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LETABA CATCHMENT RESERVE DETERMINATION STUDY – MAIN REPORT
Final
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Prepared for:

Department of Water Affairs and Forestry
Harrison Pienaar
Directorate: Resource Directed Measures
Private Bag X313
Pretoria
1200

Prepared by:

Pulles Howard & de Lange Inc.
R Heath
P O Box 861
AUCKLAND PARK
2006
Tel no: (011) 726-7027
Fax no: (011) 726-6913

Letaba Catchment Reserve Determination Main Report i

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AUTHOR	R G Heath
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APPROVED FOR PULLES HOWARD & DE LANGE (INC)

R. G. M. HEATH
PROJECT LEADER

APPROVED FOR TLOU & MALLORY ENGINEERING & MANAGEMENT SERVICES (PTY) LTD.

T. TLOU
PROJECT MANAGER

APPROVED FOR DEPARTMENT OF WATER AFFAIRS AND FORESTRY: DIRECTORATE RESOURCE DIRECTED MEASURES

H. PIENAAR
DIRECTOR

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Dr R Heath compiled this report with inputs from the following people:

Team Members

Angelina Jourdanova	Centre for Water In the Environment (Wits University)
Dr Andrew Birkhead	Streamflow
Ken Haumann	PD Naidoo & Associates
Paul Chipwanya	PD Naidoo & Associates
Robert Skoroskewski	Senqu Consultants
Gary Marneweck	Wetland Consulting Services (Pty) Ltd
Mark Rountree	Centre for Water In the Environment (Wits University)
Paul Fouche	Riparian Monitoring CC.
Dr Patsy Scherman	Coastal and Environmental Services
Deborah Vromans	Coastal and Environmental Services
Carel Haupt	WSM Civil Engineers
Karin Sami	WSM Civil Engineers
Dr Heather Malan	Freshwater Unit (UCT)

DWAF officials and members of the Project Management Team:

Ms C Thirion	DWAF (Directorate: Resource Quality Services)
Dr N Kleynhans	DWAF (Directorate: Resource Quality Services)
Ms C Todd	DWAF (Directorate: Resource Quality Services)
Ms D Louw	IWR Source-to-Sea
Mr X Hadebe	DWAF (Directorate: Resource Directed Measures)
Ms D Louw	IWRE Source-to-Sea
Mr H Pienaar	DWAF (Directorate: Resource Directed Measures)
Ms A Singh	Tlou & Mallory
Mr T Tlou	Tlou & Mallory
Mr W Tunha	DWAF (Polokwani Regional Office)
Mr D Viljoen	DWAF (Tzaneen Regional Office)
Mr J Venter	DWAF (Tzaneen Regional Office)
Mr S McGee	DWAF Surveyor
Ms J Moolman	DWAF (Directorate: Resource Quality Services)

Other inputs

Mick Angliss	Limpopo Department of Economic Development, Environment and Tourism
Dr Andrew Deacon	Kruger National Park
Mr J Venter	Kruger National Park

EXECUTIVE SUMMARY

Introduction

The Letaba Catchment is located in Limpopo Province and covers an area of *ca.* 13 400 km^2. The Groot Letaba River and its major tributaries, the Klein Letaba, Middle Letaba, Letsitele and Molototsi rivers, drain the catchment. From the confluence of the Klein and Groot Letaba rivers, the Letaba River flows through the Kruger National Park until it joins with the Olifants River near the border with Mozambique. More than 20 major instream dams have been constructed in the Groot Letaba catchment, which has resulted in this catchment being highly.

The water shortages experienced in the Letaba catchment area have led to intense competition for the available water resources between different sectors. The Kruger National Park (KNP) is located at the lower end of the catchment, is internationally renowned as a conservation resource, and is responsible for significant tourism and contribution to South Africa's GDP. In order to sustain the flow of the Letaba River in the KNP and protect aquatic biota, riparian vegetation and terrestrial animal life, water has to be released from the series of dams and weirs starting at the headwaters of the catchment. It is these conflicting water uses that have led to this study due to the need for compulsory licences in order to achieve resource protection and equity needs. In order to achieve the required resource protection in the Letaba catchment a comprehensive Reserve study was commissioned.

Objectives of study

The overall objectives of this study were as follows:

- **Groundwater Scoping:** To clarify the need for a groundwater study, based on a review of available information, focusing on the significance of groundwater to wetlands and surface flows, and the importance of groundwater to current and potential users in the catchment;
- **Wetlands Scoping:** To clarify the need for a wetland study, based on a review of available information, focussing on the ecological importance of wetlands in the catchment, and the links between wetlands, rivers and groundwater;
- **Present Ecological State (PES*):*** To define Reference Conditions and classify each Resource Unit in which EWR sites were selected, in terms of the PES of the main ecological drivers (hydrology, geomorphology and water quality) and ecological responses (riparian vegetation, aquatic invertebrates and fish), and to integrate the PES results of individual ecological components into an overall EcoStatus;
- **Recommended Ecological Category (REC) *and alternatives:*** To recommend an Ecological Category and alternative categories, based on the results of the PES, an assessment of the trends (changes) that are likely to take place assuming no change in current conditions, the Ecological Importance and Sensitivity (EIS), Socio-cultural Importance (SI), as well as an assessment of practicality of improving ecological conditions;
- **Ecological Water Requirements*:*** To recommend and motivate specific low and high flows for maintaining ecological conditions within a specific ecological category, and to present the results in the form of assurance rules for each selected EWR site for each month of the year and for each EC assessed;

- **Ecological Reserve**: To develop various operational flow scenarios; to describe their ecological and socio-economic consequences, and to recommend a scenario that minimizes impacts on users and the ecosystem;
- **Monitoring:** To assess the suitability of available data for defining baseline conditions for Ecological Reserve monitoring in the Letaba River; to recommend additional baseline data requirements, if needed; to define the Ecological Specifications (EcoSpecs) and associated Thresholds of Potential Concern (TPCs) for each monitoring site**;** and
- **Capacity Building:** To train Historically Disadvantaged Individuals (HDI's) in specific aspects of assessing Ecological Water Requirements.

Approach followed

The approach followed the generic 8-step process to Reserve determination, shown in the Figure A below. This study followed comprehensive methods for EcoClassification as well as for Ecological Water Requirement determination. The level of detail for the wetlands and groundwater components were at a scoping level only.

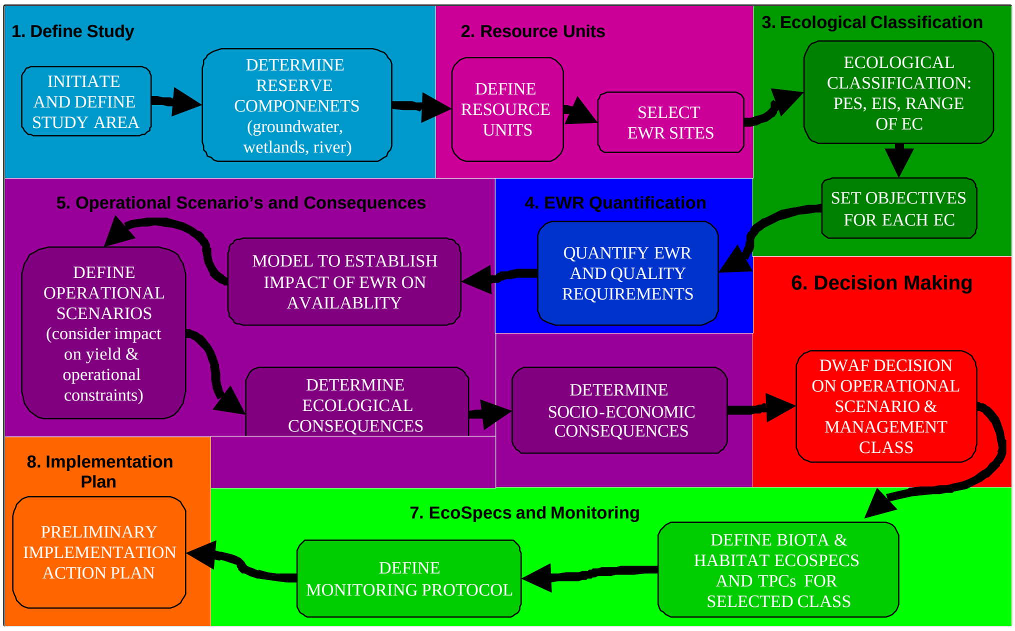

Figure A: The generic 8-step Ecological Reserve Procedure (from DWAF 2003).

Groundwater

Groundwater plays a role in the ecological Reserve determination if there is a direct hydraulic connection between groundwater and surface water bodies that jointly sustains the aquatic ecosystems.

The hydrogeology of the Letaba catchment is characterized by secondary or fractured aquifers formed by mainly metamorphic basement rocks of the Goudplaats Gneiss, Giyani and Gravelotte Greenstone belts, Igneous rocks of the Lebombo Granite, Makhutzi Granite, various younger granitoid intrusions of the Vorster Suite and gabbroic intrusions of the Rooiwater Suite Timbavati Gabbro. Intergranular aquifers occur mainly inside the Kruger Park.

The total reduction in groundwater base flow is approximately 10 Mm^3/a, however, in many cases this impact is significantly larger in dry years when irrigators rely more strongly on boreholes due to reduced streamflow. During dry years depletion of base flow and losses into the aquifer can reach 21.5 Mm^3/a. This can be as high as 85% of base flow originating from the regional aquifer.

Calculations of groundwater potential contributions to the surface water estimate that for the catchment as a whole, base flow exceeds the surface water requirements, however, much of the base flow generated in the headwater regions is abstracted from the river for irrigation, hence base flow requirements downstream are not met.

Wetlands

Wetlands form an integral part of aquatic ecosystems and the hydrological cycle, and can play a key role by contributing to river base flows and providing habitats that support aquatic biodiversity. A comprehensive assessment of EWR should therefore include an assessment of wetlands and their ecological functions.

Based on the National Land Cover (NLC) 2000 coverage, as well as the topographic analysis undertaken, there appears to be a fairly high concentration of relatively large wetlands between the Letsitele and Thabina Rivers in the south west of the catchment and in the area east and west of the Groot Letaba River immediately downstream.

It was recommended that the valley bottom systems in the Pietersburg plateau and Lowveld hydrogeological region are targeted for a wetland Reserve study. In addition, the existing Reserve method is more applicable to riparian wetlands than other types such as hill slope seepage systems, thus rendering the valley bottom wetlands in the lower part of the catchment more suitable candidates for reserve determination.

Hydrology

The Letaba catchment consists of three tertiary catchments, namely, B81, B82 and B83. Tertiary catchment B81 consists of six quaternary catchments which total a catchment area of 4 952 square kilometres flowing into the Groot Letaba River.

For analysis purposes, the Water Resources Yield Model (WRYM) and the Spatial and Time Series Information Model, SPATSIM (Institute for Water Research, 2003) have been used. The WRYM was set up to model the water resources system in the catchment, in order to convert virgin flows into present day flows and to assess the impact of environmental releases, under various supply scenarios, on the other demands in the system. SPATSIM, using the output from WRYM, was used to generate time series data of the EWR as well as to generate duration and stress response curves required to investigate whether the EWR demands are met.

Available virgin flow data for the Letaba Catchment is limited to between 1920 and 1996. The representivity of this data was tested through a pilot project on two of the quaternaries, namely, B81D as a humid catchment and B83B as a dry catchment. The purpose of this pilot project was to extend the hydrology, by applying the more recent rainfall data to these two catchments and to assess the potential changes to the hydrology for the catchment as a whole. This was done using the WRSM2000 rainfall-runoff model. For the wetter catchment, there was a small (4%) increase in MAR (20% increase in standard deviation of the MAR) due to the addition of generally wetter hydrological years of the late 90's. For the dry catchment, there was a significant lowering of the MAR (36%) and a 15% standard deviation in MAR. However, the contributions by the dry catchments to flows in the Letaba are only around 7%. It was therefore decided that the current hydrology data to 1996 would be representative

Agriculture and domestic use are the major demand sectors in the system. The decline in the present day flow, when compared to the natural flow, is mainly attributed to the large demand of irrigation in the Groot Letaba and Middle and Klein Letaba subcatchments.

Delineation

As part of Ecological Reserve determination, it is necessary to break down the catchment into Resource Units (RU's), which are significantly different to warrant their own specification of the Reserve, and to clearly delineate the geographic boundaries of each of the RUs. The Letaba catchment was broadly delineated into nine RU's (Figure B). Due to the importance of certain tributaries in terms of annual flow, not all of these RU's could be catered for in this study. Study sites were selected in the RU's. Various factors were considered when selecting the EWR sites. The key ones are the following:

- The available habitat diversity for fish, macroinvertebrates, marginal and riparian vegetation;
- The suitability of the sites for accurate hydraulic modelling throughout the range of possible flows, especially low flows; and
- Geomorphologic reaches and representative reaches within the geomorphological

Seven EWR sites (Figure B Table A) were selected

The Molototsi River, due to its highly seasonal nature and the lack of adequate monitoring data, was not chosen as an EWR site. No EWR site was chosen for the Middle Letaba River. EWR 5 (Klein Letaba) was, however, selected to be directly downstream of the confluence of Middle and Klein Letaba Rivers. No EWR site was selected in the Nsami River dues to its contribution to the MAR of the Letaba River being small in comparison to the other tributaries.

Table A: Localities of EWR sites on the Letaba River.

River and site name	RU	EWR site number	Locality
Groot Letaba - Appel	A	EWR1	S23 55 03.7; E30 03 03.0
Letsitele	F	EWR 2	S23 53 17.0; E30 21 40.5
Klein Letaba	B	EWR 5	S23 15 02.9; E30 29 44.6
Groot Letaba - Hans Marensky	C	EWR 3	S23 38 57.8; E30 39 38.3
Groot Letaba - Letaba Ranch	E	EWR 4	S23 40 39.1; E31 05 55.1
Groot Letaba – Lonely Bull	D	EWR 6	S23 45 09.5; E31 24 26.3
Groot Letaba - Letaba Bridge	D	EWR 7	S23 48 35.4; E31 35 26.9

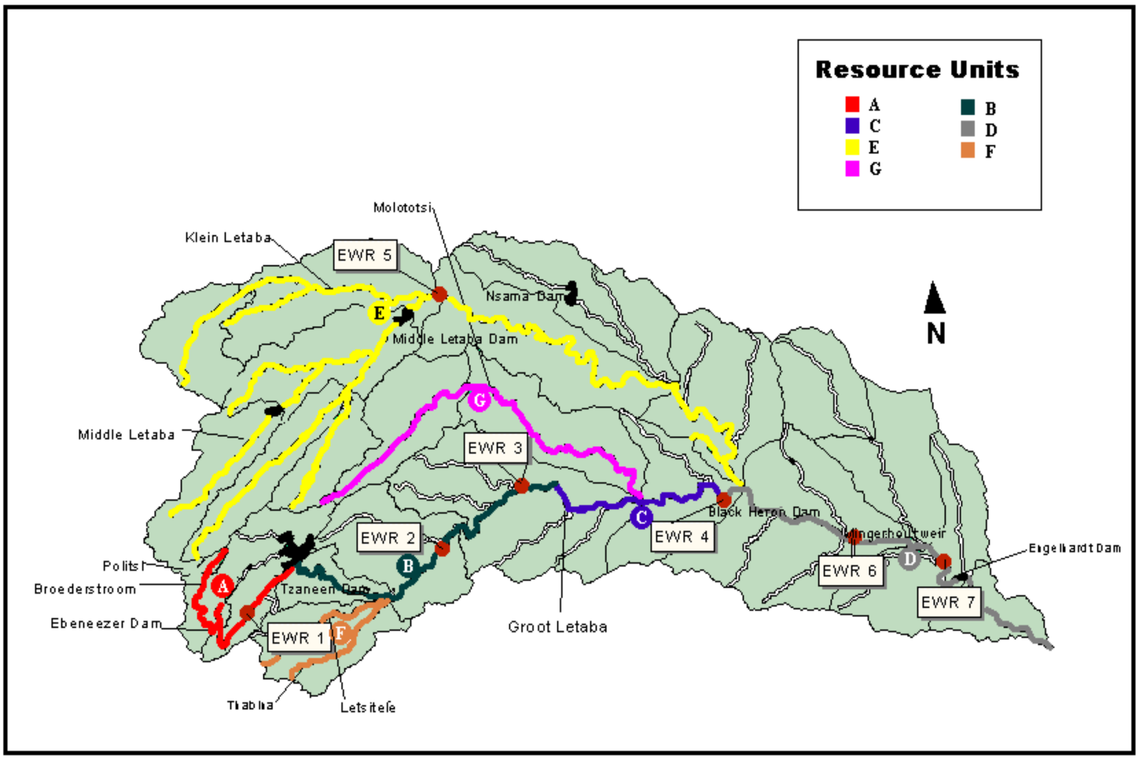

Figure B: Main resource units and chosen EWR sites in the Letaba Catchment.

EcoClassification

EcoClassification (the term used for Ecological Classification) refers to the determination and categorisation of the Present Ecological State (PES; health or integrity) of various biophysical attributes of rivers compared to the natural/close to natural, reference condition (Kleynhans *et al*., 2005). The purpose of EcoClassification is to gain insights into the causes and sources of the deviation of the PES of biophysical attributes from the reference condition. This provides the information needed to derive desirable but attainable future ecological objectives for the river. The EcoClassification process also supports a scenario-based approach where a range of ecological endpoints (Ecological Categories) has to be considered. For each of these, a flow (EWR) scenario must be described.

The results of the EcoClassification process, i.e. the PES and EC are provided as different river categories ranging from A (near natural) to F (critically modified).

Water quality

The primary land use along the rivers in the Letaba catchment is citrus and sub-tropical fruit production, with grazing in the less fertile sandy loam soils. Removal of the vegetative cover by overgrazing has led to erosion in some places, resulting in an increased sediment load in the rivers. The main industrial development points are at Tzaneen, Nkowakowa and Giyani, with a number of sewage works spread throughout the catchment. Several old gold mines exist, which lie close to the Klein Letaba River towards the northern part of the study area. An overview of the catchment therefore indicates that water quality issues are mainly related to nutrient enrichment, and fluctuating instream temperature and oxygen levels due to extensive flow regulation in the catchment. In addition to being highly regulated, conditions in the Groot Letaba River (particularly downstream from Die Eiland) are impacted by citrus plantations in the area, resulting in elevated nutrient levels and instream toxicity.

The water quality data confidence and availability ranged from very Low (toxics, dissolved oxygen and temperature) to High (salts and pH).

The water quality present state assessment showed that the Letaba River system is generally in a fair to good water quality condition (categories B-C), with a hot spot occurring at EWR 2, i.e. Letsitele Tank.

The EcoClassification results for the PES of each component are summarised per EWR site. (Table B). The EcoStatus results for the PES and REC are provided in Table C as well as the EIS results:

Table B: The EcoClassification results for the PES of each component are summarised per EWR site

EWR sites	Hydrology	Physico-chemical	Geomorphology	Fish	Invertebrates	Riparian vegetation	EcoStatus
1	**C**	**B**	**C**	**C**	**C/D**	**C**	**C**
2	**C**	**C/D**	**D/E**	**C**	**D**	**D/E**	**D**
3	**D**	**C**	**C**	**C**	**D**	**D**	**C/D**
4	**D**	**B/C**	**C/D**	**C**	**D**	**D**	**C/D**
5	**C/D**	**B**	**C**	**B**	**C**	**B**	**C**
6	**D**	**C**	**C**	**C**	**D**	**C**	**C**
7	**D**	**C**	**C**	**C**	**D**	**C**	**C**

Table C: PES, EIS, SI and REC for each EWR site

Site	PES	Importance		REC
		EIS	SI	
1	C	Mod	Low	C
2	D	Mod	Low	D
3	C/D	High	Mod	C/D
4	C/D	High	High	C/D
5	C	Mod	Mod	C
6	C	High	Low	C
7	C	High	Low	C

Groot Letaba River

Ecologically, the upper catchment (above Ebeneezer Dam) of the Groot Letaba River is considered closest to natural and has a high ecological importance. The relatively natural condition is due to limited disturbance (some areas of indigenous forests, especially in inaccessible gorges).

The most ecologically modified sections in the Groot Letaba River are those between Tzaneen Dam and the border with the KNP. This is due to the reduction in flow due to upstream impoundments (Tzaneen and Ebeneezer Dams), large weirs (Junction, Yamorna, Prieska and Jasi) as well as direct abstraction for irrigation. The water quality problems are associated with intensive irrigated agriculture (fertilizer, salts and pesticide runoff).

Although the EIS was high in the KNP, the REC was not recommended to improve the PES (Table B). Cognisance was taken on the attainability of increasing the PES.

The downstream section of the Groot Letaba River within the KNP has a PES and REC of a C (Table B).

A social survey concluded that rural communities, living adjacent to the main rivers in the middle reaches of the Letaba Catchment, particularly in the vicinity of Letaba Ranch (Site EWR 4) are highly depend on the rivers for drinking water, washing, harvesting of natural resources (particularly firewood, thatching and medicinal plants), ceremonial and cultural purposes (Table B).

Klein Letaba River

The Klein Letaba (EWR 5) is in a moderately modified to modified state mostly due to dense settlements and agriculture above the Middle Letaba Dam and upper Klein Letaba River. The EIS is moderate and no improvements in categories are required (Table B).

Letsitele River

The Letsitele River (EWR 2) is highly modified to a PES of D (Table B). The Letsitele River, a tributary of the Letaba River is unregulated, although there is a small dam on the Thabina tributary. The river channel at this site is degraded due to erosion and local sources of water quality pollution. The main impacts on water quantity and water quality at this site are upstream stream flow reduction (forestry) and a township, with no formal sanitation system, immediately upstream.

The EIS is moderate and the SI is low and hence no improvements in PES categories are required (Table B).

Recommendation

The REC was set to maintain the PES for all Resource Units.

Ecological Water Requirements

The objectives of this task were to recommend the magnitude, duration and timing of specific flows and flow patterns that are considered to be the most important for maintaining the abiotic (e.g. geomorphology) and biotic components (plants and animals) of each Resource Unit in a particular condition, or Ecological Category (EC).

Methods followed were the Habitat Flow Stressor Response for low flows and a combination of BBM and DRIFT for the high flows.

The results for each EWR site are provided in Table D.

Table D: Summary Instream Flow Requirements for EWR sites in the Letaba River expressed as a percentage of the natural Mean Annual Runoff (MAR) for the recommended Ecological Categories (ECs).

Site	REC	Maintenance low flows (%)	Drought low flows (%)	High flows (%)	Long term mean of MAR (%)
EWR 1	C	10.47	15.76	15.76	27.56
EWR 2	D	32.06	4.32	11.11	38.78
EWR 3	C/D	1.29	0.23	11.78	14.15
EWR 4	C/D	2.82	0.44	15.84	20.76
EWR 5	C	8.48	0.30	24.27	24.27
EWR 6	C	2.17	0.93	7.86	10.74
EWR 7	C	3.23	0.09	7.65	11.26

Operational scenarios

Ecological Water Requirement (quantity) scenarios were developed by ecologists as sets of possible flows to achieve different river states (or Ecological Categories) for each EWR site. During this phase constraints such as outlet sizes and user requirements are also considered. Modifications to the EWR scenarios to minimise impacts on the users e.g. are considered to determine whether any other flow scenarios can achieve the REC. The impacts of each flow scenario on the ecology, system yield, goods and services and overall economic activities could then be assessed. Thereafter, a process was followed to devise an optimised scenario (if necessary) that would have the least overall impact on the users and the ecology.

The Water Resources Yield Model (WRYM) that was set up for the feasibility study of water resource management of the Groot Letaba in 1996 was used and was updated to take into account more recent data and understanding of the catchment operations. Analyses were done using the historic inflow time series from 1922 to 1995 to determine supply to users for each scenario

Ecological consequences

The ecological evaluation is based on an assessment of the impact on the states or ECs recommended for each component. Information on the water quality assessment as a key driver is provided below, followed by the overall assessment.

Water quality consequences

Each of the flow scenarios was checked through simple concentration modelling (if appropriate data was available), as well as the Physico-Chemical Driver Assessment Index (PAI) driver tables, to determine whether the water quality objectives would be met under these flow conditions. The pollution sources and types of pollution were determined per EWR site. The different flow scenarios were then used to determine if the scenario would improve or decrease the water quality status per EWR site.

Ecological consequences

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

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

Table E: Summary of ecological results.

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

Where: Face = meet REC, X = did not meet REC, 1= Riparian vegetation a problem, Y+ = exceeds REC.

Impact of EWR flow scenario on water availability to other users

The aim of this component of the study was to quantify the consequences of various operational scenarios on the water availability to the economic user sectors with the EWR for each scenario being supplied as a priority.

User requirements were based on best available data and interviews with the Tzaneen irrigation board. It should however be noted that the water use figures are not based on a validation and verification of existing water use. Curtailment structures were developed where the available water did not meet the requirements of the existing water users. This was based on the current operating rules that are used by DWAF to provide water to the water users in the Letaba River Catchment. The water use in the upper catchments of the Middle Letaba Dam was based on assumption, as there was no data on water use.

The scenarios that were investigated were scenario 1, 4, 6 and the optimised scenario 7. The first run of the WRYM was on the present day use.

Economic impact of EWR flow scenario on water availability

The results of all flow scenarios indicated that there would be a negative impact on the available water to other users, particularly irrigation agriculture. The WRYM results of maintaining the PES (i.e. Scenario 1) of the Letaba River and its main tributary had the most severe negative impact on the availability of water in the river system for other users, particularly in the Letsitele River and the sub-catchment downstream of Tzaneen Dam. Most of the yield from Tzaneen Dam was required to meet the EWR for the flow Scenario 1. This was because the EWR sites that were driving the system are EWR 6 and 7 situated in the KNP.

The current water requirements for water users, particularly irrigators, are not being met. While releases to Kruger National Park should be 0.6 m^3/s, at present, an annual average of 0.456 m^3/s flow is released to Kruger National Park from Tzaneen Dam. This release includes domestic abstraction to Letsitele users, Ritavi, Naphuno and Letaba Citrus Processors.

The WRYM results have indicated that water users in the Lower Groot Letaba River catchments are the only ones that will not be impacted on under all the Ecological Reserve Scenarios from 1 to 7 (Figure D).

The findings of the economic valuation indicate that the flow regime associated with scenario 7 provides the best balance between ecological sustainability and social and economic development.

Goods and Services

Although there are limitations in the valuation of the ecological goods and services because water is classical non-marked resource, this assessment provides the implications of different flow scenarios on the social, economic and ecological welfare of the Letaba River catchment (Figure D). This provides both stakeholders and decision makers with information to make informed decisions on the level of preference for protecting the resource while balancing with the need for social and economic development to achieve government objectives of poverty eradication in a sustainable manner.

It is recommended that consideration be made in improving the water use efficiency levels in all the water using sectors in the Letaba River catchment.

Recommended Ecological Reserve

Implementation of EWRs in the Letaba River catchment can be realized through active management of the water resource infrastructure (dams and weirs) as well as reducing abstractions for water users in the catchment based on their curtailment structures. This however has a negative impact on the available water to users. The restrictive flow management will therefore involve changing the existing allocations to water users in the catchment to ensure that enough water is left in the river. Both types of interventions require a change in the water use practices of the stakeholders and the need for stakeholder commitment and buy-in with the level of resource protection that can be effected without significantly impacting on the socio-economy of the catchment.

The flow scenarios were considered using the traffic diagrams (Figure D). This figure illustrates that the EWR flows for **Scenario 7** is the most suitable scenario as it meets the REC and has a minimal impact on all the user categories (Figure D). (Scenario 7 is the only scenario lying on the green side of the traffic diagram). Therefore, Scenario 7 provides the best trade off between the need for protection of the ecological ecosystems in the Letaba catchment with the need to ensure the socio-economic growth is not severely negatively impacted. Scenario 7 was accepted and approved a by DWAF at a meeting in September 2005.

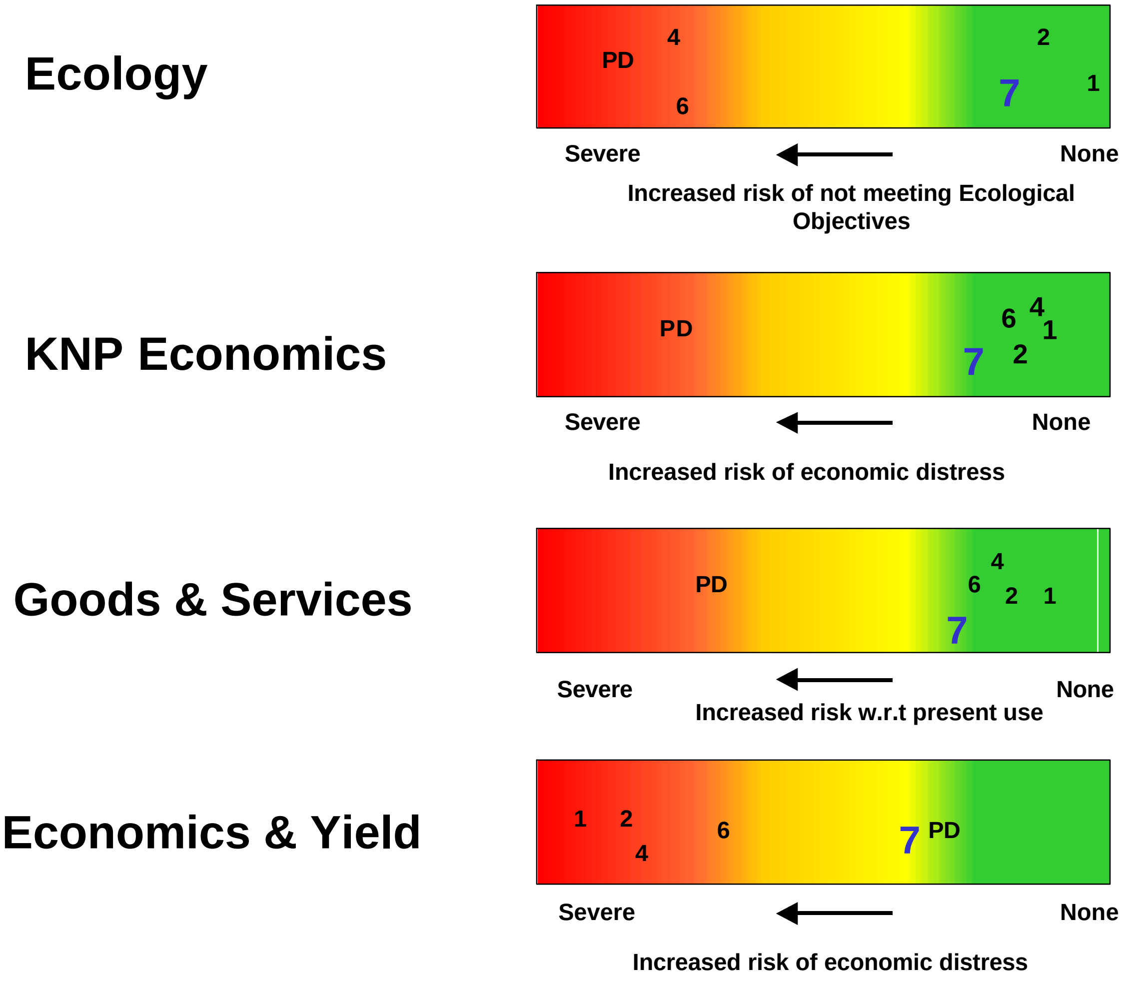

Figure D: Comparison of scenario impacts across major study components.

It must be noted that KNP officials have indicated that they have a mandate to improve biodiversity and have requested an improved PES within the KNP (PES of C to REC of B). With the currently upstream water usage, mainly for agriculture, and the difficulties in improving catchment (sediment) issues it would be problematic to improve the PES.

Consideration should also be taken to delay implementation of the EWR flow of Scenario 7 in the Letsitele River catchment because of the significant impact it will have on the irrigators until the verification and validation has been undertaken.

The Ecological Reserve is summarised as a percentage of the nMAR in Table F.

Table F: Final results of Scenario 7 summarised as a percentage of the nMAR.

Sites	Annual EWR (million m^3)	Virgin MAR (million m^3)	Annual EWR (% nMAR)
EWR 1	19.75	71.27	27.71
EWR 2	31.756	86.06	36.90
EWR 3	42.448	364.49	11.65
EWR 4	69.87	402.26	17.37
EWR 5	17.054	95.01	17.95
EWR 6	47.0317	546.59	8.60
EWR 7	51.52	561.67	9.17

EcoSpecs and ecological reserve monitoring

EcoSpecs are clear and measurable specifications of ecological attributes (e.g. water quality, flow, biological integrity) that define the Ecological Category and serve as an input to Resource Quality Objectives. EcoSpecs refer explicitly and only to ecological information whereas RQOs include economic and social objectives.

The overall aims of Ecological Reserve Monitoring are to measure and determine how the resource is changing over time, and to ensure that resource remains within acceptable limits of change, defined broadly as the Recommended Ecological Category (REC).

The primary EcoSpecs are the Ecological categories and these are summarized in Table G. These EcoSpecs were quantified in terms of measurable criteria that can be monitored for fish, invertebrates, riparian vegetation, geomorphology and water quality.

Table G: Ecological categories for the driver and response components per EWR site.

Components	EWR 1	EWR 2	EWR 3	EWR 4	EWR 5	EWR 6	EWR 7
Hydrology	C	C	D	D	C/D	D	D
Geomorphology	C	D	C	C/D	C	C	C
Water quality	B	C/D	C	B/C	B	C	C
Fish	C	C	C	C	B	C	C
Aquatic invertebrates	C/D	D	D	D	C	D	D
Riparian vegetation	C	D	D	D	B	C	C
EcoStatus	**C**	**D**	**C/D**	**C/D**	**C**	**C**	**C**

The required further baseline monitoring that needs to be undertaken per EWR site before the Ecological Reserve Monitoring programme can be initiated is summarized in Table H. The fish and invertebrates require no additional baseline monitoring at any of the EWR sites. The geomorphology at all EWR sites will require a short site visit to fully populate the

Geomorphology Assessment Index (GAI). This is due to the GAI model only having being developed after the field surveys for this study.

Table H: Summary of Baseline surveys required.

<table>
<tr><th>EWR Site</th><th>Geomorphology</th><th>Water quality</th><th>Riparian vegetation</th><th>Fish & Invertebrates</th></tr>
<tr><td>1</td><td rowspan="7">Survey required to fully populate the GAI and initiate monitoring (to assess info requirements for perimeter resistance component).</td><td rowspan="2">Temperature, dissolved oxygen, turbidity / clarity, toxicity, Chl-a: Periphyton, toxics ammonia, Al and Cu.</td><td>Data needs to be converted to VEGRAI level 4</td><td rowspan="7">No further baseline data needed</td></tr>
<tr><td>2</td><td>Need to do survey using VEGRAI level 4 and conclude uncertainty of back flooding impacts.</td></tr>
<tr><td>3</td><td rowspan="2">Temperature, dissolved oxygen, turbidity / clarity,- toxicity: should be initiated on a quarterly basis. The frequency of tests can be decreased, depending on the results of the toxicity tests.
Chlorophyll-a: Periphyton:
A full range of toxics (due to pesticide and herbicide use).</td><td rowspan="3">VEGRAI data needs to be converted to VEGRAI level 4</td></tr>
<tr><td>4</td></tr>
<tr><td>5</td><td>Temperature, dissolved oxygen, turbidity / clarity, Chlorophyll -a:, Periphyton, toxics ammonia, Al and Cu.</td></tr>
<tr><td>6</td><td rowspan="2">Temperature, dissolved oxygen, turbidity / clarity, toxicity, Chlorophyll-a, Periphyton, toxics, ammonia, Al and Cu
Selected toxicants (see EWR 4).</td><td rowspan="2">Data needs to be converted to VEGRAI level 4. If additional information is required to update the marginal vegetation an additional survey might be required</td></tr>
<tr><td>7</td></tr>
</table>

Capacity building and training

A capacity building programme formed part of this study with a dedicated budget. The objective of the capacity building was to increase the technical expertise (especially HDIs) available for Reserve related studies in the country.

To initiate the training, a number of trainees were identified and mentors appointed. Table I indicates the trainees and mentors for the areas to be developed.

Table I: Capacity building team member, mentors and areas of development.

HDI team member	Mentor	Development area	News skills developed
Kevin Pillay	Ralph Heath	Reserve determination project management	The comprehensive Reserve methodology Facilitate Reserve scenario workshops SPATSIM model training WRYM training Hands on modelling
Paul Chipwanya* Yosief Fsehazion	Ken Haumann Kevin Pillay*	Hydrology Water Resource Yield Modelling	Site selection methods SPATSIM model training WRYM training Hands on modelling Manipulation of flow scenarios
Deborah Vromans	Patsy Scherman	Water quality data analysis, graphic, statistics, trend analysis	Water quality data collation Water quality data interpretation and manipulation
Patterson Khavhagali *	Gary Marneweck	Riparian vegetation and wetland surveys	Field assessment techniques Key indicator species identification Vegetation transects Vegetation and wetlands role in the Reserve methodology
Thomas Mufanadzo *	Robert Skorozewski	Rapid biological assessment of invertebrates in field	Field assessment techniques (SASS5) Key indicator species identification Fill in and understand how assessment forms work for SASS5 and Habitat assessment.
Shaka Sebola Calvin Mawelela*	Indaran Govender/ Ralph Heath	Socio – cultural importance survey of water in the catchment.	Methodology required for Reserve determination with regards to field surveys
Duncan Munyai	Carel Haupt Karim Sami	Groundwater assessment and terms of reference for groundwater Reserve	Literature review of current available groundwater data Data collation into a situation assessment report Report writing skills

Where: * = team members that left for other employment.

The following additional capacity building exercises was undertaken:

- Regional representatives of DWAF-Polokwani and Limpopo Province were included in the first Ecospecs workshop (Mpho Daswe and Washington Tuhna); and

- DWAF Limpopo Regional office staff undertook training over two days in conjunction with the Komati workshop (Silo Kheva, Mpho Daswe, Minky Chauke, Happy Mushwana, Benson Mpefe, Sharon Mashaba, Caroline Shai).

Five of the eight trainees engaged in the study moved on to other work during the course of the study because of the need to find more permanent employment, and only three are likely to be readily available to participate in future studies of this nature. The main problem with the training programme was therefore the lack of continuity caused by the long duration of the study and the need for trainees to find alternative forms of income.

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ACRONYMS

D: RDM	Directorate: Resource Directed Measures
DWAF	Department of Water Affairs & Forestry
DSS	Decision Support System
EC	Ecological Category
EQR	Ecological Quality Requirements
EMC	Ecological Management Class
EWR	Ecological Water Requirements
EIS	Ecological Importance and Sensitivity
FAII	Fish Assemblage Integrity Index.
FD	Fast-Deep
FRAI	Fish Response Assessment Index
FS	Fast-Shallow
GAI	Geomorphology Assessment Index
HAI	Habitat Assessment Index
KNP	Kruger National Park
MIRAI	Macro Invertebrates Response Assessment Index
nMAR	naturalised Mean Annual Runoff
KNP	Kruger National Park
PAI	Physico-chemical Driver Assessment Index
PD	Present Day
PES	Present Ecological State
REC	Recommended Ecological Category
RDM	Resource Directed Measures
RHP	River Health Programme
RU	Resource Unit
RQO	Resource Quality Objective
SANP	South African National Parks
SASS	South African Scoring System
Sc	Scenario
SD	Slow-Deep
SPATSIM	Spatial and Time Series Information Modelling
SRP	Soluble Reactive Phosphorous
SS	Slow-Shallow
TIN	Total Inorganic Nitrogen
TP	Total Phosphorous
TPA	Transvaal Provincial Authority
TPC	Threshold of Potential Contamination
VEGRAI	Riparian Vegetation Response Assessment Index
WR2000	Water Resources 2000
WRYM	Water Resources Yield Model

GLOSSARY

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

INSTREAM FLOW REQUIREMENTS (IFR)	The flow patterns (magnitude, timing and duration) needed to maintain a riverine ecosystem in a particular condition. This term is used to refer to the quantity component only of Ecological Water Requirements.
MAINTENANCE FLOW	The flow required to meet the requirements of the riverine ecosystem at a particular site and maintain the resource base in a particular condition during "normal" climatic years. The distinction between "normal" and "drought" was based on an examination of monthly flow duration curves. For the Letaba River System, “normal” low-flows were defined as those that occur at or more than 30% of the time under natural conditions for each month.
PRESENT ECOLOGICAL STATE (PES)	The degree to which ecological conditions of an area have been modified from natural (reference) conditions. The measure is based on water quality variables, biotic indicators and habitat information collected 1 to 3 years prior to the assessment. Results are classified on a 6-poin scale, from Category A (*Largely Natural*) to Category F (*Critically Modified*).
REFERENCE CONDITION	Natural ecological conditions, prior to human development.
RESERVE	The quantity and quality of water required (a) to satisfy basic human needs by securing a basic water supply, as prescribed under the Water Services Act, 1997 (Act No. 108 of 1997), for people who are now or who will, in the reasonably near future, be (i) relying upon; (ii) taking water from; or (iii) being supplied from, the relevant water resource; and (b) to protect aquatic ecosystems under the National Water Act, 1998 (Act No. 36 of 1998) in order to secure ecologically sustainable development and use of the relevant water resource. The Reserve refers to the modified Ecological Water Requirement, where operational limitations, and stakeholder consultation are taken into account.
RESOURCE QUALITY OBJECTIVE	Quantitative and auditable statements about water quantity, water quality, habitat integrity and biotic integrity that specify the requirements (goals) needed to ensure a particular level of

	resource protection. This term takes into account the management *classes* and the requirements of other users. These components are not addressed in this project
RESOURCE UNIT	Stretches of river that are sufficiently ecologically distinct to warrant their own specification of Ecological Water Requirements, and that can be practically managed as a single unit.

1. INTRODUCTION

1.1 BACKGROUND

The water shortages experienced in the Letaba catchment area have led to intense competition for the available water resources between different sectors. A substantial portion of the population does not have access to the basic level of service and planned extensions to irrigation have consequently been put on hold. The Kruger National Park (KNP) is located at the lower end of the catchment, is internationally renowned as a conservation resource, and is responsible for significant tourism and contribution to South Africa's GDP. In order to sustain the flow of the Letaba River in the KNP and ultimately aquatic biota, riparian vegetation and terrestrial animal life, water has to be released from the series of dams and weirs starting at the headwaters of the catchment. Furthermore, there is an international obligation to release water to Mozambique at the eastern boundary of the KNP

It is these conflicting water uses that have led to this study due to the need for compulsory licences in order to achieve resource protection and equity needs. In order to achieve the required resource protection in the Letaba catchment (Water Management Area 2) a comprehensive Reserve study was commissioned.

This report summarises the main components of a comprehensive assessment of the Ecological Water Requirements (EWR) component of the Reserve that was commissioned by the D: RDM and undertaken by Pulles Howard & de Lange Inc Consultants. The study was conducted over a three-year period between April 2003 and March 2006. The study produced several reports, as indicated in the reporting layout (page ii). This Main Report provides a brief overview of the study. For more details refer to the individual specialist reports.

1.2 OBJECTIVES

The overall objectives of this study were as follows:

- **Groundwater Scoping:** To clarify the need for a groundwater study, based on a review of available information, focusing on the significance of groundwater to wetlands and surface flows, and the importance of groundwater to current and potential users in the catchment;

- **Wetlands Scoping:** To clarify the need for a wetland study, based on a review of available information, focussing on the ecological importance of wetlands in the catchment, and the links between wetlands, rivers and groundwater;

- **Present Ecological State (PES*):*** To define Reference Conditions and classify each Resource Unit in which EWR sites were selected, in terms of the PES of the main ecological drivers (hydrology, geomorphology and water quality) and ecological responses (riparian vegetation, aquatic invertebrates and fish), and to integrate the PES results of individual ecological components into an overall EcoStatus;

- **Recommended Ecological Category (REC)** ***and alternatives:*** To recommend an Ecological Category and alternative categories, based on the results of the PES, an assessment of the trends (changes) that are likely to take place assuming no change in current conditions, the Ecological Importance and Sensitivity (EIS), Socio-cultural

Importance (SI), as well as an assessment of practicality of improving ecological conditions;

- **Ecological Water Requirements*:*** To recommend and motivate specific low and high flows for maintaining ecological conditions within a specific ecological category, and to present the results in the form of assurance rules for each selected EWR site for each month of the year and for each EC assessed;

- **Ecological Reserve**: To develop various operational flow scenarios; to describe their ecological and socio-economic consequences, and to recommend a scenario that minimizes impacts on users and the ecosystem;

- **Monitoring:** To assess the suitability of available data for defining baseline conditions for Ecological Reserve monitoring in the Letaba River; to recommend additional baseline data requirements, if needed; to define the Ecological Specifications (EcoSpecs) and associated Thresholds of Potential Concern (TPCs) for each monitoring site**;** and

- **Capacity Building:** To train Historically Disadvantaged Individuals (HDI's) in specific aspects of assessing Ecological Water Requirements.

2. STUDY AREA

2.1 GENERAL DESCIPTION

The Letaba Catchment is located in Limpopo Province and covers an area of approximately 13 400 km^2 (Figure 2.1). The Groot Letaba River and its major tributaries, the Klein Letaba, Middle Letaba, Letsitele and Molototsi rivers, drain the catchment. From the confluence of the Klein and Groot Letaba rivers, the Letaba River flows through the Kruger National Park until it joins with the Olifants River near the border with Mozambique.

More than 20 major instream dams have been constructed in the Groot Letaba catchment, which has resulted in this catchment being highly regulated (Chutter and Heath, 1993). As a result, there have been no recordings of Tiger Fish outside the Kruger National Park (KNP) since 1990 (M Angliss *pers comm*.). The existing limited water resources in the Letaba Catchment have been severely overexploited at the expense of the environment in order to meet the commercial (irrigation, afforestation and industry) and rapidly increasing domestic water demands.

The major land uses in the Letaba catchment, and their probable impacts, as well as the variables that should be tested are listed in Table 2.1. The dense afforestation that takes place in the upper catchment and the intensive irrigated agriculture, of mainly sub tropical fruits, on the banks of the Groot Letaba outside the KNP, are the major water users in the study area. The instream dams are used for the supply of irrigation water for this intensive irrigated agriculture.

The water shortages experienced in the Letaba Catchment area have led to intense competition for the available water resources between different sectors. A substantial portion of the population does not have access to the basic level of service and planned extensions to irrigation have consequently been put on hold. The KNP is located at the lower end of the catchment, is internationally renowned as a conservation resource, and is responsible for significant tourism and contribution to South Africa’s GDP. In order to sustain the flow of the Letaba River in the KNP and ultimately aquatic biota, riparian vegetation and terrestrial animal life, water has to be released from the series of dams starting at the headwaters of the catchment. Furthermore, there is an international obligation to release water to Mozambique at the eastern boundary of the KNP.

2.2 SYSTEMS OPERATION

Broadly the Letaba water system can be grouped into four major subsystems. These are, the Dap Naude/Ebenezer/Magoebaskloof/Tzaneen subsystem (Groot Letaba subsystem), Thabina (Letsitele and Nwanedzi) subsystem, Middle Letaba and Nsami Dam subsystem (Middle and Klein Letaba (B82)) subsystem, and Lower Letaba subsystem.

The first water system is in the Groot Letaba Subcatchment mainly along the Groot Letaba River. This is the subsystem where major economic activity takes place. Due to its major contribution to the hydrology of the whole Letaba catchment, it has great significance to stability of riparian ecology in Kruger National Park.

Table 2.1: Land uses and their impacts in the Letaba catchment and associated water quality problems.

Land use	Water quality impact	Sub-catchment impacted	Water quality problems
Forestry	Increased turbidity due to sedimentation	Groot Letaba above Tzaneen Dam	Electrical conductivity
Industrial activity	Minimal as most effluent is recycled or used for irrigation	Groot Letaba, below Tzaneen	Dissolved oxygen
			PH
Irrigation agriculture	Salinisation and release of biocides into the environment	Groot Letaba from Tzaneen to Letaba Ranch	Organochlorine pesticides Endosulfan Dieldrin, Aldrin and Endrin Heptachlor and Heptachlor epoxide Lindane Triazine family of herbicides.
			Nutrients – nitrogen and phosphates
			Chlorophyll-a
			Mg^{+}, Na^{+}, Ca^{+}, SO_4^{-}, Cl^{-}
Dense settlements & informal settlements	Sewage effluent leading to eutrophication	All catchments above Kruger National Park	PO_4-P
			Total inorganic nitrogen
			Dissolved oxygen
			NH_3
			Chl *a*

The Letaba system consists of the following major dams (Table 2.2):

Table 2.2: Major Dams in the Letaba Catchment

Dam	DWAF Number	Quaternary Catchment	FSC (Million M^3)	Use
Dap Naude	B8R006	B81A	1.94	Domestic Use
Ebenezer	B8R001	B81A	70	Domestic Use
Magoebaskloof	B8R003	B81B	4.91	Irrigation
Tzaneen Dam	B8R005	B81B	157.3	Irrigation
Hans Merensky	B8R002		1.256	Irrigation
Thabina		B81D	0.28	Irrigation
Lorna Dawn		B82A	11.748	Irrigation
Middle Letaba	B8R007	B82D	184.2	Irrigation
Nsami		B82H	29.46	Irrigation

The major dam in the Letsitele and Nwanedzi subsystem is the Thabina Dam on the Thabina River. The Middle Letaba and Klein Letaba subsystem consists of the Middle Letaba and Nsami Dams. Though there is no major water supply scheme in Lower Letaba there are three dams. The impact of these three dams on water resources is insignificant because there are no major activities in the area. However, the operation or outlet structure may affect the provision of high flows to downstream riparian ecology.

The Letaba River runs from the mountainous Heanertsburg area through the Ebenezer dam into the Tzaneen dam; a distance of some 30 kilometres, by way of a fast flowing stream. No major weirs are operational between the Ebenezer and Tzaneen dams except the two small weirs that divert water, which is released from Ebenezer Dam, from the river to irrigation farms. These weirs are George’s Valley and Pusela.

Downstream, for ± 120 kilometers, to the Kruger National Park (KNP), there are five weirs, namely:

- Yamorna Weir
- Junction weir
- Jasi weir
- Prieska weir
- Nondweni weir

The Groot Letaba Water User Association operates these weirs. The weirs are opened and closed by way of manually operated sluice gates, which are frequently blocked by trees and debris.

The weirs have limited capacity, having been in use from more than 20 years and subjected to silting up.

The weirs are opened and closed in order to relieve demands for water at any given time, usually at a point where the flow of the river gets too low to deliver $0.6m^3/s$ to KNP, after primary, industrial and irrigation allocation (or rational allocations upstream) have been satisfied.

The objective is to obtain water from the nearest weir and then to “refund” the particular weir from weirs upstream and then eventually from the Tzaneen dam in order to conserve as much water in the over-allocated Tzaneen dam as possible, to lengthen the assured delivery.

These actions are activated through visual inspections and observations by the Letaba Water User Association’s water bailiffs, and through messages from various sources along the river and interpreted in view of their (the bailiffs) long experience of the behaviour of the river.

There are therefore no hard and fast operational rules and DWAF Regional Office has, up to now, been responsible for implementing the operating rules for Ebenezer and Tzaneen dams.

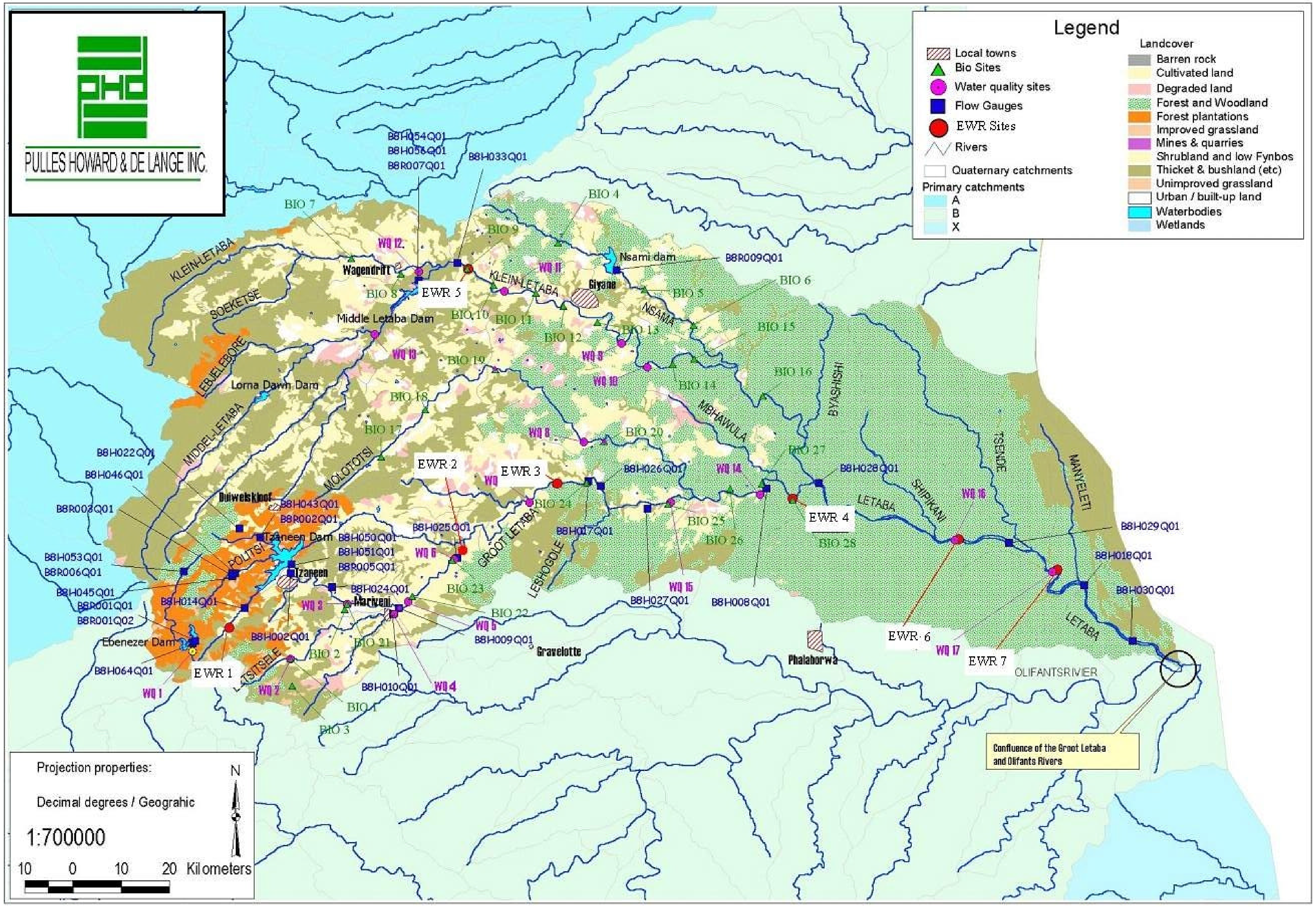

Figure 2.1: Catchment characteristics of Letaba River.

3. METHODS

3.1 APPROACH

This study followed the generic 8-step process to Reserve determination, shown in Figure 3.1.

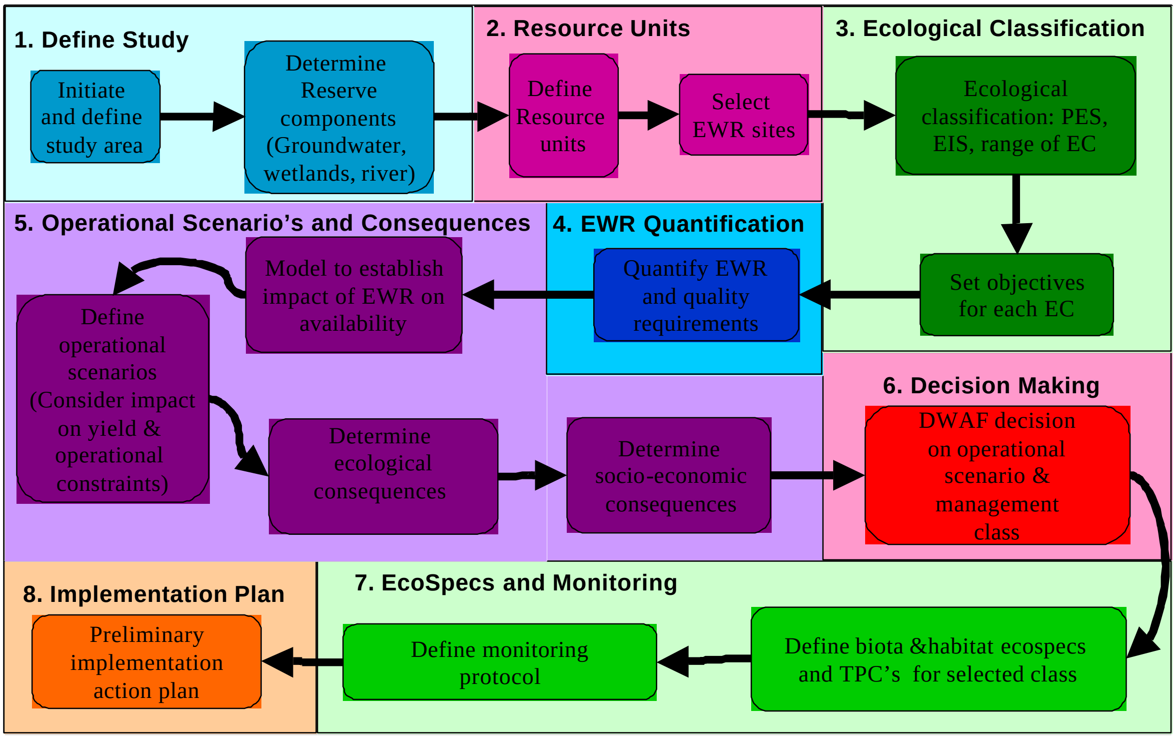

Figure 3.1: The generic 8-step Ecological Reserve Procedure (from DWAF 2003).

3.2 LEVEL OF DETAIL

This study followed comprehensive methods for EcoClassification as well as for Ecological Water Requirement determination. The level of detail for the wetlands and groundwater components were at a scoping level only.

3.3 SCHEDULE

This study was conducted over a three-year period, starting with calls for tender in December 2002 (Figure 3.2). Consultants were appointed in April 2003, and an Inception Report was drafted in May 2003 and approved in July 2004. The study area was delineated into Resource Units and sites were selected in August 2003. Primary data collection took place between August 2003 and April 2004 (high and low flow periods). The EWR was quantified at two specialist meetings (June and August 2004). Operational scenarios were developed during a series of meetings between October 2004 and June 2005. The ecological and economic consequences of the various scenarios were assessed at a workshop held in May 2005. A decision on the resource classification was taken in September 2005, and a specialist meeting on Monitoring and EcoSpecs in January 2006 followed this. Reports were finalised in February and March 2006.

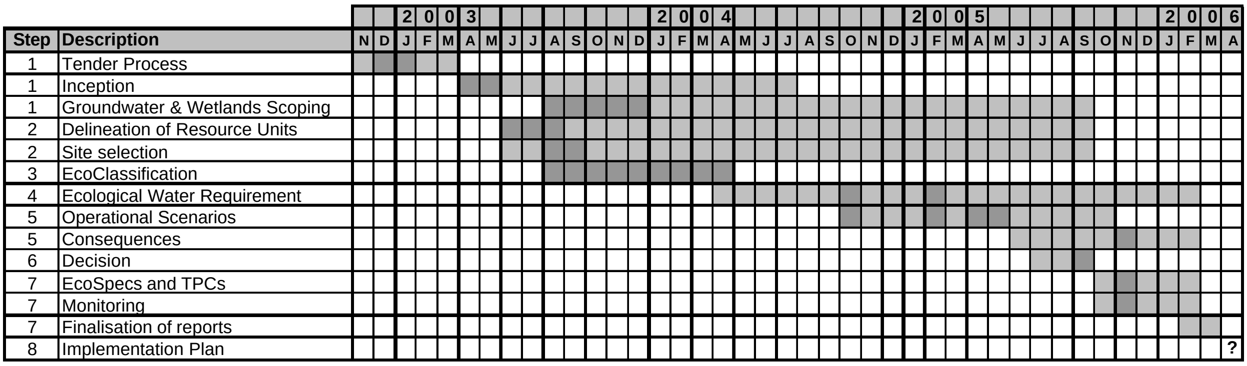

Figure 3.2: Summary of the Letaba comprehensive Reserve study schedule.

3.4 ASSUMPTIONS AND LIMITATIONS

- ***Basic Human Needs:*** The Basic Human Needs component of the Reserve were not assessed.
- ***Stakeholders:*** A stakeholder involvement programme was not included. The project team did however meet with representatives of the Kruger National Park as well as the Groot Letaba Water Users Association.
- ***EWR Sites****:* EWR sites could not be selected in all Resource Units because of funding constraints (only 7 sites budgeted for).
- ***Hydraulics:*** Confidence in high flow assessments was medium as there were some high flows recorded in March 2005 that was used for hydraulic calibration purposes during the course of the study.
- ***Hydrology:*** The best available hydrological data for the Groot Letaba River was only available up to 1992. This data set did not include the largest living memory flood of 2000. Furthermore the current water demands are not included in this data set. It was acknowledged that demand patterns are likely to be significantly different to what was included in the model.
- ***The Water Resource Yield Model*** *(2000*) was used to assess the impact on yield of the recommended and alternative EWRs. A limitation of the model is that output is presented as monthly flows. This makes it difficult to distinguish between high and low flow components that were specified as EWR requirements during months where both low flows and high flows were specified. Therefore, this did not pose a significant problem for assessing the dry season low flow component because monthly flows could be converted to m^3/s. However, dry season requirements for the Letaba River did include some small floods, so the stress duration curves for the scenarios do not exactly equate to stresses that were recommended by the ecologists.
- ***Classification System.*** No classification system as required by the National Water Act exists for integrating the results of the ecological and socioeconomic consequences to decide on the Management Class.
- ***Monitoring Plan.*** This report provides the basis for developing a monitoring plan, but it does not address monitoring requirements or implementation as this requires the development of operational rules, negotiation with and commitment by all relevant management agencies, and a comprehensive Decision Support System that allocates responsibilities, and specifies the actions that should be taken in the event of non-compliance. These aspects fell beyond the scope of this study.

4. GROUNDWATER SCOPING

4.1 INTRODUCTION

It is generally accepted that groundwater plays a role in the ecological Reserve determination if there is a direct hydraulic connection between groundwater and surface water bodies that jointly sustains the aquatic ecosystems. In such situations the often-complex role of groundwater (in terms of water level, volume, and water quality), in supporting the ecosystem and human population, has to be ascertained, so that groundwater is not subsequently misallocated. Where aquifers have minimal connection with the aquatic ecosystems, the groundwater component of Reserve would refer to the Basic Human Needs component (25 l/d/person multiplied by the number of people using the groundwater supply in the area).

As a core concept of the RDM, the Reserve covers both Basic Human Needs (BHN) and Ecological Reserve (ER), however, this study focuses primarily on the ER and existing and planned groundwater usage.

4.2 OBJECTIVES

The purpose of the groundwater component of the Letaba comprehensive Reserve was at a desk top level and to develop a Terms of Reference for a more comprehensive Reserve determination based on these preliminary findings (DWAF 2005).

The following tasks were identified:

- Determine the importance of groundwater in terms of current and future groundwater use;
- Utilize desktop study information from the RDM office to initially delineate groundwater resource units;
- Determine groundwater contribution to base flow and provide a reconnaissance level understanding of the contribution of groundwater to the ecosystem functioning of rivers and wetlands in the catchment;
- Determine the degree of groundwater stress; and
- Compile a terms of reference for conducting a comprehensive determination of the groundwater component of the reserve stating all tasks as well as a monitoring program.

4.3 METHODS

The study was largely literature-based, and methods used included:

- Use of prior expert knowledge in the area (use same bullets (see above and same format for caps, full stops etc);
- Examination of hydro-geological, topographical and geological maps;
- Examination of aerial photographs;
- The National Groundwater Database (NGDB);
- Hydrochemical data;
- Aquifer parameters, recharge, base flow (ecological role);

- Groundwater vulnerability;
- Review of population census data and population density maps. This gave an indication of the reliance of communities on groundwater; and
- Land-use information, such as large-scale agricultural, industrial and mining related activities reliant on groundwater.

The groundwater characteristics of the catchment were investigated by reviewing aspects such as the different types of aquifers present across the catchment and the characteristics of each aquifer; the yields of the boreholes intercepting the identified geological units, water level data recorded in boreholes, the ambient hydrochemistry of the aquifer units as observed in the boreholes, recharge to the groundwater system from rainfall and base flow.

4.4 RESULTS

4.4.1 Geology of the Letaba catchment

The study area is underlain by 11 major stratigraphic groups. The major stratigraphic groups in the Letaba catchment are briefly discussed below:

(i) The Goudplaats and Makhutswi Gneisses form the basement on which all other existing lithologies were deposited and preserved and underlay more than 50% of the catchment.

(ii) The Murchison Sequence is ancient supra-crustal rocks preserved in the basement gneisses. The Giyani Group is a varied assemblage of volcano-sedimentary rocks and outcrops primarily in the catchment of the middle reaches of the Klein Letaba. The Gravelotte Group outcrops only on the southern margin of the Groot Letaba, where it forms the Murchison Range. The Pietersburg Group present as isolated outcrops in the Duiwelskloof region.

(iii) The Bandolierskop Complex is a highly metamorphosed body infolded into the basement rocks and occurs in isolated outcrops in the upper to middle reaches of the Klein Letaba.

(iv) The Schiel Complex is of younger than the above granite intrusives and consists of a porphyritic hypersthene syenite and hornblende granite. It underlies the middle reaches of the Klein Letaba.

(v) The Wolkberg Group consist of shale quartzite and basalt and occurs in the upper reaches of the Groot Letaba where they form a watershed.

(vi) The Timbavati Gabbro is a non-linear ultra-mafic dyke of varying width (can be larger than 1 km) which strikes in a general north/south direction. It consists of olivine gabbro. Of similar age and composition are a series of NE trending diabase dykes that occur as swarms primarily in the western half of the catchment.

(vii) The Letaba Formation of the Karoo Supergroup occurs along the eastern part of the study area.

(xi) Quaternary age alluvium is preserved in broad shallow depressions and in the valleys of the study area.

4.4.2 Groundwater regions and response units

The catchment can be largely classified as Crystalline igneous and metamorphic basement rocks of Swazian to Randian age underlying the Lowveld region. Aquifers are predominantly secondary, with the exception of the alluvial deposits. The land surface has been dissected by erosion beginning in the early Cretaceous along the Escarpment that forms the western watershed to the early Miocene in the east.

The hydrogeology of the Letaba catchment is characterized by secondary or fractured aquifers formed by mainly metamorphic basement rocks of the Goudplaats Gneiss, Giyani and Gravelotte Greenstone belts, Igneous rocks of the Lebombo Granite, Makhutzi Granite, various younger granitoid intrusions of the Vorster Suite and gabbroic intrusions of the Rooiwater Suite Timbavati Gabbro. Intergranular aquifers (unconsolidated to semi-consolidated materials, with primary porosity) occur on the Letaba River, mainly inside the Kruger Park.

The catchment can be divided into several hydrogeological regions:

- Drakensberg Escarpment;
- Drakensberg Foothills and valleys;
- Bandolierskop;
- Giyani-Gravelotte;
- The Plains;
- Lebombo; and
- Alluvium.

The Plains covers over 50% of the catchment. This aquifer underlies the largest part of the plains of the central Letaba catchment from north of Polokwane in the east to Tzaneen past Phalaborwa, to approximately the Kruger Park boundary.

These aquifers are composed of fractured gneissoid rocks with xenoliths of undifferentiated metamorphic rocks and meta-arenaceous rocks (quartzite, gneiss and migmatite). In the north syenites and granites of the Schiel Complex, which has a low groundwater potential, have intruded the gneisses. In the east the Timbavati Gabbro and numerous diabase dykes are intrusive.

Rainfall varies from 500-600 mm/a and groundwater yields generally vary between 0.5 and 2.0 l/s, with localized zones where yields range between 2.0 and 5.0 l/s and occasionally more than 5 l/s.

Large-scale irrigation, using groundwater, for permanent crops, i.e. citrus, mango, avocado, banana, litchi and macadamia nuts takes place at Letsitele and Mooketsi to the east and north of Tzaneen, conjunctively using surface and groundwater. The now abandoned 1000 ha large tea plantations are situated on the plateau. The sole reliance of farmers on permanent crops makes agriculture, which is the most important economic activity in the greater Tzaneen area, very sensitive and highly dependent on the water supply conditions. Large-scale irrigation and agricultural activities reduce considerably towards the ‘drier’ east.

Hundreds of thousands of people living in rural communities on this aquifer rely on groundwater supply for basic human need requirements. In particular, large-scale groundwater use takes place north of Phalaborwa and Tzaneen to meet this basic need. Some of the communities to the east of Tzaneen, that are dependent on groundwater to meet their basic human need requirements, are Letsitele, Letaba Estates, Nkowakow, Lenyenye and Ritavi and in the northern part of the Letaba catchment, Giyani, Bolobedu and Namakgate. In all the above-mentioned rural communities there is a huge potential for expansion of groundwater use. Associated with the rural community lifestyle is increased nitrate and organic contamination as a result of uncontrolled animal grazing along riverbeds and lack of sanitation systems, all resulting in poorer quality groundwater base flow reaching the Letaba River.

Localized use of granite aquifers for domestic and game watering purposes in granite aquifers also takes place on private game farm property to the east. Several boreholes have been drilled in the Kruger National Park (KNP) and are utilized by private game reserves in the vicinity. Although the KNP obtains most of its domestic supplies from surface water, there is a concern that private game reserves might overexploit groundwater resources to supplement game viewing water holes. In the light of this, a fear exists that the park is not in a position to manage their groundwater resources.

4.4.3 Impacts on Groundwater

Due to the limited storage in the fractured aquifer, it is likely that over abstraction will result in rapid dewatering; hence declining water levels will have an immediate impact on abstraction. Declining base flow may be attributable to afforestation in the Escarpment and Foothills region. This will probably result in reduced base flow from through flow and perched aquifers, but will not impact on the regional valley bottom aquifers to the same extent.

4.4.4 Importance to base flows of rivers

Base flow to maintain instream flows can be attributed to discharge from the regional aquifers, or from subsurface discharge with a rapid turnover time originating from shallow fractures outcropping on steep slopes, perched water tables, through flow through the weathered zone, or highland springs above the regional valley bottom aquifer. The ecological significance of the regional aquifer is related to the connectivity of groundwater to the river reaches and the degree to which the aquifer maintains base flow.

The total reduction in groundwater baseflow is approximately 10 Mm^3/a, however, in many cases this impact is significantly larger in dry years when irrigators rely more strongly on boreholes due to reduced streamflow. During dry years depletion of baseflow and losses into the aquifer can reach 21.5 Mm^3/a. This can be as high as 85% of baseflow originating from the regional aquifer.

4.4.5 Social and Economic Importance

Assessing the use of groundwater for irrigation, livestock, and rural water supply in terms total combined surface and ground water use for each of these functions can assess the importance of groundwater to the regional economy. Groundwater usage for irrigation was based on drought usage rather than average annual, to highlight the importance of this resource during dry years.

4.4.6 Importance to Wetlands

Few wetlands exist in the catchment and only two are recorded namely Soutini/Baleni and the Eiland (DWAF 2006a). These wetlands are zones of groundwater discharge. Since both are located in catchments were groundwater usage is low, neither wetland is presently at risk.

4.4.7 Groundwater vulnerability

Aquifer vulnerability is low in the western Escarpment region of the catchment due to the presence of moderate to deep clayey loam soils overlying the granites. In the Foothills the aquifer is highly vulnerable to contamination due to the sandy loam texture of the soil. In the Giyani-Gravelotte region the aquifer is moderately vulnerable due to depth of the water table. In the plains the aquifer is overlain by sandy soils, hence is moderately vulnerable to contamination, however, the region overlying basalt, is underlain by clayey soils and has a low vulnerability.

4.4.8 Overexploitation

The groundwater resources of the Letaba are underutilized, with the exception of B81D, the catchment of the Letsitele. In this catchment abstraction for irrigation is 145% of the exploitation potential, and as a result significant depletion of base flow generated in the headwaters of the catchment occurs.

4.4.9 Drought

Aquifers can be prone to drought stress when water demand is large in relation to harvest potential, rainfall variability is high and storage is limited. Vulnerability was determined by comparing maximum abstraction, during dry years, to aquifer storage (Table 4.1). From Table 4.1 it can be sent that the majority of the groundwater in the Letaba catchment has low to insignificant vulnerability to drought.

Table 4.1: Aquifer Vulnerability to Drought.

Quaternary	Aquifer thickness (m)	Aquifer storage (Mm^3)	Abstraction as % of storage	MAP (mm)	Vulnerability
B81A	7	1.78	22%	1194	Moderate
B81B	7	10.11	67%	1163	High
B81C	7	2.92	2%	880	Low
B81D	7	10.05	180%	832	High
B81E	7	11.64	0%	667	Insignificant
B81F	17	61.18	1%	544	Low
B81G	7	10.76	10%	627	Low
B81H	7	16.36	4%	510	Low
B81J	17	33.74	0%	502	Insignificant
B82A	7	8.17	22%	721	Moderate
B82B	7	7.11	0%	702	Insignificant
B82C	7	5.24	0%	712	Insignificant
B82D	7	15.48	27%	623	Moderate
B82E	7	10.37	20%	656	Moderate
B82F	7	15.96	7%	676	Low
B82G	17	46.93	1%	524	Low
B82H	17	31.82	1%	516	Low
B82J	17	40.48	0%	540	Insignificant
B83A	17	63.75	0%	515	Insignificant
B83B	17	22.38	0%	596	Insignificant
B83C	17	35.19	0%	539	Insignificant
B83D	17	36.35	0%	552	Insignificant
B83E	17	11.33	0%	587	Insignificant

4.5 PRESENT STATE AND PROPOSED LEVEL OF GROUNDWATER RESERVE DETERMINATION

The management of the groundwater component of the Reserve for the Letaba should be based largely on protecting base flow, due to the implications on downstream users of current base flow reduction activities in the headwater regions.

Alluvial aquifers along the major Letaba River course, mainly in the KNP, are considered major aquifers and exist in delicate equilibrium with surface water and ecosystems present along the river course. These aquifers are recharged by surface water during periods of high flow. In terms of the potential for future exploitation of these aquifers, and for the modification of the river flow regime, surface water/groundwater interactions need to be quantified and the sensitivity of ecosystems along the Letaba River to a dropping water table needs to be evaluated. A high confidence groundwater reserve determination is therefore proposed.

Throughout the Letaba catchment, the basic human need requirements for various rural settlements pose huge challenges both in terms of primary water supply and also in protecting the quality of groundwater resources from increasing nitrate values in the absence of adequate sanitation systems. In addition to the above, uncontrolled animal grazing in river beds and the utilization of the major river course itself for washing purposes will have a profound water quality impact in the long term.

4.5.1 Ground water and the Ecological Reserve

The contribution of groundwater to the Ecological Reserve is dependent on the natural contribution of subsurface water to streamflow, Recommended Ecological Category (REC) and Environmental Water Requirements (EWR).

Groundwater contributions cannot be simply equated to recharge, since recharge may be lost in steeply areas before reaching the regional aquifer through interflow through the weathered zone, seepage of percolating water outcropping fractures, springs draining perched water tables, artesian springs, evapo-transpiration, or by conventional discharge into effluent streams. Therefore, it is not the recharge term that is significant to quantifying discharge of subsurface water into streams; it is the natural discharge. This component must be subdivided into discharge, which emerges in high lying areas not connected to the regional groundwater body and therefore not accessible by boreholes, and into groundwater discharge.

In the Letaba catchment, regional groundwater levels are generally below the level of the river, hence conventional groundwater baseflow is limited. Base flow is sustained by rainfall in the high lying Escarpment and foothills regions, which seeps through the shallow soils and emerges from fractured granite and gneiss above the regional aquifer as mountain springs. For this reason, recharge calculated based on rainfall and soil zone percolation is significantly different than the Harvest Potential of the regional aquifer.

Estimated present day perched and groundwater base flow was compared to EWR base flow requirements in DWAF (1994) of 70 Mm^3/a. This base flow volume represents 31.5% of virgin base flow, hence 31.5% of virgin groundwater and perched discharge was considered to be available for surface water. Differences in the water quality and timing of discharge from these two sources may be of significance for ecological purposes hence it is important to maintain proportions between the two sources.

Calculations of groundwater potential contributions to the surface water are given in Table 4.2. For the catchment as a whole, base flow exceeds the surface water requirements, however, much of the base flow generated in the headwater regions is abstracted from the river for irrigation, hence base flow requirements downstream are not met.

Table 4.2: Calculation of the Groundwater Component of the Reserve.

	Total Virgin Baseflow Mm³/a	Virgin G'water Baseflow Mm³/a	Virgin Perched Baseflow Mm³/a	Forestry Water use Mm³/a	Alien invasive Water use Mm³/a	Present Perched baseflow Mm³/a	G'water Abstract. Mm³/a	Harvest Potential - Baseflow Mm³/a	Present G'water Baseflow Mm³/a	Max. G'water Abstract. Mm³/a	Present G'water Baseflow Mm³/a	Reserve G'water baseflow Mm³/a	Reserve Perched Baseflow Mm³/a
B81A	41.67	2.71	38.96	16.11	3.07	19.78	0.39	0.00	2.32	0.39	2.32	0.86	12.30
B81B	97.13	7.72	89.41	31.98	7.94	49.49	2.70	0.00	5.02	6.74	0.98	2.44	28.23
B81C	6.76	2.04	4.72	0.49	1.80	2.43	0.05	1.29	2.02	0.06	2.01	0.64	1.49
B81D	39.82	7.80	32.02	5.12	3.59	23.31	6.79	0.00	1.01	18.09	-10.29	2.46	10.11
B81E	0.00	0.00	0.00	1.08	0.18	-1.26	0.01	8.94	0.00	0.01	0	0.00	0.00
B81F	0.00	0.00	0.00	0.00	0.08	-0.08	0.61	14.41	0.00	0.61	0	0.00	0.00
B81G	0.00	0.00	0.00	0.23	0.03	-0.26	1.07	6.73	0.00	1.07	0	0.00	0.00
B81H	0.00	0.00	0.00	0.00	0.02	-0.02	0.60	8.02	0.00	0.6	0	0.00	0.00
B81J	0.00	0.00	0.00	0.00	0.01	-0.01	0.16	6.46	0.00	0.16	0	0.00	0.00
B82A	7.35	0.96	6.39	0.41	0.40	5.58	1.35	6.41	0.28	1.8	0.06	0.30	2.02
B82B	5.76	0.78	4.98	0.86	0.47	3.65	0.00	5.72	0.78	0	0.78	0.25	1.57
B82C	4.45	0.63	3.82	1.38	0.86	1.58	0.00	4.13	0.63	0	0.63	0.20	1.21
B82D	5.52	0.96	4.56	0.60	0.43	3.53	4.22	9.15	-1.15	4.22	-1.15	0.30	1.44
B82E	4.39	0.72	3.67	0.66	0.00	3.01	2.07	5.69	-0.32	2.07	-0.32	0.23	1.16
B82F	8.87	1.32	7.55	0.36	0.06	7.13	1.14	10.73	0.75	1.14	0.75	0.42	2.39
B82G	0.00	0.00	0.00	0.00	0.04	-0.04	0.62	11.02	0.00	0.62	0	0.00	0.00
B82H	0.00	0.00	0.00	0.00	0.02	-0.02	0.16	8.47	0.00	0.16	0	0.00	0.00
B82J	0.00	0.00	0.00	0.00	0.02	-0.02	0.00	6.42	0.00	0	0	0.00	0.00
B83A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	12.08	0.00	0	0	0.00	0.00
B83B	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.51	0.00	0	0	0.00	0.00
B83C	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.74	0.00	0	0	0.00	0.00
B83D	0.00	0.00	0.00	0.00	0.01	-0.01	0.00	7.29	0.00	0	0	0.00	0.00
B83E	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.90	0.00	0	0	0.00	0.00
TOTAL		**25.64**	**196.07**	**59.28**	**19.03**	**117.76**	**21.94**	**144.11**	**11.34**	**37.74**	**-4.23**	**8.10**	**61.90**

5. WETLAND SCOPING

5.1 INTRODUCTION

Wetlands form an integral part of aquatic ecosystems and the hydrological cycle, and can play a key role by contributing to river base flows and providing habitats that support aquatic biodiversity. A comprehensive assessment of EWR should therefore include an assessment of wetlands and their ecological functions

5.2 AIMS

The brief for the wetland scoping study was as follows:

- To review any existing information that may be of use with respect to identifying the extent of and types of wetlands in the Letaba Catchment;
- Determine the functions and benefits of the wetlands;
- Identify the main constraints with respect to undertaking a wetland Reserve for the catchment;
- To define data needs for the wetland Reserve including consideration of:
  - the possible use of the new National Land Cover dataset (NLC2000) for assisting with identifying possible systems for consideration for Reserve Determinations; and
  - alternative approaches for assisting with identifying wetlands in the catchment for Reserve Determinations.
- Consider some of the new developments pertaining to our understanding of wetlands that may be relevant to undertaking a wetland Reserve for the catchment; and
- To produce a short report on the findings including recommendations for the way forward with respect to the wetland Reserve;

5.3 METHODS

This report was only intended to provide a very broad overview of the situation with respect to wetlands in the Letaba River catchment. Apart from a brief site visit to Soutini during IFR site selection in 2003, no other field verification or assessment was possible. Most of the investigation was therefore desktop. In addition to a review of existing information, the first step in the investigation was to try to establish the extent and distribution of wetlands in the catchment.

5.3.1 Sources of information

Information from the following sources was used to assist with the investigation:

- Mr. Mick Angliss (Limpopo Province Department of Agriculture Land and Environment) provided copies of the field data sheets and other information on the Soutini wetland and general literature on other thermal springs;
- Mr. Piet-Louis Grundling from Working for Wetlands was contacted regarding their experience with wetlands in the catchment;
- Dr. Wynand Vlok from the University of the North was contacted regarding his experience with wetlands in the catchment;

- Extracted data from the NLC 2000 dataset for the Letaba River catchment; and
- 1:50 000 topographic sheets of the catchment.

This investigation therefore represents the first attempt to identify the types and potential location of wetlands in the Letaba catchment. These steps were followed:

- Indication of the occurrence of wetlands in the catchment, all areas marked as wetlands on the digital 1:50 000 topographic maps were captured using heads-up digitising in ArcView 3.2;
- All low gradient (gradual slope) areas in the high rainfall areas of the upper catchment where wetlands were most likely to occur and where drainage was indicated as diffuse were identified. These were marked as dots on the 1:50 000 digital coverage; and
- All areas identified as potential wetlands on the NLC 2000 dataset extract of the catchment (raw data for the catchment supplied compliments of the CSIR) were captured in ArcView. Together this provided an indication of the potential wetland sites in the catchment. As no field verification was undertaken, the mapping can at best be considered provisional.

5.3.2 Classification of wetlands

The areas that could be collated as complex units were mapped. This served as an indication of the areas in the catchment where wetlands are likely to occur. In order to get some idea of the likely functionality of the types of wetlands found in the catchment, a generic functional assessment using the scoring system in Wetland-Assess (Kotze *et al.*, 2004) was undertaken. This was done at a very course-level (per wetland type per Hydrogeological Region in the catchment). This provided some indication of the likely ecosystem services that the various wetland types in the different Hydrogeological Regions are performing.

5.3.3 Current status of wetland

In order to establish at least a general baseline for the current status of the wetlands, and to get a first level estimate of their relative ecological importance, a generic wetland Present Ecological Status (PES) and Ecological Importance and Sensitivity (EIS) analysis was conducted (modified from Department of Water Affairs and Forestry, 1999). While it was not possible to score the different criteria for the PES as there are no field data available for the catchment, due consideration of the criteria was given in making the value judgements about the PES. These criteria considered included those provided in the procedure for determination of Resource Directed Measures for wetland ecosystems (Department of Water Affairs and Forestry, 1999). The assessment was applied generally to the different wetland types in each Hydrogeological Region in the catchment. Land use was used to establish a first level indication of the general PES of the wetlands. Experience gained from work in other catchments was also used in coming up with the PES. An evaluation of the impacts on groundwater in the catchment (DWAF 2004) was used to supplement the findings relating to the general impacts on the wetlands. General assumptions based on the biogeographics of the wetlands in the catchment were used to establish a first level indication of the EIS.

5.4 RESULTS

Based on the National Land Cover 2000 coverage, as well as the topographic analysis undertaken, there appears to be a fairly high concentration of relatively large wetlands between the Letsitele and Thabina Rivers in the south west of the catchment and in the area east and west of the Groot Letaba River immediately downstream (Figure 5.1). This appears to stretch as far as the Nsami River confluence with the Groot Letaba River. The wetlands extend from the Sour Lowveld Bushveld through a section of Mixed Lowveld Bushveld into the Mopane Bushveld. Most of the identified systems therefore occur along the Drakensberg foothills and valley and the Pieterberg plateau and lowveld hydrogeological regions of the catchment.

Topographically, the systems appear to comprise mostly valley bottom wetlands that are linked to water courses. The quaternary catchments in which these wetlands occur include predominantly B81D and B81 E although there are also some systems in B81C. Besides in this area, no other wetland systems were picked up from the NLC 2000 data source available.

Based on the topographic analysis, it is also likely that wetlands occur in the upper section of the catchment on the plateaus where slopes are gentle and rainfall is higher. In particular, wetlands are expected to occur in sections of quaternary catchments B81A, B82A and B82B. These systems fall within the Drakensberg escarpment hydrogeological region and would be restricted predominantly to isolated systems in the upper reaches of the small tributaries of the main rivers. They are expected to comprise mostly hillslope seepage and narrow channeled valley bottom wetlands. Should these occur, they are likely to contribute to baseflows in the upper sections of the streams. Valley bottom wetlands are also expected along the stream channels in these upper reaches. These are likely to be narrow and across much of the area, impacted by afforestation.

Probably the most culturally and geo-hydrologically interesting systems that occur in the catchment are the two thermal spring systems, one at Eiland (Hans Merensky Nature Reserve) and the other (Soutini-Baleni) close to the banks of the Klein Letaba River in its middle reaches. The latter is particularly culturally significant and is thought to be one of the few remaining undeveloped hot springs in South Africa and is a traditional Tsonga salt manufacturing site. Apart from the thermal springs, almost all the other wetlands identified or expected to occur in the catchment are associated with either the Rooiwater complex, granite intrusions, the Goudplaats gneiss or quaternary deposits.

Springs in the Drakensberg escarpment hydrogeological regions provide baseflow to the rivers yielding typically between 1 and 3 l/sec (DWAF 2004). Quaternary catchment B81A, which occurs in the Drakensberg escarpment region and which is expected to support wetlands, generates approximately 39% of the baseflow in the Letaba catchment (DWAF 2004).

In the Drakensberg foothills and valley region, the aquifers are of a composite type, and the wetlands are mostly seasonally to temporarily wet and expected to dry up during winter months or drought years. These systems may also contribute to base flow in the rivers and streams, particularly in quaternary catchment B81D where base flow contribution is high (approximately 13% of the total Letaba catchment according to DWAF 2004). Losses from evapotranspiration in large wetland systems like that along the Thabina River may reduce the base flow contribution from this quaternary during summer months. These losses may be far less during winter months. Winter base flow contribution is likely to be key for maintaining the aquatic ecosystems during the dry months.

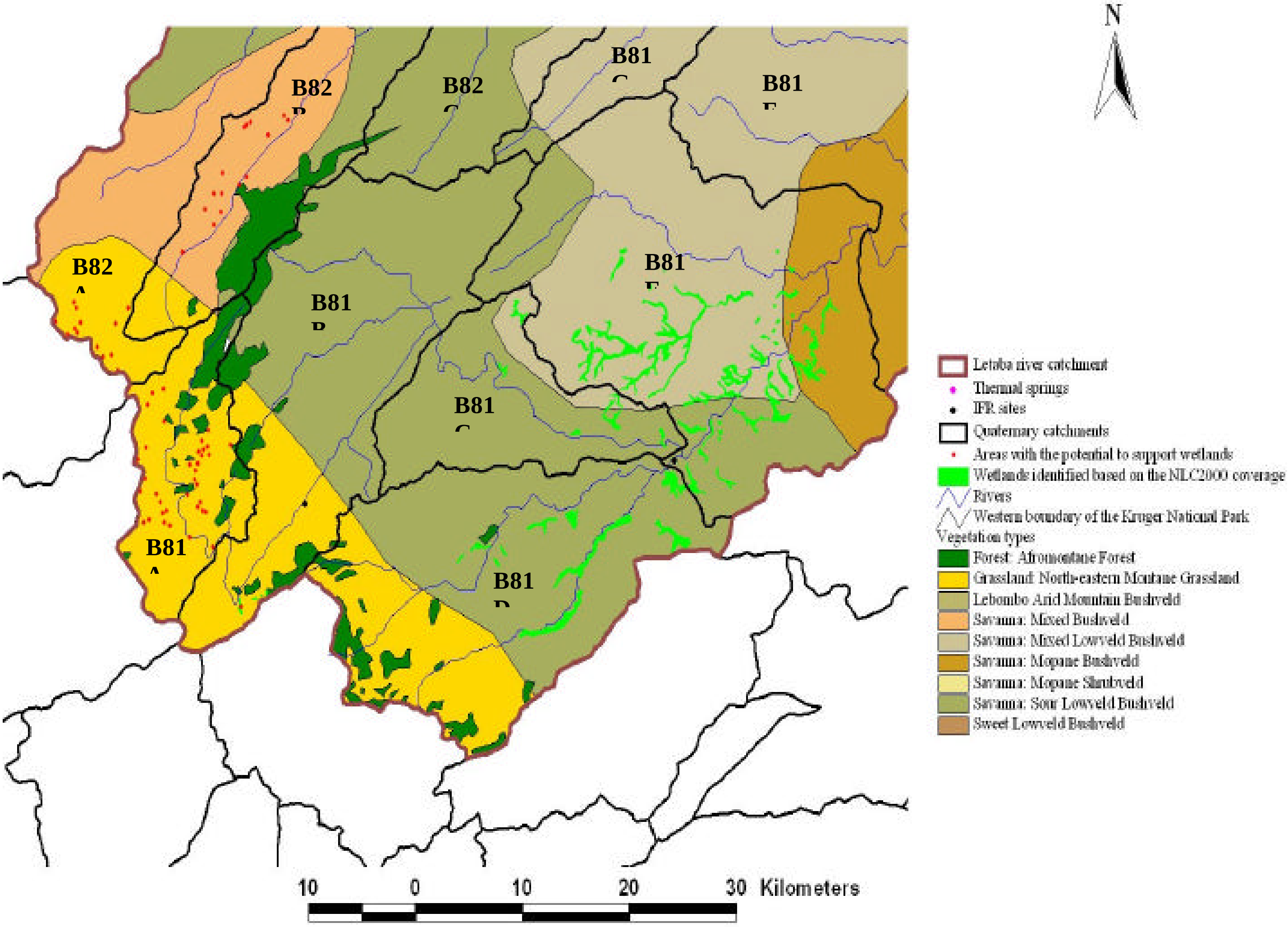

Figure 5.1: Potential wetland distribution in the upper catchment of the Letaba River in relation to vegetation type and quaternary catchments.

In the Pietersburg plateau and lowveld hydrogeological region, which covers over 50% of the catchment, groundwater levels are generally below stream level, thereby reducing the opportunity for flow augmentation in the rivers (DWAF 2004). The wetlands in this region are therefore mostly temporarily wet and are expected to dry up during winter months or drought years. These systems are likely to be important for flood attenuation where they occur in the valley bottoms since they are large and have the capacity to absorb large volumes of water, have gentle slopes, and are likely to be well vegetated. Being vegetated and given their location in the hot lowveld zone where evaporation far exceeds rainfall, evapotranspiration losses from these systems is expected to be high.

Primary aquifers consisting of saturated alluvium are also present along the major river systems and are composed of unconsolidated clayey silts to course gravel and boulders. These aquifers are recharged during periods of high streamflow and discharge to the river once the stream stage drops. These are considered important aquifers (DWAF 2004) especially with regard to their role in maintaining the ecosystems along the rivers. While these aquifers support mainly the river-related ecosystems, they may also serve to support some of the larger riparian wetlands such as those along the Thabina River and those in the Pietersburg plateau and Lowveld region.

The Santini-Baleni thermal spring wetlands that also occur in the Pietersburg plateau and Lowveld hydrogeological region have cultural significance and provide valuable resources to the local communities who utilize them. They also provide biodiversity support and should be protected.

Interpretation of the information currently available for the catchment suggests that the wetlands in the Drakensberg escarpment and Drakensberg foothills and valley regions are likely to have been more impacted upon than those in the other two hydrogeological regions. Afforestation, alien plant invasion and irrigation are likely to be the main impacts in the Drakensberg escarpment and Drakensberg foothills and valley region, while cultivation and overgrazing are likely to be the main impacts in the Pietersburg plateau and Lowveld region.

The high lying springs, perched aquifers and associated wetlands in the Drakensberg escarpment region are expected to be most vulnerable in terms of impacts. These systems are likely to be small, easily drained, have steep slopes, are susceptible to erosion and water quality changes, and are often overlooked in land-use planning. In contrast, the large valley bottom systems in the Pietersburg plateau and Lowveld region are expected to be more robust in terms of absorbing impacts related to water quality changes and flow reduction. Encroachment into these systems is also limited by flooding and the shallow gradients of these systems probably make them less susceptible to erosion than the systems in the top of the catchment.

Interpretation of the information currently available for determining the EIS suggests that the wetlands in the Drakensberg escarpment region and the thermal springs in the Pietersburg plateau and Lowveld region are likely to have the highest EIS (scoring High and considered to be ecologically important and sensitive and which play a role in moderating the quantity and quality of water of major rivers). The likely occurrence of Red Data listed species, populations of unique species, and sensitivities to water quality changes and changes in the natural hydrological regime would probably be the main attributes that account for this high EIS.

Despite the systems in the Drakensberg foothills and valley region also being considered important for moderating the quantity and quality of water in the catchment, they score lower in terms of the EIS evaluation, (Moderate – systems considered to be ecologically important and sensitive on a provincial or local scale where the biodiversity is less sensitive to flow related changes and where the system plays less of a role in moderating the quantity and quality of water to major rivers). The lower score was mainly a result of a lack of Red Data listed species and populations of unique species.

5.4 RECOMMENDATIONS

A fundamental constraint in this whole scoping exercise is the lack of an inventory of wetlands in the Letaba catchment and in particular in the main quaternaries where wetlands have been identified or are expected to occur (B81A, B81C, B81D, B81E, B82A and B82B). This together with a lack of baseline data on any of the wetlands (besides the thermal springs) in the catchment, makes it very difficult to identify priority wetland sites for undertaking Reserves. Another constraint has to do with the existing inadequacies with respect to the wetland Reserve determination method, particularly the inability of the current method to deal with groundwater-surface water interactions and the role of interflow and perched groundwater in these systems.

Given these constraints, it is recommended that the valley bottom systems in the Pietersburg plateau and Lowveld hydrogeological region are targeted for reserve studies at this stage. In addition, the existing method is more applicable to riparian wetlands than other types such as hill slope seepage systems, thus rendering the valley bottom wetlands in the lower part of the catchment more suitable candidates for reserve determination. From purely a practical point of view, at this stage it is therefore sensible to focus only on the riparian type wetlands along the valley bottoms in quaternary catchment B81E. These are candidate sites for determining an Ecological Reserve following an Intermediate approach.

The Thabina wetland in quaternary B81D is certainly a candidate site for determining an Ecological Reserve following a Comprehensive approach given that it occurs in an area where the aquifer is vulnerable to drought and where impacts on the aquifer are high. However, given the possible groundwater component of this system, this would require further refinement of the existing methods.

The wetlands in quaternary catchment B81A are candidate sites for determining an Ecological Reserve following a rapid approach because of the potential influence of further afforestation, irrigation or other development on both base flows and the biodiversity services of these systems. This must include developing Resource Quality Objectives (RQO's) for these systems.

The approach to the inventory of the wetlands should include field verification and sampling, plus a more detailed air photo analysis using stereo pairs and classification and finer resolution mapping in accordance with Kotze *et al.* (2004). Once an inventory is available for these quaternary catchments and once the systems have been classified, the wetlands could be prioritised based on functionality in accordance with Kotze *et al.* (2004) in order to provide a screening of further candidate sites for Reserve Determination. Baseline data should be collected on a stratified sample of the wetlands to inform the prioritization. This type of information is also essential for determining a "reference state" for the various HGM wetland types in these quaternary catchments. Without a basic understanding of these systems, their key drivers, and their dynamics, it will not be possible to define "reference states" or trajectories of change for these systems.

6. HYDROLOGY

6.1 INTRODUCTION

The main objective of the hydrology and related methodology used was to investigate the impacts of ecological flow releases on the Letaba water supply system for the supply of ecological water requirements in the main reach and tributaries of Letaba River, as well as in the Kruger National Park. The impact of various scenarios of ecological releases have been assessed to select an optimised scenario that can meet the ecological requirements while minimising the impacts on other users in an already stressed water system.

The Letaba catchment consists of three tertiary catchments, namely, B81, B82 and B83 (Figure 6.1). Tertiary catchment B81 consists of six quaternary catchments which total a catchment area of 4 952 square kilometres flowing into the Groot Letaba River. Major economic activities take place in this tertiary catchment. Most of the water in the system is generated in this tertiary catchment.

Tertiary catchment B82 drains to the Middle and Klein Letaba rivers, which are the major tributaries of the Letaba River. The total catchment area of B82 tertiary catchment is 5 453 square kilometres.[1]

The lower catchment tertiary catchment B83, comprises a 3 264 square kilometre area.[1] Little economic activity takes place in this tertiary catchment. This tertiary catchment is mainly characterised by natural conservation areas and game ranching, such as the Kruger National Park.

6.2 METHOD

For analysis purposes, the Water Resources Yield Model (WRYM) and the Spatial and Time Series Information Model, SPATSIM (Institute for Water Research, 2003) have been used. The WRYM was set up to model the water resources system in the catchment, in order to convert virgin flows into present day flows and to assess the impact of environmental releases, under various supply scenarios, on the other demands in the system. SPATSIM, using the output from WRYM, was used to generate time series data of the EWR as well as to generate duration and stress response curves required to investigate whether the EWR demands are met.

6.2.1 WRYM model

Comprehensive analysis of the Letaba water resources system was undertaken using the Water Resources Yield model (WRYM). WRYM is a network model that uses a sophisticated network solver to analyse complex water systems. The WRYM model was developed based on the assumption that a flow network can represent a water resources system. In the model, water resources supply and demands are represented using nodes and links. Virgin (natural) monthly flows are the primary input into the model. The model allocates the various losses and demands in the system and generates monthly "present day" flows. The allocation of specific demands in the system is achieved through the allotment of penalties, where the highest penalty demand receives first priority in the allocation of supply.

EWR SITES IN LETABA CATCHMENT

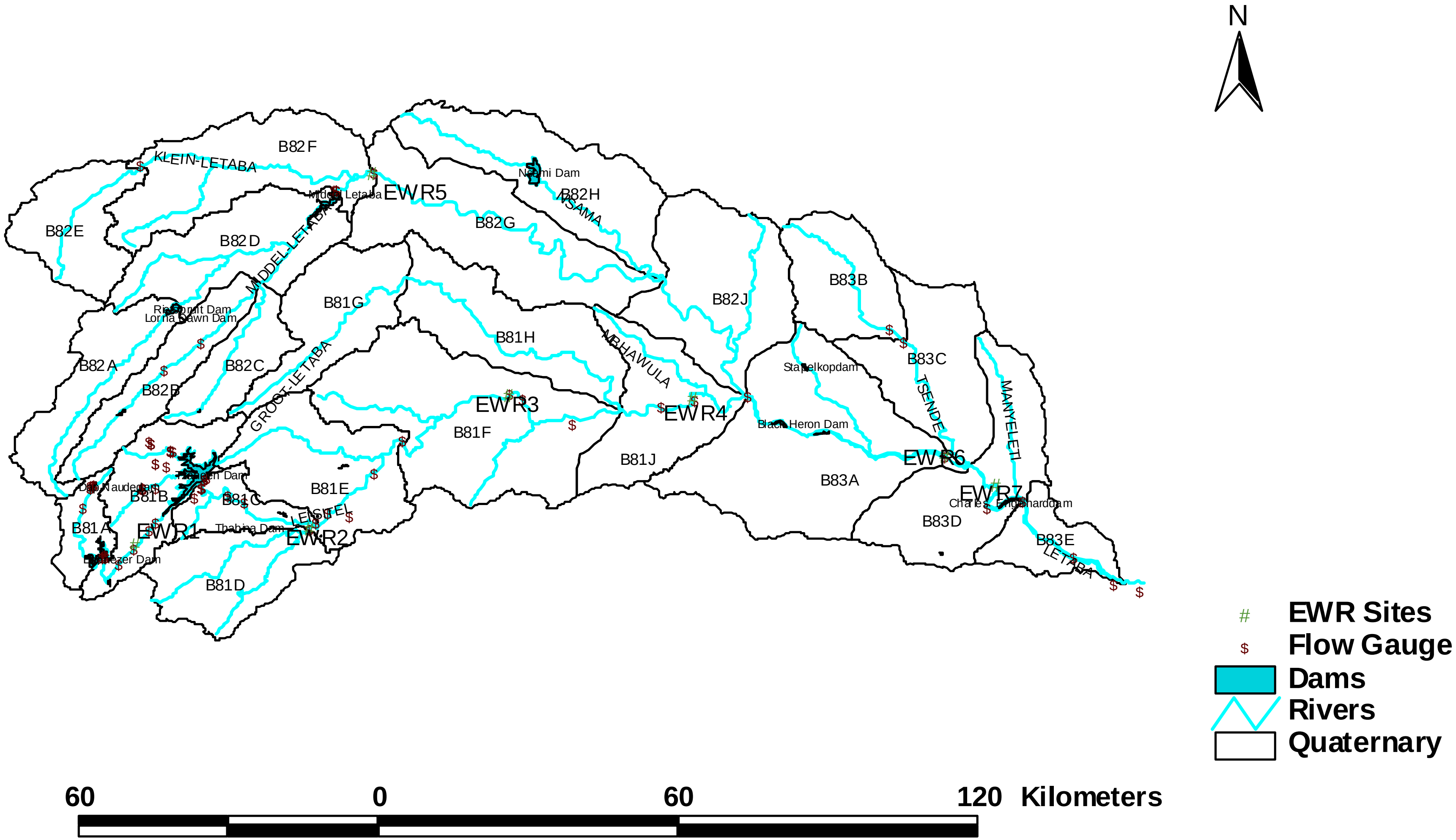

Figure 6.1: The Letaba Catchment showing Quaternary Sub-catchments, locality of flow gauging stations and EWR sites.

The WRYM system configuration for the Groot Letaba, as developed during the Feasibility Study of the Groot Letaba Water Resource Development, was adopted in this analysis with minor revisions, i.e. introducing nodes at each of the EWR sites. The Middle and Klein Letaba model, developed by DWAF in the 1990's, during an internal study on the Middle Letaba and Nsami Dams (unpublished), was appended to the Groot Letaba model. The demands for the Middle Letaba were updated in the combined model from data gathered during a situation assessment study carried out for DWAF in 2003 (DWAF 2006 b). This combined model was then initially used to convert virgin monthly flows into present day monthly flows at each of the EWR sites, taking all demands, other than ecological water requirements, into account.

The time series of the ecological flow requirements, as determined using SPATSIM as described below, were then used to generate a WRYM input file, so that the ecological demands could be simulated as a maximum priority demand in WRYM. The channel downstream of each EWR site, rather than the EWR channel itself, was used to represent each resource unit in the river system. Under a range of supply scenarios, the flow time series, generated with the WRYM model for channels downstream of EWR sites, were imported back into SPATSIM in order to generate flow duration and stress response curves that were used to determine whether the ecological flow requirements in each resource unit were met.

6.2.2 SPATSIM

The spatial and time series information model, SPATSIM has been used to generate the EWR at seven sites in the catchment for various Ecological Categories. SPATSIM is an integrated, GIS based, data management model that has been designed to allow the efficient management, processing and modelling of hydrological data for a range of water resource assessment approaches in South Africa.

Two of the integrated models in SPATSIM, namely, the Desktop Reserve Model and the Stress/Flow and Risk Indicator Model have been used for the determination of the EWR. The Desktop Reserve Model has been calibrated for each quaternary catchment in the country and, based on virgin monthly flow and the Recommended Ecological Category, generates a first order estimate, in terms of monthly flow distributions, of Ecological Reserve at a particular site. These monthly flow distributions can be manipulated and altered to generate time series flow data to suit any particular set of flow requirements.

The Stress/Flow and Risk Indicator model, within SPATSIM, uses the Habitat Flow Stressor Response methodology to determine the stress response of fish and invertebrates to a particular flow time series that has been generated by the Desktop Reserve Model, as described above. This model is used to fit the flow duration requirements to the criteria set by the specialists during the specialist workshop.

6.3 HYDROLOGY

The original terms of reference for the project assumed the use of available hydrology for the catchment and did not allow for any updating of the hydrology for the 23 quaternary catchments making up the Letaba Catchment. Available virgin flow data for the Letaba Catchment was limited to between 1920 and 1996 from the sources as shown in Table 6.1 below. However, in order to test the representivity of this data, a pilot project was initiated on two of the quaternaries, namely, B81D as a humid catchment and B83B as a dry catchment. The purpose of this pilot project was to extend the hydrology, by applying the more recent rainfall data to these two catchments and to assess the potential changes to the hydrology for the catchment as a whole. This was done using the WRSM2000 rainfall-runoff model. The conclusions drawn from the pilot project were:

- For the wetter catchment, there was a small (4%) increase in MAR, but a 20% increase in standard deviation of the MAR. This is attributed to the addition of generally wetter hydrological years of the late 90's, particularly the 1999/2000 year where the annual runoff was 6 times the average; and
- For the dry catchment, there was a significant lowering of the MAR (36%) and a 15% standard deviation in MAR. This is attributed to the difference between the regionalised parameters used to generate the original WR90 series and the detailed calibration done in the pilot project, using flow gauge B8H011. The existing regionalised flows used in this project for B83D are considered to be a fairly poor representation of the hydrology of this catchment. However, the contributions by the dry catchments to flows in the Letaba are only around 7% (Table 6.1)

The virgin flow input for the WRYM was restricted to the common series from 1925 to 1989 for the three tertiary catchments.

Table 6.1: Summarised hydrology of Tertiary catchment in Letaba.

Tertiary Catchment	Available Hydrological data	MAR ($m^3 \times 10^6$)	% of Total MAR	Source
B81	1925-1992	381.0	66.36	Pre-Feasibility Study (SRK/DWAF)
B82	1922-1996	151.9	26.45	Directorate of Hydrology (DWAF) (unpublished)
B83	1920-1989	41.3	7.19	Surface Water Resources of South Africa 1990 [1] (SRK,WLPU, SSI)
Total		**574.1**	**100**	

As shown in the Table 6.1, more than 50% of the runoff in Letaba catchment is generated in the tertiary catchment B81.

6.3.1 Present day Hydrology

Agriculture and domestic use are the major demand sectors in the system. The decline in the present day flow, when compared to the natural flow, is mainly attributed to the large demand of irrigation in the Groot Letaba and Middle and Klein Letaba subcatchments.

At present there is 14.8 million cubic metres released annually to KNP from Tzaneen Dam. Of this, 6.06 million cubic metres are abstracted downstream for domestic use. The remaining 8.74 million cubic metres go to the Kruger National Park. However, the present day flow stipulated does not include this release.

6.3.2 Observed Hydrology

The location of flow gauging stations can be seen in Figure 6.1 (Tables 6.2 and 6.3). In general, the flow gauging station network in the Letaba catchment is poor. Most of the stations are concentrated in the upper catchment.

Observed flow data can be used to undertake flood analysis in order to determine the high flood requirement of riparian ecology and geomorphology. However, in this study, because of the short period and low reliability, the observed data was mainly used to generate daily flow series from the monthly natural and present flows at each EWR site.

Table 6.2: Flow gauging stations closest to EWR sites and stations used for hydrological analysis.

EWR Sites	Closest Gauging Station	Station used to Disaggregate *
EWR1	B8H004	
EWR2	B8H010	B8H010
EWR3	B8H017	BH008
EWR4	B8H008	BH008
EWR5	B8H033	
EWR6	B8H029	BH008
EWR7	B8H018	

Table 6.3: Flow Gauge Stations in the Catchment.

Station	Period		Total Years	Remark
	Start	End		
B8H004	1948	1960	12	Short period
B8H010	1960	2002	42	
B8H017	1977	2002	35	Low flows not reliable
B8H008	1959	2003	44	
B8H033	1996	2000	4	
B8H029	None	None		
B8H018	1984	2002	18	

6.3.3 Conversion of monthly runoff to daily runoff

Daily virgin and present day flows were unavailable and observed daily flows were limited. Daily runoff data was generated, for both natural and present day hydrology, based on monthly time series data and the distribution curves of available daily-observed data.

Each observed daily flow in a month was expressed as percentage of total monthly flow in each year of observed record. These daily percentage values were then sorted in descending order for each of 12 months. These values were then plotted as a distribution curve of percentage of monthly flow versus frequency (percentage of exceedance) for each of the twelve months. These distribution curves were then applied to each of the monthly natural and present day flows at each EWR site to generate the equivalent time series of natural and present day daily data for each site.

6.3.4 Instantaneous flow records

Most of gauging stations, if not all, in the Letaba catchment measure the daily average runoff. The instantaneous peak flow is obscured in the daily average runoff. Instantaneous or peak flows are responsible for shaping the river geomorphology as well as for changing the riparian vegetation. A reduction in frequency and amount of peak flows results in terrestrialization (terrestrial vegetation encroachment). Thus, hydrological analysis on peak flows is important to have a comprehensive understanding of how the riparian ecology can be impacted as a result of water resources development. In the observed daily flow records supplied by DWAF, there is an instantaneous maximum and minimum peak factor provided for each month of observed data. In an attempt to determine daily peaks, these factors were applied to both the observed maximum and minimum daily average, respectively, for the month and then proportioned to each of the remaining intermediate daily averages in the month, to provide daily peak values. Analysis of these values provided frequency of observed peak flows as called for by the specialists.

6.3.5 Levels of confidence in hydrology

The available generated data is more than ten years old and it does not include the latest hydrological events, such as the flood during February 2000. The pilot study, undertaken to investigate the representivity of the available data, indicated that, on average, the hydrology in the wetter catchments has not changed much, in terms of mean annual runoff, but that the variability of the annual runoff has increased. This implies that there is potential for a greater variation in flow conditions from year to year without a marked change in the average flow condition over a long period. On the other hand, confidence in the dry catchments is much lower, as a result of the outcome of the pilot study. However, the contribution of the dry catchments to the hydrology is considerably less. Table 6.4 summaries the level of confidence in the hydrology used for this project.

Table 6.4: Level of Confidence in the Hydrology used.

Tertiary Catchment	Name of River	Available Periods	Origin of Data	Confidence in existing data	Source of Data	MAR as a % of the Total
B81	Groot Letaba	1925-1992	Detailed assessment made in 1994	Medium (data ten years out of date)	Pre-feasibility Study [6] (SRK/DWAF)	**66.3 %**
B82	Middle and Klein Letaba	1922-1995	Intermediate assessment made in late 1990s	Medium to Low	Directorate of Hydrology (Unpublished) (DWAF)	**26.5 %**
B83	Lower Letaba	1920-1989	Regional assessment made in the early 1990s	Low	WR90 (WRC-SRK,WLPU, SSI)	**7.2 %**

6.3.5 Hydrology at EWR sites

Each quaternary catchment was split into relevant sub-catchments in order to apportion natural runoff at the individual EWR sites. Using this virgin flow data, the WRYM was used to generate the present day hydrology at each EWR site. Table 6.5 shows a brief summary of sub-catchments contributing to EWR sites and natural and present mean annual runoff at each EWR sites:

Table 6.5: Summary of EWR Natural and Present Day Hydrology.

EWR Site	Sub-catchment No.	Quaternary Catchment	Virgin MAR (10^6 m^3/a)	Present Day MAR(10^6 m^3/a)
EWR1	A10	B81A	15.4	
	A01A		22.5	
	A01B		11.03	
	B10	B81B	7.8	
	B12		6.54	
	0.828 B14		8.43	
Sub total			**71.7**	**32.63**
EWR2	D10	B81D	38.94	
	D13		5.89	
	D16		13.4	
	D20		7.14	
	D24		7.34	
	D28		11.93	
	D01		1.42	
Subtotal			**86.06**	**63.30**
EWR3		B81A	48.93	
		B81B	151.67	
		B81C	28.48	
		B81D	86.06	
		B81E	34.42	
	F30	B81F	1.99	
	F20		6.06	
	F10		6.49	
Subtotal			**364.1**	**109.41**
EWR4		B81A	48.93	
		B81B	151.67	
		B81C	28.48	
		B81D	86.06	
		B81E	34.42	
		B81F	20.46	
		B81G	21.84	
		B81H	5.97	
	BJ10	B81J	4.03	
Subtotal			**401.86**	**206.70**
EWR5		B82A	19.7	
		B82B	15.2	
		B82C	12.40	
		B82D	13.70	
		B82E	11.0	
		B82F	23.1	
Subtotal			**95.1**	**42.44**
EWR6		B81A	48.93	
		B81B	151.67	
		B81C	28.48	
		B81D	86.06	
		B81E	34.42	
		B81F	20.46	
		B81G	21.84	
		B81H	5.97	

EWR Site	Sub-catchment No.	Quaternary Catchment	Virgin MAR (10^6 m^3/a)	Present Day MAR(10^6 m^3/a)
		B81J	6.43	
EWR 6		B82A	19.7	
		B82B	15.2	
		B82C	12.40	
		B82D	13.70	
		B82E	11.0	
		B82F	23.1	
		B82G	14.1	
		B82H	10.7	
		B82J	13.5	
		B83A	12.8	
Subtotal			**545.7**	**274.45**
EWR7		B81A	48.93	
		B81B	151.67	
		B81C	28.48	
		B81D	86.06	
		B81E	34.42	
		B81F	20.46	
		B81G	21.84	
		B81H	5.97	
		B81J	6.43	
		B82A	19.7	
		B82B	15.2	
		B82C	12.40	
		B82D	13.70	
		B82E	11.0	
		B82F	23.1	
		B82G	14.1	
		B82H	10.7	
		B82J	13.5	
		B83A	12.8	
		B83B	8.6	
		B83C	5.9	
		0. 14 B83D	1.372	
Subtotal			**561.57**	**289.41**

6.3.6 Level of Confidence in Demands

The 1995 demands were used in this study for the Groot Letaba catchment. For the Middle and Klein Letaba sub-catchment, the demand data obtained from the Situation Assessment Study in 2003 was used. No major updating has been recently carried out to verify the reliability of the available data.

There is a discrepancy in various documents, especially of the studies made in the Middle and Klein Letaba. Most of the information is based on rough estimations made in the past. For instance, during pre-feasibility study stage of the water resources development potential assessment, the total irrigable area in the Middle Letaba sub-catchment, upstream of the confluence with the Klein Letaba, is estimated to be 3 600 ha. This area has an annual water demand of 15 million cubic metres coming from surface water and the remaining 15 million cubic metres from ground water. The pre–feasibility study report indicated that the total water allocation from Middle Letaba dam is 28 million cubic metres per annum with the average release of 13 million cubic metres per annum for domestic water usage. A study, undertaken to develop operating rules for the Middle Letaba and Hudson Ntsanwisi Dams in 1994, on the other hand, estimated the irrigation allocation from these dams to be 23.59 and 2.581 million cubic meters respectively. The report also indicated that the theoretical domestic demand from these two dams was 2.85 and 3.83 million cubic metres, respectively. The actual water supply from Nsami treatment plant is indicated to be almost equal to the full capacity of the plant, which is 10.72 million m^3/annum. DWAF (2003) indicated the total allocation to be only 21.8 million cubic metres, of which 10.5 Million cubic metres are released to Nsami Dam. This report further indicated that the firm yield of the dam is about 22 million cubic metres. But there is no clear indication in the report with regard to the proportion of the irrigation and domestic allocation in the sub-catchment. In order to improve the level of confidence in the demand data, further refining and verification of the available information would be required, especially in Middle and Klein Letaba catchment.

6.4 SUMMARY

The Letaba water system is under stress. Ecological releases will impose further additional stress into the system. The relative impact of EWR releases depends on the amount, frequency and seasonal distribution of releases. Curtailing ecological releases (as reflected by some of the Operational scenarios), during the dry period, significantly improves the water supply capacity of the system without severely compromising the ecological stability.

6.5 RECOMMENDATIONS

It is recommended that the hydrology of the Groot Letaba be updated from 1992 to present.

The main consequences of extending the hydrology throughout the Letaba catchment would be to improve:

- The confidence in all flows in tertiary catchments B82 and B83;
- The confidence in the high flows in tertiary catchment B81;
- Present day flow generation from the yield model; and
- Scenario planning using the planning model with improved stochastic hydrology

The bulk of the runoff from the Letaba Catchment is generated from the Groot Letaba tertiary catchment B81. This study has indicated that the available hydrology from this catchment is reasonably reliable, but that the variability of high flows has increased.

7. DELINEATION

7.1 INTRODUCTION

This chapter concerns the second step in the generic eight-step EWR process, which is to delineate the study area into Resource Units (RUs), and to select EWR sites. River ecosystems are spatially diverse, so the EWR may differ from place to place, depending on various factors such as the structure of the riverbed, the natural water quality, topography, groundwater contributions and system operation etc.

In order to undertake a catchment Ecological Reserve determination it is necessary to break down the catchment into RUs which are each significantly different to warrant their own specification of the Reserve, and to clearly delineate the geographic boundaries of each of the RUs. It is not appropriate to set the same numerical Reserve for the headwaters of a river as for the lowland reaches as these sections of a river frequently have different natural flow patterns, react differently to stress according to their sensitivity, and require individual specifications of the Reserve appropriate for that reach.

7.2 METHODS

The delineation of the study area into RUs was based on standard methods developed for EWR assessment in South Africa.

The apportionment of a catchment into RUs for the purpose of determining the Reserve for rivers is done primarily on a biophysical basis, according to the occurrence of different ecological regions (ecoregions) within the catchment. Since the endpoint of a Reserve determination is an ecological one, the principle is to break down the catchment into units that are relatively homogenous on an ecological basis, to ensure the Reserve is set in appropriate terms.

The determination of RU's *via* ecoregions and/or geohydrological response units could then be further resolved into smaller Resource Units that are more suited to management requirements. In the Letaba catchment, this could be as a result of a weir that is used for irrigation or the Tzaneen or Ebenezer Dam. The different operational procedures of river reaches also result in biophysically different river reaches that also need to be considered in determining the RUs.

The RU determination process considers the above issues, as well as the results of the Habitat Assessment Integrity (an evaluation of river sectors according to instream and riparian Habitat Integrity). The result of overlaying all this data does not necessarily result in a logical and clear delineation and expert judgement, a consultative process, local knowledge and financial considerations are required for the final delineation.

The EWRs are determined for each Resource Unit by means of either the following:

- An EWR site is selected within the RUs and represents a critical site within the relevant river section. Results generated for the RU at the EWR site will then be relevant for the RU as a whole; and
- If no EWR site is selected within the RU then extrapolated results from adjacent Resource Units with EWR sites are used.

The EWRs are set for each of the EWR sites, and it is therefore vital that the:

- Sites are selected to provide as much information as possible about the variety of conditions in a river reach so that the specialists relate to the habitat the EWR site represents; and
- Persons involved in selecting the sites understand and are experienced with the use of sites in EWR studies.

The following was considered when selecting the EWR sites:

- Assessment of the 1994 IFR report for the Letaba River;
- Availability of previous site survey data from 1994 IFR study;
- The locality of gauging weirs with good quality hydrological data;
- The locality of the proposed developments, land use and of dams;
- The locality and characteristics of major tributaries;
- The Habitat Integrity Assessment of the different river reaches (using aerial videos available for the tributaries and main river);
- The accessibility of the sites for follow-up monitoring;
- The available habitat diversity for fish, macroinvertebrates, marginal and riparian vegetation;
- The suitability of the sites for accurate hydraulic modeling throughout the range of possible flows, especially low flows;
- The locality of geomorphological reaches and representative reaches within the geomorphological reaches;
- Discussions with local experts on potential sites per sub-catchment; and
- Viewing of available videos to pre-select potential EWR sites

7.3 RESULTS

The Letaba catchment was broadly delineated into nine RU's (Figure 7.1). Due to the importance of certain tributaries in terms of annual flow, not all of these RU's could be catered for in this study. Consequently the seven EWR site (Figure 7.1 Table 7.1) where carefully chosen to maximize the opportunities for accurately determining a comprehensive Reserve for the Letaba River.

Table 7.1: Localities of EWR sites on the Letaba River.

River and site name	RU	EWR site number	Locality
Groot Letaba - Appel	A	EWR1	S23 55 03.7; E30 03 03.0
Letsitele	F	EWR 2	S23 53 17.0; E30 21 40.5
Klein Letaba	B	EWR 5	S23 15 02.9; E30 29 44.6
Groot Letaba - Hans Marensky	C	EWR 3	S23 38 57.8; E30 39 38.3
Groot Letaba - Letaba Ranch	E	EWR 4	S23 40 39.1; E31 05 55.1
Groot Letaba – Lonely Bull	D	EWR 6	S23 45 09.5; E31 24 26.3
Groot Letaba - Letaba Bridge	D	EWR 7	S23 48 35.4; E31 35 26.9

The Molototsi River, due to its highly seasonal nature and the lack of adequate monitoring data, was not chosen as an EWR site. The influence of this river on the Groot Letaba is seen at EWR 4. No EWR site was chosen for the Middle Letaba River. EWR 5 (Klein Letaba) was, however, selected to be directly downstream of the confluence of Middle and Klein Letaba

Rivers. No EWR site was selected in the Nsami River dues to its contribution to the MAR of the Letaba River being small in comparison to the other tributaries.

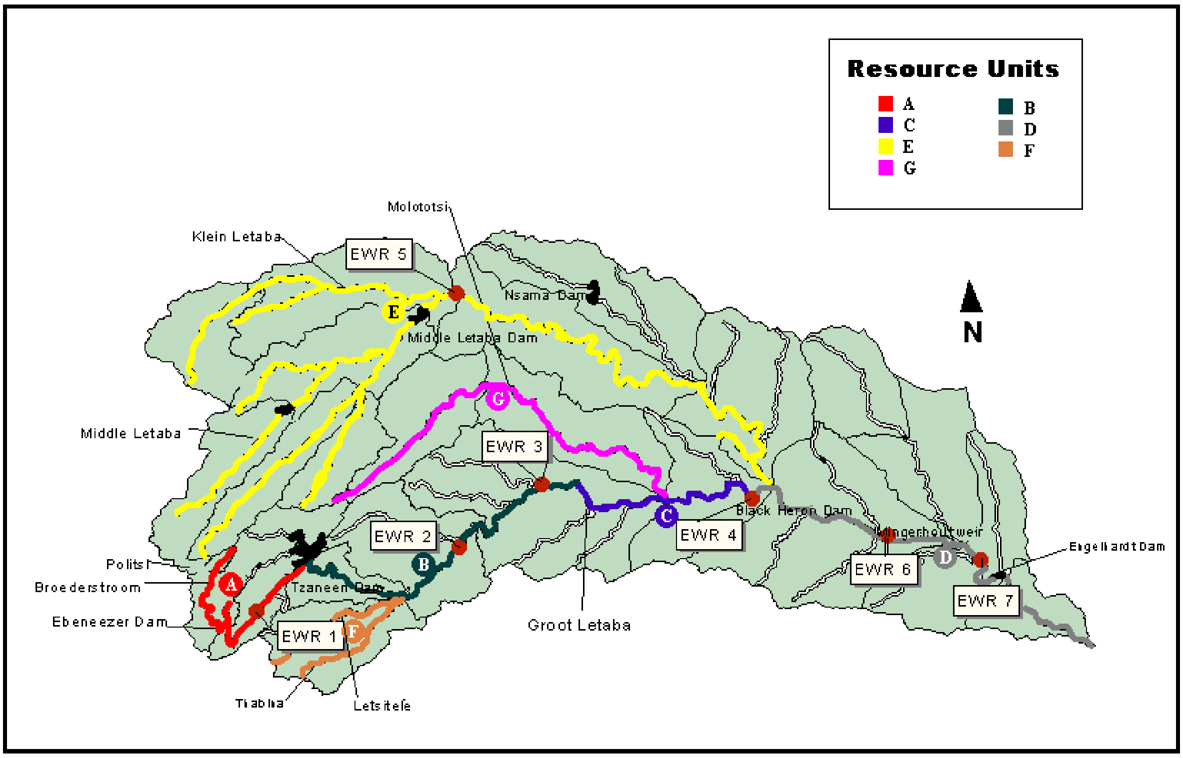

Figure 7.1: Main resource units and chosen EWR sites in the Letaba Catchment.

The 3D spatial habitat modelling was undertaken at EWR Site 7.

7.4 CONCLUSIONS

EWR 7 site is important due to future Mozambique flow releases as well as to ensure that the flows at this site meet the ecological requirements of the fauna and flora within the Kruger National Park so that this national park can honor its mandate of protecting biodiversity.

8. WATER QUALITY

8.1 BACKGROUND

Land use in the Letaba catchment consists largely of nature conservation in the form of national, provincial and private nature reserves and forest reserves. The primary land use along the rivers is citrus and sub-tropical fruit production, with grazing in the less fertile sandy loam soils. Removal of the vegetative cover by overgrazing has led to erosion in some places, resulting in an increased sediment load in the rivers. The main industrial development points are at Tzaneen, Nkowakowa and Giyani, with a number of sewage works spread throughout the catchment. Several old gold mines exist, which lie close to the Klein Letaba River towards the northern part of the study area. An overview of the catchment therefore indicates that water quality issues are mainly related to nutrient enrichment, and fluctuating instream temperature and oxygen levels due to extensive flow regulation in the catchment. In addition to being highly regulated, conditions in the Groot Letaba River (particularly downstream from Die Eiland) are impacted by citrus plantations in the area, resulting in elevated nutrient levels and instream toxicity.

8.2 METHODS AND INFORMATION USED

The water quality assessment was conducted using best available methods, as outlined in Palmer et al. (2004). These are the updated methods of September 2003 (based on the DWAF methods manual of 2002) for the water quality Reserve and available on the web site, http://projects.shands.co.za/Hydro/hydro/WQReserve/main.htm. Water quality consequences of operational flow scenarios were assessed using flow-concentration modelling as a tool for assessing impacts, as well as the physico-chemical (PAI) approach for assessing water quality state as outlined in the EcoClassification manual of Kleynhans *et al.*, (2005). The confidence in the classifications was verified using the power statistic, G-Power.

The following information was used to conduct the present state:

- Literature regarding water quality conditions in the catchment, and a field survey undertaken in December 2003 to verify the delineation of Water Quality Sub-Units (WQSUs);
- Water quality data from selected DWAF monitoring points in the catchment, as well as spot samples taken during the December field survey. Samples were analysed at Resource Quality Services (RQS), DWAF;
- Biotic integrity data (macroinvertebrates) were sourced from the relevant specialist of the Letaba Reserve study for the EWR sites (intensive invertebrate monitoring conducted); other data was accessed from SASS (i.e. rapid monitoring using the South African Scoring System version 5.0) surveys conducted of the Letaba catchment for the River Health Programme;
- Fish categories were included for the EWR sites from the relevant specialists of the Letaba Reserve study as an indicator of biotic response;
- Chlorophyll-*a* analyses were undertaken at selected points in the catchment as an indicator of algal abundance, during the field survey of December 2003. Samples were analysed for periphyton at the Coastal Research Group, Rhodes University. Phytoplankton data were not available;
- A spot samples were taken for in-stream toxicity testing from two points in the catchment in March 2004, as a preliminary indication of toxicity related to pesticide / herbicide use on citrus plantations. The following acute screening toxicity tests were

conducted at Rand Water: *Daphnia pulex*, the guppy *Poecilia reticulata* and an algal inhibition test;

- The following version of the salt model of Jooste (RQS, DWAF) was used to generate PES categories for inorganic salts: SALTBA21 (Note that the model provides categories, but not values);
- Available data were screened for toxics, e.g. metals. Toxics are listed and assessed where data were available;
- As a method does not exist for assessing the present state of turbidity, results were compared to the domestic use Target Water Quality Range (TWQR), as aquatic ecosystem guidelines do not exist; and
- As a document outlining dam operations was not available, information was obtained from the DWAF Polokwane Regional office.

8.3 WATER QUALITY PES

The water quality variables used for the present state assessment are shown in Table 8.1, together with an indication of data confidence and availability per variable for the present state, availability of Reference Condition (RC) data, and overall confidence in the assessment. The confidences for nutrients and pH are based on G-Power estimates.

Table 8.2 shows the results of the PES assessment. Note that the methods manual (methods outlined in Palmer *et al.*, 2004) was used for the assessment (column 1 of Table 8.2). The physico-chemical approach for assessing water quality state, as outlined in the EcoClassification manual of Kleynhans *et al*, (2005), was used when evaluating the water quality consequences of different flow scenarios – the results of this assessment is shown in column 2 of Table 8.2. The recommended water quality category per EWR site is shown in column 3 of Table 8.2, and uses best judgement to combine the output of columns 1 and 2.

Confidence in the present state assessments are generally medium to high, except for the Klein Letaba and Molototsi rivers, where minimal data were available.

The water quality present state assessment showed that the Letaba River system is generally in a fair to good water quality condition (categories B-C), with a hot spot occurring at EWR 2, i.e. Letsitele Tank. Current status is shown in the table below, as well as the water quality category used to design quality ecospecs (third column of Table 8.2).

8.4 RECOMMENDATIONS

These recommendations do not relate to the Letaba per se, but to the identification of method developments required through application during the Letaba and other Reserve Studies. The assessment of water quality was conducted carrying out methods updated from the DWAF methods manual of 2002, as well as the EcoClassification approach as outlined in Kleynhans *et al.*, (2005). Although the methods should be used together, i.e. the PES assessment using DWAF methods is used to populate the ratings tables in the EcoClassification manual, there are no instructions in either manual as to how this procedure should take place. The EcoClassification approach will also be using a model developed by Jooste of RQS, DWAF. A water quality manual should therefore be developed which includes instructions on how all these tools must be used to conduct a water quality assessment in an EWR study.

Further development is also required around the integration of water quality and quantity. Although flow-concentration modelling was used for this study, it was of little value as few constituents could be modelled.

Table 8.1: Confidence in the water quality PES assessment shown per Water Quality Sub-Unit.

Variable / Indicator	Water Quality Sub-Unit										
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8 + 9**	**10 + 11**	**12 + 13**	**14**	**15**
Inorganic salts (full suite of data used)	H	H	H	H	H	H	H	H	M	H	L	L
Nutrients	L	L	L	L	L	L	L	M	L	L	L	L
pH	H	H	H	H	H	H	H	L	H	H	L	L
Dissolved oxygen + temperature	X	X	X	X	X	X	X	X	X	X	X	X
Turbidity	X	v	v	v	v	v	v	v	v	v	v	v
Chl-a (periphyton)	X	v	v	v	v	X	v	v	X	X	v	X
Macroinvertebrates	v	v	v	v	v	v	v	v	X	v	v	v
Fish	X	v	X	v	X	v	v	v	X	v	X	X
In-stream toxicity	X	X	X	v	X	X	X	X	X	X	X	X
Toxics	Only fluoride information available, so low confidence.											
RC data	X	v	v	v	X	v	v	v	X	X	X	X
PES data	M	M-H	L	H	H	M	H	H	M	M	L	L
Overall confidence in the assessment	M	H	L	H	M	M	H	M-H	L	L	VL	VL

H: high confidence M: medium confidence L: low confidence
VL: very low confidence v: data available X: no data available

Table 8.2: Results of the water quality present state assessment shown per WQSU and EWR site.

Water Quality Sub-Unit and EWR site	PES: water quality - using methods manual	PES: water quality - using the EcoClassification approach	Recommended water quality category of the overall REC (quality ecospecs)
Groot Letaba River			
WQSU 1	A/B		
WQSU 2: EWR 1	B	B	B
WQSU 3	B/C		
WQSU 4: EWR 3	C	C	C
WQSU 5	B		
WQSU 6: EWR 4	B/C	C	C
Letaba River			
WQSU 7: EWR 6 + 7 *	B	C	EWR 6: B/C EWR 7: B
Letsitele River			
WQSU 8 + 9: EWR 2	C/D	C	C
Middle Letaba River			
WQSU 10 + 11	B – B/C		
Klein Letaba River			
WQSU 13: EWR 5	B/C – C	B – B/C	B/C **
WQSU 14	B		
Molototsi River			
WQSU 15	B/C		

*:Note that as EWR 6 and 7 are located in the same WQSU, a single water quality PES assessment was provided. However, a recommended water quality category had to provided per EWR site, as shown in the third column.

**The REC of B/C for EWR 5 therefore combines the results of the two assessment methods.

9. ECOCLASSIFICATION

9.1 OVERVIEW AND OBJECTIVES

EcoClassification (the term used for Ecological Classification) refers to the determination and categorisation of the Present Ecological State (PES; health or integrity) of various biophysical attributes of rivers compared to the natural/close to natural, reference condition (Kleynhans *et al.*, 2005). The purpose of EcoClassification is to gain insights into the causes and sources of the deviation of the PES of biophysical attributes from the reference condition. This provides the information needed to derive desirable but attainable future ecological objectives for the river. The EcoClassification process also supports a scenario-based approach where a range of ecological endpoints (Ecological Categories) has to be considered. For each of these, a flow (EWR) scenario must be described.

EcoClassification must not be confused with the Classification System as indicated in the National Water Act (Act 36 of 1998). The Classification System considers a range of different issues in Integrated Water Resources Management in the process of determining the class of a river, one of which is ecological.

9.2 LEVEL OF DETAIL

A comprehensive level of EcoClassification assessment was followed which included the determination of the PES at the Level 4, the most comprehensive level (Kleynhans *et al.*, 2005).

9.3 METHOD

The following process was applied to each Resource Unit:

- ***Reference Conditions:*** Reference conditions were described for the main ecological drivers (hydrology, geomorphology and water quality) and ecological responses (riparian vegetation, aquatic invertebrate and fish);
- ***Present Ecological State***: The Present Ecological States (PES) for each of the drivers and the responses were assessed, and the results integrated into an overall assessment of PES, referred to as the present EcoStatus;
- ***Changes in PES****:* An assessment was made as to whether the PES is stable under current development conditions, or whether it is changing.;
- ***Causes and Origins*****.** The causes and origins for the PES were identified, and specified as flow or non-flow related;
- ***Ecological Importance and Sensitivity:*** The Ecological Importance and Sensitivity (EIS) of the biota and habitats were assessed;
- ***Socio-cultural Importance***: The dependence of communities on a health river system for various purposes such as subsistence fishing, collecting firewood, thatching grass, religious activities etc, was assessed, and referred to as the Socio-cultural Importance (SI);
- ***Recommended Ecological Category (REC):*** A realistic Ecological Category was recommended for each component as well as for the overall EcoStatus, based on a consideration of the PES, EIS and SI; and

- ***Alternative Categories:*** Alternative categories, "up" and "down", were identified, where appropriate.

The results of the EcoClassification process, i.e. the PES and EC are provided as different river categories ranging from A (near natural) to F (critically modified) (Figure 9.1). The flow diagram adapted from DWAF (2001) illustrates the process (Figure 9.2).

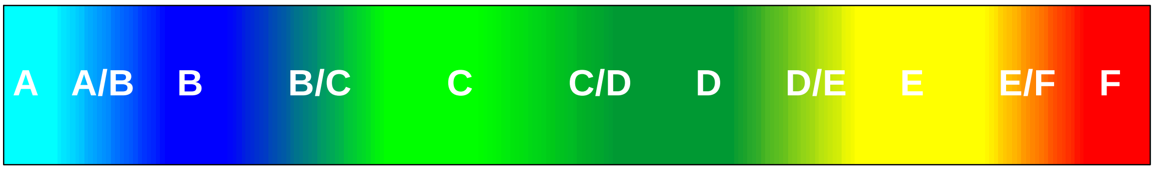

Figure 9.1: Illustration of the distribution of Ecological Categories (A to F) on a continuum

The range of Ecological Categories (ECs) for which flow scenarios were provided are guided by the rules as shown in Table 9.1.This must be seen as guidelines to determine a *realistic* range of ECs, which can be addressed within the scenario-approach.

Table 9.1: Guidelines for the range of Ecological Categories (ECs) to be addressed.

PES	Alternative EC	
	Increase (Up)	Decrease (Down)
A	N/A	N/A
A/B	N/A	B/C
B	N/A	C
B/C	B	C/D
C	B	D
C/D	B/C	D
D	C	N/A
D/E	D	N/A
E	D	N/A
E/F	D	N/A
F	D	N/A

9.4 RESULTS OF THE ECOLOGICAL CLASSIFICATION PROCESS

The Recommended ECs (from an ecological perspective) are provided spatially on maps (Figures 9.3 – 9.5) and tabulated (Table 9.2). A descriptive summary for the Letaba catchment follows.

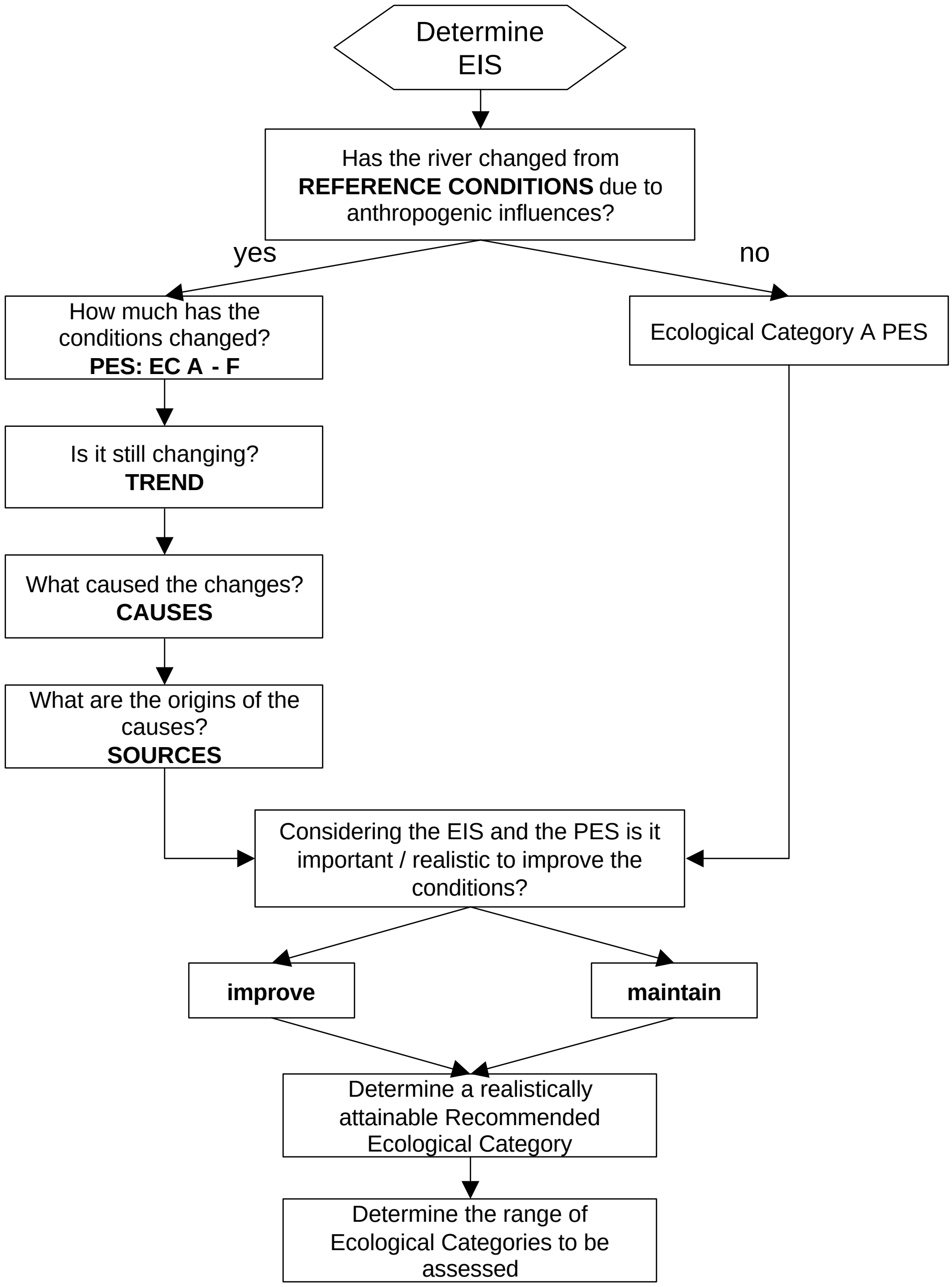

Figure 9.2: Flow diagram illustrating the information generated to determine the range of ECs for which EWRs will be determined.

9.4.1 Groot Letaba River

Ecologically, the upper catchment (above Ebeneezer Dam) of the Groot Letaba River is considered closest to natural and has a very high ecological importance. The relatively natural condition is due to limited disturbance (some areas of indigenous forests, especially in inaccessible gorges).

The most ecologically modified sections in the Groot Letaba River are those between Tzaneen Dam and the border with the KNP. This is due to the reduction in flow due to upstream impoundments (Tzaneen and Ebeneezer Dams), large weirs (Junction, Yamorna, Prieska and Jasi) as well as direct abstraction for irrigation. The water quality problems are associated with intensive irrigated agriculture (fertilizer, salts and pesticide runoff).

Table 9.2: Summary of the Present Ecological Status (PES), Ecological Importance and Sensitivity (EIS) and Socio-cultural Importance (SI) of each Site in the Letaba River Catchment, the Recommended Ecological Category (REC) suggested by the specialists and used to determine the EWR, and the most likely alternative ECs, where applicable.

Site	PES	Importance		Ecological Category		
		EIS	SI	REC	Alternatives	
1	C	Mod	Low	C	N/A	D
2	D	Mod	Low	D	N/A	N/A
3	C/D	High	Mod	C/D	C	D
4	C/D	High	High	C/D	N/A	D
5	C	Mod	Mod	C	D	N/A
6	C	High	Low	C	D	B
7	C	High	Low	C	D	B

The downstream section of the Groot Letaba River within the KNP has a PES and REC of a C (Figure 9.3).

Although the EIS was high in the KNP, the REC was not recommended to improve the PES (Figures 9.3 and 9.4). Cognisance was taken on the attainability of increasing the PES. Due to the existing high use and demand in the system, it would be unlikely sufficient water would be available to allow improvement. Some of the problems are also catchment related and not flow and improvement using only flow is not practical.

The KNP has indicated that, due to its mandate being the improvement of biodiversity, they recommend improvement of the REC to a B. Currently this would be difficult due to the upstream water usage for agriculture. In order to achieve a B the water quality would have to improve and this could only be attained by more regular, and greater, flow releases into the KNP.

A social survey concluded that rural communities, living adjacent to the main rivers in the middle reaches of the Letaba Catchment, particularly in the vicinity of Letaba Ranch (Site EWR 4) are highly depend on the rivers for drinking water, washing, harvesting of natural resources (particularly firewood, thatching and medicinal plants), ceremonial and cultural purposes (See Figure 9.5).

9.4.2 Klein Letaba River

The Klein Letaba (EWR 5) is in a moderately modified to modified state mostly due to dense settlements and agriculture above the Middle Letaba Dam and upper Klein Letaba River. The EIS is moderate and no improvements in categories are required (Figure 9.4).

9.4.3 Letsitele River

The Letsitele River (EWR 2) is highly modified to a PES of D (Figure 9.3). The Letsitele River, a tributary of the Letaba River is unregulated, although there is a small dam on the Thabina tributary. The river channel at this site is degraded due to erosion and local sources of water quality pollution. The main impacts on water quantity and water quality at this site are upstream stream flow reduction (forestry) and a township, with no formal sanitation system, immediately upstream.

The EIS is moderate and the SI is low and hence no improvements in PES categories are required (Figures 9.4 and 9.5).

9.5 CONCLUSION

The REC was set to maintain the PES for all Resource Units.

However KNP officials have indicated that they have a mandate to improve biodiversity and have requested an improved PES within the KNP (PES of C to REC of B). With the currently upstream water usage, mainly for agriculture, and the difficulties in improving catchment (sediment) issues it would be problematic to improve the PES.

The reasons for no improvement in the PES was due to the following realities in the catchment, such as:

- **Dams:** the strategic demands and requirements of the Ebeneezer and Tzaneen dams in the upper catchment, to supply domestic water to both Tzaneen and Polokwane, provide limited scope for improved flows;
- **Flow changes**: the ecological conditions downstream of large dams have changed irreversibly from historical reference conditions and it was considered untenable to recommend an improvement in current conditions; and
- **Weirs:** the ecology of the lower middle Groot Letaba River has been severely impacted by a large number of weirs and associated irrigation development. These have had major impacts on habitat availability, low flow conditions, riparian vegetation and channel morphology; and
- **Non-flow related impacts:** many of the reasons for ecological degradation in the Letaba River catchment are not flow related. For example, the subsistence agricultural land use practises and riparian vegetation removal in the river reach between Hans Marensky and Letaba Ranch Wilderness Areas is a continued source of sediment to the river.

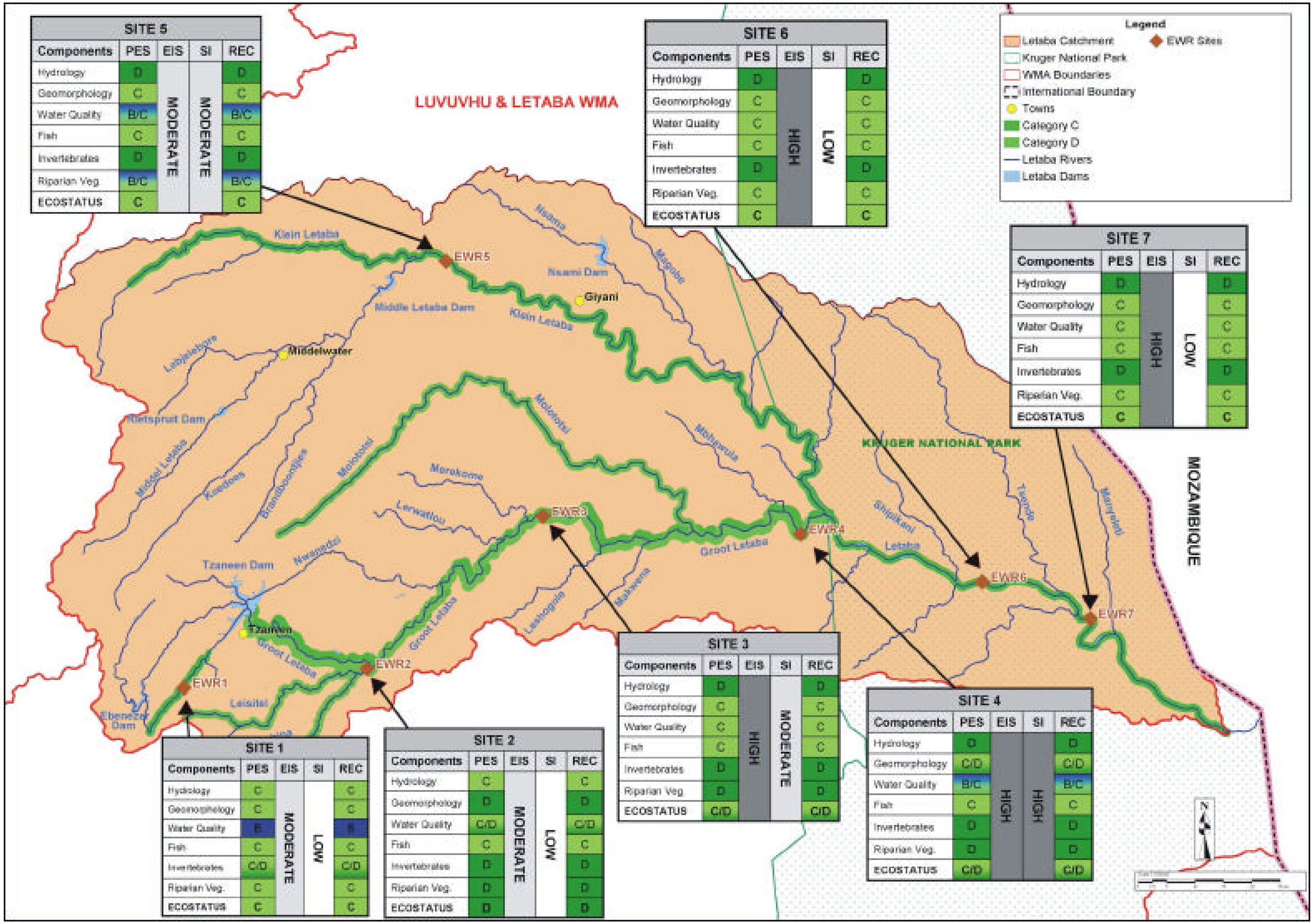

Figure 9.3: Present Ecological Status (PES), Ecological importance and sensitivity (EIS), Social importance (SI) and Recommended ecological category (REC) for the Letaba River catchment.

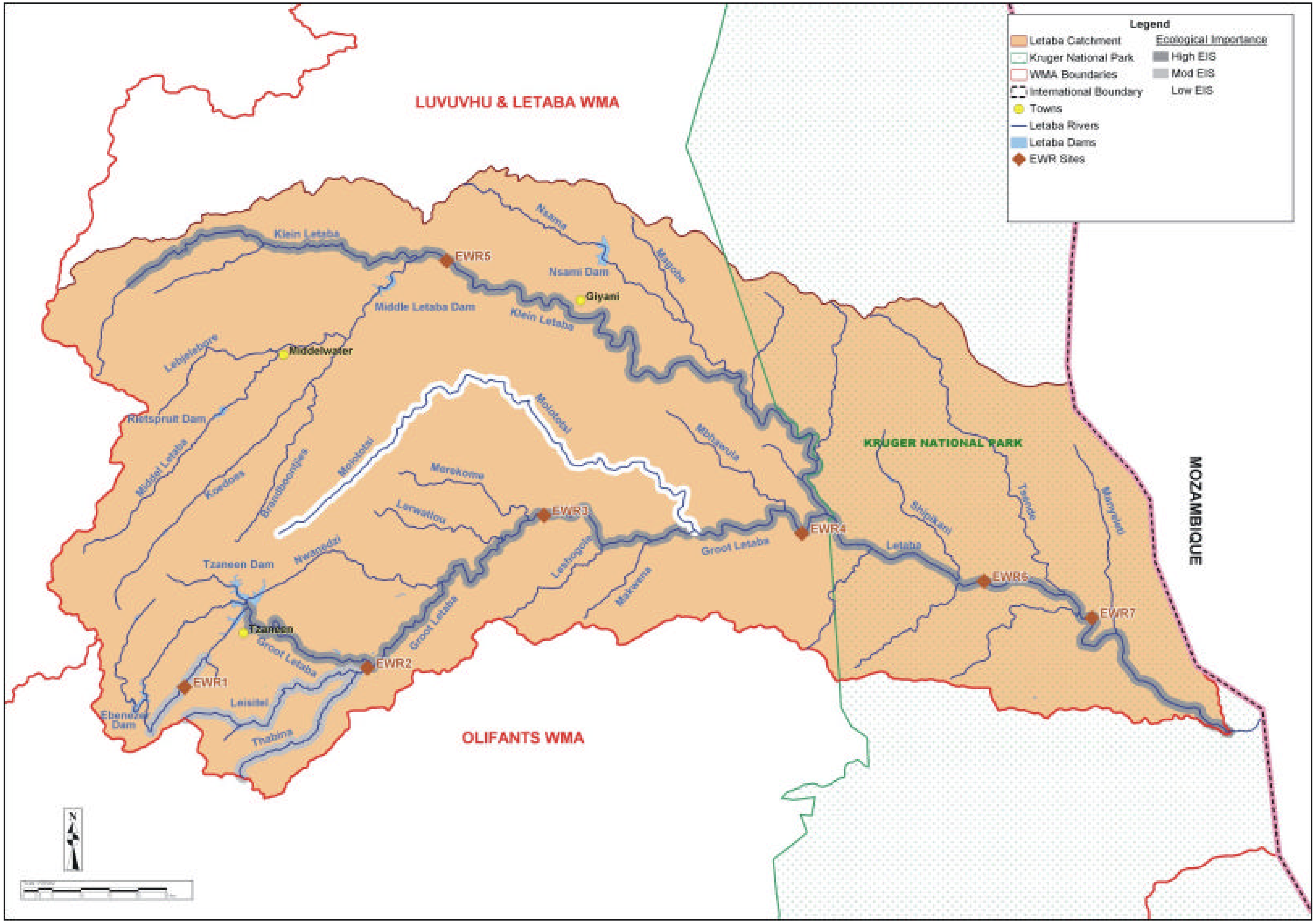

Figure 9.4: Ecological importance and sensitivity (EIS) for the different EWR sites for the Letaba River catchment.

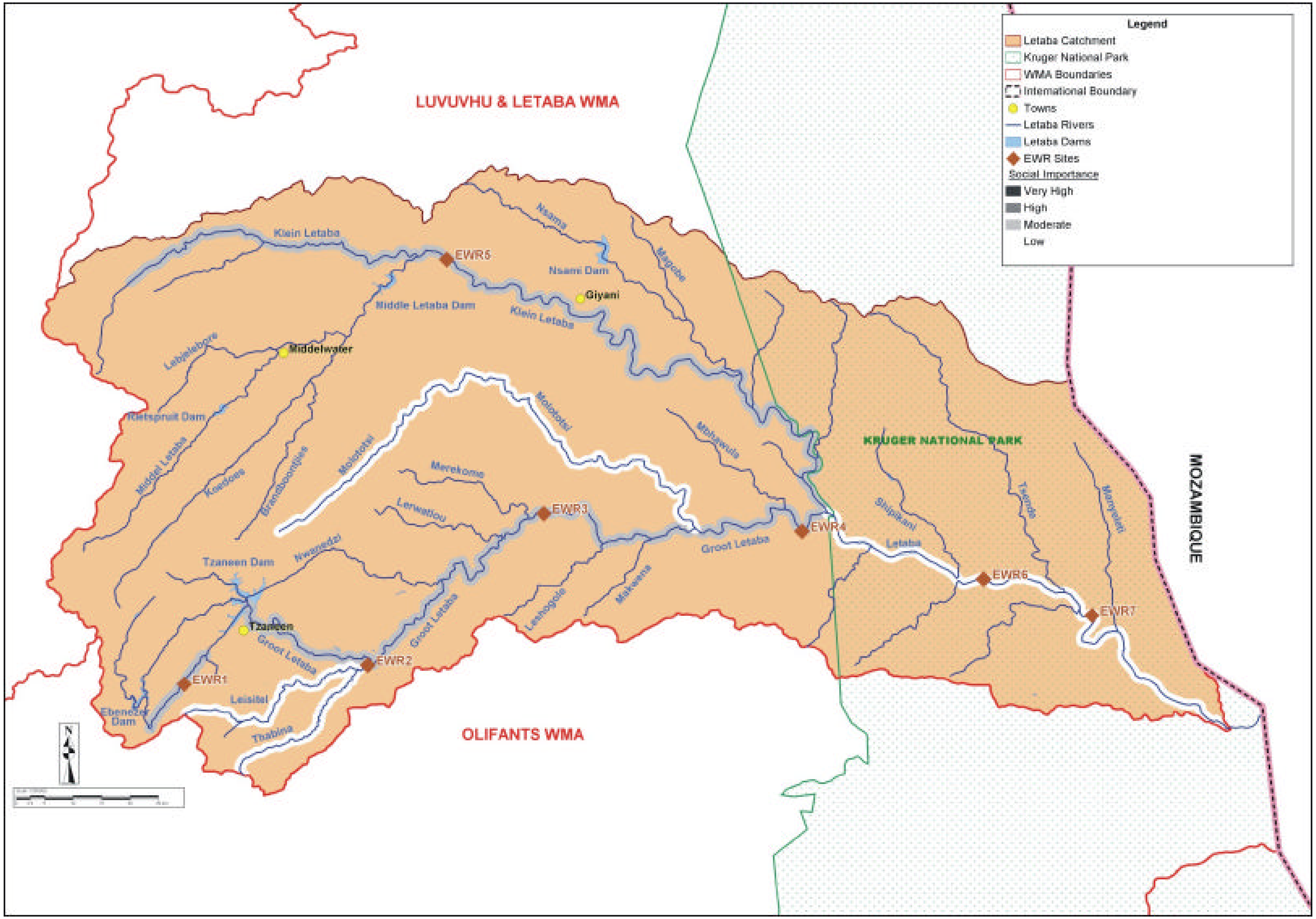

Figure 9.5: Social importance (SI) for the different EWR sites for the Letaba River catchment.

10. ECOLOGICAL WATER REQUIREMENTS

10.1 OVERVIEW AND OBJECTIVES

The objectives of this task were to recommend the magnitude, duration and timing of specific flows and flow patterns that are considered to be the most important for maintaining the abiotic (e.g. geomorphology) and biotic components (plants and animals) of each Resource Unit in a particular condition, or Ecological Category (EC).

Data analysis focussed on the relationships between discharge and habitat availability and key ecosystem processes. This process did not consider whether these flows could be supplied or managed, and impacts on users were not considered.

10.2 METHODS

The approach followed to provide the results was a combination of published South-African environmental flow requirement methods. The Habitat-Flow-Stress-Response Method (HFS-R) (IWR Source to Sea 2004) was used to provide low flow requirements, while a combination of the Building Block Method (BBM) (King and Louw 1998) and the Downstream Response to Imposed Flow Transformation (DRIFT) (Brown and King 2002) method was followed to set high flow requirements. The methods focus on identifying the size, duration and timing of specific flows and flow patterns that are considered to be the most important for maintaining the key ecological drivers (hydrology, geomorphology and water quality) and the key biological response indicators (riparian vegetation, aquatic invertebrates and fish), within an Ecological Category (EC).

The processes and the motivations for the results are provided in detail in the technical reports. These flow results were used as input to the Water Resource Yield Model (WRYM). Consequences of providing flow scenarios can then be tested based on the outputs of the WRYM.

10.3 RESULTS

The results for each EWR site are provided in Figures 10.1. Results are provided as the long-term mean percentages of the natural MAR (nMAR). The EWR flows constituted between 5.9 and 42.8 % of the nMAR. These values represent the initial flow demands used in yield models.

Table 10.1: Summary Instream Flow Requirements for EWR sites in the Letaba River expressed as a percentage of the natural Mean Annual Runoff (MAR) for the recommended Ecological Categories (ECs).

Site	REC	Maintenance low flows(%)	Drought low flows (%)	High flows (%)	Long term mean of MAR (%)
EWR 1	C	10.47	15.76	15.76	27.56
EWR 2	D	32.06	4.32	11.11	38.78
EWR 3	C/D	1.29	0.23	11.78	14.15
EWR 4	C/D	2.82	0.44	15.84	20.76
EWR 5	C	8.48	0.30	24.27	24.27
EWR 6	C	2.17	0.93	7.86	10.74
EWR 7	C	3.23	0.09	7.65	11.26

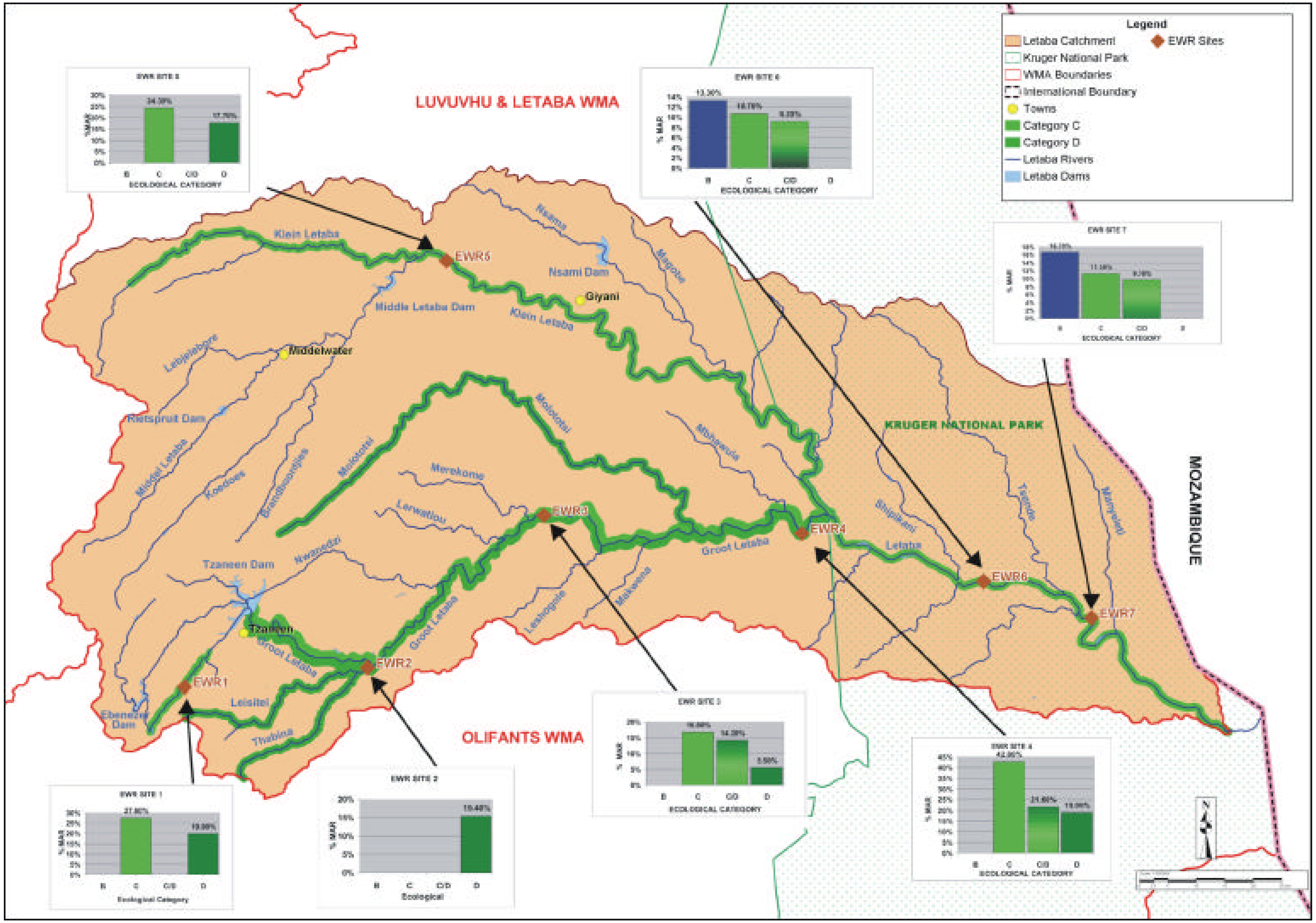

Figure 10.1: Ecological Water Requirements (EWR) for the Letaba Catchment, expressed as a long-term average percentage of the natural Mean Annual Runoff (nMAR).

11. OPERATIONAL SCENARIOS

11.1 OVERVIEW AND OBJECTIVE

Ecological Water Requirement (quantity) scenarios had now been developed by ecologists as sets of possible flows to achieve different river states (or Ecological Categories) for each EWR site. This process did not consider whether these flows could be supplied or managed. The impact on users was also not considered. To provide decision makers with more comprehensive information, it was considered necessary to examine each of the scenarios and their full range of implications. Thereafter, a process was followed to devise an optimised scenario (if necessary) that would have the least overall impact on the users and the ecology. All these Operational Scenarios were tested to determine the resulting state of the river, and the water quality consequences of each flow scenario were supplied.

The objectives of this task were to develop a range of operational scenarios that result in different impacts on different users. The impacts of each flow scenario on the ecology, system yield, goods and services and overall economic activities could then be assessed.

11.2 METHOD

Consultburo initially set up the Water Resources Yield Model (WRYM) for the feasibility study of water resource management of the Groot Letaba in 1996. The basic operating policies were retained. The model was updated to take into account more recent data and understanding of the catchment operations. Furthermore the model was modified to include EWR channels at the appropriate places and additional channels to facilitate analysis of supply to users. Analyses were done using the historic inflow time series from 1922 to 1995 to determine supply to users for each scenario

A series of meetings with regional water managers from Tzaneen were held to develop appropriate operational scenarios. The WRYM was set up in such a way that the first mechanism of curtailment was a rule curve based on the level of the dams, and EWRs were treated as a priority demand. The EWRs were first met by incremental tributary accruals and releases were made from the dams only when these accruals could not supply the EWR. In regulated Resource Units, the high flow component of EWRs was modified to account for the limited outlet capacities of upstream dams. High flow EWR requirements that could not be met because of outlet constraints were removed completely as a demand, and not capped at the maximum outlet capacity.

The decision-making process to determine a range of scenarios is as follows:

- The Water Resources Yield Model (WRYM) was run using three different EWR scenarios: one that would achieve an EC higher than recommended (Scenario 1), one that would achieve the recommended EC (Scenario 2), and one that would result in an EC lower than recommended (Scenario 3, see Table 4.1); and
- The results of the modelling process indicated that all three scenarios would result in a range of impacts on the yield and therefore on the users.

Note:

- Apart from these key scenarios, various additional interactions for preliminary evaluations to achieve an optimised scenario were required; and
- The yield model is set up to deal with the EWRs as the highest (first priority) demand unless otherwise specified.

The key scenarios are described in Table 11.1.

Table 11.1: Scenario descriptions.

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

12. ECOLOGICAL CONSEQUENCES OF FLOW SCENARIOS

12.1 OVERVIEW AND OBJECTIVES

The aim of this section is to describe water quality and ecological consequences of various operational scenarios. The ecological evaluation is based on an assessment of the impact on the states or ECs recommended for each component. Information on the water quality assessment as a key driver is provided below, followed by the overall assessment.

12.2 WATER QUALITY CONSEQUENCES

Each of the flow scenarios was checked through simple concentration modelling (if appropriate data was available), as well as the Physico-Chemical Driver Assessment Index (PAI) driver tables, to determine whether the water quality objectives would be met under these flow conditions. The pollution sources and types of pollution were determined per EWR site. The different flow scenarios were then used to determine if the scenario would improve or decrease the water quality status per EWR site.

Typically the water quality issues in the Letaba study area are driven by diffuse pollution, such as (Figure 12.1):

- Agricultural runoff from intensive fruit orchards (fertilizers, salts, nutrients, pesticides);
- Villages close to rivers (microbiological, litter, turbidity);
- Animal grazing and watering (microbiological, turbidity); and
- Afforestation (turbidity, fertilizers).

The point sources of pollution in the Letaba River are limited to effluents from wastewater treatment works from Tzaneen and Giyani and are consequently not a major contributor to the water quality in the Letaba catchment.

The flow scenarios that result in an improved water quality are those scenarios that would enable the middle reaches of the Groot Letaba (below the confluence of the Letsitele to the confluence with the Klein Letaba) to be flushed in the winter low flow periods. The large number of weirs in this reach of the river has resulted in a deterioration of the water quality to such an extent that it has become enriched with nutrients and dissolved oxygen levels become limiting to the ecology. The scenarios that would improve the water quality are Scenarios 1,2 and 7.

None of the flow scenarios would result in an improved water quality at EWR 2 due to there being no regulatory mechanisms in the Letsitele River.

The flow scenarios that would result in an improved water quality in the lower Letaba River (within the KNP) are those that will result in a more assured flow in the river during spring (August to October) when the flows become historically low and water temperatures and dissolved oxygen levels become critical for the survival of the aquatic ecology.

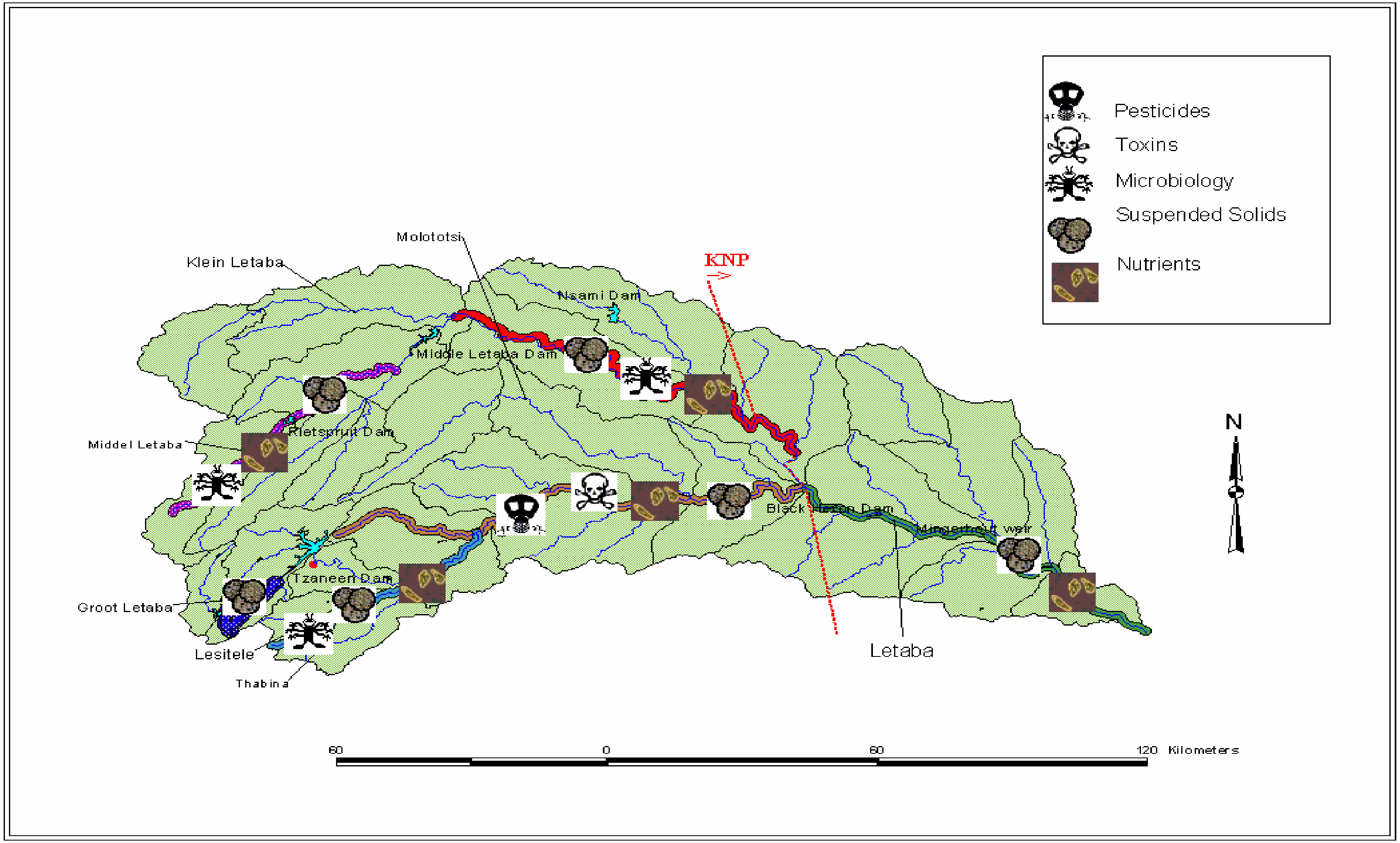

Figure 12.1: Water quality issues per major tributary in the Letaba catchment.

Note that for water quality:

- **EWR 1:** Water quality conditions will remain stable (PD) under all flows scenarios evaluated. This site's flow and water quality is mainly controlled by flow releases from Ebeneezer Dam for irrigation and Tzaneen potable water supply. Elevated nutrients (agricultural practices) as well as low flow releases (dissolved oxygen and water temperature) should be managed;
- **EWR 2:** No upstream regulation. Elevated nutrients, periphyton and higher turbidity will not be improved with different flow scenarios and water quality should be maintained;
- **EWR 3**: Increased phosphates with greater flows, increased periphyton and toxicity with low flows. Water quality not expected to change significantly under any of the flow scenarios;
- **EWR 4**: The PD flows were 60% lower than the other scenarios in high flows but in low flows the various scenarios were comparable. Large variations in dissolved oxygen and temperatures are noted during low flows. Nutrient status increased with greater flows and toxicity with low flows. Water quality conditions improved under Sc1, 2 4 and 6 when compared to PD;
- **EWR 5**: Increased periphyton with low flows. No spillage from Middle Letaba Dam is provided for. No water quality changes due to the different scenarios;
- **EWR 6**: Large variations in dissolved oxygen and higher temperatures are noted during low flows. Nutrient status increased with greater flows and toxicity with low flows. Water quality conditions will improve under all flow scenarios; and
- **EWR 7**: Large variations in dissolved oxygen and higher temperatures are noted during low flows. Nutrient status increased with greater flows and toxicity with low flows. Water quality conditions will improve under all flow scenarios

12.3 ECOLOGICAL CONSEQUENCES

The results as depicted on the Figures 12.2 are summarised in Table 12.1. A Traffic Light diagram comparing the ecological effects of the different scenarios is shown in Figure 12.2. The results per EWR site are summarised in Figure 12.2.

Table 12.1 illustrates that Scenarios 1, 2 and 7 would meet the recommended Ecological Category at all sites. Scenarios 4 and 6 would be problematic at EWR 3 (Prieska) and 4 (Letaba Ranch). The present day situation with a variable operational procedure releases from the Tzaneen Dam for the downstream irrigation and the KNP, does not meet the recommended EC at EWR's 3, 4, 6 and 7.

Table 12.1: Summary of ecological results.

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

Where: Face = meet REC, X = did not meet REC, 1= Riparian vegetation a problem, Y+ = exceeds REC.

The Traffic diagram in Figure 12.2 summarises Table 12.1(Figure 12.3) and shows the approximate difference between scenarios, from an ecological point of view, along a continuum of the scenarios.

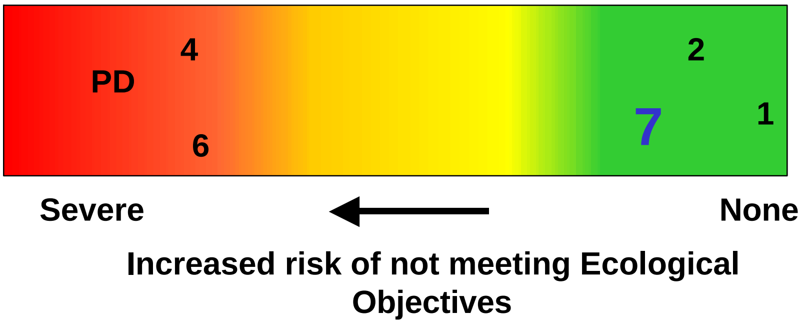

Figure 12.2: Ecological comparison of scenarios. Note that red illustrates an unacceptable situation for ecology and green an acceptable condition. The scale refers to the number of EWR sites.

The continuum illustrates how successfully the scenarios meet the EWR objectives at the 7 EWR sites. Scenarios 4, 6 and PD fail to meet the ecological objectives. EWR 3 and 4 are sites where improvement is required (both flow and water quality) due to the current regulated flow upstream. If no water flows past these EWR sites the KNP requirements will not be met (EWR sites 6 and 7). During the scenario optimisation process Scenarios 1, 2 and 7 where used to improve the assurance of water to EWR sites 3 and 4 and ultimately to the KNP. These scenarios will therefore not degrade the river at the EWR sites.

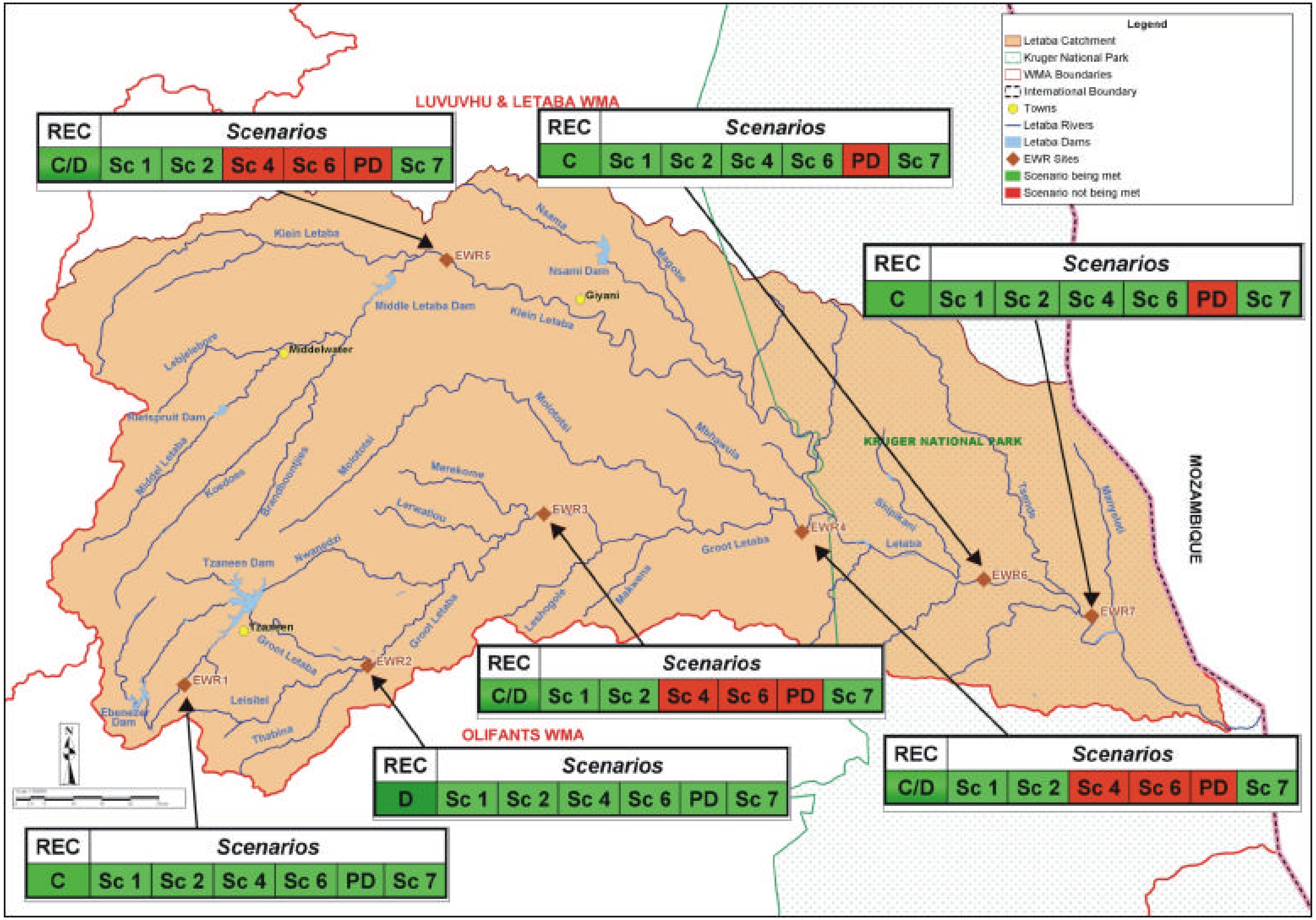

Figure 12.3: Scenarios that meet and do not meet the Recommended EC per EWR site.

13. IMPACT OF EWR FLOW SCENARIO ON WATER AVAILABILITY TO OTHER USERS

13.1 OVERVIEW

In order to determine the available water to economic water user sectors in the Letaba catchment, a yield assessment study was conducted for each EWR scenario.

13.2 OBJECTIVES

The aim of this component of the study was to quantify the consequences of various operational scenarios on the water availability to the economic user sectors with the EWR for each scenario being supplied as a priority.

13.3 METHODS

The original hydrology of the Groot Letaba Water Resources Development Study: Feasibility Study (DWAF, 1996) was used as the basis for the modelling of the water resource availability. The Water Resources Yield Model (2000) was used to assess the impacts that the EWR Scenarios will have on the available water to user sectors in each of the sub-catchments.

User requirements were based on best available data and interviews with the Tzaneen irrigation board. It should however be noted that the water use figures are not based on a validation and verification of existing water use. Curtailment structures were developed where the available water did not meet the requirements of the existing water users. This was based on the current operating rules that are used by DWAF to provide water to the water users in the Letaba River catchment. The water use in the upper catchments of the Middle Letaba Dam was based on assumption, as there was no data on water use.

The current operating rules of the infrastructure of the Letaba River system meant that the EWRs were set up to be channelled separately in the WRYM (i.e. no conjunctive river flow or "piggy-backing" of EWRs with water releases in the river for other users). This result provides slightly more conservative water availability results (i.e. slightly less water in the system than may occur in practice). The operating assumptions are justifiable at this level of investigation. Specific operating rules per river reach can be developed when a Reserve is implemented in the future.

The scenarios that were investigated were Sc's 1, 4, 6 and the optimised scenario 7. The first run of the WRYM was on the present day use.

13.4 RESULTS

The results of all flow scenarios indicated that there would be a negative impact on the available water to other users, particularly irrigation agriculture. The WRYM results of maintaining the PES (i.e. Sc 1) of the Letaba River and its main tributary had the most severe negative impact on the availability of water in the river system for other users, particularly in the Letsitele River and the sub-catchment downstream of Tzaneen Dam. Most of the yield from Tzaneen Dam was required to meet the EWR for the flow Sc 1. This was because the IFR sites that were driving the system are EWR 6 and 7 situated in the KNP.

13.4.1 Letaba River

Scenario 1 will reduced the volume of water available to water users in the Groot Letaba by 195 million m^3/a by the year 2010. This impact is most severe to the irrigators downstream of Tzaneen Dam. However by using the demand associated with a lower (than PES) EC and with further optimisation to the EWR, scenario 7 showed that volume of water available to other users was only reduced by 55.6 million m^3/a in the Groot Letaba River catchment.

Although the impact is still significant the optimised flow Sc 7 provides the best compromise between ecological water requirements for resource protection and the water available to water users to ensure the level of productivity is maintained. This can be further improved by improving the agronomic and economic efficiency of water use by the irrigation sector.

13.4.2 Middle Letaba River

Implementation of the EWRs for Sc 1 will significantly reduce the water requirements to users in the Middle Letaba catchment by 18 million m^3/a at the current level of assurance of supply or reduce the assurance of supply by 80%.

However implementation of the ecological water requirements for the optimised Sc 7 will reduce the water requirements by only 3.5 million m^3/a at the current assurance of supply.

13.4.3 Klein Letaba River

Implementation of the ecological water requirements for Sc 1 will significantly reduce the water requirements to users in the Klein Letaba catchment by 9 million m^3/a at the current level of assurance of supply or reduce the assurance of supply by 60%. However implementation of the ecological water requirements for the optimised Sc 7 will reduce the water requirements by only 3.1 million m^3/a at the current assurance of supply.

13.4.4 Letsitele River

Water allocations in this area already exceed the water resources available, since there is no storage on the Letsitele River. Irrigators are depended on run-of-river supply. The deficit at the accepted level of assurance of supply for the current water requirement is estimated to be approximately 8 million m^3/a out of a requirement of 14 million m^3/a.

Implementation of the ecological water requirements for the optimised Sc 7 will therefore further exacerbate the already negative situation and further reduce the assurance of supply to the farmers. Compulsory licensing may be required here in order to reduce existing water allocations, and to affect a balance between water use and the protection of the ecological integrity of this system. However this can only be done once verification of existing water use is conducted. There is an urgent need to undertake a validation and verification of existing water use particularly in the Letsitele River catchment.

13.4.5 Lower Groot Letaba River

The impact of providing for the EWR for any of the scenarios investigated on the water users in the Lower Groot Letaba catchment will be minimal.

13.5 CONCLUSION

The current water requirements for water users, particularly irrigators, are not being met. Nor is the 0.6 m^3/s, which should be supplied to the KNP, being supplied. The WRYM results have indicated that water users in the Lower Groot Letaba River catchments are the only ones that will not be impacted on under all the Ecological Reserve Sc's from 1 to 7.

The best comprise scenario is the ecological water requirements for Sc 7. The overall impact of this scenario is not as significant as for Sc 1. This is shown graphically in Figure 13.1.

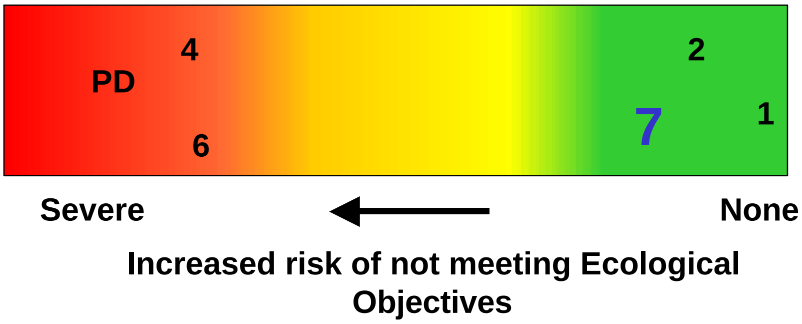

Figure 13.1: Ecological comparison of scenarios. Note that red illustrates an unacceptable situation for ecology and green an acceptable condition. The scale refers to the number of EWR sites.

14. CONSEQUENCES FOR GOOD AND SERVICES AND ECONOMY

14.1 OVERVIEW

Water resources provide important benefits to society, both as input capital for production and ecological goods and services. However, because of the increasing scarcity of water for both production and environmental benefits and scarcity of resources to develop water infrastructure, socio economic valuation plays an increasingly important role in decision making between socioeconomic development and protection of the resource for long-term sustainability. Therefore development and management of water resources cannot be interpreted without some idea of the value of water to the socioeconomic activities taking place in a catchment, and the value of ecological goods and services provided by the catchment.

14.2 OBJECTIVES

The purpose of valuing the water for production and socioeconomic activities and ecological goods and services is to assess the preference for or against environmental change.

14.3 METHODS

14.3.1 Economic value of water for commodity use

The Letaba River Catchment was divided into seven economic zones or subsystems (Figure 14.1). For each zone, a customised Water Impact Model was developed to calculate the economic value of water. The model was based on a Social Accounting Matrix (SAM) that was developed separately for the Letaba catchment. Therefore the sectoral multipliers used are specific to the economic activity in the Letaba River catchment. The underlying principal of the model was that water is scarce, and so its allocation among competing users needs to be structured to ensure that positive socioeconomic impacts are maximised. The model distinguished four water user sectors as follows:

- Irrigated Agriculture;
- Domestic including commercial and industrial;
- Commercial Forestry; and
- Transfers to Tzaneen from Ebenezer Dam

Not all scenarios were investigated. The range of scenarios investigated was such that the worst case and base case for socio economy could be determined. The scenarios that were investigated therefore were Scenarios 1, 2, 4, 6 and 7. These were compared with the present day (using year 2000 level of economic activity), which was the socioeconomic value of the present water available to the above water user sectors. The model was structured to provide a detailed description of the water availability in sub-catchments for various scenarios. Given the water availability for a new scenario, the model determined the economic and socioeconomic impacts emanating from the change in water availability.

The Water Impact Model determined the different impacts that the various scenarios will have on the economy. The marginal differences in economic and socioeconomic impacts were calculated by subtracting the impact of these situations from each other. This made it possible to quantify the impact that the various scenarios will have on the community, as well as the broader economy.

The factors that were used to determine the implication of the EWR scenarios were the following:

- The incremental change in the economic surplus or profit to the users in each sub-catchment and per water user sector;
- The incremental change in the Gross Domestic Product for each EWR scenario; and
- The number of jobs that would be generated or lost for EWR scenario.

14.3.2 Economic value of goods and service

A specialist workshop was held were the ecological goods and services in each sub-catchment were identified. In the Letaba catchment, the following ecological goods and services were identified:

- Fishing by community – Benefit;
- Fish farming – Benefit;
- Thatch grass;
- Reed harvesting;
- Wood gathering;
- Recreational fishing;
- Recreational boating;
- Cultivated floodplains;
- Sand mining;
- Recreational swimming; and
- Medicinal plants

It should be noted that the above goods and services are from direct and indirect use of the river. The specialist workshop also identified the indirect use of the in stream water namely the following:

- Waste assimilation;
- Waste dilution;
- Black flies;
- Livestock diseases;
- Malaria;
- Bilharzia;
- Cultural activities; and
- Grinding stones

Various techniques were used to measure the economic value of direct and indirect goods and services provided by the Letaba River because of the different volume of ecological water left in the river to protect the resource. These ranged from use of surrogate markets to contingency valuation methods.

14.3.3 Economic contribution of the Kruger National Park

The economic contribution of the Letaba river catchment in the Kruger National Park, subsystem 7 (Figure 14.1), was conducted separately because of the significant tourism.

The travel cost method was used to determine the economic contribution of tourism because of changes in flow in the portion of the Letaba River catchment situated in the Kruger National Park. This was based on deriving a demand curve from data supplied by the South African National Parks (SANAP) of the number of visitors going through the Phalaborwa gate. There are limitations to the methods because of the large number of camps in the Kruger National Park enabling tourists multiple destinations to visit in the park.

14.4 RESULTS

14.4.1 Ecological Goods and Services

A comparison of all scenarios indicates that there is an improvement in the direct and indirect use value of the water from providing EWR to meet the level of resource protection set for each scenario (Table 14.1). The total number of households who will benefit directly from the instream water use ranges from 1 435 households for scenario 1 to 484 households for Scenario 7. Indirect benefits were not determined.

The increase in economic contribution for each scenario due to ecological water is due to the increase in subsistence fishing, recreational swimming, and cultivated flood plains.

Table 14.1: Incremental Change in the value of goods and services. (see my previous questions

Ecological Goods & services	Economic Surplus	Impact on GDP	Impact on Low Income distribution	Households impacted
Scenario 1	6.99	11.12	0.45	1,437
Scenario 2	4.61	5.47	0.30	1,001
Scenario 4	4.23	4.88	0.26	841
Scenario 6	3.53	4.20	0.23	685
Scenario 7	2.24	2.66	0.14	484

14.4.2 Consequences of flow scenarios on the economics of the Kruger National Park

The incremental change in the economic activity for each scenario investigated for the Kruger National Park (sub catchment 7) is presented in Table 14.2. The flow requirements for Scenario 1 will have the most positive impact on the contribution to the GDP and employment. The impact increases negatively with reduction in the EWR flows for the scenarios investigated. However, all of the above scenarios have a positive impact from the present day where the required flows are not being met.

Table 14.2: Incremental change in the flow of benefits from Kruger National Park.

	Impact on surplus value (profits)-R mil.	Impact on GDP R mil.	Impact on labour Number	Impact on low-income households (R mil.)
Scenario 1	23.70	49.98	360	18.22
Scenario 2	10.21	21.54	155	7.85
Scenario 4	8.04	16.96	122	6.18
Scenario 6	6.18	13.03	94	4.75
Scenario7	4.23	8.92	64	3.25

14.4.3 Consequences of flow scenarios on the socio-Economy

The incremental change in economic activity in each subcatchment for each scenario investigated is presented in Table 14.3. The impact of Scenario 1 will have the most negative impact on the economic surplus and the contribution to the GDP. This is because more water is requirement to meet the ecological objectives of Scenario 1. The best case for the economic contribution of the Letaba catchment is Scenario 7.

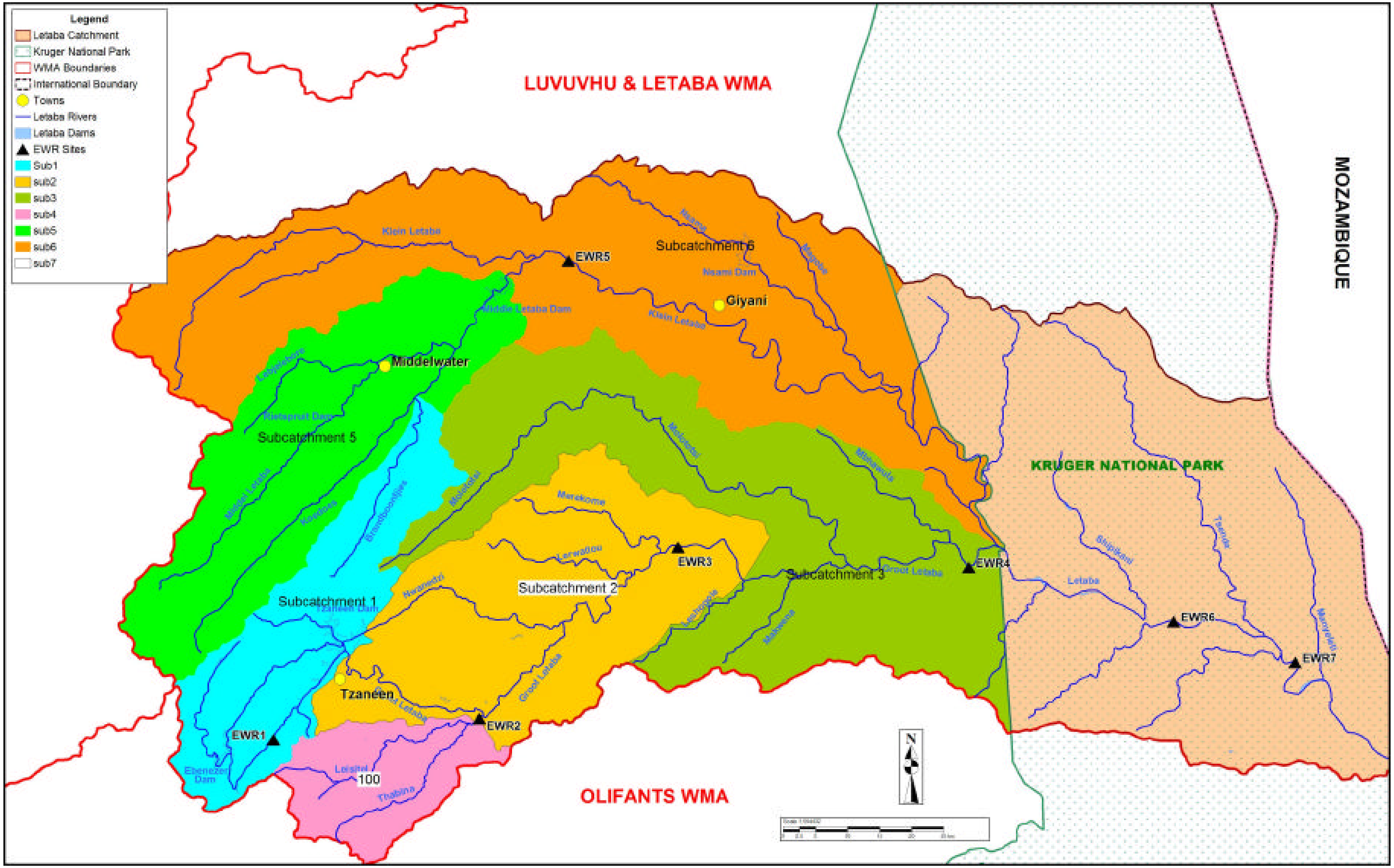

Figure 14.1: Map of the River catchment, showing the delineation of the catchment into seven economic sub-systems.

As can be seen in Table 14.4, irrigated agriculture will be the most severely negatively impacted in Scenario 1 with the number of hectares that will have to be withdrawn estimated to be approximately 18 000 hectares under current irrigation practices. The impact is severe in subcatchment 2 downstream of Tzaneen dam where the GDP contribution for Scenario 1 will reduce by approximately R611 million. However by increasing irrigation efficiency there may be potential for reducing the number of hectares that will be required to be withdrawn in order to meet the EWR for Scenario 1.

Under Scenario 7, although the irrigation agriculture is still negatively impacted, with the GDP contribution reducing by about R52 million, the impact is not as severe as all other scenario investigated and this is the best case for the economic contribution of the Letaba catchment.

Table 14.3: Incremental change in value added for each scenario.

	Total Surplus	GDP	Capital Requirements	Low Income Households	All Households
	Rand mil.	Rand mil.	Rand mil.	Rand mil.	Rand mil.
Scenario 1	(161.50)	(1,186.93)	(2,657.82)	(298.36)	(1,174.63)
Scenario 2	(95.68)	(877.00)	(1,808.64)	(216.41)	(852.09)
Scenario 4	(94.36)	(550.03)	(1,326.17)	(143.98)	(564.02)
Scenario 6	(63.87)	(371.98)	(942.99)	(101.67)	(398.26)
Scenario 7	(11.11)	(109.82)	(187.83)	(27.85)	(109.85)

Table 14.4: Impact on employment and irrigated agriculture.

	Employment	Number of Hectares Withdrawn	Percentage Irrigation Withdrawn
	Numbers		Hectares
Scenario 1	(92,244)	(18,056)	95.1%
Scenario 2	(71,635)	(13,797)	72.6%
Scenario 4	(38,974)	(7,752)	40.8%
Scenario 6	(24,485)	(4,750)	25.0%
Scenario 7	(9,859)	(2,093)	11.0%

14.5 CONCLUSIONS

The overall impact of the various scenarios on the goods and services is not highly significant, with the worst case scenario being Scenario 7 and the best case being Scenario 1 as shown in the traffic diagram below (Figure 14.2 to 14.4).

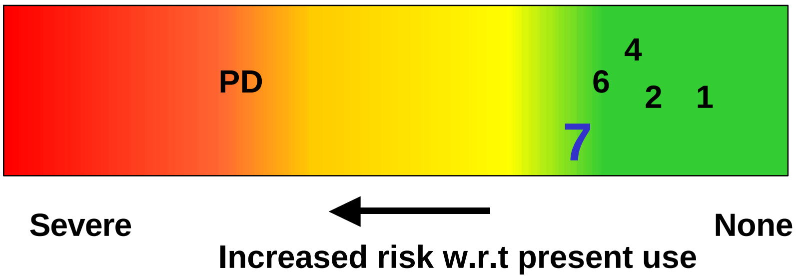

Figure 14.2: Consequences for various operational scenarios on Goods and Services in the Letaba River.

The overall impact of the various scenarios on the economy is highly variable for the scenarios investigated. The worst case EWR scenario is Scenario 1 and the best-case EWR scenario being scenario 7. This is as shown in the traffic diagram below (Figure 14.3).

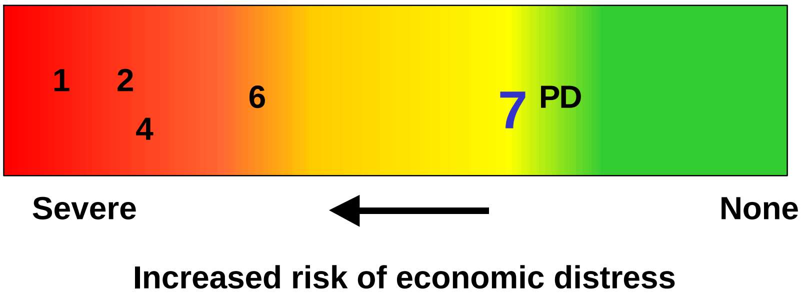

Figure 14.3: Economic consequences for various operational scenarios in the Letaba River.

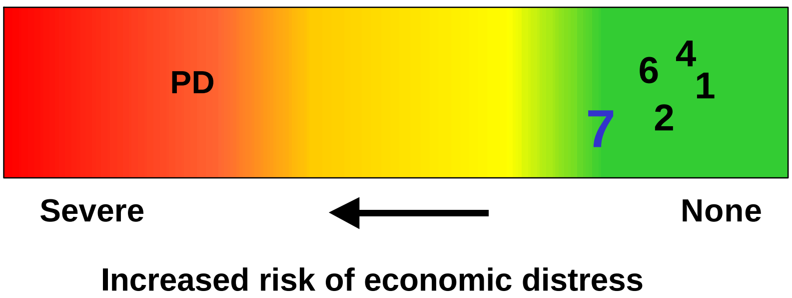

Figure 14.4: Economic consequences to the Kruger National Park of the various operational scenarios in the Letaba River.

15. RECOMMENDED ECOLOGICAL RESERVE

15.1 OPTIMISED SCENARIO

The Letaba River catchment is highly regulated particularly in the upper catchments where most of the runoff is generated. Implementation of ecological flows in the Letaba River catchment can therefore be realised through active management of the water resource infrastructure such a the dams and weirs in the catchment as well as through reducing abstractions for water users in the catchment based on their curtailment structures. This however has a negative impact on the available water to users. The restrictive flow management will therefore involve changing the existing allocations to water users in the catchment to ensure that enough water is left in the river. Both types of interventions require a change in the water use practices of the stakeholders and the need for stakeholder commitment and buy-in with the level of resource protection that can be effected without significantly impacting on the socio-economy of the catchment.

The original scenarios (Table 11.1) were run using the Water Resources Yield Model (WRYM) and the results presented to a meeting with key members of the project team (hydrologist and project manager) and the Project Management Consultants (Toriso Tlou and Delana Louw). Guidance was given to the hydrologist on how to develop an optimised scenario to optimise flow requirements that would have the least potential impact on all sectors. The WRYM was rerun with the adjusted demands as specified in Table 11.1. Several such iterations took place with further discussions, further refinements suggested and the model rerun until the key project team members were happy that the optimised flow requirements As such, Scenario 7 was developed.

This optimised scenario was presented in the Briefing Document (DWAF 2006c) and this scenario was presented to senior officials in DWAF (September 2005) as the recommended Reserve.

The ecological consequences of the flow scenarios are present in Figure 15.1. It is noted that the ecological objectives are being met for most scenarios with the exception of Scenarios 4, 6 and the present day for EWRs 3, 4 and 5. The ecological objectives for the present day are not being met in the Kruger National Park despite the fact that there is supposed to be an existing allocation of 0.6 m^3/s from Tzaneen Dam.

The impact of the ecological water requirements on the socio economy of the Letaba catchment was premised on the water use that was not verified and validated. Therefore depending on the verification of water use in the Letaba River catchment, particularly in the Middle Letaba river catchment upstream of the Middle Letaba Dam and the Letsitele River catchment, the extent of the impact may not be as severe. The impact of the EWR flow scenarios on the ecological goods and services as well as the socio-economy is provided in Figure15.1.

After consideration of the flow scenario that were investigated, it is apparent that the EWR flows for **Scenario 7** is the most suitable scenario as it meets the REC, most of the ecological objectives, and has a minimal impact on all the user categories (Figure 15.1). Furthermore, Scenario 7 provides the best trade off between the need for protection of the ecological ecosystems in the Letaba catchment with the need to ensure the socio-economic growth is not severely negatively impacted. In the traffic diagrams, it can be seen that Scenario 7 is the only scenario that was lying on the green side (Figure 15.1). This was the recommendation presented to DWAF in absence of a Classification System. Scenario 7 was accepted and approved a by DWAF at the meeting of September 2005.

It should be noted that there is currently no treaty between South Africa and Mozambique with regards to the Olifants River. Once this treaty has been concluded, the Mozambique requirements will have to be taken into account.

KNP officials have indicated that they have a mandate to improve biodiversity and have requested an improved PES within the KNP (PES of C to REC of B). With the currently upstream water usage, mainly for agriculture, and the difficulties in improving catchment (sediment) issues it would be problematic to improve the PES.

Consideration should also be taken to delay implementation of the EWR flow of Scenario 7 in the Letsitele River catchment because of the significant impact it will have on the irrigators until the verification and validation of present use have been undertaken.

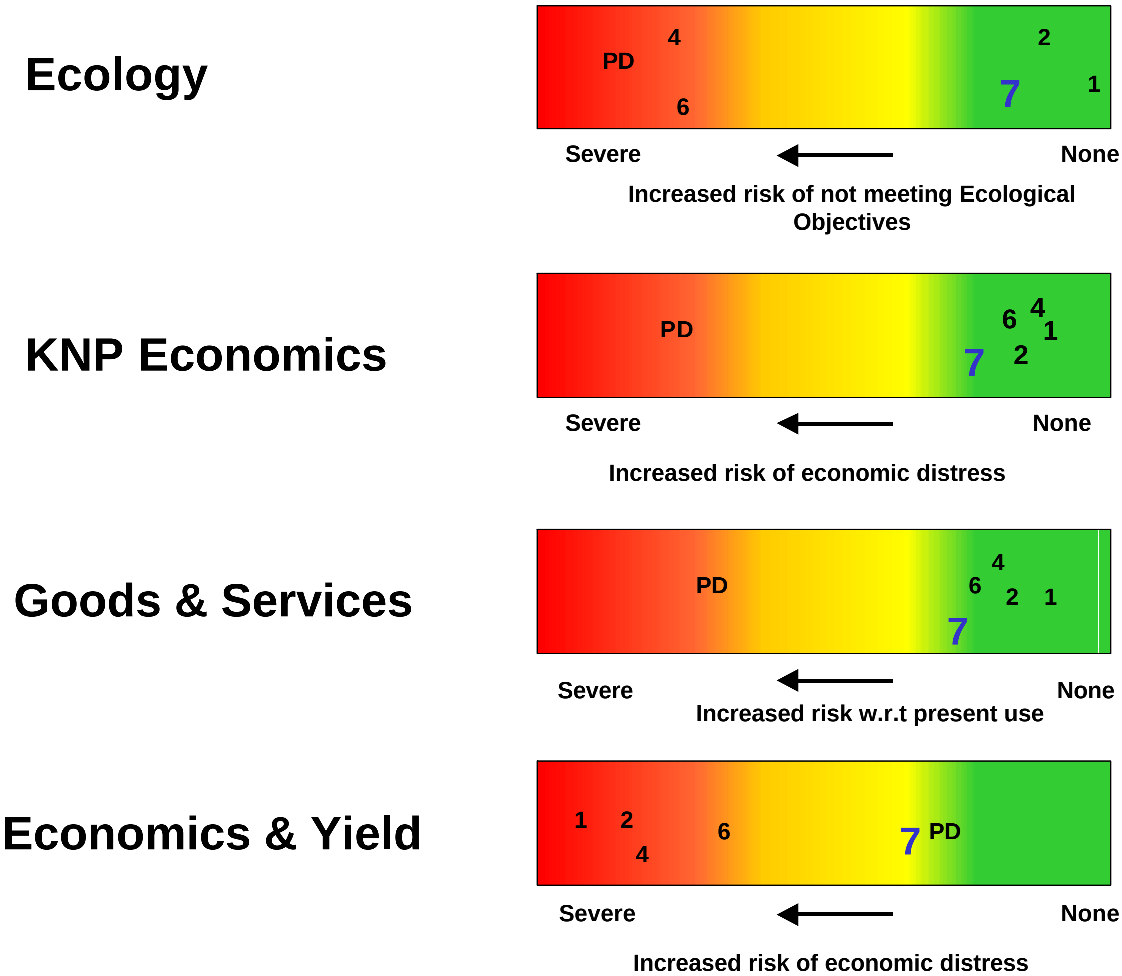

Figure15.1: Comparison of scenario impacts across major study components.

Scenario 7 was therefore recommended as the Ecological Reserve and the EWR rules are in Appendix A and is summarised as a percentage of the nMAR in the Table-15.1. This recommendation was accepted at the DWAF meeting of September 2005.

Table 15.1: Final results of Scenario 7 summarised as a percentage of the nMAR.

Sites	Annual EWR (million m^3)	Virgin MAR (million m^3)	Annual EWR (% nMAR)
EWR 1	19.75	71.27	27.71
EWR 2	31.756	86.06	36.90
EWR 3	42.448	364.49	11.65
EWR 4	69.87	402.26	17.37
EWR 5	17.054	95.01	17.95
EWR 6	47.0317	546.59	8.60
EWR 7	51.52	561.67	9.17
Total	279.4297		49.75

15.2 RECOMMENDATIONS

The following list of issues needs to be addressed for the full implementation of the Letaba Reserve:

No stakeholder participation was conducted for the determination of the EWR. The EWR studies and stakeholder involvement should be part of an integrated Water Resources Planning study. This will ensure that:

- All possible flow scenarios are considered that serve the interests of all the water users in the catchment are considered;
- Provide transparency and accountability regarding both decisions taken and the process by which those decisions on the level of resource protection are taken;
- Accustom stakeholder to the fact that some difficult choices may have to be made in order to manage water resources effectively and in a sustainable manner. This will mean change in the allocation mechanism and the need for water allocation reform;
- Build a broad base of commitment to options by creating an environment that takes into account the benefits, risks and costs of the options and that provides a meaningful basis for informed consent to DWAF decisions on the Reserve; and
- Increase the probability of implementation of the Reserve through restrictive management of the water users as may be necessary.
- Implement and monitor the Ecological Reserve

16. ECOSPECS AND ECOLOGICAL RESERVE MONITORING

16.1 INTRODUCTION

EcoSpecs are clear and measurable specifications of ecological attributes (e.g. water quality, flow, biological integrity) that define the Ecological Category and serve as an input to Resource Quality Objectives. EcoSpecs refer explicitly and only to ecological information whereas RQOs include economic and social objectives.

It is understood that Ecological Reserve (ER) monitoring is a process which encompasses the following (Kleynhans and Louw, 2006):

- Determination of the Present Ecological State (PES) of the resource
- Formulation of the Recommended Ecological Category (REC)
- Specification of the EcoSpecs)
- Specification of the ecological attributes that would indicate the attainment of the REC

Thresholds of Potential Concern are upper and lower levels along a continuum of change in selected environmental indicators (Kleynhans and Louw, 2006). When a TPC is reached, or when modelling predicts that the threshold will be reached, an assessment of the causes of the change is triggered. The assessment provides the basis for deciding whether management action is needed, or if the TPC needs to be recalibrated. The TPCs provide specific targets and form the basis of an inductive approach to adaptive management, as they are hypotheses of limits of acceptable change in ecosystem structure, function and composition. As such their validity and appropriateness are open to challenge and they must be adaptively modified as understanding and experience of the system increases (Kleynhans and Louw, 2006).

The overall aims of Ecological Reserve monitoring are to measure and determine how the resource is changing over time, and to ensure that resource remains within acceptable limits of change, defined broadly as the Recommended Ecological Category (REC). If the ecological category deteriorates significantly compared to baseline conditions and the cause is known, management interventions are triggered. If the cause of deterioration is unknown, more intensive monitoring or research may be needed to identify the cause(s). Monitoring therefore provides the critical link between objectives and management interventions. The essential requirements of a monitoring programme are therefore clearly defined baseline conditions against which future changes may be compared, clearly defined objectives, and clearly defined Thresholds of Potential Concern (TPC).

The purpose of monitoring is to:

- Determine whether the ecological objectives (in terms of Ecological Categories and EcoSpecs) are being met;
- Identify the possible cause of the problem; and
- Determine the required actions according to a Monitoring DSS to be followed if the ecological objectives are not being met.

16.2 OBJECTIVES

The draft generic guidelines for ER Monitoring, detailed in Kleynhans and Louw (2006) were used to provide guidance on ER monitoring which includes guidelines for monitoring, assessment of data for adequacy of a baseline and the methods to determine EcoSpecs and TPCs.

16.3 METHOD

The Ecological Reserve Monitoring programme will be set according to the guidelines given by Kleynhans and Louw (2006) with site-specific adjustments made where necessary. Monitoring will be undertaken in the context of Adaptive Environmental Management and the Ecological Reserve Monitoring Decision Support System.

In order to assess the status of the current baseline studies and monitoring programmes as well as to develop a site specific monitoring programme a Letaba EcoSpecs and monitoring workshop was held 17 to 18 January 2006.

The following approach was followed:

- The adequacy of available data to serve, as a baseline was evaluated and additional work to set the baseline identified; and
- A workshop was held where the EcoSpecs linked to the required EC and the associated TPCs were identified. The methods used are linked to the EcoStatus models and described in the generic document. (Kleynhans and Louw (2006), Appendix A to DWAF 2006d).

16.4 ECOSPECS

The primary EcoSpecs are the Ecological categories and these are summarized in Table 16.1.

These EcoSpecs were quantified in terms of measurable criteria that can be monitored for fish, invertebrates, riparian vegetation, geomorphology and water quality.

Table 16.1: Ecological categories for the driver and response components per EWR site.

Components	**EWR 1**	**EWR 2**	**EWR 3**	**EWR 4**	**EWR 5**	**EWR 6**	**EWR 7**
Hydrology	C	C	D	D	C/D	D	D
Geomorphology	C	D	C	C/D	C	C	C
Water quality	B	C/D	C	B/C	B	C	C
Fish	C	C	C	C	B	C	C
Aquatic invertebrates	C/D	D	D	D	C	D	D
Riparian vegetation	C	D	D	D	B	C	C
EcoStatus	**C**	**D**	**C/D**	**C/D**	**C**	**C**	**C**

16.5 BASELINE MONITORING

The required further baseline monitoring that needs to be undertaken per EWR site before the Ecological Reserve Monitoring programme can be initiated is summarized in Table 16.2. The fish and invertebrates require no additional baseline monitoring at any of the EWR sites. The geomorphology at all EWR sites will require a short site visit to fully populate the Geomorphology Assessment Index (GAI). This is due to the GAI model only having being developed after the field surveys for this study.

The existing vegetation survey data needs to be converted to VEGRAI level 4 for EWRs 1, 3, 4 and 5, 6 and 7. At EWR 2 the vegetation needs to be surveyed in detail using VEGRAI level 4 once the uncertainty of back flooding impacts at this site has been concluded. Additional information is required to update the marginal vegetation an additional information on the marginal zone at EWR sites 6 and 7 might be required.

The minimal set of parameters for water quality are pH, EC/TDS, DO, temperature, turbidity / water clarity, nutrients (nitrate and nitrite, ammonium and ortho-phosphate). Additional variables that are highly recommended for inclusion at the EWR sites are inorganic salts and Chlorophyll-*a*, and toxicants relevant to the site, e.g. metals ions, pesticides or in-stream toxicity (particularly as a proxy for pesticide contamination). In-stream toxicity tests should be conducted using the recommended suite of indicator organisms.

Table 16.2: Summary of surveys required to establish a baseline

EWR Site	Geomorphology	Water quality	Riparian vegetation	Fish & Invertebrates
1	Survey required to fully populate the GAI and initiate monitoring (to assess info requirements for perimeter resistance component).	Temperature, dissolved oxygen, turbidity / clarity, toxicity, Chl-*a*: Periphyton, toxics ammonia, Al and Cu.	Data needs to be converted to VEGRAI level 4	No further baseline data needed
2			Need to do survey using VEGRAI level 4 and conclude uncertainty of back flooding impacts.	
3		Temperature, dissolved oxygen, turbidity / clarity,- toxicity: should be initiated on a quarterly basis. The frequency of tests can be decreased, depending on the results of the toxicity tests. Chl-*a*: Periphyton: A full range of toxics (due to pesticide and herbicide use).	VEGRAI data needs to be converted to VEGRAI level 4	
4				
5		Temperature, dissolved oxygen, turbidity / clarity, Chl-*a*, Periphyton, toxics ammonia, Al and Cu.		
6		Temperature, dissolved oxygen, turbidity / clarity, toxicity, Chl-*a*, Periphyton, toxics, ammonia, Al and Cu Selected toxicants (see EWR 4).	Data needs to be converted to VEGRAI level 4. If additional information is required to update the marginal vegetation an additional survey might be required	
7				

17. CAPACITY BUILDING AND TRAINING

17.1 OVERVIEW AND OBJECTIVES

A capacity building programme formed part of this study with a dedicated budget. The objective of the capacity building was to increase the technical expertise (especially HDI's) available for Reserve related studies in the country.

17.2 METHOD

To initiate the training, a number of trainees were identified and mentors appointed. Trainees were selected largely from HDIs as persons who had relevant skills and who were interested in the Reserve Determination process. Table 17.1 indicates the trainees and mentors for the areas to be developed.

Table 17.1: Capacity building team member, mentors and areas of development.

HDI team member	Mentor	Development area	News skills developed
Kevin Pillay*	Ralph Heath	Reserve determination project management	The comprehensive Reserve methodology Facilitate Reserve scenario workshops SPATSIM model training WRYM training Hands on modelling
Paul Chipwanya* Yosief Fsehazion	Ken Haumann Kevin Pillay*	Hydrology Water Resource Yield Modelling	Site selection methods SPATSIM model training WRYM training Hands on modelling Manipulation of flow scenarios
Deborah Vromans	Patsy Scherman	Water quality data analysis, graphic, statistics, trend analysis	Water quality data collation Water quality data interpretation and manipulation
Patterson Khavhagali *	Gary Marneweck	Riparian vegetation and wetland surveys	Field assessment techniques Key indicator species identification Vegetation transects Vegetation and wetlands role in the Reserve methodology
Thomas Mufanadzo *	Robert Skorozewski	Rapid biological assessment of invertebrates in field	Field assessment techniques (SASS5) Key indicator species identification Fill in and understand how assessment forms work for SASS5 and Habitat assessment.
Shaka Sebola Calvin Mawelela*	Indaran Govender/ Ralph Heath	Socio – cultural importance survey of water in the catchment.	Methodology required for Reserve determination with regards to field surveys

HDI team member	Mentor	Development area	News skills developed
Duncan Munyai	Carel Haupt Karim Sami	Groundwater assessment and terms of reference for groundwater Reserve	Literature review of current available groundwater data Data collation into a situation assessment report Report writing skills

Where: * = team members that left for other employment.

Each HDI was given a mentor whose responsibility was to assist the trainee to undertake the following:

- Understand the 8 broad principles and steps required to undertake the Reserve process;
- Undertakes at least 1 field visit (if appropriate) to the Letaba River to observe the chosen EWR sites;
- Assists in the determination of his/her specific aspect of the Reserve (hands on trainee and undertaking specific tasks); and
- Attend all specialist workshops

The following additional capacity building exercises was undertaken:

- Regional representatives of DWAF-Polokwani and Limpopo Province were included in the first Ecospecs workshop (Mpho Daswe and Washington Tuhna); and
- DWAF Limpopo Regional office staff undertook training over two days in conjunction with the Komati workshop (26/27 October 2004, Silo Kheva, Mpho Daswe, Minky Chauke, Happy Mushwana, Benson Mpefe, Sharon Mashaba, Caroline Shai).

17.3 RESULTS OF CAPACITY BUILDING

The aim of this task was to assist with building HDIs capacity that could be engaged in future aspects of Reserve studies. Five of the eight trainees engaged in the study moved on to other work during the course of the study because of the need to find more permanent employment, and only three are likely to be readily available to participate in future studies of this nature (See * in Table 17.1). The main problem with the training programme was therefore the lack of continuity caused by the long duration of the study and the need for trainees to find alternative forms of income. These trainees successfully gained employment in other fields and are lost to the pool of expertise that could assist in future Reserve studies

17.4 CONCLUSIONS AND RECOMMENDATIONS

The training component of this project was active and successful during the data collection phase of this project. Trainees attended key meetings and all relevant site visits with their mentors and helped to collect data and prepare the specialist reports that formed part of workshop documentation. Some trainees also participated in the specialist workshops and gave input. The aim of training Historically Disadvantaged Individuals (HDI) was therefore met.

To address the shortcomings of a sustainable pool of trained HDI's to undertake Reserve studies the following recommendations are made:
Approved reference material: The manuals used to undertake the Reserve process need to be approved by DWAF and then made available on the website. Once this process is made available to practitioners the development of HDI's using a consistent readily available method will assist with the development of HDI's as well as the trainees.

Dedicated Training: A dedicated EWR training programme is recommended. Although the mentor-trainee partnerships are important, they cannot be expected to provide the full range of training that can be provided by a dedicated training programme. The training should include not only a detailed description of the principles and processes of EWR determination, but should also include a comprehensive introduction to hydrology and scenario analysis.

There is an urgent need for some for of pre-training of the trainees as it was difficult to balance the project plan and deadlines with appropriate training. A two-day workshop on the Reserve process needs to take place before any of the trainees venture out into the field.

National role out of Reserve process: There is a need to have a series of national workshops to train practitioners in the available methods for Reserve determination.

Register of Trainees: Trainees for EWR studies should be sourced from a pool of trainees that are permanently employed, preferably at state or semi-state organisations, and readily available to undertake such work. This means that when such studies go out for tender, each proposed team should not be responsible for identifying and appointing their own team of trainees. The RDM Office should be responsible for identifying and appointing the trainees from a register of EWR trainees, so that the same group of individuals are generally used, irrespective of which PSP wins the tender. This would enable follow-up training so that trainees would eventually reach a level that they would be able to undertake the work required without the need for additional training. It is recommended that the RDM Directorate develop and maintain a database of EWR trainees. The proposed database should include:

- Names of personnel potentially available for EWR training;
- Their qualifications;
- Their specialist fields and level of understanding of EWR processes;
- Contact details; and
- Any other relevant details.

Training Budget: It is recommended that training budgets should be specified in the Terms of Reference for such projects, either as a sum of money to be allocated to training or as a percentage of the overall study budget.

Regional office training: DWAF should put emphasis on building expertise within regional offices, as well as head office, to be able to guide both consultants and DWAF personnel in order to undertake both intermediate as well as comprehensive Reserve determinations. It is important that this regional capacity is in place so as to implement the recommended monitoring programme.

Formal tertiary training: A Master's course work degree is being planned to assist in the roll out of the Reserve methodology.

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APPENDIX A: Final demand rules per site

	EWR1-Final Rule Tab (m3/s)									
	10%	20%	30%	40%	50%	60%	70%	80%	90%	98%
October	0.217	0.217	0.216	0.214	0.211	0.201	0.181	0.130	0.113	0.088
November	0.594	0.591	0.587	0.576	0.558	0.510	0.422	0.303	0.211	0.147
December	1.129	1.123	1.110	1.049	1.027	0.907	0.739	0.519	0.294	0.190
January	0.641	0.594	0.572	0.521	0.476	0.439	0.373	0.255	0.204	0.136
February	3.723	3.283	3.015	2.266	1.999	1.479	1.269	0.921	0.727	0.442
March	0.859	0.794	0.759	0.686	0.622	0.564	0.453	0.298	0.250	0.176
April	1.245	1.236	1.211	1.182	1.142	1.030	0.834	0.552	0.401	0.250
May	0.344	0.342	0.339	0.332	0.322	0.301	0.262	0.195	0.156	0.122
June	0.319	0.318	0.316	0.309	0.302	0.283	0.248	0.187	0.146	0.112
July	0.280	0.280	0.279	0.274	0.269	0.254	0.224	0.170	0.133	0.101
August	0.268	0.268	0.267	0.264	0.259	0.246	0.218	0.164	0.125	0.091
September	0.242	0.242	0.242	0.240	0.237	0.226	0.203	0.152	0.115	0.081

	EWR1-Final Rule Curves as percentage of MAR									
	10%	20%	30%	40%	50%	60%	70%	80%	90%	98%
October	0.815	0.815	0.815	0.812	0.805	0.791	0.755	0.679	0.488	0.425
November	2.159	2.159	2.149	2.135	2.095	2.029	1.855	1.535	1.103	0.767
December	4.243	4.243	4.219	4.171	3.942	3.860	3.408	2.777	1.950	1.106
January	2.537	2.411	2.234	2.151	1.957	1.789	1.651	1.403	0.958	0.766
February	13.359	12.636	11.144	10.234	7.692	6.785	5.020	4.308	3.126	2.468
March	3.426	3.229	2.984	2.854	2.578	2.339	2.120	1.703	1.121	0.939
April	4.533	4.526	4.494	4.404	4.299	4.153	3.746	3.033	2.009	1.459
May	1.294	1.294	1.287	1.275	1.249	1.211	1.131	0.985	0.734	0.588
June	1.159	1.159	1.156	1.149	1.125	1.097	1.030	0.902	0.679	0.532
July	1.054	1.054	1.054	1.048	1.031	1.010	0.954	0.843	0.640	0.500
August	1.006	1.006	1.006	1.003	0.993	0.972	0.925	0.821	0.617	0.470
September	0.881	0.881	0.881	0.881	0.874	0.862	0.822	0.737	0.554	0.417

	EWR2-Final Rule Tab (m3/s)									
	10%	20%	30%	40%	50%	60%	70%	80%	90%	98%
October	0.596	0.595	0.585	0.575	0.527	0.458	0.358	0.289	0.118	0.044
November	1.038	0.940	0.803	0.756	0.682	0.620	0.445	0.341	0.220	0.100
December	1.768	1.760	1.311	1.124	0.835	0.653	0.608	0.530	0.369	0.168
January	2.001	1.915	1.826	1.719	1.534	1.295	1.015	0.845	0.460	0.190
February	4.110	3.807	3.470	3.143	2.290	1.799	1.564	1.033	0.645	0.395
March	3.722	3.525	3.177	2.968	2.190	1.888	1.374	1.128	0.626	0.370
April	1.437	1.433	1.412	1.385	1.324	1.223	1.044	0.778	0.366	0.218
May	0.995	0.993	0.981	0.962	0.924	0.859	0.740	0.560	0.339	0.172
June	0.796	0.795	0.786	0.772	0.743	0.688	0.590	0.441	0.250	0.118
July	0.696	0.696	0.687	0.674	0.643	0.602	0.513	0.375	0.201	0.067
August	0.557	0.556	0.550	0.535	0.499	0.461	0.391	0.276	0.149	0.043
September	0.497	0.496	0.490	0.480	0.459	0.418	0.348	0.243	0.115	0.018

	EWR2- Final Rule Curves as percentage of MAR									
	10%	20%	30%	40%	50%	60%	70%	80%	90%	98%
October	1.857	1.852	1.823	1.790	1.641	1.426	1.115	0.900	0.368	0.138
November	3.128	2.833	2.420	2.279	2.056	1.869	1.341	1.028	0.663	0.301
December	5.507	5.481	4.083	3.501	2.601	2.034	1.894	1.651	1.149	0.523
January	6.231	5.964	5.687	5.353	4.779	4.033	3.161	2.631	1.434	0.591
February	11.562	10.708	9.762	8.841	6.442	5.061	4.400	2.906	1.814	1.110
March	11.591	10.978	9.893	9.244	6.821	5.880	4.279	3.513	1.950	1.153
April	4.331	4.320	4.256	4.176	3.992	3.687	3.145	2.345	1.103	0.657
May	3.098	3.093	3.055	2.995	2.877	2.676	2.303	1.743	1.056	0.535
June	2.398	2.395	2.369	2.328	2.240	2.072	1.778	1.330	0.753	0.356
July	2.167	2.167	2.140	2.098	2.001	1.876	1.599	1.167	0.626	0.208
August	1.734	1.731	1.713	1.666	1.554	1.436	1.218	0.860	0.465	0.134
September	1.498	1.495	1.478	1.448	1.383	1.259	1.050	0.734	0.347	0.053

	EWR3-Final Rule Tab (m3/s)									
	10%	20%	30%	40%	50%	60%	70%	80%	90%	98%
October	0.164	0.164	0.161	0.158	0.151	0.138	0.112	0.080	0.025	0.001
November	0.627	0.625	0.615	0.602	0.532	0.459	0.316	0.213	0.103	0.057
December	1.730	1.722	1.693	1.657	1.494	1.195	1.105	0.804	0.170	0.068
January	2.527	2.232	1.976	1.739	1.486	1.188	0.741	0.624	0.231	0.033
February	11.306	10.035	8.643	6.658	3.937	3.000	1.737	0.863	0.270	0.096
March	15.469	13.800	9.367	6.460	3.717	2.430	1.712	0.966	0.344	0.114
April	0.709	0.707	0.696	0.676	0.650	0.599	0.506	0.369	0.184	0.079
May	0.271	0.270	0.268	0.260	0.248	0.230	0.195	0.142	0.072	0.027
June	0.213	0.213	0.211	0.207	0.196	0.183	0.155	0.114	0.062	0.018
July	0.164	0.164	0.163	0.160	0.152	0.143	0.122	0.090	0.050	0.014
August	0.131	0.131	0.130	0.127	0.121	0.112	0.096	0.069	0.037	0.013
September	0.119	0.119	0.118	0.117	0.113	0.108	0.097	0.078	0.048	0.000

	EWR3-Final Rule Curves as percentage of MAR									
	10%	20%	30%	40%	50%	60%	70%	80%	90%	98%
October	0.120	0.120	0.118	0.116	0.111	0.101	0.082	0.058	0.018	0.001
November	0.446	0.444	0.437	0.428	0.378	0.326	0.225	0.151	0.073	0.041
December	1.271	1.265	1.244	1.218	1.098	0.878	0.812	0.591	0.125	0.050
January	1.857	1.640	1.452	1.278	1.092	0.873	0.545	0.459	0.170	0.024
February	7.504	6.660	5.736	4.419	2.613	1.991	1.153	0.573	0.179	0.064
March	11.367	10.141	6.883	4.747	2.731	1.786	1.258	0.710	0.253	0.084
April	0.504	0.503	0.495	0.481	0.462	0.426	0.360	0.262	0.131	0.056
May	0.199	0.199	0.197	0.191	0.182	0.169	0.143	0.104	0.053	0.019
June	0.152	0.151	0.150	0.147	0.140	0.130	0.111	0.081	0.044	0.013
July	0.120	0.120	0.120	0.117	0.112	0.105	0.090	0.066	0.036	0.010
August	0.097	0.096	0.095	0.094	0.089	0.083	0.070	0.051	0.027	0.010
September	0.085	0.085	0.084	0.083	0.081	0.077	0.069	0.056	0.034	0.000

	EWR4- Final Rule Tab (m3/s)									
	10%	20%	30%	40%	50%	60%	70%	80%	90%	98%
October	0.469	0.370	0.369	0.357	0.333	0.307	0.229	0.190	0.096	0.060
November	2.667	1.339	0.776	0.655	0.543	0.527	0.345	0.215	0.131	0.092
December	2.953	2.953	2.938	1.855	1.592	1.349	1.162	0.804	0.174	0.068
January	4.138	4.034	3.773	3.146	2.746	1.627	0.898	0.796	0.248	0.087
February	32.961	30.796	27.311	9.151	5.244	3.056	1.811	0.964	0.270	0.096
March	12.129	12.107	10.716	7.952	5.441	3.008	2.084	0.966	0.397	0.114
April	3.057	3.057	3.046	2.843	2.663	2.363	1.494	0.886	0.199	0.091
May	1.092	1.092	1.090	1.037	0.942	0.855	0.654	0.368	0.193	0.074
June	0.907	0.907	0.905	0.857	0.781	0.655	0.347	0.251	0.123	0.066
July	0.604	0.604	0.604	0.577	0.531	0.413	0.278	0.206	0.105	0.062
August	0.454	0.352	0.352	0.338	0.311	0.271	0.203	0.134	0.079	0.057
September	0.378	0.238	0.176	0.173	0.166	0.150	0.121	0.095	0.062	0.054

	EWR4-Final Rule Curves as percentage of MAR									
	10%	20%	30%	40%	50%	60%	70%	80%	90%	98%
October	0.312	0.247	0.246	0.238	0.222	0.205	0.153	0.127	0.064	0.040
November	1.720	0.863	0.500	0.422	0.350	0.340	0.222	0.139	0.084	0.059
December	1.968	1.968	1.958	1.236	1.061	0.899	0.774	0.536	0.116	0.045
January	2.757	2.688	2.514	2.096	1.830	1.084	0.598	0.530	0.165	0.058
February	19.835	18.533	16.435	5.507	3.156	1.839	1.090	0.580	0.162	0.058
March	8.081	8.066	7.140	5.298	3.625	2.004	1.389	0.644	0.265	0.076
April	1.971	1.971	1.964	1.833	1.717	1.524	0.963	0.571	0.128	0.059
May	0.728	0.728	0.726	0.691	0.628	0.570	0.436	0.245	0.128	0.049
June	0.585	0.585	0.584	0.552	0.503	0.423	0.224	0.162	0.079	0.043
July	0.403	0.403	0.403	0.384	0.354	0.275	0.185	0.137	0.070	0.041
August	0.302	0.235	0.235	0.225	0.207	0.181	0.135	0.089	0.053	0.038
September	0.244	0.153	0.113	0.112	0.107	0.097	0.078	0.061	0.040	0.035

	ERW5-Final Rule Tab (m3/s)									
	10%	20%	30%	40%	50%	60%	70%	80%	90%	98%
Oct	0.242	0.239	0.233	0.220	0.205	0.163	0.110	0.057	0.026	0.009
Nov	1.021	0.902	0.835	0.743	0.658	0.496	0.263	0.178	0.094	0.037
Dec	0.814	0.797	0.755	0.697	0.594	0.389	0.231	0.152	0.073	0.038
Jan	1.171	0.992	0.822	0.627	0.472	0.323	0.209	0.109	0.066	0.055
Feb	2.916	2.574	2.030	1.489	1.057	0.814	0.622	0.307	0.172	0.082
Mar	3.552	1.887	1.024	0.810	0.724	0.606	0.456	0.329	0.157	0.055
Apr	0.923	0.715	0.607	0.547	0.504	0.456	0.365	0.303	0.123	0.063
May	0.376	0.372	0.357	0.344	0.282	0.249	0.157	0.096	0.032	0.013
Jun	0.336	0.331	0.319	0.306	0.267	0.216	0.136	0.073	0.031	0.012
Jul	0.305	0.304	0.296	0.288	0.258	0.228	0.175	0.105	0.057	0.011
Aug	0.242	0.239	0.230	0.221	0.177	0.156	0.097	0.062	0.027	0.009
Sep	0.215	0.213	0.203	0.194	0.168	0.135	0.098	0.057	0.022	0.006

	EWR5-Final Rule Curves as percentage of MAR									
	10%	20%	30%	40%	50%	60%	70%	80%	90%	98%
Oct	0.683	0.675	0.656	0.620	0.578	0.459	0.310	0.162	0.073	0.026
Nov	2.785	2.461	2.278	2.027	1.795	1.353	0.717	0.486	0.256	0.101
Dec	2.294	2.248	2.129	1.966	1.674	1.097	0.653	0.428	0.206	0.107
Jan	3.301	2.795	2.317	1.767	1.329	0.909	0.590	0.307	0.185	0.154
Feb	7.426	6.553	5.168	3.791	2.691	2.074	1.585	0.781	0.437	0.209
Mar	10.013	5.320	2.887	2.283	2.041	1.708	1.285	0.927	0.443	0.155
Apr	2.518	1.951	1.656	1.492	1.375	1.244	0.996	0.827	0.336	0.172
May	1.060	1.048	1.007	0.970	0.796	0.703	0.443	0.270	0.092	0.038
Jun	0.917	0.904	0.870	0.836	0.728	0.589	0.370	0.200	0.084	0.033
Jul	0.861	0.856	0.836	0.813	0.728	0.644	0.495	0.296	0.161	0.031
Aug	0.682	0.673	0.649	0.622	0.500	0.440	0.274	0.176	0.075	0.026
Sep	0.586	0.580	0.555	0.530	0.459	0.368	0.266	0.156	0.059	0.017

	ERW6-Final Rule Tab (m3/s)									
	10%	20%	30%	40%	50%	60%	70%	80%	90%	98%
Oct	0.386	0.383	0.380	0.377	0.374	0.372	0.352	0.336	0.287	0.126
Nov	1.670	1.108	0.774	0.674	0.614	0.517	0.435	0.407	0.326	0.170
Dec	2.192	2.177	2.142	2.069	1.841	1.573	1.328	0.985	0.251	0.088
Jan	2.589	2.347	2.098	1.868	1.702	1.408	1.202	0.759	0.484	0.175
Feb	22.767	19.648	17.079	12.485	6.698	3.805	1.851	1.000	0.475	0.230
Mar	0.697	0.694	0.683	0.667	0.638	0.597	0.506	0.407	0.249	0.175
Apr	2.316	2.309	2.271	2.222	2.111	1.911	1.539	0.866	0.296	0.126
May	0.557	0.556	0.550	0.537	0.509	0.482	0.386	0.315	0.202	0.085
Jun	0.800	0.700	0.602	0.556	0.520	0.505	0.448	0.434	0.298	0.085
Jul	0.507	0.507	0.502	0.493	0.472	0.426	0.361	0.266	0.146	0.069
Aug	0.390	0.389	0.386	0.377	0.358	0.335	0.286	0.204	0.122	0.049
Sep	0.348	0.347	0.343	0.333	0.318	0.282	0.230	0.156	0.083	0.014

	ERW6-Final Rule Curves as percentage of MAR									
	10%	20%	30%	40%	50%	60%	70%	80%	90%	98%
Oct	0.189	0.188	0.186	0.185	0.183	0.182	0.172	0.165	0.141	0.062
Nov	0.792	0.525	0.367	0.320	0.291	0.245	0.206	0.193	0.154	0.081
Dec	1.074	1.067	1.050	1.014	0.902	0.771	0.651	0.483	0.123	0.043
Jan	1.269	1.150	1.028	0.915	0.834	0.690	0.589	0.372	0.237	0.086
Feb	10.077	8.696	7.559	5.526	2.965	1.684	0.819	0.443	0.210	0.102
Mar	0.341	0.340	0.335	0.327	0.313	0.292	0.248	0.200	0.122	0.086
Apr	1.098	1.095	1.077	1.054	1.001	0.906	0.730	0.411	0.140	0.060
May	0.273	0.273	0.269	0.263	0.249	0.236	0.189	0.155	0.099	0.042
Jun	0.379	0.332	0.286	0.264	0.246	0.240	0.212	0.206	0.141	0.040
Jul	0.249	0.248	0.246	0.241	0.231	0.209	0.177	0.130	0.072	0.034
Aug	0.191	0.190	0.189	0.185	0.175	0.164	0.140	0.100	0.060	0.024
Sep	0.165	0.165	0.162	0.158	0.151	0.134	0.109	0.074	0.040	0.006

	EWR7-Final Rule Tab (m3/s)									
	10%	20%	30%	40%	50%	60%	70%	80%	90%	98%
Oct	0.386	0.383	0.380	0.377	0.374	0.372	0.352	0.336	0.287	0.123
Nov	1.698	1.108	0.774	0.674	0.614	0.517	0.435	0.407	0.337	0.135
Dec	2.609	2.590	2.556	2.479	1.841	1.573	1.328	0.985	0.251	0.088
Jan	3.066	2.843	2.639	2.313	2.022	1.752	1.216	0.840	0.484	0.142
Feb	23.147	19.869	17.495	12.485	6.698	3.805	1.851	1.000	0.475	0.230
Mar	1.197	1.190	1.164	1.138	1.069	0.979	0.771	0.551	0.199	0.035
Apr	2.664	2.655	2.608	2.546	2.410	2.179	1.539	0.866	0.296	0.126
May	0.835	0.833	0.821	0.796	0.744	0.695	0.515	0.384	0.173	0.028
Jun	0.765	0.763	0.756	0.734	0.709	0.624	0.448	0.323	0.177	0.027
Jul	0.654	0.654	0.647	0.633	0.603	0.462	0.431	0.307	0.135	0.025
Aug	0.422	0.420	0.419	0.419	0.419	0.419	0.409	0.274	0.139	0.016
Sep	0.387	0.379	0.376	0.375	0.375	0.374	0.364	0.243	0.125	0.010

	EWR7-Final Rule Curves as percentage of MAR									
	10%	20%	30%	40%	50%	60%	70%	80%	90%	98%
Oct	0.184	0.183	0.181	0.180	0.178	0.177	0.168	0.160	0.137	0.059
Nov	0.784	0.511	0.357	0.311	0.283	0.239	0.201	0.188	0.155	0.062
Dec	1.244	1.235	1.219	1.182	0.878	0.750	0.633	0.470	0.120	0.042
Jan	1.462	1.356	1.258	1.103	0.964	0.835	0.580	0.401	0.231	0.068
Feb	9.970	8.558	7.535	5.377	2.885	1.639	0.797	0.431	0.205	0.099
Mar	0.571	0.568	0.555	0.543	0.510	0.467	0.368	0.263	0.095	0.017
Apr	1.229	1.225	1.204	1.175	1.112	1.006	0.710	0.400	0.137	0.058
May	0.398	0.397	0.392	0.380	0.355	0.332	0.246	0.183	0.083	0.014
Jun	0.353	0.352	0.349	0.339	0.327	0.288	0.207	0.149	0.082	0.012
Jul	0.312	0.312	0.308	0.302	0.288	0.220	0.206	0.147	0.064	0.012
Aug	0.201	0.200	0.200	0.200	0.200	0.200	0.195	0.131	0.066	0.007
Sep	0.179	0.175	0.174	0.173	0.173	0.173	0.168	0.112	0.058	0.005