.122	42.762	1.933	2.669	1.497	1.888	4.557
Nov	61.154	83.674	1.368	4.388	2.427	6.644	11.033
Dec	60.793	68.597	1.128	4.366	2.415	6.605	10.971
Jan	87.022	114.792	1.319	5.979	3.286	18.145	24.124
Feb	84.753	134.700	1.589	6.187	3.399	3.621	9.808
Mar	61.915	74.764	1.208	5.704	3.138	7.243	12.947
Apr	39.342	35.321	0.898	4.660	2.573	1.527	6.186
May	27.559	26.248	0.952	4.582	2.531	0.000	4.582
Jun	19.383	12.588	0.649	3.608	2.005	0.000	3.608
Jul	15.092	6.712	0.445	3.103	1.732	0.000	3.103
Aug	12.393	5.349	0.432	2.661	1.493	0.000	2.661
Sep	11.065	6.608	0.597	2.330	1.314	0.000	2.330

A.5.6 IFR6 IFR estimate: PES=E, REC = D

Note possible error in .tab file Drought=Maintenance

APP TABLE 13: SUMMARY OF IFR ESTIMATE FOR IFR6 (CLASS D).

```
Total Runoff : REGION I  B31F
Annual Flows (Mill. cu. m or index values):
MAR                  =   63.417
S.Dev.               =   50.068
CV                   =    0.790
Q75                  =    1.500
Q75/MMF              =    0.284
BFI Index            =    0.474
CV(JJA+JFM) Index =       1.971
IFR Management Class = D
Total IFR            =   11.328 (17.86 %MAR)
Maint. Lowflow       =    4.008 ( 6.32 %MAR)
Drought Lowflow      =    4.008 ( 6.32 %MAR)
Maint. Highflow      =    7.320 (11.54 %MAR)
Monthly Distributions (Mill. cu. m.)
Distribution Type : Olifants
```

Month	Natural Flows			Modified Flows (IFR)			
				Low flows		High Flows	Total Flows
	Mean	SD	CV	Maint.	Drought	Maint.	Maint.
Oct	2.273	3.831	1.685	0.188	0.188	0.077	0.264
Nov	7.379	12.536	1.699	0.337	0.337	0.239	0.576
Dec	8.354	9.870	1.181	0.375	0.375	1.420	1.796
Jan	12.234	21.007	1.717	0.536	0.536	1.123	1.659
Feb	10.416	15.423	1.481	0.484	0.484	2.685	3.169
Mar	7.462	10.111	1.355	0.455	0.455	1.537	1.992
Apr	4.822	5.269	1.093	0.363	0.363	0.239	0.602
May	3.170	2.269	0.716	0.348	0.348	0.000	0.348
Jun	2.368	1.190	0.503	0.285	0.285	0.000	0.285
Jul	1.937	0.854	0.441	0.241	0.241	0.000	0.241
Aug	1.626	0.680	0.418	0.214	0.214	0.000	0.214
Sep	1.376	0.577	0.419	0.181	0.181	0.000	0.181

A.5.7 IFR6B IFR estimate: PES=E, REC=C

APP TABLE 14: SUMMARY OF IFR ESTIMATE FOR IFR6B (CLASS B).

```
Total Runoff : Quaternaries B31A B31B B31C B31D
Annual Flows (Mill. cu. m or index values):
MAR                  =   42.351
S.Dev.               =   38.654
CV                   =    0.913
Q75                  =    0.700
Q75/MMF              =    0.198
BFI Index            =    0.411
CV(JJA+JFM) Index =       2.606
IFR Management Class = B
Total IFR            =   13.325 (31.46 %MAR)
Maint. Lowflow       =    8.451 (19.96 %MAR)
Drought Lowflow      =    2.675 ( 6.32 %MAR)
Maint. Highflow      =    4.874 (11.51 %MAR)
Monthly Distributions (Mill. cu. m.)
Distribution Type : Olifants
```

Month	Natural Flows			Modified Flows (IFR)			
				Low flows		High Flows	Total Flows
	Mean	SD	CV	Maint.	Drought	Maint.	Maint.
Oct	1.528	2.031	1.330	0.376	0.121	0.161	0.536
Nov	5.144	10.105	1.964	0.767	0.242	0.689	1.456
Dec	5.503	7.899	1.436	0.816	0.258	0.737	1.553
Jan	8.899	18.910	2.125	1.282	0.403	2.082	3.364
Feb	6.633	10.165	1.532	1.032	0.325	0.344	1.376
Mar	5.309	9.713	1.829	1.033	0.325	0.687	1.720
Apr	3.656	5.483	1.499	0.897	0.283	0.175	1.072
May	2.026	2.306	1.138	0.710	0.225	0.000	0.710
Jun	1.207	1.048	0.868	0.475	0.152	0.000	0.475
Jul	0.964	0.703	0.729	0.414	0.132	0.000	0.414
Aug	0.813	0.596	0.733	0.358	0.115	0.000	0.358
Sep	0.669	0.488	0.729	0.291	0.094	0.000	0.291

APP TABLE15: SUMMARY OF IFR ESTIMATE FOR IFR6B (CLASS C).

Total Runoff : Quaternaries B31A B31B B31C B31D
Annual Flows (Mill. cu. m or index values):
MAR = 42.351
S.Dev. = 38.654
CV = 0.913
Q75 = 0.700
Q75/MMF = 0.198
BFI Index = 0.411
CV(JJA+JFM) Index = 2.606
IFR Management Class = C
Total IFR = 9.787 (23.11 %MAR)
Maint. Lowflow = 4.911 (11.60 %MAR)
Drought Lowflow = 2.675 (6.32 %MAR)
Maint. Highflow = 4.876 (11.51 %MAR)
Monthly Distributions (Mill. cu. m.)
Distribution Type : Olifants

Month	Natural Flows			Modified Flows (IFR)			
				Low flows		High Flows	Total Flows
	Mean	SD	CV	Maint.	Drought	Maint.	Maint.
Oct	1.528	2.031	1.330	0.220	0.121	0.161	0.381
Nov	5.144	10.105	1.964	0.445	0.242	0.689	1.134
Dec	5.503	7.899	1.436	0.474	0.258	0.737	1.211
Jan	8.899	18.910	2.125	0.742	0.403	2.083	2.824
Feb	6.633	10.165	1.532	0.598	0.325	0.344	0.941
Mar	5.309	9.713	1.829	0.598	0.325	0.687	1.285
Apr	3.656	5.483	1.499	0.520	0.283	0.175	0.695
May	2.026	2.306	1.138	0.412	0.225	0.000	0.412
Jun	1.207	1.048	0.868	0.277	0.152	0.000	0.277
Jul	0.964	0.703	0.729	0.242	0.132	0.000	0.242
Aug	0.813	0.596	0.733	0.210	0.115	0.000	0.210
Sep	0.669	0.488	0.729	0.171	0.094	0.000	0.171

A.5.8 IFR6C IFR estimate, PES=C, REC=B

APP TABLE 16: SUMMARY OF IFR ESTIMATE FOR IFR6C (CLASS B).

Total Runoff : Quaternaries B31A B31B B31C
Annual Flows (Mill. cu. m or index values):
MAR = 31.327
Dev. = 28.751
CV = 0.918
Q75 = 0.480
Q75/MMF = 0.184
BFI Index = 0.400
CV(JJA+JFM) Index = 2.614
IFR Management Class = B
Total IFR = 9.770 (31.19 %MAR)
Maint. Lowflow = 6.174 (19.71 %MAR)
Drought Lowflow = 1.978 (6.32 %MAR)
Maint. Highflow = 3.596 (11.48 %MAR)
Monthly Distributions (Mill. cu. m.)
Distribution Type : Olifants

Month	Natural Flows			Modified Flows (IFR)			
				Low flows		High Flows	Total Flows
	Mean	SD	CV	Maint.	Drought	Maint.	Maint.
Oct	1.111	1.617	1.456	0.271	0.088	0.116	0.387
Nov	3.863	7.541	1.952	0.573	0.183	0.513	1.086
Dec	4.131	6.057	1.466	0.610	0.195	0.549	1.159
Jan	6.641	13.872	2.089	0.955	0.304	1.531	2.487
Feb	5.010	7.716	1.540	0.777	0.248	0.253	1.030
Mar	3.925	7.258	1.849	0.762	0.243	0.507	1.269
Apr	2.678	4.177	1.560	0.656	0.209	0.127	0.783
May	1.448	1.714	1.184	0.507	0.162	0.000	0.507
Jun	0.840	0.739	0.880	0.331	0.107	0.000	0.331
Jul	0.663	0.490	0.739	0.285	0.093	0.000	0.285
Aug	0.557	0.415	0.746	0.246	0.080	0.000	0.246
Sep	0.461	0.343	0.745	0.200	0.066	0.000	0.200

APP TABLE 17: SUMMARY OF IFR ESTIMATE FOR IFR6C (CLASS C).

```
Summary of IFR estimate for Quaternary Catchment Area :
Total Runoff : Quaternaries B31A B31B B31C
Annual Flows (Mill. cu. m or index values):
MAR                 =   31.327
S.Dev.              =   28.751
CV                  =    0.918
Q75                 =    0.480
Q75/MMF             =    0.184
BFI Index           =    0.400
CV(JJA+JFM) Index =    2.614
IFR Management Class = C
Total IFR           =    7.245 (23.13 %MAR)
Maint. Lowflow      =    3.649 (11.65 %MAR)
Drought Lowflow     =    1.978 ( 6.32 %MAR)
Maint. Highflow     =    3.596 (11.48 %MAR)
Monthly Distributions (Mill. cu. m.)
Distribution Type : Olifants
Month     Natural Flows          Modified Flows (IFR)
                                  Low flows    High Flows Total Flows
       Mean     SD       CV      Maint.  Drought     Maint.     Maint.
Oct    1.111    1.617    1.456    0.162   0.088      0.116      0.278
Nov    3.863    7.541    1.952    0.338   0.183      0.513      0.851
Dec    4.131    6.057    1.466    0.360   0.195      0.549      0.909
Jan    6.641   13.872    2.089    0.562   0.304      1.531      2.093
Feb    5.010    7.716    1.540    0.458   0.248      0.253      0.711
Mar    3.925    7.258    1.849    0.449   0.243      0.507      0.956
Apr    2.678    4.177    1.560    0.387   0.209      0.127      0.514
May    1.448    1.714    1.184    0.299   0.162      0.000      0.299
Jun    0.840    0.739    0.880    0.197   0.107      0.000      0.197
Jul    0.663    0.490    0.739    0.170   0.093      0.000      0.170
Aug    0.557    0.415    0.746    0.147   0.080      0.000      0.147
Sep    0.461    0.343    0.745    0.120   0.066      0.000      0.120
```

A.5.9 IFR7 IFR estimate: PES=E, REC=D

APP TABLE 18: SUMMARY OF IFR ESTIMATE FOR IFR7 (CLASS D).

```
Summary of IFR estimate for Quaternary Catchment Area:
Total Runoff : REGION I  B51C
Annual Flows (Mill. cu. m or index values):
MAR                 =  704.793
S.Dev.              =  441.756
CV                  =    0.627
Q75                 =   16.650
Q75/MMF             =    0.283
BFI Index           =    0.474
CV(JJA+JFM) Index =    1.742
IFR Management Class = D
Total IFR           =   89.386 (12.68 %MAR)
Maint. Lowflow      =   27.073 ( 3.84 %MAR)
Drought Lowflow     =   27.073 ( 3.84 %MAR)
Maint. Highflow     =   62.313 ( 8.84 %MAR)
Monthly Distributions (Mill. cu. m.)
Distribution Type : Olifants
Month     Natural Flows         Modified Flows (IFR)
                                  Low flows    High Flows Total Flows
       Mean     SD       CV      Maint.  Drought     Maint.     Maint.
Oct   28.743   51.775    1.801    1.205   1.205      0.514      1.719
Nov   87.269  110.527    1.267    2.462   2.462      2.834      5.296
Dec   90.983   86.371    0.949    2.544   2.544      7.828     10.373
Jan  127.861  163.477    1.279    3.616   3.616      8.703     12.318
Feb  120.158  171.489    1.427    3.629   3.629     33.703     37.331
Mar   84.888   94.092    1.108    3.214   3.214      7.720     10.934
Apr   53.370   46.491    0.871    2.462   2.462      1.012      3.475
May   35.699   28.749    0.805    2.411   2.411      0.000      2.411
Jun   25.027   13.993    0.559    1.814   1.814      0.000      1.814
Jul   19.823    8.581    0.433    1.473   1.473      0.000      1.473
Aug   16.360    6.866    0.420    1.205   1.205      0.000      1.205
Sep   14.612    8.239    0.564    1.037   1.037      0.000      1.037
```

A.5.10 IFR8 IFR estimate:: PES=D, REC=D

APP TABLE 19: SUMMARY OF IFR ESTIMATE FOR IFR8 (CLASS D)

(differs markedly from the table in the text).

```
Total Runoff : REGION I  B71B
Annual Flows (Mill. cu. m or index values):
MAR               =  834.533
S.Dev.            =  523.136
CV                =    0.627
Q75               =   17.470
Q75/MMF           =    0.251
BFI Index         =    0.450
CV(JJA+JFM) Index =    1.728
IFR Management Class = D
Total IFR         =  127.047 (15.22 %MAR)
Maint. Lowflow    =   35.850 ( 4.30 %MAR)
Drought Lowflow   =   35.850 ( 4.30 %MAR)
Maint. Highflow   =   91.197 (10.93 %MAR)
Monthly Distributions (Mill. cu. m.)
Distribution Type : Olifants
```

Month	Natural Flows			Modified Flows (IFR)			
				Low flows		High Flows	Total Flows
	Mean	SD	CV	Maint.	Drought	Maint.	Maint.
Oct	31.672	59.823	1.889	2.036	2.036	1.057	3.093
Nov	105.157	129.359	1.230	3.266	3.266	3.944	7.210
Dec	115.985	103.084	0.889	3.509	3.509	8.668	12.177
Jan	161.971	204.051	1.260	4.500	4.500	21.264	25.764
Feb	146.830	207.200	1.411	4.355	4.355	48.086	52.441
Mar	98.744	111.023	1.124	3.830	3.830	7.211	11.041
Apr	58.417	51.701	0.885	3.111	3.111	0.968	4.078
May	37.235	29.365	0.789	2.866	2.866	0.000	2.866
Jun	25.831	14.208	0.550	2.385	2.385	0.000	2.385
Jul	20.481	8.749	0.427	2.196	2.196	0.000	2.196
Aug	16.934	6.978	0.412	1.982	1.982	0.000	1.982
Sep	15.277	8.502	0.557	1.814	1.814	0.000	1.814

A.5.11 IFR9 IFR estimate: PES=D, REC=D

APP TABLE 20: SUMMARY OF IFR ESTIMATE FOR IFR9 (CLASS D).

```
Total Runoff : REGION I  B41H
Annual Flows (Mill. cu. m or index values):
MAR               =  171.580
IFR Management Class = D
Total IFR         =   26.031 (15.17 %MAR)
Maint. Lowflow    =   13.667 ( 7.97 %MAR)
Drought Lowflow   =   13.667 ( 7.97 %MAR)
Maint. Highflow   =   12.364 ( 7.21 %MAR)
Monthly Distributions (Mill. cu. m.)
Distribution Type : Olifants
```

Month	Natural Flows			Modified Flows (IFR)			
				Low flows		High Flows	Total Flows
	Mean	SD	CV	Maint.	Drought	Maint.	Maint.
Oct	5.372	5.571	1.037	0.750	0.750	0.549	1.299
Nov	19.691	20.090	1.020	1.192	1.192	0.503	1.696
Dec	25.441	22.122	0.870	1.393	1.393	1.406	2.799
Jan	36.361	41.657	1.146	1.821	1.821	5.119	6.941
Feb	30.950	35.963	1.162	1.693	1.693	2.132	3.826
Mar	20.719	20.182	0.974	1.500	1.500	2.174	3.674
Apr	13.546	15.080	1.113	1.296	1.296	0.480	1.776
May	7.303	6.853	0.938	1.071	1.071	0.000	1.071
Jun	4.096	2.595	0.633	0.829	0.829	0.000	0.829
Jul	3.105	1.902	0.613	0.750	0.750	0.000	0.750
Aug	2.542	1.589	0.625	0.696	0.696	0.000	0.696
Sep	2.454	1.842	0.750	0.674	0.674	0.000	0.674

A.5.12 IFR10 IFR estimate: PES=D, REC=D

APP TABLE 21: SUMMARY OF IFR ESTIMATE FOR IFR10 (CLASS D).

```
Total Runoff : REGION I  B41K
Annual Flows (Mill. cu. m or index values):
MAR                  =  406.231
IFR Management Class = D
Total IFR            =   49.172 (12.10 %MAR)
Maint. Lowflow       =   30.179 ( 7.43 %MAR)
Drought Lowflow      =   30.179 ( 7.43 %MAR)
Maint. Highflow      =   18.993 ( 4.68 %MAR)
Monthly Distributions (Mill. cu. m.)
Distribution Type : Olifants
Month     Natural Flows          Modified Flows (IFR)
                                  Low flows    High Flows Total Flows
       Mean     SD       CV     Maint.  Drought    Maint.     Maint.
 Oct  11.945  12.688   1.062     1.607   1.607      0.847      2.454
 Nov  46.098  48.665   1.056     2.592   2.592      0.746      3.338
 Dec  61.478  50.513   0.822     3.161   3.161      1.938      5.098
 Jan  79.709  75.111   0.942     3.750   3.750     10.857     14.607
 Feb  76.887 103.259   1.343     3.871   3.871      1.876      5.746
 Mar  50.784  48.486   0.955     3.375   3.375      1.972      5.347
 Apr  29.979  22.369   0.746     2.592   2.592      0.757      3.349
 May  16.999  10.877   0.640     2.384   2.384      0.000      2.384
 Jun  10.655   4.723   0.443     1.918   1.918      0.000      1.918
 Jul   8.266   3.416   0.413     1.768   1.768      0.000      1.768
 Aug   6.847   2.957   0.432     1.607   1.607      0.000      1.607
 Sep   6.585   3.873   0.588     1.555   1.555      0.000      1.555
```

A.5.13 IFR11 IFR estimate: PES=E, REC=D

APP TABLE 22: SUMMARY OF IFR ESTIMATE FOR IFR11 (CLASS D).

```
Total Runoff : Quaternaries B71H
Annual Flows (Mill. cu. m or index values):
MAR                  = 1393.158
IFR Management Class = D
Total IFR            =  117.682 ( 8.45 %MAR)
Maint. Lowflow       =   83.398 ( 5.99 %MAR)
Drought Lowflow      =   83.398 ( 5.99 %MAR)
Maint. Highflow      =   34.284 ( 2.46 %MAR)
Monthly Distributions (Mill. cu. m.)
Distribution Type : Olifants
Month     Natural Flows          Modified Flows (IFR)
                                  Low flows    High Flows Total Flows
       Mean     SD       CV     Maint.  Drought    Maint.     Maint.
 Oct  42.906  71.137   1.658     3.884   3.884      0.913      4.797
 Nov 172.644 203.010   1.176     7.777   7.777      1.244      9.021
 Dec 192.606 173.812   0.902     8.572   8.572      3.049     11.620
 Jan 270.573 312.940   1.157    11.251  11.251      5.589     16.840
 Feb 265.590 353.883   1.332    11.855  11.855     17.197     29.052
 Mar 187.048 199.670   1.067    10.447  10.447      4.736     15.183
 Apr 104.327  98.674   0.946     7.777   7.777      1.555      9.332
 May  57.043  43.896   0.770     6.429   6.429      0.000      6.429
 Jun  35.169  20.399   0.580     4.666   4.666      0.000      4.666
 Jul  26.193  13.612   0.520     4.018   4.018      0.000      4.018
 Aug  20.552  11.099   0.540     3.482   3.482      0.000      3.482
 Sep  18.507  13.567   0.733     3.240   3.240      0.000      3.240
```

A.5.14 IFR12 IFR estimate: PES=B, REC=B

APP TABLE 23: SUMMARY OF IFR ESTIMATE FOR IFR12 (CLASS B).

```
Total Runoff : REGION I  B60J
Annual Flows (Mill. cu. m or index values):
MAR                  =  383.703
IFR Management Class = B
Total IFR            =  132.325 (34.49 %MAR)
Maint. Lowflow       =  107.266 (27.96 %MAR)
Drought Lowflow      =   33.130 ( 8.63 %MAR)
Maint. Highflow      =   25.058 ( 6.53 %MAR)
Monthly Distributions (Mill. cu. m.)
Distribution Type : E.Escarp
```

Month	Natural Flows			Modified Flows (IFR)			
				Low flows		High Flows	Total Flows
	Mean	SD	CV	Maint.	Drought	Maint.	Maint.
Oct	12.111	3.697	0.305	5.625	2.143	1.229	6.853
Nov	18.942	10.224	0.540	5.962	2.074	2.395	8.357
Dec	32.152	51.930	1.615	7.232	2.411	3.826	11.058
Jan	52.610	69.414	1.319	10.178	2.946	4.261	14.439
Feb	78.912	113.095	1.433	13.790	3.871	7.904	21.694
Mar	69.638	99.392	1.427	14.463	4.018	3.764	18.227
Apr	38.518	48.771	1.266	11.923	3.370	1.680	13.603
May	22.696	8.628	0.380	9.642	2.946	0.000	9.642
Jun	17.813	5.121	0.287	8.035	2.592	0.000	8.035
Jul	15.061	3.772	0.250	7.500	2.411	0.000	7.500
Aug	12.878	3.143	0.244	6.696	2.277	0.000	6.696
Sep	12.372	6.839	0.553	6.221	2.074	0.000	6.221

A.5.15 IFR13 IFR estimate: PES=C, REC=B

APP TABLE 24: SUMMARY OF IFR ESTIMATE FOR IFR13 (CLASS B).

```
Total Runoff : REGION I  B72D
Annual Flows (Mill. cu. m or index values):
MAR                  = 1845.375
IFR Management Class = B
Total IFR            =  434.864 (23.57 %MAR)
Maint. Lowflow       =  358.469 (19.43 %MAR)
Drought Lowflow      =  110.686 ( 6.00 %MAR)
Maint. Highflow      =   76.395 ( 4.14 %MAR)
Monthly Distributions (Mill. cu. m.)
Distribution Type : Olifants
```

Month	Natural Flows			Modified Flows (IFR)			
				Low flows		High Flows	Total Flows
	Mean	SD	CV	Maint.	Drought	Maint.	Maint.
Oct	61.253	75.797	1.237	21.427	5.892	1.089	22.516
Nov	181.231	185.450	1.023	27.475	8.294	8.068	35.543
Dec	227.664	196.301	0.862	31.337	9.642	6.641	37.977
Jan	333.077	329.630	0.990	39.908	13.124	9.235	49.143
Feb	354.439	436.118	1.230	43.545	14.515	40.870	84.415
Mar	262.207	296.009	1.129	41.247	13.660	9.133	50.379
Apr	144.298	121.407	0.841	32.400	10.109	1.361	33.760
May	87.083	44.799	0.514	29.462	9.106	0.000	29.462
Jun	62.132	22.756	0.366	25.401	7.517	0.000	25.401
Jul	50.335	16.058	0.319	23.570	6.964	0.000	23.570
Aug	42.282	13.082	0.309	21.963	6.160	0.000	21.963
Sep	39.375	16.456	0.418	20.736	5.702	0.000	20.736

APP TABLE 25: SUMMARY OF IFR ESTIMATE FOR IFR13 (CLASS C).

```
Total Runoff : REGION I  B72D
      Annual Flows (Mill. cu. m or index values):
      MAR                 = 1845.375
      IFR Management Class = C
      Total IFR           =  284.456 (15.41 %MAR)
      Maint. Lowflow      =  208.061 (11.27 %MAR)
      Drought Lowflow     =  110.686 ( 6.00 %MAR)
      Maint. Highflow     =   76.395 ( 4.14 %MAR)
      Monthly Distributions (Mill. cu. m.)
      Distribution Type : Olifants
```

Month	Natural Flows			Modified Flows (IFR)			
				Low flows		High Flows	Total Flows
	Mean	SD	CV	Maint.	Drought	Maint.	Maint.
Oct	61.253	75.797	1.237	12.428	5.892	1.089	13.516
Nov	181.231	185.450	1.023	15.941	8.294	8.068	24.008
Dec	227.664	196.301	0.862	18.213	9.642	6.641	24.853
Jan	333.077	329.630	0.990	23.034	13.124	9.235	32.269
Feb	354.439	436.118	1.230	25.256	14.515	40.870	66.126
Mar	262.207	296.009	1.129	23.837	13.660	9.133	32.970
Apr	144.298	121.407	0.841	18.792	10.109	1.361	20.153
May	87.083	44.799	0.514	17.088	9.106	0.000	17.088
Jun	62.132	22.756	0.366	14.774	7.517	0.000	14.774
Jul	50.335	16.058	0.319	13.660	6.964	0.000	13.660
Aug	42.282	13.082	0.309	12.856	6.160	0.000	12.856
Sep	39.375	16.456	0.418	12.182	5.702	0.000	12.182

A.5.16 IFR14A IFR estimate: PES=C, REC=C

APP TABLE 26: SUMMARY OF IFR ESTIMATE FOR IFR14A (CLASS C).

```
Total Runoff : REGION I  B72H B72E B72F B72G B72E
Annual Flows (Mill. cu. m or index values):
MAR                 =   54.930
IFR Management Class = C
Total IFR           =   17.123 (31.17 %MAR)
Maint. Lowflow      =   10.759 (19.59 %MAR)
Drought Lowflow     =    0.000 ( 0.00 %MAR)
Maint. Highflow     =    6.364 (11.59 %MAR)
Monthly Distributions (Mill. cu. m.)
Distribution Type : Lowveld
```

Month	Natural Flows			Modified Flows (IFR)			
				Low flows		High Flows	Total Flows
	Mean	SD	CV	Maint.	Drought	Maint.	Maint.
Oct	1.098	0.394	0.359	0.402	0.000	0.000	0.402
Nov	1.272	0.623	0.490	0.337	0.000	0.226	0.563
Dec	3.432	6.699	1.952	0.536	0.000	0.218	0.753
Jan	9.079	23.562	2.595	1.125	0.000	0.712	1.837
Feb	14.314	30.075	2.101	1.935	0.000	4.536	6.471
Mar	11.714	23.900	2.040	1.821	0.000	0.672	2.493
Apr	5.038	7.973	1.583	1.244	0.000	0.000	1.244
May	2.648	1.603	0.606	0.830	0.000	0.000	0.830
Jun	2.065	1.119	0.542	0.778	0.000	0.000	0.778
Jul	1.694	0.807	0.476	0.670	0.000	0.000	0.670
Aug	1.406	0.580	0.413	0.589	0.000	0.000	0.589
Sep	1.169	0.419	0.358	0.492	0.000	0.000	0.492

A.5.17 IFR16/17 IFR estimate: PES=C, REC=B

APP TABLE 27: SUMMARY OF IFR ESTIMATE FOR IFR16/17 (CLASS B).

```
Total Runoff : REGION I  B73C
Annual Flows (Mill. cu. m or index values):
MAR                  = 1968.007
IFR Management Class = B
Total IFR          =  425.731 (21.63 %MAR)
Maint. Lowflow     =  361.015 (18.34 %MAR)
Drought Lowflow    =   95.014 ( 4.83 %MAR)
Maint. Highflow    =   64.716 ( 3.29 %MAR)
Monthly Distributions (Mill. cu. m.)
Distribution Type : Olifants
```

Month	Natural Flows			Modified Flows (IFR)			
				Low flows		High Flows	Total Flows
	Mean	SD	CV	Maint.	Drought	Maint.	Maint.
Oct	64.267	78.188	1.217	18.749	5.357	1.089	19.838
Nov	188.322	191.836	1.019	26.698	7.258	8.129	34.827
Dec	239.225	208.018	0.870	31.605	8.303	6.604	38.210
Jan	355.569	357.066	1.004	42.855	10.981	6.962	49.817
Feb	383.890	475.492	1.239	48.384	12.096	32.798	81.182
Mar	283.757	326.211	1.150	45.533	11.517	6.757	52.290
Apr	154.031	132.130	0.858	33.437	8.554	2.377	35.814
May	92.431	47.008	0.509	29.463	7.767	0.000	29.463
Jun	66.123	24.198	0.366	24.365	6.480	0.000	24.365
Jul	53.591	17.095	0.319	21.963	5.893	0.000	21.963
Aug	44.999	13.819	0.307	19.820	5.625	0.000	19.820
Sep	41.801	17.267	0.413	18.144	5.184	0.000	18.144

APP TABLE 28: SUMMARY OF IFR ESTIMATE FOR IFR16/17 (CLASS C).

```
Total Runoff : REGION I  B73C
Annual Flows (Mill. cu. m or index values):
MAR                  = 1968.007
IFR Management Class = C
      Total IFR          =  289.634 (14.72 %MAR)
      Maint. Lowflow     =  224.917 (11.43 %MAR)
      Drought Lowflow    =   95.014 ( 4.83 %MAR)
      Maint. Highflow    =   64.716 ( 3.29 %MAR)

      Monthly Distributions (Mill. cu. m.)
      Distribution Type : Olifants
```

Month	Natural Flows			Modified Flows (IFR)			
	Low flows		High Flows Total Flows				
	Mean	SD	CV	Maint.	Drought	Maint.	Maint.
Oct	64.267	78.188	1.217	11.249	5.357	1.089	12.338
Nov	188.322	191.836	1.019	16.070	7.258	8.129	24.200
Dec	239.225	208.018	0.870	19.017	8.303	6.604	25.621
Jan	355.569	357.066	1.004	34.284	10.981	6.962	41.246
Feb	383.890	475.492	1.239	29.030	12.096	32.798	61.828
Mar	283.757	326.211	1.150	27.320	11.517	6.757	34.077
Apr	154.031	132.130	0.858	19.958	8.554	2.377	22.335
May	92.431	47.008	0.509	17.677	7.767	0.000	17.677
Jun	66.123	24.198	0.366	14.515	6.480	0.000	14.515
Jul	53.591	17.095	0.319	13.124	5.892	0.000	13.124
Aug	44.999	13.819	0.307	11.785	5.625	0.000	11.785
Sep	41.801	17.267	0.413	10.886	5.184	0.000	10.886

APP TABLE 29: HIGH-FLOW (FRESHETS AND FLOODS) EWRS FROM THE COMPREHENSIVE RESERVE (DWAF 2001A-C)

		Oct	Nov		Dec		Jan		Feb			Mar		Apr	Vol ($10^6 m^3$)	% MAR
IFR1	Discharge (m^3/s)	3	3	5	10		10	30	100	10		10		3		
nMAR	Duration (days)	1	2	2	3		3	3	4	3		3		1		
148.094	Return period (yrs)	1	1	1	1		1	1	2	1		1		1		
Olifants River	Max. depth (m)	0.52	0.52	0.6	0.78		0.78	1.2	1.93	0.78		0.78		0.52		
Upper Olifants	Monthly vol ($10^6 m^3$)	0.23	0.84		1.44		5.95		14.52			1.45			24.43	16.496
IFR2	Discharge (m^3/s)	5	12	12	12	15	35	12	120	140	15	15		5		
nMAR	Duration (days)	2	3	3	3	3	4	3	5	5	4	3		2		
489.7	Return period (yr)	1	1	1	1	1	1	1	2	3	1	1		1		
Olifants River	Max. depth (m)	0.63	0.84	0.84	0.84	0.9	1.18	0.84	1.78	1.92	0.9	0.9		0.63		
Upper Olifants	Monthly vol ($10^6 m^3$)	0.48	2.99		2.89		6.71		21.5			1.76		0.29	36.62	7.478
IFR3	Discharge (m^3/s)	5	3	3	3	15	15		50			6		5		
nMAR	Duration (days)	2	1	1	2	2	3		4			2		2		
73.7	Return period (yrs)	1	1	1	1	1	1		3			1		1		
Klein-Olifants	Max. depth (m)	0.65	0.57	0.57	0.57	0.93	0.93		1.5			0.69		0.65		
Upper Olifants	Monthly vol ($10^6 m^3$)	0.58	0.47		2.08		2.25		3.54			0.67		0.56	10.15	13.777
IFR4	Discharge (m^3/s)	6	5	10	14		34		45			34	14	5		
nMAR	Duration (days)	2	2	3	3		3		4			4	3	2		
192.6	Return period (yr)	1	1	1	1		1		2			1	1	1		
Wilge River	Max. depth (m)	1.07	1.02	1.23	1.34		1.69		1.82			1.69	1.34	1.02		
Upper Olifants	Monthly vol ($10^6 m^3$)	0.53	2.05		1.99		5.09		7.89			8.17		0.58	26.3	13.637
IFR5	Discharge (m^3/s)	5	8		25		90		180	90		25		9		
nMAR	Duration (days)	2	3		4		5		5	5		4		3		
503	Return period (yrs)	1	1		1		1		3	0.66		1		1		
Olifants River	Max. depth (m)	0.84	0.96		1.3		1.86		2.39	1.86		1.3		0.99		
Middle Olifants	Monthly vol ($10^6 m^3$)	0.417	0.832		4.07		17.7		17.6			3.93		0.96	45.509	9.055
IFR6	Discharge (m^3/s)	1	3		12		5	5	5	13	25	13		3		
nMAR	Duration (days)	1	1		2		2	5	2	2	3	2		1		
63.4	Return period (yrs)	1	1		1		1	1	1	2	2	1		1		
Elands River	Max. depth (m)	0.53	0.8		1.34		0.96	0.96	0.96	1.38	1.77	1.38		0.8		
Middle Olifants	Monthly vol ($10^6 m^3$)	0.077	0.238		1.42		1.12		2.68			1.54		0.24	7.315	11.534

		Oct	Nov		Dec			Jan		Feb				Mar		Apr	Vol ($10^6 m^3$)	% MAR
IFR7	Discharge (m^3/s)	5	20		40			45		300	150			40		10		
nMAR	Duration (days)	2	3		5			5		6	6			5		2		
704	Return period (yrs)	1	1		1			1		2	2			1		1		
Olifants River	Max. depth (m)	1.02	1.71		2.22			2.32		4.73	3.65			2.22		1.32		
Middle Olifants	Monthly vol ($10^6 m^3$)	0.5	2.8		7.8			8.7		33.7				7.7		1	62.2	8.825
IFR8	Discharge (m^3/s)	10	20	10	35	10	10	50	10	10	10	350	150	35	10	10		
nMAR	Duration (days)	2	3	2	4	2	2	5	2	2	2	6	6	4	2	2		
834.5	Return period (yrs)	1	1	1	1	1	1	1	1	1	1	2	2	1	1	1		
Olifants River	Max. depth (m)	0.98	1.31	0.98	1.65	0.98	0.98	1.91	0.98	0.98	0.98	4.26	3	1.65	0.98	0.98		
Middle Olifants	Monthly vol ($10^6 m^3$)	1.06	3.94		8.67			21.26		48.084				7.21		0.968	91.192	10.927
IFR9	Discharge (m^3/s)	5	5		10			20	65	15				15		5		
nMAR	Duration (days)	2	2		3			5	5	3				3		2		
171.58	Return period (yrs)	1	1		1			1.5	3	1				1		1		
Steelpoort River	Max. depth (m)	0.63	0.63		0.81			1.06	1.75	0.95				0.95		0.63		
Lower Olifants	Monthly vol ($10^6 m^3$)	0.55	0.5		1.41			5.19		2.13				2.17		0.48	12.43	7.244
IFR10	Discharge (m^3/s)	8	8		15			50	80	15				15		8		
nMAR	Duration (days)	2	2		3			6	6	3				3		2		
406.231	Return period (yrs)	1	1		1			1.5	2	1				1		1		
Steelpoort River	Max. depth (m)	0.77	0.77		0.98			1.6	1.96	0.98				0.98		0.77		
Lower Olifants	Monthly vol ($10^6 m^3$)	0.85	0.75		1.94			10.8		1.88				1.99		0.76	18.97	4.670
IFR11	Discharge (m^3/s)	9	11		20			35		80				30		13		
nMAR	Duration (days)	2	3		4			4		6				4		3		
1393	Return period (yrs)	1	1		1			1		1				1		1		
Olifants River	Max. depth (m)	1.01	1.08		1.33			1.63		2.18				1.54		1.15		
Lower Olifants	Monthly vol ($10^6 m^3$)	0.91	1.244		3.048			5.59		17.2				4.74		1.56	34.292	2.462
IFR12	Discharge (m^3/s)	10	10	10	15	15		15	20	15	30	75		15	20	10	10	
nMAR	Duration (days)	3	3	3	3	3		3	3	3	4	5		3	3	3	3	
383.7	Return period (yrs)	1	1	1	1	1		1	1	1	1	3		1	1	1	1	
Blyde River	Max. depth (m)	0.76	0.76	0.76	0.89	0.89		0.89	1	0.89	1.16	1.68		0.89	1	0.76	0.76	
Lower Olifants	Monthly vol ($10^6 m^3$)	1.23	2.39		3.83			4.26		7.9				3.76		1.68	25.05	6.523

		Oct	Nov	Dec		Jan	Feb		Mar	Apr	Vol (10^6m^3)	% MAR
IFR13	Discharge (m^3/s)	15	50	30	30	60	180	250	60	20		
nMAR	Duration (days)	3	5	4	4	5	7	7	5	4		
1845	Return period (yrs)	1	1	1	1	1	1	3	1	1		
Olifants River	Max. depth (m)	0.92	1.56	1.25	1.25	1.69	2.75	3.44	1.69	1.04		
Lower Olifants	Monthly vol (10^6m^3)	1.09	8.07	6.64		9.23	40.9		9.13	1.36	76.42	4.142
IFR14a	Discharge (m^3/s)		2	2		5	40	80	5			
nMAR	Duration (days)		2	2		3	4		2			
54.9	Return period (yrs)		1	1		1	1	3	1			
Selati River	Max. depth (m)		0.64	0.64		0.78	1.5	1.97	0.78			
Lower Olifants	Monthly vol (10^6m^3)		0.226	0.218		0.72	4.54		0.67		6.374	11.610
IFR14b	Discharge (m^3/s)		3	3		7	60	100	7			
nMAR	Duration (days)		2	1		3	4	4	2			
64.9	Return period (yrs)		1	1		1	1	3	1			
Selati River	Max. depth (m)		0.76	0.76		0.99	2.03	2.42	0.99			
Lower Olifants	Monthly vol (10^6m^3)		0.351	0.342		1.03	5.81		0.79		8.323	12.811
IFR16/17	Discharge (m^3/s)	14	50	30	30	50	150	250	50	26		
nMAR	Duration (days)	3	5	4	4	5	7	7	5	4		
1968	Return period (yrs)	1	1	1	1	1	1	3	1	1		
Olifants	Max. depth (m)	0.6	1	0.81	0.81	1	1.55	2.05	1	0.77		
Lower Olifants	Monthly vol (10^6m^3)	1.09	8.13	6.6		6.96	32.8		6.76	2.38	64.72	3.289

A.6 Dwars

APP TABLE 30: CATEGORY B/C (THE REC) EWRS FOR DWA-EWR1 (STASSEN 2008B).

Please note different units for summary statistics (MCM) and monthly distribution (mill m^3/s)

```
Desktop Version 2, Printed on 2008/04/21
Summary of EWR estimate for: Dwars_EWR1
Total runoff, cumulative at EWR site 1 (S24°50’38.1”; E30°05’30.8”) in quaternary catchment B41H
        Annual Flows (Mill. cu. m or index values):
        MAR                =   31.429*
        S.Dev.             =   22.106
        CV                 =    0.703
        Q75                =    0.660
        Q75/MMF            =    0.252
        BFI Index          =    0.431
        CV(JJA+JFM) Index =     1.747
        ERC = B/C**
        Total IFR          =    8.142 (25.91 %MAR)
        Maint. Lowflow     =    6.099 (19.41 %MAR)
        Drought Lowflow    =    2.289 ( 7.28 %MAR)
        Maint. Highflow    =    2.042 ( 6.50 %MAR)
        Monthly Distributions (cu.m./s)
        Distribution Type : Olifants
        Month    Natural Flows          Modified Flows (IFR)
                                         Low flows    High Flows Total Flows
               Mean     SD       CV     Maint.  Drought    Maint.      Maint.
         Oct   0.337   0.418   0.463    0.107   0.043     0.060      0.167
         Nov   1.149   1.464   0.492    0.160   0.061     0.060      0.220
         Dec   1.841   1.754   0.356    0.215   0.080     0.144      0.359
         Jan   1.977   2.007   0.379    0.251   0.092     0.141      0.392
         Feb   2.230   2.964   0.550    0.310   0.113     0.293      0.603
         Mar   1.576   2.140   0.507    0.280   0.102     0.094      0.374
         Apr   1.049   0.902   0.332    0.264   0.097     0.000      0.264
         May   0.659   0.530   0.300    0.215   0.080     0.000      0.215
         Jun   0.420   0.244   0.224    0.173   0.066     0.000      0.173
         Jul   0.305   0.137   0.168    0.134   0.052     0.000      0.134
         Aug   0.257   0.131   0.190    0.114   0.045     0.000      0.114
         Sep   0.242   0.122   0.195    0.107   0.043     0.000      0.107
```

* Virgin mean annual runoff (VMAR) based on the total flow from quaternary catchment B41G and 18% of B41H. Flow record scaled from the Steelpoort River flow record as determined during the high confidence Reserve determination study for the Olifants River.

** Recommended Ecological category determined during the intermediate III Reserve determination study on the Dwars River at EWR site (S24° 50’ 38.1”; E30° 05’ 30.8”) in quaternary catchment B41H.

The flood requirements are provided in App Table .

APP TABLE 31: CATEGORY B/C (THE REC) FLOOD EWRS FOR DWA-EWR1 (STASSEN 2008A)

Floods	Flood size (range)	Integrated requirement	Spatsim output
Class 1	1-2 daily average	Oct, Nov, Dec, Jan, Feb 5 total	Oct, Nov, Dec, Jan, Feb 1 m^3/s, 1day duration
Class 2	2 - 4 daily average	2 in either Nov/Dec/Jan /Feb 2 total	December, January 1 m^3/s (Dec) and 3 m^3/s (Jan), 1 day duration
Class 3	10 m^3/s daily average	1:2 (summer)	January 10 m^3/s (1:2 years)
Class 4	16 m^3/s	1: 4 (summer)	March 12 m^3/s (1:4 years), 1 day duration
Class 5	40 m^3/s	1: 10 (summer)	February 18 m^3/s (1:10 years), 1 day duration

A.7 Elefantes

APP TABLE 32: CATEGORY C (REC) EWRS FOR M-EWR1 (SALOMAN, 2007A)

ERC = C	Natural Flow Statistics			EWR Flows (m^3/s)			
				Low Flows		High Flows	Total Flows
Month	Mean	SD	CV	Maint.	Drought	Maint.	Maint.
Oct	28.637	21.711	0.283	7.500	3.000	0.000	7.500
Nov	85.191	79.304	0.359	9.000	3.700	0.000	9.000
Dec	127.198	5.829	0.311	10.300	4.300	4.974	15.274
Jan	196.434	96.176	0.373	12.300	5.200	0.516	12.816
Feb	251.423	87.397	0.473	14.000	6.000	36.814	50.814
Mar	151.322	51.147	0.373	11.000	4.600	4.974	15.974
Apr	79.877	52.133	0.252	8.900	3.600	2.220	11.120
May	48.468	24.860	0.191	8.100	3.300	0.000	8.100
Jun	35.359	12.767	0.139	7.700	3.100	0.000	7.700
Jul	27.868	8.328	0.112	7.500	3.000	0.000	7.500
Aug	23.369	6.695	0.107	7.400	2.900	0.000	7.400
Sep	21.891	7.909	0.139	7.300	2.900	0.000	7.300
Total (calc)	1077.04	454.256	3.112	111.000	45.600	49.498	160.498
% of MAR (MAR=1077.04 m^3/s)				10.306	4.234	4.596	14.902
2819.020 MCM (calc)							

APP TABLE 33: CATEGORY C (REC) EWRS FOR M-EWR2 (SALOMAN, 2007A)

ERC = C	Natural Flow Statistics			EWR Flows (m3/s)			
				Low Flows		High Flows	Total Flows
Month	Mean	SD	CV	Maint.	Drought	Maint.	Maint.
Oct	44.40	33.04	0.28	8.50	3.50	0.00	8.50
Nov	129.94	127.53	0.38	10.20	4.10	0.00	10.20
Dec	238.57	165.09	0.26	12.70	4.90	18.27	30.97
Jan	546.49	635.42	0.43	19.30	7.10	54.85	74.15
Feb	847.88	892.53	0.44	25.00	9.00	139.48	164.48
Mar	487.01	469.09	0.36	18.00	6.70	39.37	57.37
Apr	250.86	242.55	0.37	12.80	4.90	8.70	21.50
May	134.17	140.63	0.39	10.40	4.10	0.00	10.40
Jun	93.07	171.42	0.71	9.50	3.80	0.00	9.50
Jul	62.33	88.82	0.53	8.90	3.60	0.00	8.90
Aug	40.22	23.83	0.22	8.40	3.50	0.00	8.40
Sep	35.74	17.14	0.19	8.30	3.40	0.00	8.30
Total (cals)	2910.67	3007.095	4.557	152.000	58.600	260.671	412.671
% of MAR (MAR=2910.67 m^3/s)				5.222	2.013	8.956	14.178
7618.345 MCM (calc)							

APP TABLE 34: CATEGORY C (REC) FLOOD REQUIREMENT EWRS FOR M-EWR1 AND 2 (SALOMAN, 2007A)

<table>
<tr><th></th><th colspan="4">Class I</th><th colspan="6">Class II</th><th colspan="3">Class III</th><th colspan="3">Class IV</th><th>Class V</th></tr>
<tr><td>EWR1</td><td colspan="4"></td><td colspan="6"></td><td colspan="3"></td><td colspan="3"></td><td></td></tr>
<tr><td>Peak flow (m^3/s)</td><td colspan="4">16</td><td colspan="6">75</td><td colspan="3">150</td><td colspan="3">300</td><td></td></tr>
<tr><td>Month</td><td>Jan</td><td>Feb</td><td>Mar</td><td>Dec</td><td colspan="2">Feb</td><td colspan="2">Apr</td><td colspan="2">Dec</td><td colspan="3">Feb</td><td colspan="3">Feb</td><td></td></tr>
<tr><td>Duration (days)</td><td>1</td><td>1</td><td>1</td><td>1</td><td colspan="2">3</td><td colspan="2">3</td><td colspan="2">3</td><td colspan="3">3</td><td colspan="3">1</td><td></td></tr>
<tr><td># of Events</td><td>1</td><td>1</td><td>1</td><td>1</td><td colspan="2">1</td><td colspan="2">1</td><td colspan="2">1</td><td colspan="3">1</td><td colspan="3">1</td><td></td></tr>
<tr><td>EWR2</td><td colspan="4"></td><td colspan="6"></td><td colspan="3"></td><td colspan="3"></td><td></td></tr>
<tr><td>Peak flow (m^3/s)</td><td colspan="4">67</td><td colspan="6">145</td><td colspan="3">270</td><td colspan="3">540</td><td>1080</td></tr>
<tr><td>Month</td><td>Jan</td><td>Feb</td><td>Mar</td><td>Dec</td><td colspan="3">Feb</td><td colspan="3">Apr</td><td>Jan</td><td>Feb</td><td>Mar</td><td>Jan</td><td>Feb</td><td>Mar</td><td>Feb</td></tr>
<tr><td>Duration (days)</td><td>1</td><td>1</td><td>1</td><td>1</td><td colspan="3">3</td><td colspan="3">3</td><td>3</td><td>3</td><td>3</td><td>4</td><td>4</td><td>4</td><td>3</td></tr>
<tr><td>#of Events</td><td>1</td><td>1</td><td>1</td><td>1</td><td colspan="3">1</td><td colspan="3">1</td><td>1</td><td>1</td><td>1</td><td>1</td><td>1</td><td>1</td><td>1</td></tr>
</table>

Appendix C:
EWR results at nodes (Classification study)

* *MAR: Mean Annual Run-off*

[1] *Based on the argument that the higher the EI-ES, the closer to the reference the REC should be. Default REC: Very high = A; High = B; Moderate = C and Low to Very Low = D. This does not consider attainability. DWA 2010 PES update (DWA, 2010).*

[2] *Based on EWR for maintenance and drought flows only*

EWR sites are shaded. This excludes Nou-EWR1 and Tre-EWR1 for which we have no additional information.

PLEASE NOTE: *The EWRs are for the PES, not the REC.*

APP TABLE 35: IUA1 UPPER OLIFANTS: SUMMARY OF ECO-CLASSIFICATION AND EWR

Node	Quat	Nodes	EI	ES	PES	REC / Default REC[1]	Natural MAR* (mcm/ a)	EWR (PES) as % of natural MAR[2]
		Recommended Class III						
HN1	B11A, B11B	Olifants (confluence with Steenkoolspruit)	High	High	C	B	61.3	10.25
HN2	B11C	Piekespruit (confluence with Steenkoolspruit)	High	High	B	B	-	-
HN3	B11D	Dwars-indieWegspruit (confluence with Trichardtspruit)	Moderate	High	C	B	-	-
HN4	B11D	Steenkoolspruit (outlet of quaternary)	Moderate	High	D	B	44.6	4.7
HN5	B11E	Blesbokspruit (confluence with Rietspruit)	High	High	B	B	-	-
HN6	B11E	Steenkoolspruit (confluence with Olifants)	Moderate	High	D	B	65.4	4.7
HN7	B11F	Olifants (outlet of quaternary)	Moderate	High	D	B	147.9	4.7
HN8	B11G	Noupoortspruit (EWR site - NOU-EWR1) (existing)	Moderate	Moderate	C/D	C/D	4.28	13.9
HN9	B11G	Olifants (releases from Witbank Dam)	Moderate	High	D	B	164	4.7
HN10	B11H	Spookspruit (confluence with Olifants)	High	High	C	B	11.4	10.25
HN11	B11J	Olifants (EWR site 1 - EWR1) (existing)	Moderate	Moderate	(E) D	D	184.5	4.7
HN12	B11K, B11L	Klipspruit (confluence with Olifants)	High	Moderate	(E) D	B	45.7	4.67
HN14	B12A	Boschmansfontein (confluence with Klein Olifants)	Moderate	High	C	B	-	-
HN15	B12A	Klein Olifants (outlet of quaternary)	High	High	C	B	12.7	18.85
HN16	B12B	Klein Olifants (outlet of quaternary)	Moderate	High	D	B	16.9	8.11
HN17	B12C	Klein Olifants (EWR site - OLI-EWR1) (Rapid site)	Low	Low	C	C	44.5	18.85
HN18	B12C	Klein Olifants (releases from Middelburg Dam)	Moderate	High	D	B	53.5	5.52
HN19	B12D	Vaalbankspruit (confluence with Klein Olifants)	Moderate	High	D	B	-	-
HN20	B12D	Klein Olifants (outlet of quaternary)	Moderate	High	D	B	67.3	5.52

APP TABLE 36: UA 2 WILGE RIVER CATCHMENT: SUMMARY OF ECO-CLASSIFICATION AND EWR

Node	Quat	Nodes	EI	ES	PES	REC / Default REC[1]	Natural *MAR (mcm/ a)	EWR (PES) as % of natural MAR[2]
		Recommended Class II						
HN21	B20A	Bronkhorstspruit (outlet of quaternary)	Moderate	High	C	B	27.7	13.38
HN22	B20B	Koffiespruit (confluence with Bronkhorstspruit)	Moderate	High	C	B	15.5	13.38
HN23	B20C	Osspruit (inflow to Bronkhorstspruit Dam)	Moderate	High	D	B	-	-
HN24	B20C	Bronkhorstpruit (outlet from Bronkhorstspruit Dam)	High	High	C	B	56.4	13.44
HN25	B20D	Hondespruit (confluence with Bronkhorstspruit)	High	High	C	B	11.9	13.39
HN26	B20D	Bronkhorstpruit (confluence with Wilge)	High	Very high	C	A	79.9	13.45
HN27	B20E, B20F	Wilge (confluence with Bronkhorstspruit	High	Very high	C	A	45.8	13.42
HN28	B20G	Saalboomspruit (confluence with Wilge)	Moderate	High	C	B	22.1	13.4
HN29	B20H	Grootspruit (confluence with Wilge)	High	Very high	C	A	12.8	13.4
HN30	B20H	Wilge (outlet of quaternary)	High	Very high	B	A	158.2	17.92
HN31	B20J	Wilge (EWR site - EWR4, outlet of IUA2) (existing)	High	High	C	B	175.5	12.16

APP TABLE 37: IUA 3 SELONS RIVER CATCHMENT: SUMMARY OF ECO-CLASSIFICATION AND EWR

Node	Quat	Nodes	EI	ES	PES	REC / Default REC[1]	Natural *MAR (mcm/ a)	EWR (PES) as % of natural MAR[2]
		Recommended Class II						
HN32	B12E	Doringboomspruit (confluence with Klein Olifants)	High	High	B	B	-	-
HN33	B12E	Keeromspruit (confluence with Klein Olifants)	High	Very High	C	A	-	-
HN34	B12E	Klein Olifants (EWR site - EWR3) (existing)	Moderate	Moderate	C	C	81.5	12.72
HN35	B32A	Kranspoortspruit (EWR site - OLI-EWR3) (Rapid site)	Very high	Very high	B	A/B	4.7	24.42
HN36	B32A	Boekenhoutloop (inflow to Loskop Dam)	High	High	B	B	-	-
HN37	B32A	Olifants (EWR site - EWR2) (existing)	High	High	C	B	500.6	12.53
HN38	B32B, B32C	One node at confluence of Selons with Olifants in B32C. Included: Klipspruit (confluence with Selons) Kruis (confluence with Selons) Selons (confluence with Olifants)	High	High	B	B	-	-
HN39	B32C	Olifants (releases from Loskop Dam)	High	High	D	B	568.6	7.22
HN40	B32C	Olifants (outlet of quaternary - outlet of IUA3)	High	High	D	B	576.8	7.22

APP TABLE 38: IUA 4 ELANDS RIVER CATCHMENT: SUMMARY OF ECO-CLASSIFICATION AND EWR

Node	Quat	Nodes	EI	ES	PES	REC / Default REC[1]	Natural *MAR (mcm/ a)	EWR (PES) as % of natural MAR[2]
		Recommended Class III						
HN41	B31A, B, C	One node at outlet of B31C, releases from Rust de Winter Dam. Included:B31A (Elands) B31B (Hartbeesspruit) B31C (Elands)	High	Very High	C	A	33.5	12.34
HN42	B31D	Enkeldoringspruit (confluence with Elands)	High	High	C	B	-	-
HN43	B31F	Elands (releases from Mkumbe Dam)	High	High	C	B	59.8	12.34
HN44	B31G	Kameel (upper part only	Moderate	High	D	B	-	-
HN45	B31G	Elands (EWR site - EWR6) (existing)	Moderate	Moderate	D	D	60.3	6.32
HN46	B31G	Elands (outlet of quaternary - outlet of IUA4)	Low	Moderate	E	D	69.6	6.32 (D)

APP TABLE 39: IUA 5 MIDDLE OLIFANTS UP TO FLAG BOSHIELO DAM: SUMMARY OF ECO-CLASSIFICATION AND EWR

Node	Quat	Nodes	EI	ES	PES	REC / Default REC[1]	Natural *MAR (mcm/ a)	EWR (PES) as % of natural MAR[2]
		Recommended Class III						
HN47	B31H, B31J	Elands (outlet of quaternary, confluence with Olifants)	Low	Moderate	E	D	84.1	6.32 (D)
HN48	B32E, B32F	One node at confluence with Olifants in B32F Included: B32E (Bloed), B32F (Doringpoortloop, Diepkloof and Bloed)	Moderate	High	B	B	17.2	13.9
HN49	B32G, H	One node at outlet of B32H, confluence with Olifants Included: B32G (Moses) B32H (Mametse and Moses)	High	High	C	B	35.4	9.93
HN50	B32D	Olifants (EWR site - EWR5) (existing)	Moderate	Moderate	C	C	570.9	9.96
HN51	B51B	Puleng (upper part only)	High	High	B	B	-	-
HN52	B51B	Olifants (releases from Flag Boshielo Dam)	Moderate	High	D	B	723.4	3.91
HN53	B51D, B51E	Olifants (outlet of quaternary- outlet of IUA5)	Moderate	High	D	B	726.6	3.81

APP TABLE 40: IUA 6 STEELPOORT RIVER CATCHMENT: SUMMARY OF ECO-CLASSIFICATION AND EWR

Node	Quat	Nodes	EI	ES	PES	REC / Default REC[1]	Natural *MAR (mcm/ a)	EWR (PES) as % of natural MAR[2]
		Recommended Class III						
HN54	B41A	One node at outlet of B41A. Included: Grootspruit (outlet of quaternary) Langspruit, including Lakenvleispruit and Kleinspruit	High	High	C	B	41.9	20.78
HN55	B41B	Steelpoort (EWR site - OLI-EWR2) (Rapid site)	Moderate	Moderate	C	C	63.5	20.78
HN56	B41C	Masala (confluence with Steelpoort), including Tonteldoos and Vlugkraal)	High	High	C	B	-	-
HN57	B41D, B41E	Steelpoort (inflow to De Hoop Dam)	High	Very high	C	A	117	20.78
HN58	B41F	Draaikraalspruit (confluence with Klip)	High	Very high	B	A	-	-
HN59	B41F	Klip (EWR site - OLI-EWR4) (Rapid site)	Moderate	Moderate	C	B/C	5.2	12.44
HN60	B41G	Kraalspruit (confluence with Groot Dwars)	High	Very high	B	A	-	-
HN61	B41G	Klein Dwars (Confluence with Groot Dwars)	High	High	D	B	-	-
HN62	B41G	Upper reaches of Dwars (before mining impacts)	High	Very high	C	A	24.5	13.33
HN63	B41H	Dwars (EWR site - DWA-EWR1) (existing)	High	High	B/C	B/C	31.4	19.41
HN64	B41H	Steelpoort	Moderate	Moderate	D	C	-	-
HN65	B41J	Steelpoort (EWR site - EWR9) (existing)	High	High	D	D	120.2	7.97
HN66	B41J, B41K	Steelpoort (EWR site - EWR10) (existing) (confluence with Olifants - outlet of IUA6)	Moderate	High	D	D	336.6	7.43

APP TABLE 41: IUA 7 MIDDLE OLIFANTS BELOW FLAG BOSHIELO DAM: SUMMARY OF ECO-CLASSIFICATION AND EWR

Node	Quat	Nodes	EI	ES	PES	REC / Default REC[1]	Natural *MAR (mcm/ a)	EWR (PES) as % of natural MAR[2]
		Recommended Class III						
HN67	B51F	Upper Nkumpi (outlet of quaternary)	High	Moderate	C	B	3.8	10.73
HN68	B51G	Olifants (EWR site – EWR7) (existing)	EIS= Moderate		E	D	726.5	3.84 (D)
HN69	B52E	Palangwe (confluence with Olifants)	High	High	C	B	-	-
HN70	B52F	Hlakaro (outlet)	High	High	C	B	-	-
HN71	B52J	Mphogodima (confluence with Olifants)	High	High	C	B	-	-
HN72	B52A, E, G, J	Olifants (outlet of quaternary - outlet of IUA7)	Moderate	High	D	D	799.7	3.88

APP TABLE 42: IUA 8 SPEKBOOM CATCHMENT: SUMMARY OF ECO-CLASSIFICATION AND EWR

Node	Quat	Nodes	EI	ES	PES	REC / Default REC[1]	Natural *MAR (mcm/ a)	EWR (PES) as % of natural MAR[2]
		Recommended Class II						
HN73	B42A, B42B	One node for Dorpspruit at outlet of B42B. Included: Hoppe se Spruit (confluence) Doringbergspruit (confluence)	Moderate High	High High	CC	BB	-	-
HN74	B42B	Dorpspruit (EWR site – OLI-EWR9) (Rapid site)	EIS=Low		C/D	C/D	63.2	11.99
HN75	B42C	Potloodspruit (confluence with Dorps)	High	High	C	B	-	-
HN76	B42D, B42E	Dorps (confluence with Spekboom)	High	High	C	B	69.7	14.95
HN77	B42D	Spekboom (EWR site – OLI-EWR6) (Rapid site)	EIS=High		C	B/C	28	17.15
HN78	B42F	Potspruit (confluence with Watervals)	High	High	C	B	-	-
HN79	B42F	Watervals (releases from Buffelskloof Dam)	High	Very high	C	A	28.6	17.36
HN80	B42G	Rooiwalhoek-se-Loop (confluence with Watervals)	High	Very high	B	A	-	-
HN81	B42G	Watervals (EWR site - OLI-EWR5) (Rapid site)	EIS= Moderate		C	C	36.4	15.47
HN82	B42H	Spekboom (outlet of quaternary - outlet of IUA 8)	High	Moderate	B	B	149	24.84

APP TABLE 43: IUA 9 OHRIGSTAD CATCHMENT: SUMMARY OF ECO-CLASSIFICATION AND EWR

Node	Quat	Nodes	EI	ES	PES	REC / Default REC[1]	Natural *MAR (mcm/ a)	EWR (PES) as % of natural MAR[2]
		Recommended Class III						
HN83	B60E, B60F	One node at outlet of B60F. Included: Kranskloofspruit, Mantshibi, Ohrigstad (outlet of quaternary)	Moderate	Very high	D	A	35.6	6.31
HN84	B60G	Vyehoek (confluence with Ohrigstad)	High	Very high	C	A	-	-
HN85	B60H	Ohrigstad (EWR site - OLI-EWR8) (Rapid site)	EIS = Moderate		C	C	65.5	16.59
HN86	B60H	Ohrigstad (outlet of quaternary - outlet of IUA9)	High	Very high	D	D	69.7	8.05

APP TABLE 44: IUA 10 LOWER OLIFANTS (INCLUDES LOWER BLYDE): SUMMARY OF ECO-CLASSIFICATION AND EWR

Node	Quat	Nodes	EI	ES	PES	REC / Default REC[1]	Natural *MAR (mcm/ a)	EWR (PES) as % of natural MAR[2]
		Recommended Class II						
HN87	B60J	Sandspruit, including Rietspruit & Qunduhlu	High	Moderate	B	B	-	-
HN88	B60J	Blyde (EWR site - EWR12) (existing)	EIS = High		B	B	383.7	27.9
HN89	B60J	Blyde (confluence with Olifants)	Very high	Very high	C	A	385.7	16.13
HN90	B71A	Paardevlei (confluence with Tongwane)	High	Very high	B	A	-	-
HN91	B71A	Tongwane (confluence with Olifants)	High	High	B	B	-	-
HN92	B71B	Olifants (EWR site - EWR8) (existing)	EIS = Moderate	D	D	C	813	4.3
HN93	B71C	Mohlapitse (upper reaches)	Very high	Very high	B	A	42.1	26.5
HN94	B71D	Kgotswane (confluence with Olifants)	High	Moderate	B	B	-	-
HN95	B71D, B71F	Olifants (confluence with Steelpoort)	High	Very high	D	A	937.9	4.3
HN96	B71G, H, J	Olifants (EWR11, confluence with Blyde) (existing)	EIS = High		E	D	1321.8	11.2 (D)
HN97	B72A	Makhutswi, including Moungwane & Malomanye	High	High	C	B	38	12.89
HN98	B72C	Olifants (outlet - outlet of IUA10)	High	High	C	C	1755.5	18.07

APP TABLE 45: IUA 11 GA-SELATI RIVER: SUMMARY OF ECO-CLASSIFICATION AND EWR

Node	Quat	Nodes	EI	ES	PES	REC / Default REC[1]	Natural *MAR (mcm/ a)	EWR (PES) as % of natural MAR[2]
		Recommended Class III						
HN99	B72E	Ngwabatse (confluence with Ga-Selati)	High	Very high	D	A	25.7	9.05
HN100	B72F, G	Ga-Selati (outlet of quaternary)	High	Very high	C	A	13.5	19.59
HN101	B72H	Ga-Selati (EWR site - EWR14a) (existing)	EIS= Moderate		C	C	52.2	19.59
HN102	B72J	Molatle (confluence with Ga-Selati)	Moderate	Moderate	B	C	11.4	12.67
HN103	B72K	Ga-Selati (EWR site - EWR14b) (existing)	EIS= Moderate		E	D	72.7	11.99 (D)
HN104	B72K	Ga-Selati (outlet of quaternary - outlet of UIA11)	High	High	E	D	72.7	11.95 (D)

APP TABLE 46: IUA 12 LOWER OLIFANTS WITHIN KNP: SUMMARY OF ECO-CLASSIFICATION AND EWR

Node	Quat	Nodes	EI	ES	PES	REC / Default REC[1]	Natural *MAR (mcm/ a)	EWR (PES) as % of natural MAR[2]
		Recommended Class II						
HN105	B72D	Olifants (EWR site - EWR13) (existing)	EIS= Moderate		C	C	1760.7	11.36
HN106	B73A	Klaserie (EWR site - OLI-EWR7) (Rapid site)	EIS=High		B/C	B	25.5	22.31
HN107	B73B	Klaserie (confluence with Olifants)	High	High	C	B	37.1	15.41
HN108	B73C	Tsiri (confluence with Olifants)	High	High	B	B	-	-
HN109	B73C	Tshutshi (confluence with Olifants)	High	High	B	B	-	-
HN110	B73D	Nhlaralumi, including Machaton, Nyameni and Thlaralumi	High	High	B	B	6.8	13.65
HN111	B73E	Sesete (confluence with Timbavati)	High	High	B	B	11.1	12.24
HN112	B73F	Timbavati (outlet of quaternary)	High	High	B	B	18.7	12.12
HN113	B73G	Timbavati, including Shisakashonghondo	High	High	B	B	-	-
HN114	B73G, B73H	Olifants (EWR site - EWR16) (existing)	EIS=High		C	B	1916.9	10.75
HN115	B73J	Hlahleni (confluence with Olifants)	High	High	A	A	-	-
HN116	B73J	Olifants (outlet of quaternary - outlet of IUA12)	High	High	C	B	1918.3	14.72

APP TABLE 47: IUA 13 BLYDE RIVER CATCHMENT: SUMMARY OF ECO-CLASSIFICATION AND EWR

Node	Quat	Nodes	EI	ES	PES	REC / Default REC[1]	Natural *MAR (mcm/ a)	EWR (PES) as % of natural MAR[2]
		Recommended Class I						
HN117	B60A	Blyde (confluence with Lisbon)	High	Very high	C	A	87.1	18.73
HN118	B60B	Lisbon, including Heddelspruit & Watervalspruit	High	Very high	B	A	-	-
HN119	B60B	Blyde (outlet of quaternary)	High	Very high	B	A	183.8	32.86
HN120	B60C	Treur (EWR site – TRE-EWR1) (existing)	EIS=Very high		A/B	A/B	46.8	34.6
HN121	B60D	Blyde (inflow to Blyderivierpoort Dam - outlet of IUA13)	High	Very high	B	A	283.9	31.57

The Association for Water and Rural Development

AWARD is a non-profit organisation specialising in participatory, research-based project implementation. Their work addresses issues of sustainability, inequity and poverty by building natural-resource management competence and supporting sustainable livelihoods. One of their current projects, supported by USAID, focuses on the Olifants River and the way in which people living in South Africa and Mozambique depend on the Olifants and its contributing waterways. It aims to improve water security and resource management in support of the healthy ecosystems to sustain livelihoods and resilient economic development in the catchment.

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