water & forestry

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DIRECTORATE: RESOURCE DIRECTED MEASURES

LETABA CATCHMENT
RESERVE DETERMINATION STUDY –
ECOSPECS AND MONITORING REPORT
Final
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EXECUTIVE SUMMARY

The water shortages experienced in the Letaba Catchment area have led to intense competition for the available water resources between different sectors. 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.

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

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

Table A: 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 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.

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

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 A. 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) and initiate monitoring. 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 EWR sites 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 B: Summary of Ecological Reserve Monitoring Letaba catchment

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				

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 generic guidelines and Monitoring DSS developed were used as a template.
- The emphasis at the workshop was on identifying all the EcoSpecs linked to the required EC and the associated TPCs.
- The generic Monitoring DSS and generic guidelines were adjusted for the specific systems in parallel sessions during the workshops.
- A short report on the generic approaches to be made available for all the studies and serve as an appendix to the river specific monitoring reports.
- The river specific monitoring report places the emphasis on the EcoSpecs and TPCs and only on the generic Monitoring DSS and survey guidelines where these deviate.

The fish and invertebrates require no additional baseline monitoring at any of the EWR sites and the TPC monitoring can be initiated immediately at the prescribed frequency per EWR site.

The geomorphology at all EWR sites will require a short site visit to fully populate the Geomorphology Assessment Index (GAI) and initiate monitoring. This is due to the GAI model only having being developed after the field surveys for this study. A short time on site will be required to assess info requirements for perimeter resistance component of the GAI model.

The existing vegetation survey data needs to be converted to VEGRAI level 4 for EWR sites 1, 3, 4 and 5. 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. At EWR 6 and 7 the surveyed vegetation 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

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 a suite of indicator organisms (minimum 3).

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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

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 a comprehensive Reserve study was commissioned.

During the past decade the standard approach for Reserve (previously EWR) monitoring has been followed. This approach is summarised in the following steps and in more detail in Appendix A (Kleynhans and Louw 2006)

- A detailed programme of required surveys was identified for the baseline surveys.
- A detailed programme was designed for the long-term monitoring.
- A document was produced with the aim that this would provide guidance for the formulation of a TOR and implementation of the monitoring.

Since 1994, when the first Luvuvhu monitoring programme was designed, no monitoring programme has been implemented apart from a Berg River monitoring programme. Due to the lack of monitoring, little development and effort have taken place to refine the standard approaches.

The newest developments around monitoring have been:

- The design of a monitoring DSS for the Mhlathuze and Thukela Rivers. The Monitoring DSS is essential to ensure that the required response can be undertaken during monitoring and that one is not just undertaking monitoring for monitoring's sake (Appendix A);
- The incorporation of the concepts of TPCs in the monitoring linked to the Monitoring DSS and EcoSpecs.

1.2 APPROACH TO THE DESIGN OF THE LETABA ECOSPECS AND MONITORING PROGRAMME

For the current comprehensive studies a generic approach has been followed to identify the EcoSpecs, TPCs and a Reserve monitoring programme and this approach is adjusted for the case specific rivers (Kleynhans and Louw 2006, Appendix A).

The other developments during the recent years have been the development and extensive use of the EcoStatus models to provide Ecological Categories as part of the EcoClassification system. The use of these models during monitoring is essential and the link between the EC, the EcoSpecs and the TPCs must be defined.

The following steps were followed:

- Produce a generic guideline for the required surveys for baseline monitoring.
- Adjust the baseline generic guidelines for use for the specific rivers.
- Produce a generic guideline for the required surveys for long term monitoring.
- Adjust the longterm generic guidelines for use for the specific rivers.
- Formulate a generic approach to link EcoSpecs and TPCs to the EcoStatus models
- Base this approach on the FRAI and modify for generic approaches for the other models.
- Identify the specific EcoSpecs and TPCs for each EWR site in the different river systems.
- Establish links between RHP and the Reserve Monitoring (including technical levels, numbers of sites etc)
- Identify the approaches required (e.g. Level 3 EcoStatus) at sites other than the Reserve sites.

Refinement of the Monitoring DSS is required as well as specific links to the EcoStatus models is required. This will be undertaken as part of a dedicated Ecological Reserve Monitoring development study.

1.3 LETABA ECOSPECS AND MONITORING WORKSHOP

The Letaba EcoSpecs and monitoring workshop was held 17 to 18 January 2006.

The following approach was followed:

- The generic guidelines and Monitoring DSS developed by Kleynhans and Louw (2006) were used as a template.
- The emphasis on the workshop was on identifying all the EcoSpecs linked to the required EC and the associated TPCs.
- The Letaba River monitoring report places the emphasis on the EcoSpecs and TPCs and only on the generic Monitoring DSS and survey guidelines where these deviate.

2. APPROACH USED TO DETERMINE ECOSPECS AND MONITORING

This section is a summary from the Ecological Reserve Monitoring: Preliminary Generic Guidelines Kleynhans and Louw (2006) as part of a separate study and attached as Appendix A.

2.1 BACKGROUND OF ECOLOGICAL RESERVE MONITORING

It is understood that Ecological Reserve (ER) monitoring is a process which encompasses the following (Kleynhans *et al*., 2005 in Kleynhans and Louw, 2006):

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

The purpose of this type of monitoring is to measure and determine how the resource is changing over time, i.e. to measure the trend. Trend monitoring can be more rigorously approached by putting it into a management objective. This means that the objective will be to keep the resource in a particular REC. If the ecological category decrease over a period of time and the cause is unknown, more intensive monitoring or research may be initiated to determine the cause of the decrease. If a cause for decrease is suspected, appropriate management intervention may be indicated (Elzinga *et al*., 1998 in Kleynhans and Louw, 2006).

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;
- determine the required actions according to a Monitoring DSS to be followed if the ecological objectives are not being met.

This concept of "adaptive management" involves a cycle of monitoring progress by reviewing whether set objectives are achieved. If these objectives are not met an alternative management strategy is implemented. This process is illustrated in Figure 2.1.

Monitoring under the adaptive management framework will provide new insights into ecosystem functioning and structure. As with the EcoStatus, the biota, specifically instream, will be the indicators used during monitoring to detect problems. The instream biota (macro-invertebrates in particular) usually respond rapidly to any significant driver changes.

2.1.1 Ecological Specifications (EcoSpecs)

EcoSpecs are derived from Resource Quality Objectives (RQOs) as per the Resource Directed Measures (RDM) and 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.

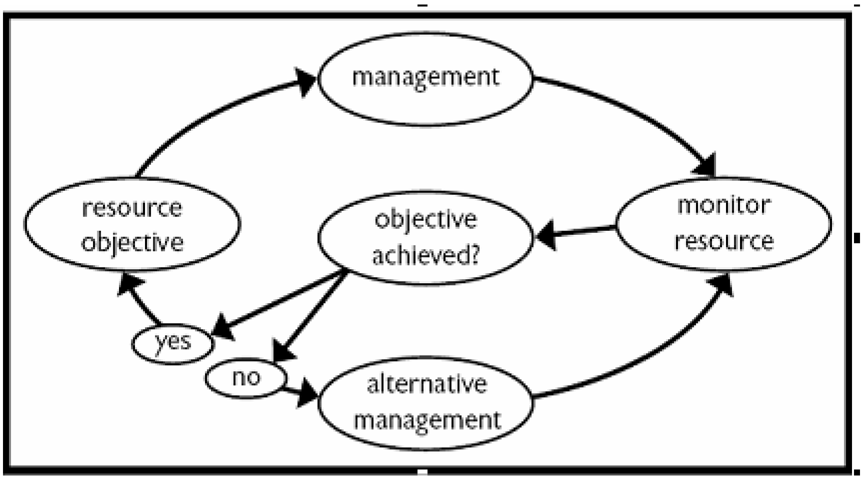


Figure 2.1: The adaptive management cycle. Monitoring provides the critical link between objectives and adaptive (alternative) management (from: Elzinga *et al*., 1998 in Kleynhans and Louw, 2006).

Burton and Gerritsen (2003) specify that biomonitoring for Ecological Reserve purposes is the formulation of biocriteria that are numerical values or narrative statements that define a desired biological condition for a water body (Kleynhans and Louw, 2006).

2.1.2 Threshold of Potential Concern (TPC)

TPCs are upper and lower levels along a continuum of change in selected environmental indicators. When this level is reached (or when modelling predicts it will be reached), it prompts an assessment of the causes of the extent of the change. The assessment provides the basis for deciding whether management action is needed or recalibrates the TPC. TPCs provide management with strategic goals or endpoints within which to manage the system. They form the basis of an inductive approach to adaptive management, as they are invariably hypotheses of limits of acceptable change in ecosystem structure, function and composition. As such their validity and appropriateness are always open to challenge and they must be adaptively modified as understanding and experience of the system being managed increases" (Rogers and Bestbier, 1997 in Kleynhans and Louw, 2006).

2.1.3 Baseline investigation requirements

Under Ecological Reserve Monitoring change is measured against the baseline standard, which indirectly implies a change from reference.

Before baseline assessment and reserve monitoring is undertaken, it is assumed that the Ecological Reserve has been determined through the process of EcoClasssification (PES, EIS, REC, alternative EC's), determining the management class, deciding on whether the reserve can be implemented, converting the management class to ecological categories for all driver and response components and determining the ecological responses to the selected flow scenario.

The usefulness of the baseline data collected can be used to formulate preliminary EcoSpecs and TPCs. The preliminary values may be refined once data has been collected specifically for baseline purposes. Relative confidences for each of the components (driver and responses) will be specified according to a descriptive numerical scale as outlined in Appendix A.

Site specific information (number and location of sites, number and time of surveys, sampling techniques, analytical methods, purpose) is standardised per component. Guidelines for collecting baseline data for each driver and response component is described in Appendix A, Chapter 2).

Collating existing data per driver and response components relating specifically to; 1) where data is available (spatial and temporal context), 2) during which season it was collated and, 3) the techniques used is extrapolated through answering a set of component specific questions. These questions are evaluated using the following ratings:

- Very high = 1
- High = 2
- Moderate = 3
- Low = 4
- Very Low = 5

The overall purpose is to estimate the confidence in the response of fish, aquatic invertebrates and riparian vegetation (response components) assemblages according to driver changes that occur. Data is considered adequate and sufficient to construct a baseline when criteria as set out in Appendix A, Chapter 2.4.4 to 2.4.6. are satisfied at a confidence level of at least moderate.

Ecological Reserve Monitoring can only be initiated once the Baseline has been formulated at least at a moderate level of confidence for the drivers and the instream biological responses. It is assumed that the Ecological Reserve has been determined through the process of EcoClasssification (PES, EIS, REC, alternative EC's), determining the management class, deciding on whether the reserve can be implemented, converting the management class to ecological categories for all driver and response components and determining the ecological responses to the selected flow scenario (output of the classification system).

2.2 DETERMINING ADEQUACY OF EXISTING DATA

The first step is to collate all data to determine

- where it is available (spatial and temporal context);
- during which season it was collated;
- the techniques used.

2.2.1 Driver: Hydrology

It is accepted that the Reserve flow requirements (in terms of modified flow regime characteristics) were determined from a combination of a natural hydrological signal, the hydraulic characteristics of the site and the ecological specialists' interpretation of the habitat requirements of biota. It is further assumed that the Reserve flow requirements are defined as a set of Reserve assurance rules (frequency of occurrence tables of flow rates or volumes for the different months of a year) and that the future month-by-month, or day-by-day flows that are required will be determined by an equivalent time series of natural flows. In this context 'equivalent' means that the future (used during monitoring) and historical (used during the Reserve determination) natural flow signals should be stationary.

2.2.2 Driver: Water Quality

The aim is to determine how suitable and reliable (i.e. in terms of confidence) the physico-chemical data is for the interpretation of biological responses and determining whether water quality is a problem. The assessment of the current water quality data was undertaken per site using a standard set of questions as prescribed in Kleynhans and Louw (2006).

A summary of the output of the Letaba Reserve study used for the development of the monitoring protocol is indicated in Table 2.1.

Table 2.1: Water quality information generated during the Letaba Reserve study

EWR Site	Overall PES	WQ PES *	WQ category for MC	Ecological Category		
				REC	Alternatives	
1	**C**	B	**B**	**C**	N/A	D
2	**D**	C	**C**	**D**	N/A	N/A
3	**C/D**	C	**C**	**C/D**	C	D
4	**C/D**	C	**C**	**C/D**	N/A	D
5	**C**	B – B/C	**B/C**	**C**	D	N/A
6	**C**	C	**B/C**	**C**	D	B
7	**C**	C	**B**	**C**	D	B

*: using the assessment based on the EcoClassification manual (Kleynhans *et a*l., 2005).

The information presented in the monitoring protocol per EWR site includes the following:

- An assessment of confidence in the baseline water quality data (shown on attached spreadsheet), e.g. position and number of monitoring points, length of data record, variables monitored, and the understanding of water quality impacts in the system.
- A table of EcoSpecs, TPC and monitoring frequency
- Notes on water quality around the EWR site
- A PAI rating table showing the importance rating of physico-chemical metrics at the EWR site. The *rank* (a rank of 1 or 2 indicates a high contribution to overall water quality category) and related *%wt* columns determine the significance or contribution of the water quality variable to the overall water quality category of the site (and is therefore site-specific).
- Short conclusion identifying primary monitoring requirements

The following general procedure should be adopted in selecting variables for Ecological Reserve monitoring:

- Ongoing monitoring and comparison against TPCs in an iterative adaptive management process will indicate whether monitoring of selected variables should be discontinued or the frequency adapted.
- If conditions at the site (e.g. a pollution event or significant change in land-use) and / or the *site-specific weighted rating* (see PAI rating tables) indicate a variable to be of

high significance, more frequent monitoring may be required. Alternatively, if there is little change in a monitored variable, less frequent monitoring can be undertaken.

- The water quality monitoring point to be used for collecting data should be the same site used for setting the water quality baseline. This monitoring point is shown on the Ecospec and TPC table per EWR site. The water quality monitoring point should be selected so as to reflect the water quality conditions at the monitoring site.
- Monitoring currently being undertaken by DWAF does not include temperature, dissolved oxygen, Chl-*a*: periphyton, turbidity or toxics (other than fluoride).
- The appropriate set of parameters to be monitored must reflect activities at the site. The minimal set of parameters are as follows:

  - Physico-chemical variables: pH, EC/TDS, DO, temperature, turbidity / water clarity
  - Nutrients: nitrate, nitrate, ammonium and ortho-phosphate

Highly recommended additional variables are the recommended suite of 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 a suite of indicator organisms (minimum 3).

Limited information is currently available for toxics, with only fluoride being regularly monitored by DWAF. Note that the TPC for metals such as copper, cadmium and lead is dependent on the hardness of the water. Hardness levels (categories shown below) must therefore be calculated before metal data can be interpreted.

- Soft water: < 60 mg/L $CaCO_3$
- Moderately hard water: 60 – 119 mg/L $CaCO_3$
- Hard water: > 120 mg/L $CaCO_3$

2.2.3 Driver: Geomorphology

Information required prior to commencement of monitoring process:

1. Geomorphological zonation of stream from source to mouth
2. General catchment information:
   - Catchment size
   - Landuse and landuse history
   - Schematic diagram including positions of sites relative to tributary junctions, towns, major developments (e.g. sewage works), etc. Diagram needn't be to scale.
   - Rainfall record
3. At least one geomorphic assessment (at least for each EWR site, but preferably for reaches in each geomorphic zone) by a specialist. The assessment should preferably comprise an assessment using the GAI as well as additional descriptive data with regards to the following at the EWR sites:
   - Bed material size distribution (quantitative)
   - Date of construction of major impoundments
   - Cross-sectional data (for EWR sites)
   - Flood history, where possible
4. Photographs taken at each site.

The overall purpose would be to estimate the confidence in the geomorphological information and the geomorphological response to hydrological and catchment changes. Data is considered adequate and sufficient to construct a baseline when criteria (in tables supplied in Appendix A, Kleynhans and Louw 2006) are satisfied at a confidence level of at least moderate.

2.2.4 Biological Response (Fish, invertebrates and riparian vegetation)

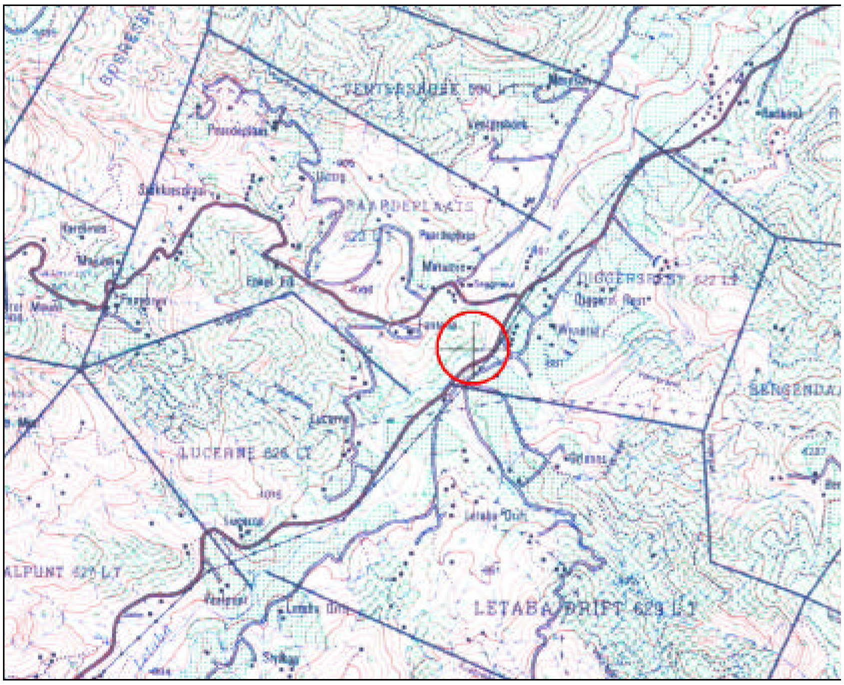
The overall purpose would be to estimate the confidence in the response of the fish, invertebrate and riparian assemblage according to driver changes that occur. data is considered adequate and sufficient to construct a baseline when criteria (in the tables supplied in Appendix A, Kleynhans and Louw 2006) are satisfied at a confidence level of at least moderate.

3. RESOURCE UNIT A – EWR SITE 1: APPEL

3.1 SITE DESCRIPTION

EWR 1 is located between Ebenezer and Tzaneen Dams. There are three weirs between the dams are all small structures and there purpose is to divert water for abstraction for irrigation and water supply to Tzaneen Municipality. The land use upstream is dominated by exotic afforestation with smaller areas of subtropical fruit tress closer to the site. These weirs were not considered important enough to subdivide this Resource Unit (RU). The Tzaneen Dam due to its large size and being in stream it makes a logical end point to this RU.

Locality: S23 55 03.7; E30 03 03.0



EWR 1

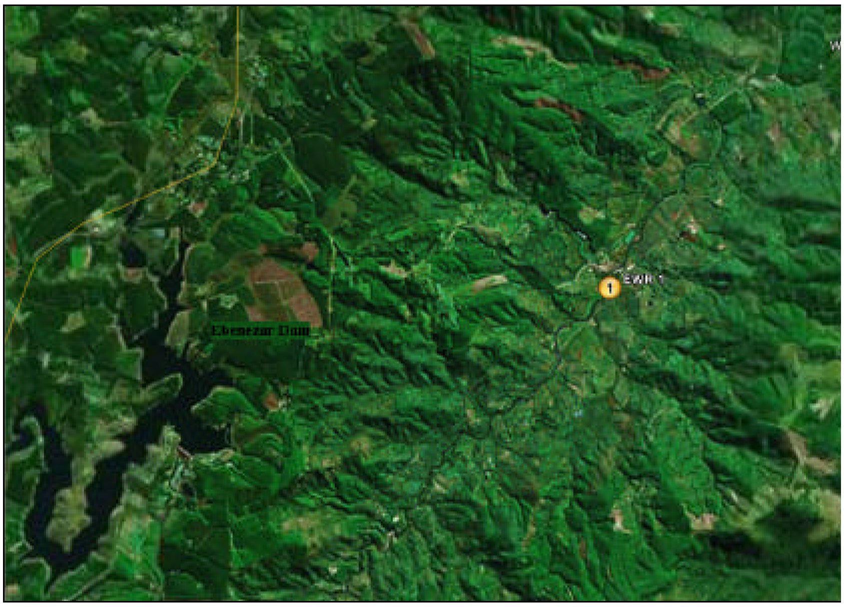


Figure 3.1: Map of EWR 1 (taken from 1:50 000 scale map) as well as from Google .earth

3.2 BASELINE REQUIREMENTS

The limitations and confidence in the available data for each component at EWR 1 are summarised in the following tables.

Geomorphology

1. Spatial data	**Very High**	Only one site in resource unit but is representative and relatively unimpacted (by direct impacts)
2. Temporal field data	**Very low**	No previous field surveys.
3a. Temporal remote data (availability of aerial photographs)	**Very high**	Very good aerial photo record available (from 1938 until recent)
3b. Anecdotal/historical info on land use and flows	**High**	Long flow record and good modelled flows available at a gauge station close to the site
4. Monitoring assessment method	**High**	Assessment by geomorphological specialist
5. Environmental Change		No significant change since last survey.
Conclusion	**A site visit is required to fully populate the GAI and initiate monitoring (The GAI model was developed after the field surveys for this study. Time on site will be required to assess info requirements for perimeter resistance component of the GAI model).**	

Water quality

1. Number of WQ stations	**Very High**	Several DWAF water quality monitoring stations within Resource Unit
2. Locality of WQ stations	**Very High**	Two WQU in Resource Unit. Water quality data available above and below EWR site
3. Adequacy of data	**Very High**	Water quality data from a single site (B8H014Q01) can be used for both PES and RC.
4. Frequency of sampling	**High**	Minimum of monthly samples for 3 years available for RC and 5 years for PES.
5. Appropriate parameters	**High**	No dissolved oxygen, turbidity, temperature or Chlorophyll-a data available
6. Understanding of impacts	**Low**	No instream toxicity tests undertaken. SASS and fish surveys have been undertaken at this site.
7. Interpreting biological responses	**High**	No instream toxicity tests undertaken. SASS and fish surveys have been undertaken at this site as well as the RHP is using this site for assessments of the state of the catchment.
Conclusion	**No further baseline data needed, unless there is a significant change in environmental conditions, prior to the initiation of monitoring.**	

Riparian vegetation

1. Spatial data	**High**	One survey only, detailed data available from EWR Site only which is representative of the Resource Unit
2. Temporal data	**Moderate to Low**	One site visits in 2004 and aerial photo record (although relatively low resolution) back to 1930's
3. Interpretive characteristics	**Moderate**	*Breonardia salicina in all zones* and certain hydrophytic grasses including *Leersia hexandra*in the marginal zone
4. Quality of assessment	**Very High**	Interim model of VEGRAI was used. Habitat Integrity assessment undertaken. Riparian vegetation specialist did survey
5. Data sources	**High**	Aerial photos and video. Local knowledge. Landcover data
6. Environmental Change	**High**	No significant change since last survey
Conclusion	**No additional survey needed, prior to the initiation of monitoring, as EWR site is representative. Data needs to be converted to VEGRAI level 4.**	

Fish

RHP surveys conducted: 2000 and 2003 for the entire Letaba catchment.

1. Spatial data	**High**	Historical data available at this site and through the resource unit, collected by University of the North and Limpopo Environmental Affairs as part of the RHP.
2. Temporal data	**High**	Periodic sampling by Limpopo Province over the past 15 years
3. Interpretive characteristics	**Very high**	High proportion of species considered to be good indicators of flow and water quality. Remaining species present have well-documented ecological requirements.
4. Environmental Change		No significant change since last survey. Ebenezer Dam has not changed operational procedures although upper catchment runoff has been seriously modified due to forestry and other management practices.
Conclusion	*** No further baseline data needed, unless there is a significant change in environmental conditions. prior to the initiation of monitoring.**	

Aquatic invertebrates

1. Spatial data	**Very High**	Historical data available at different sites between the dams
2. Temporal data	**High to Moderate**	More than 15 years ago, irregular, Chutter, RHP and 2 surveys as part of this study
3. Interpretive characteristics	**High to Moderate**	*Tricorythidae* and *Perlidae, Heptageniidae* found at this site
4. Environmental Change		No significant change since last survey. Ebenezer Dam has not changed operational procedures
Conclusion	**No further baseline data needed, unless there is a significant change in environmental conditions, prior to the initiation of monitoring**	

3.3 ECOSPECS AND TPCS

The Ecological Categories (ECs) associated with the EcoSpecs are provided in Table 3.1. The EcoSpecs and Thresholds of Potential Concern (TPCs) for each component for the ECs as in Table 3.1 are provided in the sections below.

Table 3.1: Driver and response results for PES, REC and Eco Status for EWR 1.

Driver Components	PES	REC	EcoSpecs
Hydrology	**C**	**C**	**C**
Geomorphology	**C**	**C**	**C**
Water quality	**B**	**B**	**B**
Response Components			
Fish	**C**	**C**	**C**
Aquatic invertebrates	**C/D**	**C/D**	**C/D**
Riparian vegetation	**C**	**C**	**C**
EcoStatus	**C**	**C**	**C**

3.3.1 Water quality (Category B)

The area around the EWR site is predominantly forested (*Eucalyptus* and *Pinus* species), with water abstracted for irrigation (cultivated lands – bananas, mangoes and tea plantations) and rural / urban settlements. Impacts relate to the site being downstream of the Ebenezer Dam, although the upstream section of river is considered to be in a relatively good state. Analysis of data and consultation with other specialists suggest the following potential water quality issues[1] at EWR 1:

[1] Potential issues provide motivation for rating scores.

- Nutrient elevation, particularly periphyton.
- Potential increases in oxygen, turbidity and temperature, which will be impacted more during low flows, although the conditions at Appel are relatively fast-flowing for most of the year.
- SRP may increase during high flows due to wash-off etc.

Table 3.2 is the PAI rating table for the EWR site, showing the comparative importance of physico-chemical metrics and the contribution of each metric to the water quality condition at the site, while Table 3.2 lists the EcoSpecs and TPCs. From the weighted scores in the PAI table, it can be seen that the temperature, nutrients and oxygen would be the key variables to monitor.

Table 3.2: PAI rating table for EWR 1

SCORING GUIDELINES	EWR1		Scenario: Present		
Physico-chemical Metrics	Rank	%wt	Rating	Weight	Weighted score
pH	5	40	0.00	0.07	0.00
SALTS	2	95	0.00	0.17	0.00
NUTRIENTS	2	95	2.00	0.17	0.35
TEMPERATURE	3	85	1.00	0.15	0.15
TURBIDITY	4	50	1.00	0.09	0.09
OXYGEN	3	85	1.00	0.15	0.15
TOXICS	1	100	0.00	0.18	0.00
TOTALS		550			0.75
PHYSICO-CHEMICAL PERCENTAGE SCORE					85.09
PHYSICO-CHEMICAL CATEGORY					B

Table 3.3: EcoSpecs and TPC table for EWR 1

River	Groot Letaba River: Grysappel			
Monitoring Site	B8H014Q01			
EWR Site	1			
EcoSpecs		**TPC**		**Monitoring Frequency**
Inorganic salts	$MgSO_4$	95th percentile of data must be less than the TPC	16 mg/L	Monthly
	Na_2SO_4		20 mg/L	
	$MgCl_2$		15 mg/L	
	$CaCl_2$		21 mg/L	
	NaCl		45 mg/L	
	$CaSO_4$		351 mg/L	
Nutrients	SRP	50th percentile of data must be less than the TPC	0.017 mg/L	Monthly
	TIN		0.129 mg/L	
Physical variables	pH (pH units)	95th percentile of data must be less than the TPC	6.5 to 8.0	Monthly
	Temperature		Vary by not more than 2º C	
	Dissolved oxygen		7 – 8 mg/L	
	Turbidity (NTU)		Small change allowed – largely natural and related to natural catchment processes such as rainfall runoff.	
	Chl-a: periphyton	50th percentile of data must be less	21 mg/m²	Quarterly

<table>
<tr><td>River</td><td colspan="4">Groot Letaba River: Grysappel</td></tr>
<tr><td>Monitoring Site</td><td colspan="4">B8H014Q01</td></tr>
<tr><td>EWR Site</td><td colspan="4">1</td></tr>
<tr><td colspan="2">EcoSpecs</td><td colspan="2">TPC</td><td>Monitoring Frequency</td></tr>
<tr><td rowspan="2">Response variables</td><td>Chl-a: phytoplankton</td><td>than the TPC</td><td>15 µg/L</td><td></td></tr>
<tr><td>In-stream toxicity</td><td>In-stream toxicity should not occur</td><td>Any indication of in-stream toxicity</td><td>In response to a biotic trigger</td></tr>
<tr><td rowspan="6">Toxics #</td><td>Fluoride</td><td rowspan="6">95^{th} percentile of data must be less than the TPC</td><td>1500 µg/L</td><td rowspan="6">Monthly</td></tr>
<tr><td>Ammonia</td><td>15 µg/L</td></tr>
<tr><td>Al</td><td>20 µg/L</td></tr>
<tr><td>Cu soft*</td><td>0.5 µg/L</td></tr>
<tr><td>Cu mod**</td><td>1.5 µg/L</td></tr>
<tr><td>Cu hard***</td><td>2.4 µg/L</td></tr>
</table>

Note that current monitoring conducted by DWAF does not include aluminium, copper or any toxics other than fluoride.

Water quality monitoring should include the following parameters not currently monitored at this site:

- Temperature, dissolved oxygen, turbidity / clarity: particularly important during low flows
- In-stream toxicity: only in response to a biotic trigger
- Chl-a: Periphyton: important as nutrient elevations expected during low flows
- Toxics related to wash-off and domestic use: F, ammonia, Al and Cu

3.3.2 Invertebrates

The preliminary EcoSpecs for invertebrates for EWR are indicated in Table 3.4.

Table 3.4: Invertebrate EcoSpecs and Thresholds of Probable Concern (TPC) for EWR1 (Appel), for Category C/D.

PRELIMINARY EcoSpecs	TPCs
• To ensure that the SASS5 scores and ASPT values occur in the following range: SASS5 score 100 to 140; ASPT 6.0 to 6.5	• The SASS5 score < 110 and ASPT < 6.0.
• To ensure that the MIRAI score is within the range for Category C/D (ie: 58 to 62).	• The MIRAI score <58.
• To ensure that no group consistently dominates the fauna, defined as D abundance for more than two consecutive surveys.	• Any taxon abundance 'D' (> 1000) in two consecutive surveys.
• To maintain suitable conditions for the following flow-dependent species in the SIC biotope: *Perlidae Present *Heptageniidae Present *Tricorythidae: Abundance B *Hydropsychidae - 2 species: Abundance B	• Perlidae absent from two consecutive surveys • Heptageniidae absent from two consecutive surveys • Tricorythidae absent from any survey • Hydropsychidae <2 species or absent in two consecutive surveys.
• To maintain suitable conditions for the following five key taxa: * Baetidae * Perlidae	• Less than three of the five key taxa listed.

PRELIMINARY EcoSpecs	TPCs
* Tricorythidae * Heptageniidae * Hydropsychidae	

3.3.3 Geomorphology

Morphological change is the metric at EWR 1 that has the highest weighted score and by monitoring for it the active channel at this site will be maintained (Table 3.5).

Table 3.5: Geomorphology EcoSpecs and Thresholds of Probable Concern (TPC) for EWR1 (Appel).

METRIC	ECOSPECS	TPCs
	HYDRAULIC GEOMETRY	
Reach Type	Maintain pool depth and dominant in-channel morphological unit	TPC reached if the pools on the cross-sections infill (with sediment) by more than 50% and/or there is a change from pool-riffle to run characteristics at the site *(Assess through resurveying of cross-sections at 5 year intervals and after any extreme flood or drought events).*
Cross-section Shape	Maintain channel width	Narrowing of the active channel by more than 20% on the cross-sections. *(Assess through resurveying of cross-sections at 5 year intervals and after any extreme flood or drought events).*

The main issue at this site in terms of geomorphology is the narrowing of the active channel and reduction in potential bed material transport (by approximately 61%). In historical times, the active channel width has reduced by more than 50%, and this narrowing began when the upstream Ebenezer Dam was completed. The objective for the TPCs is to maintain the width and depth of the current channel condition, despite the reduction in peak flows and sediment transport caused by Ebenezer Dam.

3.3.4 Fish

The rationale for the metric groups, metrics and species for monitoring are specified below and Table 3.6:

- Velocity-depth and cover are the most important metrics for EWR 1.
- For velocity-depth, Fast-Shallow is the most important aspect and *Amphilius uranoscopus* (AURA), and *Chiloglanis pretoriae* (CPRE) were selected as the indicator species at this EWR site.
- For cover, substrate was ranked the most important and AURA and CPRE were selected again. Overhanging vegetation was also evaluated and *Barbus eutaenia* (BEUT) was used in this case.

Fish EcoSpecs (preferences / intolerances relating to frequency of occurrence) and TPCs are provided in Table 3.7 and Table 3.8.

Table 3.6: Metric groups, metrics and species for monitoring fish at EWR 1.

Fish EC Metric Groups	Metric Group: Calculated Rating	Weighted Rating For Group	Rank Of Metric Group	% Weight For Metric Group
Velocity-Depth Metrics	82.1	18.7	1	100
Cover Metrics	66.8	15.2	1	100
Flow Modification Metrics	72.6	14.9	2	90
Migration Metrics	46.4	8.4	2	80
Physico-Chemical Metrics	81.6	13.0	3	70
Impact Of Introduced Spp (Negative)	0	0	5	0
	5			440
FRAI (%)			70.10	
EC: FRAI			C	

Table 3.7:– Fish EcoSpecs for Site EWR 1.

FS			Marg veg			Substrate		
SPP	PREF: FREQ	RANK	SPP	PREF: FREQ	RANK		PREF: FREQ	RANK
CPRE	0.98	1	TSPA	0.72	1	AURA	1	1
AURA	0.92	2	BPAU	0.504	2	CPRE	0.98	2
BMAR	0.704	3	BEUT	0.492	3	BMAR	0.72	3
LCYL	0.576	4	BTRI	0.468	4	LCYL	0.588	4
BEUT	0.564	5	BNEE	0.468	4	BNEE	0.528	5
LMOL	0.344	6	BVIV	0.392	6	BEUT	0.492	6
AMOS	0.264	7	PPHI	0.36	7	AMOS	0.392	7
			MMAC	0.304	8	LMOL	0.376	8
			PCAT	0.264	9	AMAR	0.168	9
			MACU	0.248	10	BLIN	0.156	10
			BUNI	0.184	11			

Table 3.8: Site EWR 1 – Fish TPCs

Species	Reference frequency of occurrence	Present,observed & habitat derived frequency of occurrence	TPCs % for PES	Motivation
AURA	5	5	80	A minimum of 5 specimens should be sampled at 80% of sites during a survey of FS and FD substrate habitat using a shocker for periods not less than 20 minutes.
BEUT	3	2	25	A minimum of 5 specimens should be sampled at 25% of sites during a survey of MV and substrate habitat using a shocker for periods not less than 20 minutes or a hand seine / 4m pole seine for 10 sweeps.
CPRE	5	5	100	A minimum of 20 specimens should be sampled at 100% of sites during a survey of FS and

Species	Reference frequency of occurrence	Present,observed & habitat derived frequency of occurrence	TPCs % for PES	Motivation
				FD substrate habitat using a shocker for periods not less than 20 minutes.

3.3.5 Riparian vegetation

The Riparian vegetation EcoSpecs and TPCs for EWR1 are indicated in Table 3.9.

Table 3.9: Riparian vegetation EcoSpecs and Thresholds of Probable Concern (TPC) for EWR1 (Appel).

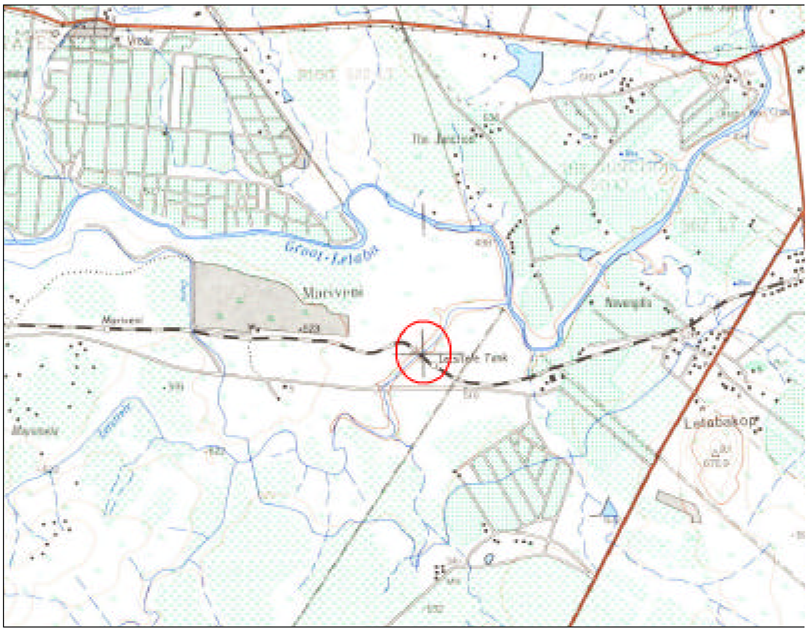
METRIC GROUP	METRIC	ECOSPECS	TPCs
Marginal zone	Vegetation abundance	▪ Maintain marginal hydrophyte fringe along the active channel – motivation fish and marginal habitat. ▪	▪ Marginal fringe absent
	Vegetation cover	▪ Maintain marginal hydrophyte fringe along the active channel.	▪ Marginal fringe absent
	Species richness	▪ Maintain a marginal fringe component.	▪ Cover and abundance is more important than number of species
	Species composition	▪ Maintain the marginal hydrophyte zone	▪ Noticeable increase in exotic weedy herbaceous species ▪ Absence of indigenous marginal macrophytes - motivation should always have a narrow marginal zone present along the active channel
Lower riparian zone	Vegetation cover	▪ Maintain *Breonardia salicina* abundance and cover - motivation key bedrock riparian tree. ▪ Maintain *Syzigium cordatum* abundance and cover - motivation key riparian tree in this section of river. ▪ *Arunda donax* cover should ideally be decreased but even maintaining the existing cover will suffice – motivation exotic invasive	▪ Measurable decrease in *Breonardia salicina* of 50% ▪ Measurable decrease in *Syzigium cordatum* of 50% ▪ A 50% or greater increase in the cover of *Arunda donax* or any other alien invasive riparian woody species
	Species richness	▪ Maintain a marginal fringe component.	▪ Cover and abundance is more important than number of species
	Species composition	▪ Maintain *Breonardia salicina* ▪ Maintain *Syzigium cordatum*	▪ Measurable decrease in *Breonardia salicina* of 50% ▪ Measurable decrease in *Syzigium cordatum* of 50%
	Vegetation structure	▪ Maintain *Breonardia salicina* population in the lower riparian zone	▪ Absence of a range of age classes of *Breonardia salicina*
Upper riparian zone	Vegetation cover	-	-
	Species richness	▪ Maintain terrestrial – riparian species mix - motivation preventing terrestrialisation of the upper zone	▪ When the proportion of terrestrial species reaches 50% of the total species count

4. RESOURCE UNIT B: LESITELE EWR 2

4.1 SITE DESCRIPTION

This EWR site is situated on the Letsitele River, which is a tributary of the Letaba River, and is not unregulated, although there is a small dam on the Thabina tributary. The river channel at this site is largely degraded due to erosion and local sources of water quality pollution. The Letsitele River (EWR 2) is highly modified to a PES of D. The site is in a highly disturbed area and extends below a railway bridge. A DWAF gauging weir occurs just upstream which allows accurate measurement of flow. The main impacts on water quantity and water quality at this site are upstream stream flow reduction (forestry) and a township with no formal sewer system immediately upstream

Locality: S23 53 17.0; E30 21 40.5



EWR 2

Figure 4.1: Map of EWR 2 (taken from 1:50 000 scale map) as well as from Google .earth

4.2 BASELINE REQUIREMENTS

The limitations and confidence in the available data for each component at EWR 2 are summarised in the following tables.

Geomorphology

1. Spatial data	Moderate	One site in resource unit which is fairly representative, but site is highly impacted
2. Temporal field data	Moderate	Previous field survey conducted at site as part of earlier EWR assessment
3a. Temporal remote data (availability of aerial photographs)	High	Very good aerial photo record available (from 1938 until recent), but some at a scale that are not useful for analysis
3b. Anecdotal/historical info on land use and flows	Moderate	Long flow record and good modelled flows available at a gauge station close to the site, catchment landuse change information is limited.
4. Monitoring assessment method	High	Assessment by geomorphological specialist
5. Environmental Change		No significant change since last survey.
Conclusion	**A site visit is required to fully populate the GAI and initiate monitoring (The GAI model was developed after the field surveys for this study. Time on site will be required to assess info requirements for perimeter resistance component of the GAI model).**	

Water quality

1. Number of WQ stations	Very High	One water quality site above the EWR site and a water quality monitoring point in the upper RU.
2. Locality of WQ stations	Very High	Two WQU in Resource Unit. Water quality data available above the EWR site
3. Adequacy of data	Very High	Single sites water quality data used for RC and PES
4. Frequency of sampling	Very High	Minimum of monthly samples available for 3 years for RC and 5 years for PES.
5. Appropriate parameters	High	
6. Understanding of impacts	Low	
7. Interpreting biological responses	High	No instream toxicity tests undertaken. SASS and fish surveys have been undertaken at this site as well as the RHP is using this site for assessments of the state of the catchment.
Conclusion	*** No further baseline data needed, unless there is a significant change in environmental conditions, prior to the initiation of monitoring.**	

Invertebrates

1. Spatial data	Very High	Chutter sampled a site upstream as well as at the site, RHP and two surveys as part of this study
2. Temporal data	High to Moderate	Data available for more than 15 years but irregular survey frequency
3. Interpretive characteristics	High to Moderate	*Cheumatopsyche thomasetti*, *Hydropsyche longifurca*, *Amphisyche scottae*, *Tricorythidae* and *Philopotamidae*
4. Environmental Change		No significant change since last survey.
Conclusion	**No further baseline data needed, unless there is a significant change in environmental conditions, prior to the initiation of monitoring.**	

Fish

1. Spatial data	Very high	Extensive data collections made by TPA, Gazankulu Nature Conservation and later by Limpopo Environmental Affairs as part of the RHP.
2. Temporal data	High	Extensive data collections made by TPA, Gazankulu Nature Conservation and later by Limpopo Environmental Affairs as part of the RHP. Several sites along the Letsitele were surveyed during this period.
3. Interpretive characteristics	High	Good species numbers (13) and indicators of different flow regimes
4. Environmental Change		Significant change in upper catchment runoff, numerous farm dams and impacts to water quality through rural settlements.
Conclusion	*** No further baseline data needed, unless there is a significant change in environmental conditions, prior to the initiation of monitoring.**	

Riparian vegetation

1. Spatial data	Moderate to Low	Not assessed due to perceived impact of back flooding. Used Kemper 1994 survey profile and data
2. Temporal data	Moderate to Low	Kemper 1994 survey and none since
3. Interpretive characteristics	Low	*Lower riparian Combretum erythrophyllum* and *Ficus sycomorus* and left bank with *Acacia polyacantha. Diospyros mespiliformis* on upper bank
4. Quality of assessment	Moderate to Low	Riparian IHI Habitat Integrity assessment undertaken
5. Data sources	High	* Aerial photos and video. * Local knowledge * Landcover data
6. Environmental Change	Low	Changes were clearly evident since last survey due to 2000 floods
Conclusion	**Need to do survey using VEGRAI level 4 and conclude uncertainty of back flooding impacts, prior to the initiation of monitoring**.	

4.3 ECOSPECS AND TPCS

The Ecological Categories (ECs) associated with the EcoSpecs are provided in Table 4.1. The EcoSpecs and Thresholds of Potential Concern (TPCs) for each component for the ECs as in Table 4.1 are provided in the sections below.

Table 4.1: Driver and response results for PES, REC and Eco Status for EWR 2.

Driver Components	PES	REC	EcoSpecs
Hydrology	**C**	**C**	**C**
Geomorphology	**D/E**	D	D
Water quality	**C/D**	C/D	C/D
Response Components			
Fish	**C**	C	C
Aquatic invertebrates	**D/E**	D	D
Riparian vegetation	**D/E**	D	D
EcoStatus	**D**	D	D

4.3.1 Water quality (category B)

Landuse activities in the upper catchment focus on irrigation agriculture, namely citrus plantations (mangos and bananas) and afforestation. Landuse in WQU 9, where EWR 2 is situated, is predominantly urban/domestic water use with little cultivated lands. The Nkowankowa Sewage Treatment Works is situated in this area. Abstraction for agricultural purposes and solid waste pollution also occurs. Analysis of data and consultation with other specialists suggest the following potential water quality issues at EWR 2:

- Increased SRP with increased flow due to wash-off etc.
- Increased periphyton with decreased flow, which will also result in increased turbidity.

Due to low flows much of the year, temperature and oxygen impacts are anticipated. Table 4.2 is the PAI rating table for the EWR site, showing the comparative importance of physico-chemical metrics and the contribution of each metric to the water quality condition at the site, while Table 4.3 lists the EcoSpecs and TPCs.

Taking into account the ranking, rating and the resultant weighted score the suggested water quality monitoring Eco specs and TPCs for EWR 2 are indicated in Table 4.3. The water quality monitoring should include the following parameters not currently monitored at EWR 2:

- Temperature, dissolved oxygen (DO), turbidity / clarity: Temperature and DO elevations particularly important during low flows
- In-stream toxicity: in response to a biotic trigger, but at least twice a year during high (impacts due to wash-off) and low (less dilution of toxics) flows
- Chl-a: Periphyton: important as nutrient elevations expected during low flows
- Toxics related to wash-off and domestic use: F, ammonia, Al and Cu

Table 4.2: PAI rating table for EWR 2.

SCORING GUIDELINES		EWR2	Scenario: Present		
Physico-chemical Metrics	Rank	%wt	Rating	Weight	Weighted score
pH	5	40	0.50	0.07	0.04
SALTS	2	95	0.50	0.17	0.08
NUTRIENTS	2	95	3.00	0.17	0.51
TEMPERATURE	3	85	2.00	0.15	0.30
TURBIDITY	4	50	3.00	0.09	0.27
OXYGEN	2	95	2.00	0.17	0.34
TOXICS	1	100	0.50	0.18	0.09
TOTALS		560			1.63
PHYSICO-CHEMICAL PERCENTAGE SCORE					67.41
PHYSICO-CHEMICAL CATEGORY					C

Table 4.3: EcoSpecs and TPC table for EWR 2.

River	Letsitele River			
Monitoring Site	B8H010Q01			
EWR Site	2			
EcoSpecs		**TPC**		**Monitoring Frequency**
Inorganic salts	$MgSO_4$	95[th] percentile of data must be less than the TPC	16 mg/L	Monthly
	Na_2SO_4		20 mg/L	
	$MgCl_2$		15 mg/L	
	$CaCl_2$		21 mg/L	
	NaCl		45 mg/L	
	$CaSO_4$		351 mg/L	
Nutrients	SRP	50[th] percentile of data must be less than the TPC	0.025 mg/L	Monthly
	TIN		0.624 mg/L	
Physical variables	pH (pH units)	95[th] percentile of data must be less than the TPC	6.5 to 8.0	Monthly
	Temperature		Vary by not more than 2º C	
	Dissolved oxygen		6 – 7 mg/L	
	Turbidity (NTU)		Moderate change allowed – catchment + landuse changes result in temporary sediment loads during rainfall events	
Response	Chl-a: periphyton	50[th] percentile of data must be less than the TPC	21 mg/m²	Quarterly
	Chl-a: phytoplankton		20 µg/L	

variables	In-stream toxicity	In-stream toxicity should not occur	Any indication of in-stream toxicity	In response to a biotic trigger, or twice a year during high and low flows
Toxics #	Fluoride	95^{th} percentile of data must be less than the TPC	1500 µg/L	Monthly
	Al		20 µg/L	
	Ammonia		43.75 µg/L	
	Cu soft*		0.5 µg/L	
	Cu mod**		1.5 µg/L	
	Cu hard***		2.4 µg/L	

Note that current monitoring does not include toxics other than fluoride. Background ammonia levels should be assessed and the TPCs adjusted accordingly if required.

4.3.2 Invertebrates

The preliminary EcoSpecs for invertebrates for EWR are indicated in Table 4.4.

Table 4.4: Invertebrate EcoSpecs and Thresholds of Probable Concern (TPC) for EWR2 (Letsitele), for Category D.

PRELIMINARY EcoSpecs	TPCs
• To ensure that the SASS5 scores and ASPT values occur in the following range: SASS5 score 100 to 120; ASPT 5.0 to 5.5	• The SASS5 score < 105 and ASPT < 5.1.
• To ensure that the MIRAI score is within the range for Category D ie: 42 to 68).	• The MIRAI score <42.
• To ensure that no group consistently dominates the fauna, defined as D abundance for more than two consecutive surveys.	• Any taxon abundance 'D' (>1000) in two consecutive surveys.
• To maintain suitable conditions for the following flow-dependent species in the SIC biotope: *_Cheumatopsyche thomasetti_: Present *Tricorythidae: Present * _Hydropsyche sp_. Present	• Tricorythidae absent from two consecutive surveys, • Hydropsyche absent from two consecutive surveys • _Cheumatopsyche thomasetti_ absent from two surveys
• To maintain suitable conditions for the following four key taxa: * Baetidae > 1 species * _Cheumatopsyche thomasetti_ * _Hydropsyche sp_. * Tricorythidae	• Less than three of the four key taxa listed.

4.3.3 Geomorphology

A wide, sandy channel existed at this site on the Letsitele River in the 1930’s, but it changed to a narrow, incised channel by the 1990’s. In response to the 2000 floods, the deep pool that existed at the site infilled with sediment. We anticipate the natural deepening of this channel in the next 5 years.

Morphological change is the metric at EWR 2 that has the highest weighted score and by monitoring for it the active channel at this site will be maintained (Table 4.5).

Table 4.5: Geomorphology EcoSpecs and Thresholds of Probable Concern (TPC) for EWR 2.

METRIC	ECOSPECS	TPCs
HYDRAULIC GEOMETRY		
Cross-section Shape	Increase channel depth	TPC reached if the depth of the bed of the active channel does not incise *(Assess through resurveying of cross-sections at 5 year intervals and after any extreme flood or drought events).*

The deep active channel that existed at this site in the 1990's was filled in response to the floods in 2000, changing the conditions at the site to a very shallow riffle. It is anticipated that a deeper active channel will reform here within 5-10 years after the 2000 floods.

4.4.4 Fish

The rationale for the metric groups, metrics and species for monitoring are specified below:

- Velocity-depth, cover, flow modification and physico-chemical are the most important metrics for EWR 2.
- The spreadsheets were further analysed for cover, flow modification and physico-chemical aspects to select the best indicators for TPCs based on pre-issued guidelines.

Fish EcoSpecs (preferences / intolerances relating to frequency of occurrence) and TPCs are provided in Table 4.6 and Table 4.7.

Table 4.6: Site EWR2 – Fish EcoSpecs Table.

FS		
SPP	PREF: FREQ	RANK
CPRE	0.98	1
BMAR	0.88	2
LMOL	0.86	3
CPAR	0.784	4
LCYL	0.576	5
BEUT	0.564	6
AURA	0.552	7
AMOS	0.264	8

INSTREAM VEG		
SPP	PREF:FREQ	RANK
TSPA	0.72	1
BVIV	0.64	2
BPAU	0.576	3
TREN	0.492	4

OVERHANG VEG		
SPP	PREF:FREQ	RANK
BVIV	0.98	1
PPHI	0.9	2
TSPA	0.9	2
BTRI	0.78	4
BUNI	0.736	5
BPAU	0.672	6
TREN	0.516	7
MACU	0.496	8
BEUT	0.492	9
MMAC	0.456	10
BTOP	0.376	11
BNEE	0.312	12
PCAT	0.264	13

MOD INTOLERANT PHYS CHEM		
SPP	PREF: FREQ	RANK
CPRE	0.9	1
BEUT	0.588	2
AURA	0.576	3
BLIN	0.184	4
OPER	0.176	5

MOD INTOLERANT NO FLOW		
SPP	PREF: FREQ	RANK
LMOL	0.66	1
BMAR	0.64	2
CPAR	0.512	3
MACU	0.496	4
LCYL	0.372	5
BNEE	0.272	6

INTOLERANT NO FLOW		
SPP	PREF: FREQ	RANK
CPRE	0.96	1
AURA	0.576	2
BEUT	0.552	3
OPER	0.196	4
BLIN	0.176	5

Table 4.7: Site EWR2 – Fish TPCs

Species	Reference frequency of occurrence	Pres. Observed & habitat derived frequency of occurrence	TPCs% for PES	Motivation
AURA	3	2	**20**	A priority indicator for no flow and phys-chem, and for substrate. A minimum of 3 specimens should be sampled at 20% of sites during a survey of FS and FD substrate habitat using a shocker for periods not less than 20 minutes.
BEUT	3	3	**35**	A priority indicator for no flow, phys-chem and changing vegetation. A minimum of 5 specimens should be sampled at 35% of sites during a survey of MV and substrate habitat using a shocker for periods not less than 20 minutes or a hand seine / 4m pole seine for 10 sweeps.
BVIV	5	3	**40**	A good indicator for changing marginal vegetation. A minimum of 20 specimens should be sampled at 50% of the sites, using a shocker for periods not less than 20 minutes or a hand seine / 4m pole seine for 10 sweeps.
CPRE	5	5	**100**	A priority indicator for no flow and phys-chem, and for substrate. A minimum of 20 specimens should be sampled at 100% of sites during a survey of FS and FD substrate habitat using a shocker for periods not less than 20 minutes.

* TPCs are expressed as a percentage within the range associated with the relevant frequency.

4.4.5 Riparian vegetation

The Letsitele EWR site was excluded from the site surveys mainly because of the artificial influence on the vegetation due to back flooding in the river and the impacts at the site from the adjacent settlement area. Some information on the riparian vegetation was however already available for the site from previous work by Kemper (Department of Water Affairs and Forestry, 1996). While the site was fairly representative of the riparian vegetation in the resource unit, the effects of back flooding reduced the confidence of this assumption. A few individuals of indicator species were present at the site but the general structure of the riparian component had been severely impacted by the removal of trees, which further limited what could be derived from the vegetation at the site.

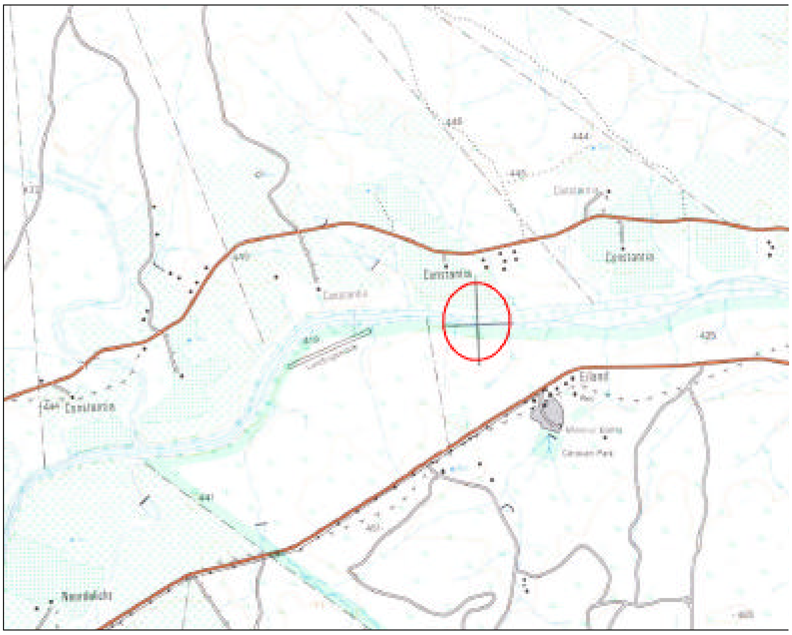
In addition, the profile data collected during the 1996 survey by Kemper was of no use as the 2000 floods had considerably modified the macro-channel. There was also no other available riparian vegetation data for the reach. There was not accurate information on actual return periods for various high flows, which also made it difficult to consider scenarios in terms of likely vegetation response. As a result of all these confounding factors, it was not possibly to develop or set TPC for the riparian components at this site.

5. RESOURCE UNIT C: PRIESKA EWR 3

5.1 SITE DESCRIPTION

This EWR site is situated on the Groot Letaba River, downstream of the Tzaneen Dam and upstream of the Molototsi River confluence. This site is located about 7km upstream of Prieska Weir, but does not experience backwater effects from the weir. The river at this site is characterised by the presence of boulders, cobbles, pebbles and pools. The main impacts at this site are the reduction in flow due to upstream impoundments (Tzaneen and Ebeneezer Dams), large weirs (Junction, Yamorna and Jasi weirs) as well as direct abstraction for irrigation.

Locality: S23 15 02.9; E30 29 44.6



EWR 3

Figure 5.1: Map of EWR 3 (taken from 1:50 000 scale map) as well as from Google .earth

5.2 BASELINE REQUIREMENTS

The limitations and confidence in the available data for each component at EWR 3 are summarised in the following tables.

Geomorphology

1. Spatial data	**High**	Only one site in resource unit which is representative, but banks are somewhat impacted
2. Temporal field data	**Very Low**	No previous field surveys.
3a. Temporal remote data (availability of aerial photographs)	**Very High**	Very good aerial photo record available (from 1938 until recent)
3b. Anecdotal/historical info on land use and flows	**High**	Long flow record and good modelled flows available at a gauge station close to the site, and good anecdotal info on catchment landuse change (also available from aerial photo record)
4. Monitoring assessment method	**High**	Assessment by geomorphological specialist
5. Environmental Change		No significant change since last survey.
Conclusion	**A site visit is required to fully populate the GAI and initiate monitoring. (The GAI model was developed after the field surveys for this study. Time on site will be required to assess info requirements for perimeter resistance component of the GAI model).**	

Water quality

1. Number of WQ stations	**High**	Water quality monitoring point at the upper end of the WQU (and above the EWR site). Data compared to monitoring point at lower end of WQU - conditions stable across WQU.
2. Locality of WQ stations	**Very high**	Four WQU in this Resource Unit.
3. Adequacy of data	**Very high**	Single sites water quality data used for RC and PES
4. Frequency of sampling	**Very high**	Minimum of monthly samples available for 2 years for RC and 5 years available.
5. Appropriate parameters	**High**	SASS and fish surveys have been undertaken at this site as well as the RHP is using this site for assessments of the state of the catchment.
6. Understating of impacts	**High**	Single instream toxicity tests undertaken using 3 indicator species.
7. Interpreting biological responses	**High**	Several biomonitoring (SASS and fish) surveys have been undertaken at this site as well as the RHP is using this site for assessments of the state of the catchment. Note that an instream toxicity test was undertaken (high - very high?).
Conclusion	*** No further baseline data needed, unless there is a significant change in environmental conditions, prior to the initiation of monitoring.**	

Invertebrates

1. Spatial data	**Very High**	Chutter sampled a site upstream as well as at the site, RHP and two surveys as part of this study.
2. Temporal data	**High to Moderate**	Data available for more than 15 years but irregular survey frequency
3. Interpretive characteristics	**High to Moderate**	*Cheumatopsyche thomasetti*, *Hydropsyche longifurca, Amphisyche scottae, Tricorythidae* and *Philopotamidae*
4. Environmental Change		No significant change since last survey.
Conclusion	**No further baseline data needed, unless there is a significant change in environmental conditions, prior to the initiation of monitoring.**	

Fish

1. Spatial data	**Very High**	Extensive data collections made by TPA, Gazankulu Nature Conservation and later by Limpopo Environmental Affairs as part of the RHP. Entire Letaba system surveyed throughout this period.
2. Temporal data	**Very High**	Above data available for more than 15 years
3. Interpretive characteristics	**Very High**	Good distribution of species and good ecological knowledge. A limited number of indicator species available.
4. Environmental Change		No significant change since last survey, although catchment considered to be massively over-utilized. No EWR implementation since last EWR study.
Conclusion	**No further baseline data needed, unless there is a significant change in environmental conditions, prior to the initiation of monitoring.**	

Riparian vegetation

1. Spatial data	**High**	Data available, site not representative of the whole resource unit (downstream is impacted by high pressure on riparian vegetation)
2. Temporal data	**Moderate**	Kemper 1994 survey (>5 years) and this survey
3. Interpretive characteristics	**High to Moderate**	*Breonadia salicina, F. sycomorus*
4. Quality of assessment	**Very High**	Interim model of VEGRAI was used. Habitat Integrity assessment undertaken. Riparian vegetation specialist did survey
5. Data sources	**Very High**	Aerial photos and video. Local knowledge Landcover data, Habitat modeling
6. Environmental Change	**Low to Very Low**	Significant change since last survey due to 2000 floods
Conclusion	**No additional survey needed, prior to the initiation of monitoring, as EWR site is representative. VEGRAI Level III site in the rural area upstream of the Klein Letaba confluence. For EWR 3 VEGRAI data needs to be converted to VEGRAI level 4**	

5.3 ECOSPECS AND TPCS

The Ecological Categories (ECs) associated with the EcoSpecs are provided in Table 5.1. The EcoSpecs and Thresholds of Potential Concern (TPCs) for each component for the ECs as in Table 5.1 are provided in the sections below.

Table 5.1: Driver and response results for PES, REC and Eco Status for EWR 3.

Driver Components	PES	REC	EcoSpecs
Hydrology	D	D	D
Geomorphology	C	C	C
Water quality	C	C	C
Response Components			
Fish	C	C	C
Aquatic invertebrates	D	D	D
Riparian vegetation	D	D	D
EcoStatus	C/D	C/D	C/D

5.3.1 Water quality (Category B)

The primary landuse in the area is irrigation agriculture, particularly for citrus plantations. Pesticide and herbicide use is widespread in the area. Available data and consultation with other specialists suggest the following potential water quality issues at EWR 3:

- Increased SRP with increased flow due to wash-off etc.
- Increased periphyton with decreased flow, therefore modifying the nutrient status.
- Increased toxics with low flows.

Although no data was available for assessing temperature, a high impact is expected as low flows occur for approximately 4 months of the year and the river substrate is largely bedrock with little subsurface flow to provide cooling. Although there is input from turbid tributaries, high turbidities are temporary. The use of biocides in the system was determined with the use of a short biocide survey.

Table 5.2 is the PAI rating table for the EWR site, showing the comparative importance of physico-chemical metrics and the contribution of each metric to the water quality condition at the site, while Table 5.3 lists the EcoSpecs and TPCs.

Taking into account the ranking, rating and the resultant weighted score the suggested water quality monitoring Eco specs and TPCs for EWR 3 are indicated in Table 5.3. The water quality monitoring should include the following parameters not currently monitored at EWR 3:

- Temperature, dissolved oxygen, turbidity / clarity: temperature increases are particularly important during low flows
- In-stream toxicity: tests should be conducted at times of known impact (e.g. pesticide use), or in response to a biotic trigger. However, tests 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: important as nutrient elevations expected during low flows
- A full range of toxics due to extensive pesticide and herbicide use in the area.

Table 5.2: PAI rating table for EWR 3

SCORING GUIDELINES	EWR3		Scenario: Present, Sc4, Sc6		
Physico-chemical Metrics	Rank	%wt	Rating	Weight	Weighted score
pH	4	40	0.00	0.07	0.00
SALTS	2	95	0.50	0.17	0.08
NUTRIENTS	2	95	2.00	0.17	0.33
TEMPERATURE	2	95	2.00	0.17	0.33
TURBIDITY	3	50	1.00	0.09	0.09
OXYGEN	2	95	2.00	0.17	0.33
TOXICS	1	100	3.00	0.18	0.53
TOTALS		570			1.70
PHYSICO-CHEMICAL PERCENTAGE SCORE					66.05
PHYSICO-CHEMICAL CATEGORY					C

Table 5.3: EcoSpecs and TPC table for EWR 3.

River	Groot Letaba River: Prieska			
EWR Site	3			
Monitoring Site	B8H009Q01			
EcoSpecs		**TPC**		**Monitoring Frequency**
Inorganic salts	$MgSO_4$	95th percentile of data must be less than the TPC	23 mg/L	Monthly
	Na_2SO_4		20 mg/L	
	$MgCl_2$		15 mg/L	
	$CaCl_2$		21 mg/L	
	NaCl		191 mg/L	
	$CaSO_4$		351 mg/L	
Nutrients	SRP	50th percentile of data must be less than the TPC	0.019 mg/L	Monthly
	TIN		0.416 mg/L	
Physical variables	pH (pH units)	95th percentile of data must be less than the TPC	6.5 to 8.0	Monthly
	Temperature		Vary by not more than 2º C	
	Dissolved oxygen		6 – 7 mg/L	
	Turbidity (NTU)		Small change allowed – largely natural and related to natural catchment processes such as rainfall runoff.	
Response variables	Chl-a: periphyton	50th percentile of data must be less than the TPC	21 mg/m²	Quarterly
	Chl-a: phytoplankton		20 µg/L	
	In-stream toxicity	In-stream toxicity should not occur	Any indication of in-stream toxicity	Evidence of in-stream toxicity suggests tests should be undertaken at times of known impacts (e.g. pesticide use), or in response to a biotic trigger. Tests should be initiated on a quarterly basis.
Toxics #	Fluoride	95th percentile of data must be less than the TPC	1500 µg/L	Monthly
	Al		20 µg/L	
	Ammonia		15 µg/L	
	Atrazine		19µg/L	
	Cd soft*		0.2 µg/L	
	Cd mod**		0.2 µg/L	
	Cd hard***		0.3 µg/L	
	Chorine (free)		0.4 µg/L	
	Cr(VI)		14 µg/L	
	Cu soft*		0.5 µg/L	
	Cu mod**		1.5 µg/L	
	Cu hard***		2.4 µg/L	
	Endosulfan		0.02 µg/L	
	Pb soft *		0.5 µg/L	
	Pb mod**		1 µg/L	
	Pb hard***		2 µg/L	
	Hg		0.08 µg/L	

Note that current monitoring does not include toxics other than fluoride. As no data exists, background levels of toxicants should be assessed and the TPCs adjusted accordingly if required.

5.3.2 Invertebrates

The preliminary EcoSpecs for invertebrates for EWR 3 are indicated in Table 5.4.

Table 5.4: Invertebrate EcoSpecs and Thresholds of Probable Concern (TPC) for EWR 3 (Prieska), for Category D.

PRELIMINARY EcoSpecs	TPCs
• To ensure that the SASS5 scores and ASPT values occur in the following range: SASS5 score 100 to 130; ASPT 5.0 to 5.5	• The SASS5 score < 110 and ASPT < 5.1.
• To ensure that the MIRAI score is within the range for Category D (ie: 42 to 68).	• The MIRAI score <42.
• To ensure that no group consistently dominates the fauna, defined as D abundance for more than two consecutive surveys.	• Any taxon abundance 'D' (>1000) in two consecutive surveys.
• To maintain suitable conditions for the following flow-dependent species in the SIC biotope: *Leptophlebiidae: Abundance 'B' *Tricorythidae: Present *Hydropsychidae > 2 species: Abundance 'B'.	• Leptophlebiidae absent from two consecutive surveys. • Tricorythidae absent from two consecutive surveys • Hydropsychidae less than three species in two consecutive surveys.
• To maintain suitable conditions for the following five key taxa: *Leptophlebiidae *Tricorythidae *Hydropsychidae .> 2 species *Elmidae *Baetidae	• Less than four of the five key taxa listed.

5.3.3 Geomorphology

Morphological change is the metric at EWR 3 that has the highest weighted score and by monitoring for it the active channel at this site will be maintained (Table 5.5).

Table 5.5: Geomorphology EcoSpecs and Thresholds of Probable Concern (TPC) for EWR 3.

METRIC	ECOSPECS	TPCs
	SUBSTRATE CHANGES	
Channel Bed	Maintain exposed bedrock in the active channel	TPC reached if there is a loss (greater than some proportion) of exposed bedrock in the active channel *(need data to quantify the minimum value of acceptable bedrock proportion)*
	HYDRAULIC GEOMETRY	
Reach Type	Maintain the dominant in-channel morphological unit	TPC reached if the dominant instream morphological unit at the site changes from a riffle to a run.

The approximately 48% reduction in potential bed material transport at the site, coupled with the large weir (Prieska) located downstream, make this site susceptible to enhanced sediment deposition and storage. Monitoring the exposed bedrock and dominant in channel morphological unit at the site would be an effective method for assessing sedimentation. Sedimentation on the macro-channel floor outside of the active channel is not expected to be of concern, as the width of the macro-channel is expected to decrease after the widening caused by the 2000 floods.

5.3.4 Fish

The rationale for the metric groups, metrics and species for monitoring are specified below:

- Velocity-depth, cover, and physico-chemical are the most important metrics for EWR 3.
- The spreadsheets were further analysed for cover, flow modification and physico-chemical aspects to select the best indicators for TPCs based on pre-issued guidelines.

Fish EcoSpecs (preferences / intolerances relating to frequency of occurrence) and TPCs are provided in Table 5.6 and Table 5.7.

Table 5.6: Site EWR 3 – Fish EcoSpecs Table.

F/S			Water column			Physico-chemical		
SPP	PREF: FREQ	RANK	SPP	PREF:FREQ	RANK	SPP	PREF: FREQ	RANK
CPRE	0.98	1	MBRE	1	1	CPRE	0.96	1
CPAR	0.98	1	BMAR	0.82	2	BEUT	0.184	2
BMAR	0.88	3	MACU	0.8	3			
LMOL	0.86	4	OMOS	0.78	4			
LCYL	0.576	5	BPAU	0.56	5			
BEUT	0.188	6	SINT	0.376	6			
AMOS	0.132	7	BIMB	0.376	6			

Table 5.7: Site EWR 3 – Fish TPCs.

Species	Reference frequency of occurrence	Pres. Observed & habitat derived frequency of occurrence	TPCs % for PES	Motivation
CPAR	5	5	**100**	A good indicator for no flow and phys-chem, and for substrate. A minimum of 10 specimens should be sampled at 100% of sites during a survey of FS and FD substrate habitat using a shocker for periods not less than 20 minutes.
CPRE	5	5	**100**	A priority indicator for no flow and phys-chem, and for substrate. A minimum of 20 specimens should be sampled at 100% of sites during a survey of FS and FD substrate habitat using a shocker for periods not less than 20 minutes.

TPCs are expressed as a percentage within the range associated with the relevant frequency.

5.3.5 Riparian vegetation

The Riparian vegetation EcoSpecs and TPCs for EWR 3 are indicated in Table 5.8.

Table 5.8: Riparian vegetation EcoSpecs and Thresholds of Probable Concern (TPC) for EWR 3.

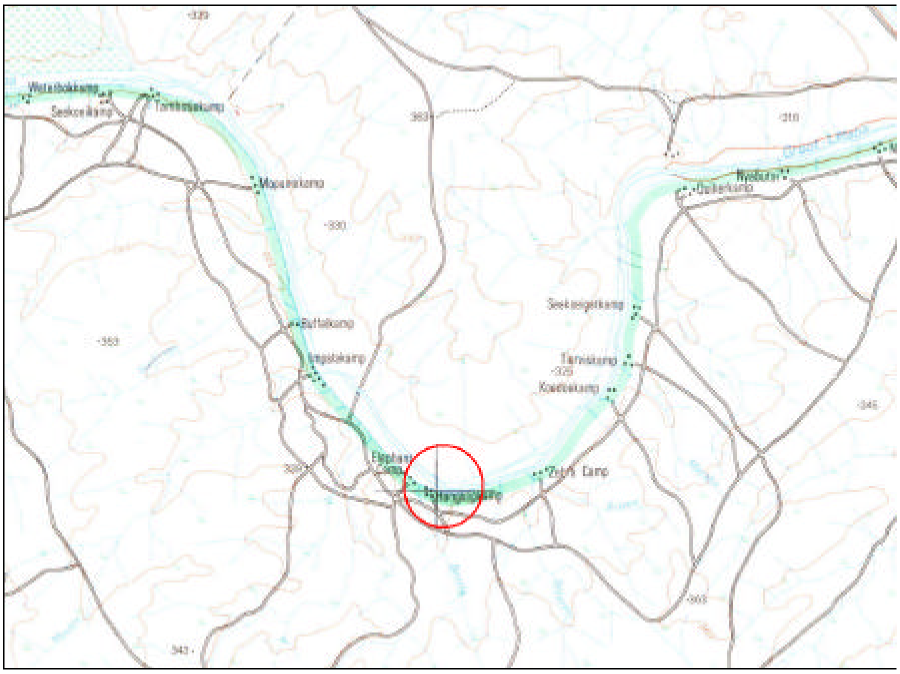
METRIC GROUP	METRIC	ECOSPECS	TPCs
Marginal zone	Vegetation abundance	▪ Maintain *Phragmites* and hydrophyte fringe along the active channel - motivation fish and marginal habitat.	▪ *Phragmites* fringe visibly (fixed photo) increasing in abundance
	Vegetation cover	▪ Maintain *Phragmites* fringe along the active channel	▪ *Phragmites* fringe increasing in cover to 50% of the macro-channel floor motivation historically reeds have not exceeded this % cover of the macro-channel floor ▪ Less than 5% marginal vegetation cover (including *Phragmites* - more baseline data is needed to verify these cover values and to quantify the existing cover) - motivation should always have a narrow marginal zone present along the active channel
	Species richness	▪ Maintain a marginal fringe component.	▪ Cover and abundance is more important than number of species
	Species composition	▪ Maintain the *Phragnites* habitat and the marginal hydrophyte zone	▪ Noticeable increase in exotic weedy herbaceous species ▪ Absence of *Phragmites*
Lower riparian zone	Vegetation cover	▪ Maintain the cover-abundance of *Ficus sycomorus* jn the lower riparian zone – motivation keep the lower riparian fig habitat in tact ▪ General increase in other species of indigenous riparian tree cover – motivation 2000 floods removed the terraces and most of the lower riparian zone and this is necessary for the re-establishment of this zone ▪ *Maintain the Cyperus patches* on the banks in the lower riparian – motivation key lower riparian habitat in this reach of the river	▪ Decrease in the abundance and cover of *Ficus sycomorus* in the lower riparian zone – motivation a key species dependent on baseflow and bank storage ▪ No increase in other species of indigenous riparian tree cover within 5 years ▪ Decrease in abundance and cover of *Cyperus* on the banks in the lower riparian zone
	Species richness	-	-
	Species composition	▪ Maintain *Ficus sycomorus* population population on lower terraces – motivation keep the lower riparian fig habitat in tact ▪ Improved conditions for the re-establishment of *Breonardia salicina* population – motivation population removed during 2000 floods and need to re-establish this population on the exposed bedrock	▪ Absence of *Ficus sycomorus* – motivation a key species dependent on baseflow and bank storage ▪ Absence of *Cyperus patches* ▪ No visible increase in the density of *Breonardia salicina* within 5 years
	Vegetation structure	▪ Maintain *Ficus sycomorus* population in the lower riparian zone motivation a key species dependent on baseflow and bank storage	▪ Absence of a range of age classes of *Ficus sycomorus*
Upper riparian zone	Vegetation cover and composition	▪ Maintain *Diospyros mespiliformis* population – motivation typical upper zone species relying on bank storage	▪ Visible decrease in *Diospyros mespiliformis* cover-abundance - motivation possible decrease in bank storage
	Species richness	▪ Maintain terrestrial – riparian species mix – motivation prevent terrestrialisation of the upper zone	▪ When the proportion of terrestrial species reaches 50% of the total species count

6. RESOURCE UNIT D: LETABA RANCH EWR 4

6.1 SITE DESCRIPTION

This EWR site is situated on the Groot Letaba River, downstream of the Molototsi River and upstream of the confluence with the Klein Letaba River. The river channel at this site is large (> 150m) and is characterised by the presence of bedrock, large boulders, cobbles, pebbles and pools. The main impacts at this site are the reduction in flow due to upstream impoundments (Tzaneen and Ebeneezer Dams) as well as the irrigation abstraction weirs and canals.

Locality: S23 38 57.8; E30 39 38.3



EWR 4

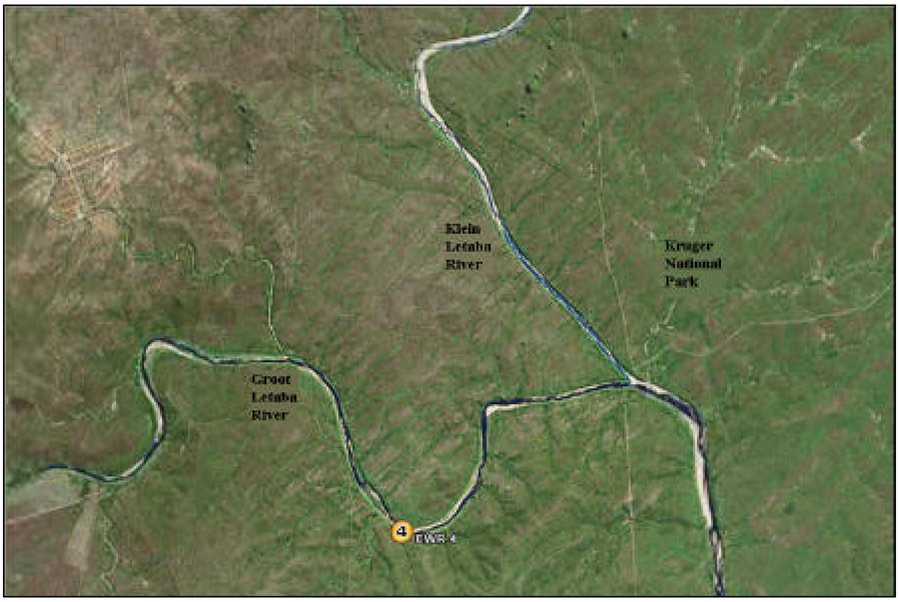


Figure 6.1: Map of EWR 4 (taken from 1:50 000 scale map) as well as from Google .earth

6.2 BASELINE REQUIREMENTS

The limitations and confidence in the available data for each component at EWR 4 are summarised in the following tables.

Geomorphology

1. Spatial data	**Very High**	Only one site in resource unit which is very representative and unimpacted
2. Temporal field data	**Moderate**	No previous field surveys at site, but other longterm studies at similar sites nearby (in Kruger Park)
3a. Temporal remote data (availability of aerial photographs)	**Very High**	Very good aerial photo record available (from 1938 until recent)
3b. Anecdotal/historical info on land use and flows	**Very High**	Long flow record and good modelled flows available at a gauge station close to the site, and good anecdotal info on catchment landuse change (also available from aerial photo record)
4. Monitoring assessment method	**High**	Assessment by geomorphological specialist
5. Environmental Change		No significant change since last survey.
Conclusion	**A site visit is required to fully populate the GAI and initiate monitoring. (The GAI model was developed after the field surveys for this study. Time on site will be required to assess info requirements for perimeter resistance component of the GAI model.**	

Water quality

1. Number of WQ stations	**Very High**	
2. Locality of WQ stations	**Very High**	Two WQU in this Resource Unit.
3. Adequacy of data	**Very High**	One site used for RC and PES
4. Frequency of sampling	**High**	Minimum of monthly samples for 2 years for RC and 4 years for PES available.
5. Appropriate parameters	**High**	
6. Undersanding of impacts	**Low**	No instream toxicity undertaken
7. Interpreting biological responses	**High**	Several biomonitoring (SASS and fish) surveys have been undertaken at this site as well as the RHP is using this site for assessments of the state of the catchment.
Conclusion	*** No further baseline data needed, unless there is a significant change in environmental conditions, prior to the initiation of monitoring.**	

Invertebrates

1. Spatial data	**Very High**	Chutter, Moore at two sites in the reserve, RHP and two surveys as part of this study
2. Temporal data	**High**	Data available for more than 15 years but irregular survey frequency
3. Interpretive characteristics	**Moderate**	*Tricorythidae, Amphisyche scottae, Baetidae* (>2 species)
4. Environmental Change		No significant change since last survey.
Conclusion	*** No further baseline data needed, unless there is a significant change in environmental conditions, prior to the initiation of monitoring.**	

Fish

1. Spatial data	**Very High**	Extensive data collections made by TPA, Gazankulu Nature Conservation and later by Limpopo Environmental Affairs as part of the RHP. Entire Letaba system surveyed throughout this period.
2. Temporal data	**Very High**	Above data available for more than 15 years
3. Interpretive characteristics	**Very High**	Good distribution of species and good ecological knowledge. A limited number of indicator species available.
4. Environmental Change	**High**	No significant change since last survey, although catchment considered massively over-utilized. No EWR implementation since last EWR study.
Conclusion	**No further baseline data needed, unless there is a significant change in environmental conditions, prior to the initiation of monitoring.**	

Riparian vegetation

1. Spatial data	**Moderate**	Data available, site not representative of the whole resource unit (downstream is impacted by high pressure on riparian vegetation)
2. Temporal data	**Moderate**	Kemper 1994 survey (>5 years) and this survey. Reasonably good air photo record
3. Interpretive characteristics	**High to Moderate**	*Breonadia salicina* in marginal zone, *Combretum erythrophyllum* on lower riparian terrace. Problem that morphology of the site modified by 2000 floods which, despite good indicator species, made interpretation difficult.E42
4. Quality of assessment	**Very High**	Interim model of VEGRAI was used. Habitat Integrity assessment undertaken. Riparian vegetation specialist did survey
5. Data sources	**High**	Aerial photos and video. Local knowledge Landcover data

6. Environmental Change	**Low to Very Low**	Significant change since last survey due to 2000 floods
Conclusion	**No additional survey needed as EWR site is representative, prior to the initiation of monitoring.**	

6.3 ECOSPECS AND TPCS

The Ecological Categories (ECs) associated with the EcoSpecs are provided in Table 6.1. The EcoSpecs and Thresholds of Potential Concern (TPCs) for each component for the ECs as in Table 6.1 are provided in the sections below.

Table 6.1: Driver and response results for PES, REC and Eco Status for EWR 4.

Driver Components	PES	REC	EcoSpecs
Hydrology	**D**	**D**	**D**
Geomorphology	**C/D**	**C/D**	**C/D**
Water quality	**B/C**	**B/C**	**B/C**
Response Components			
Fish	**C**	**C**	**C**
Aquatic invertebrates	**D**	**D**	**D**
Riparian vegetation	**D**	**D**	**D**
EcoStatus	**C/D**	**C/D**	**C/D**

6.3.1 Water quality (Category B)

Landuse is primarily rural and domestic water use, i.e. limited cultivated lands and subsistence agriculture and livestock, before entering Letaba Ranch Nature Reserve. Analysis of data and consultation with other specialists suggest the following potential water quality issues at EWR 4:

- Nutrient status. Increased flows will increase the SRP concentration.
- Toxics may be a problem due to wash-off from the agricultural area upstream
- Temperature and oxygen variations at low flows

Large variations in oxygen and temperature are noted during low flows. Although turbidity increases are partly natural due to input from the Klein Letaba and Molototsi rivers, which are sandy-bed rivers, conditions are exacerbated compared to the natural state. Toxics may be evident due to agricultural activities along the Groot Letaba River.

Table 6.2 is the PAI rating table for the EWR site, showing the comparative importance of physico-chemical metrics and the contribution of each metric to the water quality condition at the site, while Table 6.3 lists the EcoSpecs and TPCs.

Taking into account the ranking, rating and the resultant weighted score the suggested water quality monitoring Eco specs and TPCs for EWR 4 are indicated in Table 6.3. The water quality monitoring should include the following parameters not currently monitored at EWR 4:

- Temperature, dissolved oxygen (DO), turbidity / clarity: temperature and DO elevations are expected during low flows
- In-stream toxicity: in response to a biotic trigger, but initiate tests twice a year during high and low flows. Test frequency can be decreased depending on test results.
- Chl-a: Periphyton: important as nutrient elevations expected during low flows
- Selected toxics related to agricultural activities

Table 6.2: PAI rating table for EWR 4.

SCORING GUIDELINES	EWR4 Scenario: Present				
Physico-chemical Metrics	Rank	%wt	Rating	Weight	Weighted score
PH	4	40	0.50	0.07	0.04
SALTS	2	95	0.50	0.17	0.08
NUTRIENTS	2	95	2.00	0.17	0.33
TEMPERATURE	2	95	3.00	0.17	0.50
TURBIDITY	3	50	2.00	0.09	0.18
OXYGEN	2	95	3.00	0.17	0.50
TOXICS	1	100	1.50	0.18	0.26
TOTALS		570			1.89
PHYSICO-CHEMICAL PERCENTAGE SCORE					62.19
PHYSICO-CHEMICAL CATEGORY					C

Table 6.3: EcoSpecs and TPC table for EWR 4.

River	Groot Letaba River: Letaba Ranch			
Monitoring Site	B8H008Q01			
EWR Site	4			
EcoSpecs		**TPC**		**Monitoring Frequency**
Inorganic salts	$MgSO_4$	95th percentile of data must be less than the TPC	16 mg/L	Monthly
	Na_2SO_4		20 mg/L	
	$MgCl_2$		15 mg/L	
	$CaCl_2$		21 mg/L	
	NaCl		191 mg/L	
	$CaSO_4$		351 mg/L	
Nutrients	SRP	50th percentile of data must be less than the TPC	0.025 mg/L	Monthly
	TIN		0.107 mg/L	
Physical variables	pH (pH units)	95th percentile of data must be less than the TPC	6.5 to 8.5	Monthly
	Temperature		Vary by not more than 2º C	
	Dissolved oxygen		6 – 7 mg/L	

River	Groot Letaba River: Letaba Ranch			
Monitoring Site	B8H008Q01			
EWR Site	4			
EcoSpecs		**TPC**		**Monitoring Frequency**
	Turbidity (NTU)		Moderate change allowed – catchment + landuse changes result in temporary sediment loads during rainfall events	
Response variables	Chl-a: periphyton	50^{th} percentile of data must be less than the TPC	21 mg/m^2	Quarterly
	Chl-a: phytoplankton		15 µg/L	
	In-stream toxicity	In-stream toxicity should not occur	Any indication of in-stream toxicity	In response to a biotic trigger, or twice a year during high and low flows
Toxics #	Fluoride	95^{th} percentile of data must be less than the TPC	1500 µg/L	Monthly
	Ammonia		15 µg/L	
	Al		20 µg/L	
	Cu soft*		0.5 µg/L	
	Cu mod**		1.5 µg/L	
	Cu hard***		2.4 µg/L	
	Pb soft*		0.5 µg/L	
	Pb mod**		1 µg/L	
	Pb hard***		2 µg/L	

Note that current monitoring does not include toxics other than fluoride. As no data exists, background levels of ammonia should be assessed and the TPCs adjusted accordingly if required.

6.3.2 Invertebrates

The preliminary EcoSpecs for invertebrates for EWR 4 are indicated in Table 6.4.

Table 6.4: Invertebrate EcoSpecs and Thresholds of Probable Concern (TPC) for EWR 4 (Letaba Ranch), for Category D.

PRELIMINARY EcoSpecs	TPCs
• To ensure that the SASS5 scores and ASPT values occur in the following range: SASS5 score 100 to 130; ASPT 5.5 to 6.0	• The SASS5 score < 110 and ASPT < 5.6.
• To ensure that the MIRAI score is within the range for Category D (ie: 42 to 68).	• The MIRAI score <42.
• To ensure that no group consistently dominates the fauna, defined as D abundance for more than two consecutive surveys.	• Any taxon abundance 'D' (>1000) in two consecutive surveys.

PRELIMINARY EcoSpecs	TPCs
• To maintain suitable conditions for the following flow-dependent species in the SIC biotope: *Tricorythidae: Present **Amphipsyche scottae* Abundance'B' * Baetidae .> 2 sp: Abundance 'B'	• Tricorythidae absent from two consecutive surveys, • *Amphipsyche scottae* absent on any one survey • Less than 3 species of Baetidae on any one survey
• To maintain suitable conditions for the following five key taxa: *Amphipsyche scottae *Tricorythidae *Baetidae . 2 species *Leptoplebiidae *Elmidae	• Less than three of the five key taxa listed.

6.3.3 Geomorphology

Morphological change is the metric at EWR 4 that has the highest weighted score and by monitoring for it the active channel at this site will be maintained (Table 6.5).

Table 6.5: Geomorphology EcoSpecs and Thresholds of Probable Concern (TPC) for EWR4

METRIC	ECOSPECS	TPCs
	HYDRAULIC GEOMETRY	
Reach Type	Maintaining present channel type assemblages	Monitor channel type change. TPC reached if there is a loss of secondary channels in nearby anastomosing channel type reaches *(Assess at 5 year intervals and after any extreme flood or drought events).*

This site has shown a progressive reduction in the number and extent of active channels and progressive vegetation encroachment on the macro-channel floor. In many sections the channel patterns have changed from mixed anastomosing to single thread pool-rapid patterns in recent historical times. These changes would have been associated with a reduction in instream habitat biodiversity and species richness. The continued loss of multi-channel sections of the river is of high concern. Monitoring their condition (using aerial photographs) would allow assessment of this trend.

6.3.4 Fish

The rationale for the metric groups, metrics and species for monitoring are specified below:

- Velocity-depth and cover are the most important metrics for EWR 4.
- The spreadsheets were further analysed for cover, flow modification and physico-chemical aspects to select the best indicators for TPCs based on pre-issued guidelines.

Fish EcoSpecs (preferences / intolerances relating to frequency of occurrence) and TPCs are provided in Table 6.6 and Table 6.7.

Chiloglanis pretoria and *Chiloglanis paratus* were selected for TPCs due to the ease of monitoring. Other high-value indicator species are all absent at this time from Letaba Ranch.

Table 6.6: Site EWR 4 – Fish EcoSpecs Table.

FS			Substrate		
SPP	PREF: FREQ	RANK	SPP	PREF:FREQ	RANK
CPRE	0.86	1	LROS	1	1
CPAR	0.84	2	LCYL	0.98	2
BMAR	0.82	3	CPRE	0.98	2
LCYL	0.68	4	CPAR	0.98	2
LMOL	0.66	5	LRUD	0.94	5
LCON	0.6	6	LMOL	0.94	5
HVIT	0.432	7	BMAR	0.9	7
AMOS	0.408	8	LCON	0.6	8
			GCAL	0.588	9
			CSWI	0.588	9
			AMOS	0.588	9
			AMAR	0.336	12
			GGIU	0.196	13
			BNEE	0.176	14
			BMAT	0.164	15

Table 6.7: Site EWR 4 – Fish TPCs

Species	Reference frequency of occurrence	Pres. Observed & habitat derived frequency of occurrence	TPCs % for PES	Motivation
CPAR	5	5	**100**	A good indicator for no flow and phys-chem, and for substrate. A minimum of 20 specimens should be sampled at 100% of sites during a survey of FS and FD substrate habitat using a shocker for periods not less than 20 minutes.
CPRE	5	4	**100**	A priority indicator for no flow and phys-chem, and for substrate. A minimum of 20 specimens should be sampled at 100% of sites during a survey of FS and FD substrate habitat using a shocker for periods not less than 20 minutes.

* TPCs are expressed as a percentage within the range associated with the relevant frequency.

6.3.5 Riparian vegetation

The Riparian vegetation EcoSpecs and TPCs for EWR 4 are indicated in Table 6.8.

Table 6.8: Riparian vegetation EcoSpecs and Thresholds of Probable Concern (TPC) for EWR 4.

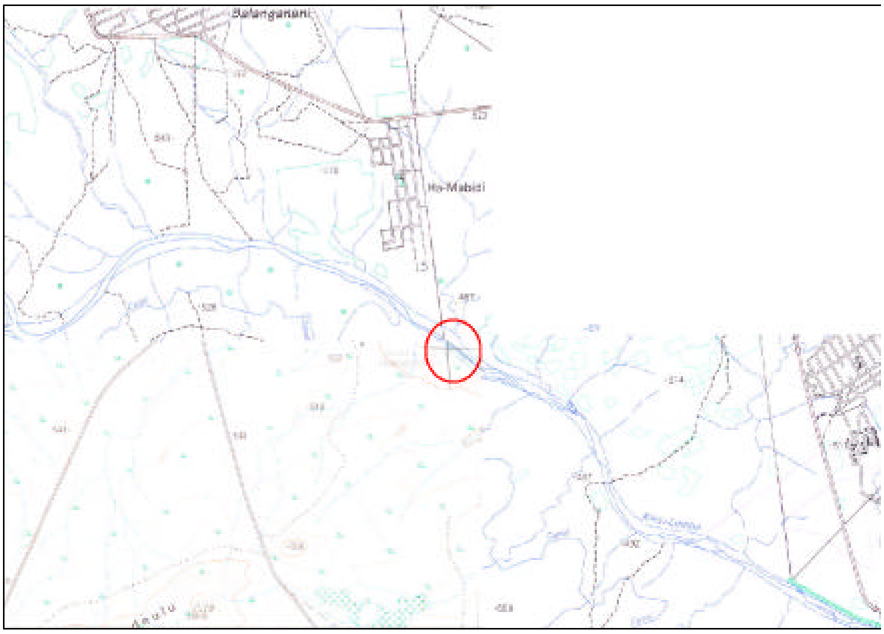
METRIC GROUP	METRIC	ECOSPECS	TPCs
Marginal zone	Vegetation abundance	▪ Maintain *Phragmites* and hydrophyte fringe along the active channel - motivation fish and marginal habitat	▪ *Phragmites* fringe visibly (fixed photo) increasing in abundance
	Vegetation cover	▪ Maintain *Phragmites* fringe along the active channel ▪ Maintain marginal hydrophyte vegetation fringe along the active channel	▪ *Phragmites* fringe increasing in cover to 30% of the macro-channel floor - motivation reed cover over 30% may affect the channel dynamics and e-establishment of the vegetated core bars in this reach - motivation historically reeds have not exceeded this % cover of the macro-channel floor – would affect sediment dynamics ▪ Less than 5% marginal vegetation cover (including *Phragmites* - more baseline data is needed to verify these cover values and to quantify the existing cover) – motivation should always have a narrow marginal zone present along the active channel
	Species richness	▪ Maintain a marginal fringe component.	▪ Cover and abundance is more important than number of species
	Species composition	▪ Maintain a mixed marginal macrophyte community that includes *Phragmites* – motivation mixed species composition of the riparian fringe more important than just reeds in this section	▪ Noticeable increase in exotic weedy herbaceous species ▪ Absence of *Phragmites*
Lower riparian zone	Vegetation cover	▪ Improve *Nuxia floribunda* and *Combretum erythrophyllum* populations in lower riparian zone – motivation this zone and these species particularly affected by 2000 floods	▪ No increase in abundance and cover of *Nuxia floribunda* and *Combretum erythrophyllum*
	Species richness	▪ Maintain at least 10 indigenous riparian tree species in this zone – motivation avg. number of species recorded in this zone during field surveys	▪ Less than 10 indigenous riparian tree species – motivation avg. number of species recorded in this zone during field surveys
	Species composition	▪ Maintain *Nuxia floribunda* and *Combretum erythrophyllum* populations in lower riparian zone ▪ Maintain the *Breonardia salicina* population ▪ Maintain terrestrial – riparian species mix	▪ Absence of *Nuxia floribunda* or ▪ Absence of *Combretum erythrophyllum* or ▪ Absence of *Phoenix reclinata* or ▪ Absence of *Breonardia salicina* ▪ When the proportion of terrestrial species reaches 50% of the total species count
	Vegetation structure	▪ Improve *Nuxia floribunda* and *Combretum erythrophyllum* population structure	▪ No increase in the number of juveniles of *Nuxia floribunda* and *Combretum erythrophyllum*
Upper riparian zone	Vegetation cover	-	-
	Species richness	-	-

7. RESOURCE UNIT E: KLEIN LETABA EWR 5

7.1 SITE DESCRIPTION

This EWR site is situated on the Klein Letaba River, downstream of the confluence of the Middle Letaba River and Middle Letaba Dam. 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 impacts of the Middle Letaba Dam have led to the coarsening of bed material, encroachment of terrestrial vegetation and the loss of secondary channels. The site provides a good compromise between hydraulics, habitat diversity and accessibility.

Locality: **S23 40 39.1; E31 05 55.1**



EWR 5

Figure 7.1: Map of EWR 5 (taken from 1:50 000 scale map) as well as from Google .earth.

7.2 BASELINE REQUIREMENTS

The limitations and confidence in the available data for each component at EWR 5 are summarised in the following tables.

Geomorphology

1. Spatial data	**Very High**	Only one site in resource unit which is very representative and fairly unimpacted
2. Temporal field data	**High**	No previous field surveys at site, but aerial photo info provides good, detailed insight into recent changes
3a. Temporal remote data (availability of aerial photographs)	**Very High**	Very good aerial photo record, with lots of details visible, available (from 1938 until recent)
3b. Anecdotal/historical info on land use and flows	**Very High**	Long flow record and good modelled flows available at a gauge station close to the site, and good anecdotal info on flood records
4. Monitoring assessment method	**High**	Assessment by geomorphological specialist
5. Environmental Change		No significant change since last survey.
Conclusion	**A site visit is required to fully populate the GAI and initiate monitoring. (The GAI model was developed after the field surveys for this study. Time on site will be required to assess info requirements for perimeter resistance component of the GAI model).**	

Water quality

1. Number of WQ stations	**Moderate**	
2. Locality of WQ stations	**High**	Three WQU in this Resource Unit.
3. Adequacy of data	**Low**	
4. Frequency of sampling	**High**	Minimum of monthly samples for 5 years available for PES only.
5. Appropriate parameters	**High**	
6. Understanding of impacts	**Low**	No instream toxicty tests undertaken.
7. Interpreting biological responses	**High**	Several biomonitoring (SASS and fish) surveys have been undertaken at this site as well as the RHP is using this site for assessments of the state of the catchment.
Conclusion	*** No further baseline data needed, unless there is a significant change in environmental conditions, prior to the initiation of monitoring.**	

Invertebrates

1. Spatial data	**Moderate**	Data available at this site from RHP and two surveys as part of this study
2. Temporal data	**Moderate**	Irregular surveys, less than 5 years, RHP
3. Interpretive characteristics	**Moderate to Low**	*Cheumatopsyche thomasetti, Baetidae*
4. Environmental Change		
Conclusion	*** No further baseline data needed, unless there is a significant change in environmental conditions, prior to the initiation of monitoring.**	

Fish

1. Spatial data	**High**	Extensive surveys throughout the river by Gazankulu Nature Conservation and Limpopo Environmental Affairs as part of the RHP. Data available at this site, as well as sites above and below
2. Temporal data	**High**	Regular surveys but going back more than 15 years
3. Interpretive characteristics	**High to Moderate**	Good info on all species that represent a wide range of tolerances
4. Environmental Change		No significant change since last survey
Conclusion	**No further baseline data needed, unless there is a significant change in environmental conditions, prior to the initiation of monitoring.**	

Riparian vegetation

1. Spatial data	**High**	Site representative of Resource Unit
2. Temporal data	**Moderate to Low**	Site survey plus air photo record but resolution not too good
3. Interpretive characteristics	**High to Moderate**	*Combretum erythrophyllum* and *Gymnosporia buxifolia* on the lower riparian zone terraces, *Phragmites mauritianus* on channel floor, numerous channels on floor with *Cyperus marginatus.* Macro-channel modified since 2000 floods which made interpretation difficult despite good indicators
4. Quality of assessment	**Very High**	VEGRAI undertaken Habitat Integrity assessment undertaken
5. Data sources	**High**	Aerial photos and video. Local knowledge Land cover data
6. Environmental Change	**Low to Very Low**	Significant change due to 2000 floods
Conclusion	**Data needs to be converted to VEGRAI level 4**	

7.3 ECOSPECS AND TPCS

The Ecological Categories (ECs) associated with the EcoSpecs are provided in Table 7.1. The EcoSpecs and Thresholds of Potential Concern (TPCs) for each component for the ECs as in Table 7.1 are provided in the sections below.

Table 7.1: Driver and response results for PES, REC and Eco Status for EWR 5.

Driver Components	PES	REC	EcoSpecs
Hydrology	**D**	**C/D**	**C/D**
Geomorphology	**C**	**C**	**C**
Water quality	**B/C**	**B**	**B**
Response Components			
Fish	**C**	**B**	**B**
Aquatic invertebrates	**D**	**C**	**C**
Riparian vegetation	**B/C**	**B**	**B**
EcoStatus	**C**	**C**	**C**

7.3.1 Water quality (Category B)

The main land-use is dense urban settlements (e.g. Giyani) and informal settlements (limited subsistence and cultivated agriculture, with livestock, occurs). A number of sewage works and waste disposal sites were noted in the area – expected water quality impacts are therefore related to sewage effluents in the river leading to eutrophication. Analysis of data and consultation with other specialists suggest the following potential water quality issues at EWR 5:

- Periphyton during low flows, which may increase the nutrient status.

Although the Klein Letaba is a sandy bed river, turbidities are not very high due to the shallow nature of the system. Toxics are not expected to be significant due to the limited presence of commercial farming.

Table 7.2 is the PAI rating table for the EWR site, showing the comparative importance of physico-chemical metrics and the contribution of each metric to the water quality condition at the site, while Table 7.3 lists the EcoSpecs and TPC.

Taking into account the ranking, rating and the resultant weighted score the suggested water quality monitoring Eco specs and TPCs for EWR 5 are indicated in Table 7.3. The water quality monitoring should include the following parameters not currently monitored at EWR 5:

- Temperature, dissolved oxygen, turbidity / clarity: particularly as no baseline data exists for these parameters
- In-stream toxicity: only in response to a biotic trigger
- Chl-a: Periphyton: important as nutrient elevations expected during low flows
- Toxics related to wash-off and domestic use: F, ammonia, Al and Cu

Table 7.2: PAI rating table for EWR 5.

SCORING GUIDELINES	EWR5 Scenarios PES/Sc1, Sc2, Sc4, Sc6, Present				
Physico-chemical Metrics	Rank	%wt	Rating	Weight	Weighted score
pH	5	40	0.50	0.07	0.04
SALTS	2	95	0.50	0.17	0.09
NUTRIENTS	2	95	2.50	0.17	0.43
TEMPERATURE	3	85	1.00	0.15	0.15
TURBIDITY	4	50	1.50	0.09	0.14
OXYGEN	3	85	1.00	0.15	0.15
TOXICS	1	100	0.00	0.18	0.00
TOTALS		550			1.00
PHYSICO-CHEMICAL PERCENTAGE SCORE					80.00
PHYSICO-CHEMICAL CATEGORY					B (B/C)

Table 7.3: EcoSpecs and TPC for EWR 5.

River	Klein Letaba River			
Monitoring Site	B8H033Q01			
EWR Site	5			
EcoSpecs		**TPC**		**Monitoring Frequency**
Inorganic salts	$MgSO_4$	95th percentile of data must be less than the TPC	23 mg/L	Monthly
	Na_2SO_4		20 mg/L	
	$MgCl_2$		15 mg/L	
	$CaCl_2$		21 mg/L	
	NaCl		191 mg/L	
	$CaSO_4$		351 mg/L	
Nutrients	SRP	50th percentile of data must be less than the TPC	0.025 mg/L	Monthly
	TIN		0.070 mg/L	
Physical variables	pH (pH units)	95th percentile of data must be less than the TPC	6.5 to 8.8	Monthly
	Temperature		Natural temperature range	
	Dissolved oxygen		7 – 8 mg/L	
	Turbidity (NTU)		Small change allowed – largely natural and related to natural catchment processes such as rainfall runoff.	
Response	Chl-a: periphyton	50th percentile of data must be less than the TPC	21 mg/m²	Quarterly
	Chl-a: phytoplankton		15 µg/L	

River	Klein Letaba River			
Monitoring Site	B8H033Q01			
EWR Site	5			
EcoSpecs		**TPC**		**Monitoring Frequency**
variables	In-stream toxicity	In-stream toxicity should not occur	Any indication of in-stream toxicity	In response to a biotic trigger
Toxics #	Fluoride	95^{th} percentile of data must be less than the TPC	1500 µg/L	Monthly
	Ammonia		15 µg/L	
	Al		20 µg/L	
	Cu soft*		0.5 µg/L	
	Cu mod**		1.5 µg/L	
	Cu hard***		2.4 µg/L	

Note that current monitoring does not include toxics other than fluoride. As no data exists, background levels of toxics should be assessed and the TPCs adjusted accordingly if required.

7.3.2 Invertebrates

The preliminary EcoSpecs for invertebrates for EWR 4 are indicated in Table 7.4.

Table 7.4: Invertebrate EcoSpecs and Thresholds of Probable Concern (TPC) for EWR 5 (Klein Letaba), for Category D.

PRELIMINARY EcoSpecs	TPCs
• To ensure that the SASS5 scores and ASPT values occur in the following range: SASS5 score 80 to 100; ASPT 4.5 to 5.5	• The SASS5 score < 85 and ASPT < 4.5.
• To ensure that the MIRAI score is within the range for Category D (ie: 42 to 68).	• The MIRAI score <42.
• To ensure that no group consistently dominates the fauna, defined as D abundance for more than two consecutive surveys.	• Any taxon abundance 'D' (>1000) in two consecutive surveys.
• To maintain suitable conditions for the following flow-dependent species in the SIC biotope: *Hydroptilidae Present' * Baetidae .> 2 species: Abundance 'B'. * Simuliidae Abundance 'A'	• Hydroptiliidae absent from two consecutive surveys. • Less than 3 species of Baetidae in any one survey • Simuliidae absent from two consecutive surveys
• To maintain suitable conditions for the following four key taxa: *Hydroptiliidae Baetidae (>2 species) * Simuliidae * Gomphidae*	• Less than three of the four key taxa listed.

7.3.3 Geomorphology

Channel perimeter resistance is the metric at EWR 5 that has the highest weighted score and by monitoring for it the active channel at this site will be maintained (Table 7.5).

Table 7.5: Geomorphology EcoSpecs and Thresholds of Probable Concern (TPC) for EWR 5 for Channel Perimeter Resistance.

METRIC	ECOSPECS	TPCs
Floodzone (macro-channel) stability	▪ 0-50% cover of *Phragmites* on the macro-channel floor. ▪ Maintain present sediment volume stored on the macro-channel floor.	▪ TPC reached if reed cover equals or exceeds 50% of the aerial cover of the macro-channel floor at this site. ▪ TPC reached if the level of sediment on the macro-channel floor elevation increases *(Assess through resurveying of cross-sections at 5 year intervals and after any extreme flood or drought events).*

The site has experienced a moderate (approximately 26%) reduction in potential bed material transport. Aerial photographic analyses show that the site was very stable from the beginning of the photographic record (1937) until 1977. However, after the completion of the Middle Letaba Dam, rapid, extensive vegetation encroachment of the macro-channel floor occurred. Although this has been partly reversed by the 2000 floods, it is almost certain to follow that pattern of change again in the coming years. The removal of high flows from the dam, coupled with the loss of sediment transport potential and vegetation encroachment will increase the sediment storage in the channel. In seasonal rivers such as this one, this has serious implications for continued surface water availability. The increased sediment storage in the channel results in a greater depth from surface to water table, and thus decreased likelihood of permanent water bodies (e.g. pools) exposed during low flow periods. The objective for these TPCs are thus to monitor the vegetation encroachment and associated enhanced sediment storage in the channel.

7.3.4 Fish

The rationale for the metric groups, metrics and species for monitoring are specified below:

- Velocity-depth and cover are the most important metrics for EWR 5.
- The spreadsheets were further analysed for cover, flow modification and physico-chemical aspects to select the best indicators for TPCs based on pre-issued guidelines.

Fish EcoSpecs (preferences / intolerances relating to frequency of occurrence) and TPCs are provided in Table 7.6 and Table 7.7.

Table 7.6: Site EWR5 – Fish EcoSpecs Table.

SD			SS		
SPP	PREF: FREQ	RANK	SPP	PREF: FREQ	RANK
BUNI	1	1	BVIV	0.96	1
TREN	0.98	2	PPHI	0.86	2
OMOS	0.92	3	BUNI	0.86	2
CGAR	0.86	4	BTOP	0.86	2
BTRI	0.78	5	TREN	0.78	5
BPAU	0.78	5	BPAU	0.78	5
LRUD	0.752	7	OMOS	0.76	7
MBRE	0.688	8	CGAR	0.68	8

BTOP	0.66	9	MBRE	0.672	9
SINT	0.6	10	BTRI	0.64	10
LROS	0.564	11	GCAL	0.376	11
LMOL	0.444	12	BMAR	0.272	12
SZAM	0.4	13	**Overh**		
BMAR	0.352	14	SPP	PREF:FREQ	RANK
FS			BVIV	0.98	1
SPP	PREF: FREQ	RANK	BTOP	0.94	2
CPAR	0.588	1	BUNI	0.92	3
LCYL	0.576	2	PPHI	0.9	4
LMOL	0.516	3	TREN	0.86	5
BMAR	0.352	4	BPAU	0.84	6
			BTRI	0.78	7

Table 7.7: Site EWR5 – Fish TPCs.

Species	Reference frequency of occurrence	Pres. Observed & habitat derived frequency of occurrence	TPCs % for PES	Motivation
BUNI	5	4	70	A good indicator for changing marginal vegetation and slow habitats even in times of no-flow. A minimum of 10 specimens should be sampled at 60% of the sites, using a shocker for periods not less than 20 minutes or a hand seine / 4m pole seine for 10 sweeps.
BVIV	5	5	100	A good indicator for changing marginal vegetation. A minimum of 20 specimens should be sampled at 85% of the sites, using a shocker for periods not less than 20 minutes or a hand seine / 4m pole seine for 10 sweeps.
CPAR	3	2	25	A good indicator for no flow and phys-chem, and for substrate. A minimum of 5+H53 specimens should be sampled at 20% of sites during a survey of FS and FD substrate habitat using a shocker for periods not less than 20 minutes.

- TPCs are expressed as a percentage within the range associated with the relevant frequency.

7.3.5 Riparian vegetation

The Riparian vegetation EcoSpecs and TPCs for EWR 5 are indicated in Table 7.8.

Table 7.8: Riparian vegetation EcoSpecs and Thresholds of Probable Concern (TPC) for EWR 5

METRIC GROUP	METRIC	ECOSPECS	TPCs
Marginal zone	Vegetation abundance	▪ Maintain *Phragmites* and hydrophyte fringe along the active channel. ▪ Maintain a *Cyperus marginatus* zone in places along the active channel - motivation should always have a narrow marginal zone present along the active channel and in this reach characterised by *C. marginatus*	▪ *Phragmites* fringe visibly (fixed photo) increasing in abundance ▪ Absence of a *Cyperus marginatus* zone - motivation should always have a narrow marginal zone present along the active channel and in this reach characterised by *C. marginatus*
	Vegetation cover	▪ Maintain *Phragmites* fringe along the active channel ▪ Maintain between 25% to 50% marginal hydrophyte vegetation cover in secondary channels during summer months - motivation secondary channels and backwaters should have water in summer and thus should have at least 25% marginal macrophyte cover	▪ *Phragmites* exceeding 50% cover of the macro-channel floor - motivation historically reeds have not exceeded this % cover of the macro-channel floor ▪ Less than 5% *Cyperus marginatus and Leersia hexandra* cover (*more baseline data is needed to verify these cover values and to quantify the existing cover*) ▪ Less than 25% of marginal macrophyte cover in the secondary channels during the summer months – motivation secondary channels and backwaters should have water in summer and thus should have at least 25% marginal macrophyte cover
	Species richness	▪ Maintain a marginal fringe component.	▪ Cover and abundance is more important than number of species
	Species composition	▪ Maintain the *Phragnites* habitat and the marginal hydrophyte zone dominated by *Cyperus marginatus*, *Schoenoplectus*, *Cynodon dactylon* and *Leersia hexandra.*	▪ Noticeable increase in exotic weedy herbaceous species ▪ Absence of *Phragmites mauritianus*, *Cyperus marginatus* or *Typha capensis* or *Leersia hexandra*
Lower riparian zone	Vegetation cover	▪ Increase the abundance of *Ficus sycomorus* jn the lower riparian zone - motivation a key species dependent on baseflow and bank storage in the lower riparian zone	▪ No increase in the abundance and cover of *Ficus sycomorus* in the lower riparian zone within 5 years
	Species richness	▪ Maintain at least 14 indigenous riparian tree species in this zone – motivation avg. number of species recorded in this zone during field surveys	▪ Less than 10 indigenous riparian tree species – motivation avg. number of species recorded in this zone during field surveys
	Species composition	▪ Maintain *Ficus sycomorus* population and *Combretum erythrophyllum* populations on lower terraces – motivation key lower riparian zone species with both dependent on baseflow	▪ Absence of *Ficus sycomorus* ▪ Absence of *Combretum erythrophyllum*

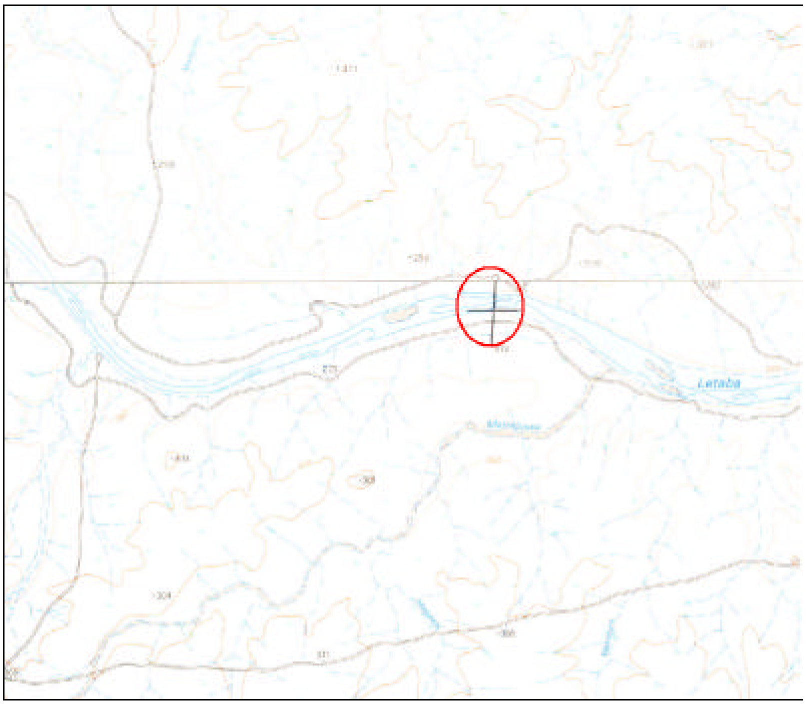
METRIC GROUP	**METRIC**	**ECOSPECS**	**TPCs**
		and the latter also relying on flooding	
	Vegetation structure	▪ Maintain *Ficus sycomorus* and *Combretum erythrophyllum* populations in the lower riparian zone	▪ Absence of a range of age classes of *Ficus sycomorus*
Upper riparian zone	Vegetation cover and composition	▪ Maintain *Diospyros mespiliformis* and *Trichelia emitica* population – motivation typical upper zone species relying on bank storage	▪ Visible decrease in *Diospyros mespiliformis* and/or *Trichelia emitica* cover-abundance
	Species richness	▪ Maintain terrestrial – riparian species mix – motivation prevent terrestrialisation of the upper zone	▪ When the proportion of terrestrial species reaches 50% of the total species count

8. RESOURCE UNIT E: LONELY BULL EWR 6

8.1 SITE DESCRIPTION

This EWR site is situated on the Groot Letaba River in the Kruger National Park, downstream of the confluence with the Klein Letaba River. The main impacts at this site are the reduction in flow due to upstream impoundments as well as direct abstraction for irrigation. The river channel at this site is large (> 150m) and is characterised by the presence of bedrock controls, small cobbles, sand and pebbles. There were very little stones in current habitat due to the low flows experienced at the time of sampling.

Locality: S23 45 09.5; E31 24 26.3



EWR 6

Figure 8.1: Map of EWR 6 (taken from 1:50 000 scale map) as well as from Google .earth

8.2 BASELINE REQUIREMENTS

The limitations and confidence in the available data for each component at EWR 6 are summarised in the following tables.

Geomorphology

1. Spatial data	**Very High**	Only one site in resource unit which is very representative and unimpacted
2. Temporal field data	**Moderate**	No previous field surveys at site, but other long-term studies at similar sites nearby (in Kruger Park)
3a. Temporal remote data (availability of aerial photographs)	**Very High**	Very good aerial photo record available (from 1938 until recent)
3b. Anecdotal/historical info on land use and flows	**Very High**	Long flow record and good modelled flows available at a gauge station close to the site, and good anecdotal info on flood records
4. Monitoring assessment method	**High**	Assessment by geomorphological specialist
5. Environmental Change		No significant change since last survey.
Conclusion	**A site visit is required to fully populate the GAI and initiate monitoring. (The GAI model was developed after the field surveys for this study. Time on site will be required to assess info requirements for perimeter resistance component of the GAI model).**	

Water quality

1. Number of WQ stations	**High**	Single WQU
2. Locality of WQ stations	**High**	
3. Adequacy of data	**Very high**	RC and PES from same water quality monitoring point
4. Frequency of sampling	**High**	Minimum of monthly samples for 5 years available for both RC and PES.
5. Appropriate parameters	**High**	
6. Understanding of impacts	**Low**	No instream toxicity
7. Interpreting biological responses	**High**	Several biomonitoring (SASS and fish) surveys have been undertaken at this site as well as the RHP is using this site for assessments of the state of the catchment.
Conclusion	*** No further baseline data needed, unless there is a significant change in environmental conditions, prior to the initiation of the monitoring. The same baseline data source was used for EWR sites 6 and 7.**	

Invertebrates

1. Spatial data	**Very High**	Chutter, Moore, Deacon (RHP) as well as two surveys as part of this study
2. Temporal data	**High to Moderate**	Irregular surveys more than 15 years
3. Interpretive characteristics	**Moderate**	*Tricorythidae, Amphisyche scottae, Hydropsyche longifurca*
4. Environmental Change		No significant change since last survey.
Conclusion	*** No further baseline data needed, unless there is a significant change in environmental conditions, prior to the initiation of the monitoring.**	

Fish

1. Spatial data	**Very High**	Good historical data available at this site, as well as sites above and below. 3 sites upstream and 2 sites downstream in KNP.
2. Temporal data	**Very High**	Good historical data available at this site for more than 20 years, as well as sites above and below. Pienaar and Gaigher in the 1960-1970's, and Russell in the 1980's. Deacon and RHP since 1990.
3. Interpretive characteristics	**Very High**	Good distribution of species and good ecological knowledge. A limited number of indicator species available.
4. Environmental Change		Since 2004 low flows persisted and cessation of flows has contributed to the deterioration of the environmental integrity of the system.
Conclusion	**No further baseline data needed, unless there is a significant change in environmental conditions, prior to the initiation of the monitoring.**	

Riparian vegetation

1. Spatial data	**Very High**	Data available, site representative of the whole resource unit and EWR 7 also falls in this Resource Unit
2. Temporal data	**Moderate**	Only data available from this survey plus historical air photo record but resolution was difficult for riparian vegetation interpretation
3. Interpretive characteristics	**Moderate**	Woodies are far from the main stream and do not supply interpretative information and as marginal vegetation more useful. *Cyperus marginatus, Leersia hexandra* and *Phragmites mauritianus* good low flow indicators
4. Quality of assessment	**Very High**	Interim model of VEGRAI was used. Habitat Integrity assessment undertaken. Riparian vegetation specialist did survey
5. Data sources	**High**	Aerial photos and video. Local knowledge Landcover data

6. Environmental Change	**Low to Very Low**	Significant change due to 2000 floods
Conclusion	**No additional survey needed, prior to the initiation of the monitoring.as EWR site is representative, two sites within the Resource Units (EWR 6 and 7). Data needs to be converted to VEGRAI level 4. If additional information is required to update the marginal vegetation and additional survey might be required**	

8.3 ECOSPECS AND TPCS

The Ecological Categories (ECs) associated with the EcoSpecs are provided in Table 8.1. The EcoSpecs and Thresholds of Potential Concern (TPCs) for each component for the ECs as in Table 8.1 are provided in the sections below.

Table 8.1: Driver and response results for PES, REC and Eco Status for EWR 6.

Driver Components	Component	REC	EcoSpecs
Hydrology	**D**	**D**	**D**
Geomorphology	**C**	**C**	**C**
Water quality	**C**	**C**	**C**
Response Components			
Fish	**C**	**C**	**C**
Aquatic invertebrates	**D**	**D**	**D**
Riparian vegetation	**C**	**C**	**C**
EcoStatus	**C**	**C**	**C**

8.3.1 Water quality (Category B)

Landuse in this RU and WQU is protected land or conservation area, i.e. the Kruger National Park. Analysis of data and consultation with other specialists suggest the following potential water quality issues at EWR 6:

- Nutrient status. Increased flows will increase the SRP concentration and decreased flows will increase the Periphyton levels. The potential for the latter is greater.
- Toxics may be a problem due to wash-off from the agricultural area upstream (namely herbicides or pesticides).
- Temperature increases during low flows.
- A drop in oxygen levels during low flows.

Large variations in turbidity, oxygen and temperature are noted during low flows. Although increases are partly natural due to input from the Klein Letaba and Molototsi rivers, which are sandy-bed rivers, conditions are exacerbated compared to the natural state.

Table 8.2 is the PAI rating table for the EWR site, showing the comparative importance of physico-chemical metrics and the contribution of each metric to the water quality condition at the site, while Table 8.3 lists the EcoSpecs and TPCs.

Taking into account the ranking, rating and the resultant weighted score the suggested water quality monitoring Eco specs and TPCs for EWR 6 are indicated in Table 8.3. The water quality monitoring should include the following parameters not currently monitored at EWR 6:

- Temperature, dissolved oxygen, turbidity / clarity: particularly important during low flows
- In-stream toxicity: in response to a biotic trigger, but initiate tests twice a year during high and low flows. Test frequency can be decreased depending on test results.
- Chl-a: Periphyton: important as nutrient elevations expected during low flows
- Selected toxics related to agricultural activities

Table 8.2: PAI rating table for EWR 6.

SCORING GUIDELINES		EWR6	Scenario Present		
Physico-chemical Metrics	Rank	%wt	Rating	Weight	Weighted score
pH	5	40	0.50	0.07	0.04
SALTS	2	95	2.00	0.17	0.35
NUTRIENTS	2	95	3.00	0.17	0.52
TEMPERATURE	3	85	2.00	0.15	0.31
TURBIDITY	4	50	2.00	0.09	0.18
OXYGEN	3	85	2.00	0.15	0.31
TOXICS	1	100	0.50	0.18	0.09
TOTALS		550			1.79
PHYSICO-CHEMICAL PERCENTAGE SCORE					64.18
PHYSICO-CHEMICAL CATEGORY					C

Table 8.3: EcoSpecs and TPC table for EWR 6.

River	Letaba River: Lonely Bull			
Monitoring Site	B8H028Q01			
EWR Site	6			
EcoSpecs		**TPC**		**Monitoring Frequency**
Inorganic salts	$MgSO_4$	95th percentile of data must be less than the TPC	23 mg/L	Monthly
	Na_2SO_4		20 mg/L	
	$MgCl_2$		30 mg/L	
	$CaCl_2$		57 mg/L	
	NaCl		191 mg/L	
	$CaSO_4$		351 mg/L	
Nutrients	SRP	50th percentile of data must be less than the TPC	0.021 mg/L	Monthly
	TIN		0.070 mg/L	
Physical variables	pH (pH units)	95th percentile of data must be less than the TPC	6.5 to 8.8	Monthly
	Temperature		Vary by not more than 2º C	
	Dissolved oxygen		6 – 7 mg/L	
	Turbidity (NTU)		Moderate change allowed – catchment + landuse changes result in temporary sediment loads during rainfall events	
Response variables	Chl-a: periphyton	50th percentile of data must be less than the TPC	21 mg/m²	Quarterly
	Chl-a: phytoplankton		15 µg/L	
	In-stream toxicity	In-stream toxicity should not occur	Any indication of in-stream toxicity	In response to a biotic trigger, or twice a year during high and low flows
Toxics #	Fluoride	95th percentile of data must be less than the TPC	1500 µg/L	Monthly
	Ammonia		15 µg/L	
	Al		20 µg/L	
	Cu soft*		0.5 µg/L	
	Cu mod**		1.5 µg/L	
	Cu hard***		2.4 µg/L	
	Pb soft*		0.5 µg/L	
	Pb mod**		1 µg/L	
	Pb hard***		2 µg/L	

Note that current monitoring does not include toxics other than fluoride. As no data exists, background levels of toxics should be assessed and the TPCs adjusted accordingly if required.

8.3.2 Invertebrates

The preliminary EcoSpecs for invertebrates for EWR 4 are indicated in Table 8.4.

Table 8.4: Invertebrate EcoSpecs and Thresholds of Probable Concern (TPC) for EWR 6 (Lonely Bull), for Category D.

PRELIMINARY EcoSpecs	TPCs
• To ensure that the SASS5 scores and ASPT values occur in the following range: SASS5 score 80 to 130; ASPT 5.0 to 6.0	• The SASS5 score < 85 and ASPT < 5.2.
• To ensure that the MIRAI score is within the range for Category D (ie: 42 to 68).	• The MIRAI score <42.
• To ensure that no group consistently dominates the fauna, defined as D abundance for more than two consecutive surveys.	• Any taxon abundance D' (>1000) in two consecutive surveys. • Thiaridae abundance C' (>100) in two consecutive surveys.
• To maintain suitable conditions for the following flow-dependent species in the SIC biotope: *Elmidae: Abundance 'B' *Hydropsychidae > 2 species: Abundance 'B'. *Leptophlebiidae Abundance B	• Elmidae absent from two consecutive surveys. • Hydropsychidae less than two species in any one survey. • Leptophlebiidae absent in any one survey.
• To maintain suitable conditions for the following five key taxa: *Elmidae *Hydropsychidae *Leptophlebiidae *Corbiculidae *Thiaridae	• Less than four of the five key taxa listed.

8.3.3 Geomorphology

Channel perimeter resistance and Morphological change are the two metrices at EWR 6 that has the highest weighted score and by monitoring for it the active channel at this site will be maintained (Table 8.5).

Table 8.5: Geomorphology EcoSpecs and Thresholds of Probable Concern (TPC) for EWR6 (Category D).

Channel Perimeter Resistance

METRIC	ECOSPECS	TPCs
Bank (in)stability	Increase the reed fringes along active channel margins to promote a more stable active channel	TPC reached if there is no increase, relative to the 2000 condition of the river, of the length of reed fringes adjacent to the active channel/s at the site.

Morphological Change

METRIC	ECOSPECS	TPCs
	HYDRAULIC GEOMETRY	
Reach Type	Maintaining present channel type assemblages	Monitor channel type change. TPC reached if there is a loss of secondary channels in nearby anastomosing channel type reaches *(Assess at 5 year intervals and after any extreme flood or drought events).*

Channel segments in this area have shown a progressive reduction in the number and extent of active channels, and progressive vegetation encroachment on the macro-channel floor. In many sections the channel patterns have changed from mixed anastomosing to single thread pool-rapid patterns in recent historical times. The 2000 floods caused a reversal of some of these changes, but we anticipate that with the (approximately 38%) reduction in sediment transport capacity because of reduced flows, the pattern is likely to recur in the near future. A loss of multi-channel sections of the river is of high concern because this results in a reduction of instream habitat biodiversity and species richness. Monitoring channel pattern change (using aerial photographs) would allow effective assessment of this trend.

Additionally, the restoration of low flows at this site would promote the development of a stabilised active channel through the development of marginal vegetation, specifically reeds. This would allow scouring of the active channel during higher flows (rather than sediment redistribution and infilling if the channel was unconfined/unstable). This would allow for increased instream morphological diversity.

8.3.4 Fish

The rationale for the metric groups, metrics and species for monitoring are specified below:

- Velocity-depth and cover are the most important metrics for EWR 6.
- The spreadsheets were further analysed for cover, flow modification and physico-chemical aspects to select the best indicators for TPCs based on pre-issued guidelines.

Fish EcoSpecs (preferences / intolerances relating to frequency of occurrence) and TPCs are provided in Table 8.6 and Table 8.7.

Table 8.6: Site EWR 6 – Fish EcoSpecs Table.

FS			DS		
SPP	**PREF: FREQ**	**RANK**	**SPP**	**PREF: FREQ**	**RANK**
CPAR	0.98	1	SINT	1	1
BMAR	0.88	2	BUNI	1	1
LMOL	0.86	3	LROS	0.94	3
LCYL	0.768	4	HVIT	0.94	3
AMOS	0.264	5	BRAD	0.94	3
Substrate			OMOS	0.92	6
SPP	PREF:FREQ	RANK	BMAR	0.88	7
LROS	1	1	SZAM	0.8	8
CPAR	0.98	2	TREN	0.784	9
LMOL	0.94	3	BTRI	0.78	10
BMAR	0.9	4	LRUD	0.752	11

FS			**DS**		
SPP	**PREF: FREQ**	**RANK**	**SPP**	**PREF: FREQ**	**RANK**
LCYL	0.784	5	LMOL	0.74	12
LRUD	0.752	6	MBRE	0.688	13
LCON	0.6	7	MACU	0.688	13
GGIU	0.588	8	CGAR	0.688	13
AMOS	0.392	9	LCON	0.6	16
AMAR	0.336	10	BANN	0.6	16
WC			PCAT	0.564	18
SPP	PREF:FREQ	RANK	BIMB	0.564	18
HVIT	0.98	1	MMAC	0.504	20
SINT	0.94	2	BPAU	0.468	21
BMAR	0.82	3	AMAR	0.352	22
MBRE	0.8	4	AMOS	0.272	23
OMOS	0.78	5	BTOP	0.264	24
MACU	0.64	6			
BIMB	0.564	7			
BANN	0.564	7			
BPAU	0.42	9			
LCON	0.408	10			

Table 8.7: Site EWR 6 – Fish TPCs

Species	Reference frequency of occurrence	Pres. Observed & habitat derived frequency of occurrence	TPCs % for PES	Motivation
BMAR	5	5	**100**	Good indicator of low flows and poor water quality (temperature). A minimum of 20 fish should be recorded at every site through surveys of all available habitats using appropriate methods.
CPAR	5	4	**70**	A good indicator for no flow and phys-chem, and for substrate. A minimum of 10 specimens, should be found at 70% of sites during a survey of FS and FD substrate habitat using a shocker for periods not less than 20 minutes.
HVIT	5	4	**52**	Flagship species. A good indicator for good water quality and deep water habitats. A minimum of 3 fish should be sampled at 50% sites using appropriate methods which could include: large seine (2 drags), cast net 15 casts or angling techniques (1 rod - 1 hour).

* TPCs are expressed as a percentage within the range associated with the relevant frequency.

8.3.5 Riparian vegetation

The Riparian vegetation EcoSpecs and TPCs for EWR 4 are indicated in Table 8.8.

Table 8.8: Riparian vegetation EcoSpecs and Thresholds of Probable Concern (TPC) for EWR 6.

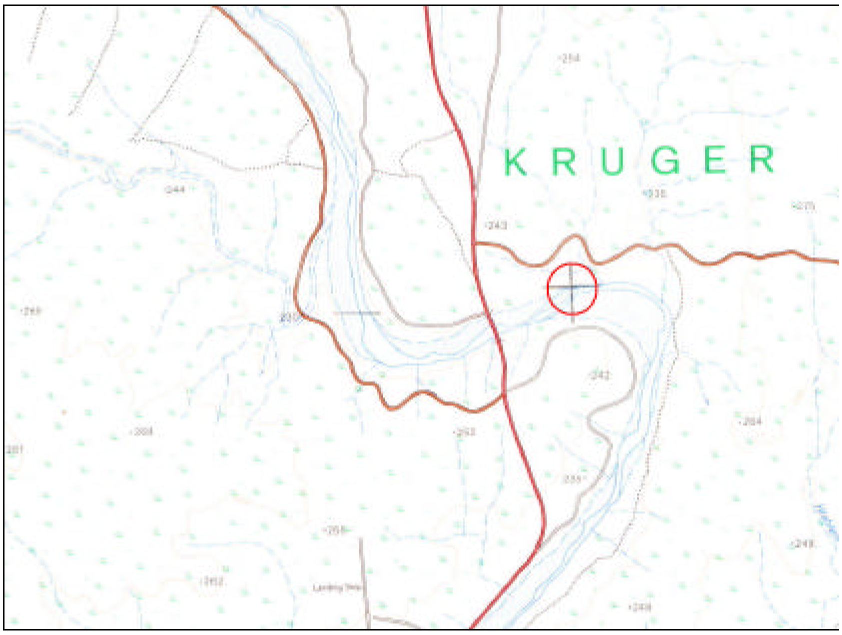
METRIC GROUP	METRIC	ECOSPECS	TPCs
Marginal zone	Vegetation abundance	▪ Maintain *Phragmites* and hydrophyte fringe along the active channel.	▪ *Phragmites* fringe shrinking and/or becoming more fragmented along the active channel – abundance decreasing from current levels (more baseline data to quantify the existing patchiness)
	Vegetation cover	▪ Maintain *Phragmites* fringe along the active channel ▪ Ideally a cover of greater than 5% and less than 50% required but need more baseline data to quantify the minimum requirement – <u>motivation</u> need to maintain reed habitat for fish and concentration of channel flow but should not exceed 50% cover of the macro-channel floor	▪ *Phragmites* fringe shrinking and/or becoming more fragmented along the active channel ▪ Less than 5% and greater than 50% *Phragmites* cover (*more baseline data is needed to verify these cover values and to quantify the existing cover*) – <u>motivation</u> need to maintain reed habitat for fish and concentration of channel flow but should not exceed 50% cover of the macro-channel floor ▪ Absence of marginal macrophye zone - <u>motivation</u> should always have a narrow marginal zone present along the active channel
	Species richness	▪ Maintain a marginal fringe component.	▪ Cover and abundance is more important than number of species
	Species composition	▪ Maintain the *Phragnites* habitat and the marginal hydrophyte zone dominated by *Cyperus marginatus*, *Schoenoplectus*, *Cynodon dactylon* and *Leersia hexandra*.	▪ Noticeable increase in exotic weedy herbaceous species ▪ Absence of *Phragmites mauritianus* ▪ Absence of *Cyperus marginatus* and/or *Leersia hexandra* and/or *Schoenoplectus* and/or *Cynodon* ▪ Absence of *Typha capensis*
Lower riparian zone	Vegetation cover	General increase in indigenous riparian tree cover – <u>motivation</u> 2000 floods removed the terraces and most of the lower riparian zone and this is necessary for the re-establishment of this zone	▪ No increase in indigenous riparian tree cover within 5 years
	Species richness	-	-
	Species composition	-	-
	Vegetation structure	-	-
Upper riparian zone	Vegetation cover and composition	▪ Maintain *Hyphanaea natalensis* population ▪ Maintain *Diospyros mespiliformis* population ▪ Maintain *Combretum microphyllum* population ▪ Maintain *Combretum imberbe* population – <u>motivation</u> all typical upper zone species relying on bank storage	▪ Absence of *Hyphanaea natalensis* (indicates a possible drop in bank groundwater storage) ▪ Visible decrease in *Diospyros mespiliformis* and/or *Combretum microphyllum* cover-abundance ▪ Dying of *Combretum imberbe*adults – <u>motivation</u> all typical upper zone species relying on bank storage
	Species richness	▪ Maintain terrestrial – riparian species mix – <u>motivation</u> prevent terrestrialisation of the upper zone	▪ When the proportion of terrestrial species reaches 50% of the total species count

9. RESOURCE UNIT E: LETABA BRIDGE EWR 7

9.1 SITE DESCRIPTION

This EWR site is situated on the Groot Letaba River, downstream of the EWR 6 site. The river channel at this site is large (> 150m) and is characterised by the presence of bedrock controls, small cobbles, sand and pebbles. Between the EWR 6 and EWR 7 sites there is a tributary that flows north south from within the Kruger National Park that during the summer season contributes to the flow at this EWR site. There are very little stones in current habitat due to the low flows experienced at the time of sampling. EWR 7 was selected to determine only the low flows during the dry season upstream of Letaba Rest Camp.

Locality: **S23 48 35.4; E31 35 26.9**



EWR 7

Figure 9.1: Map of EWR 7 (taken from 1:50 000 scale map) as well as from Google .earth

9.2 BASELINE REQUIREMENTS

The limitations and confidence in the available data for each component at EWR 7 are summarised in the following tables.

Geomorphology

1. Spatial data	**Very High**	Only one site in resource unit which is very representative and unimpacted
2. Temporal field data	**Moderate**	No previous field surveys at site, but other long-term studies at similar sites nearby (in Kruger Park)
3a. Temporal remote data (availability of aerial photographs)	**Very High**	Very good aerial photo record available (from 1938 until recent)
3b. Anecdotal/historical info on land use and flows	**High**	Flow records a problem due to floods and upstream dams
4. Monitoring assessment method	**High**	Assessment by geomorphological specialist
5. Environmental Change		No significant change since last survey.
Conclusion	**A site visit is required to fully populate the GAI and initiate monitoring. (The GAI model was developed after the field surveys for this study. Time on site will be required to assess info requirements for perimeter resistance component of the GAI model).**	

Water quality

1. Number of WQ stations	**High**	Single WQU
2. Locality of WQ stations	**High**	
3. Adequacy of data	**Very high**	RC and PES from same water quality monitoring point
4. Frequency of sampling	**High**	Minimum of monthly samples for 5 years available for both RC and PES.
5. Appropriate parameters	**High**	
6. Understating of impacts	**Low**	No instream toxicity
7. Interpreting biological responses	**High**	Several biomonitoring (SASS and fish) surveys have been undertaken at this site as well as the RHP is using this site for assessments of the state of the catchment.
Conclusion	*** No further baseline data needed, unless there is a significant change in environmental conditions, prior to the initiation of monitoring. The same baseline data source was used for EWR sites 6 and 7.**	

Invertebrates

1. Spatial data	**Very High**	Chutter, Moore, Deacon (RHP) as well as two surveys as part of this study
2. Temporal data	**High to Moderate**	Irregular surveys more than 15 years
3. Interpretive characteristics	**Moderate**	*Leptophlebiidae, Hydropsyche longifurca, Cheumatopsyche thomasetti*
4. Environmental Change		No significant change since last survey.
Conclusion	*** No further baseline data needed, unless there is a significant change in environmental conditions, prior to the initiation of monitoring.**	

Fish

1. Spatial data	**Very High**	Good historical data available at this site, as well as sites above and below. 3 sites upstream and 2 sites downstream in KNP.
2. Temporal data	**Very High**	Good historical data available at this site for more than 20 years, as well as sites above and below. Pienaar and Gaigher in the 1960-1970's, and Russell in the 1980's. Deacon and RHP since 1990.
3. Interpretive characteristics	**Very High**	Good distribution of species and good ecological knowledge. A limited number of indicator species available.
4. Environmental Change		Since 2004 low flows persisted and cessasion of flows have contributed to the deterioration of the environmental integrity of the system.
Conclusion	**No further baseline data needed, unless there is a significant change in environmental conditions, prior to the initiation of monitoring.**	

Riparian vegetation

1. Spatial data	**Very High**	Data available, site representative of the whole resource unit and EWR 7 also falls in this Resource Unit
2. Temporal data	**Moderate**	Only data available from this survey plus historical air photo record but resolution was difficult for riparian vegetation interpretation
3. Interpretive characteristics	**Moderate**	Woodies are far from the main stream and do not supply interpretative information and as marginal vegetation more useful. *Cyperus marginatus*, *Leersia hexandra* and *Phragmites mauritianus* good low flow indicators
4. Quality of assessment	**Very High**	Interim model of VEGRAI was used. Habitat Integrity assessment undertaken. Riparian vegetation specialist did survey
5. Data sources	**High**	Aerial photos and video. Local knowledge Landcover data

6. Environmental Change	**Low to Very Low**	Significant change due to 2000 floods
Conclusion	**No additional survey needed, prior to the initiation of monitoring. as EWR site is representative, two sites within the Resource Units (EWR 6 and 7). Data needs to be converted to VEGRAI level 4. If additional information is required to update the marginal vegetation and additional survey might be required**	

9.3 ECOSPECS AND TPCS

The Ecological Categories (ECs) associated with the EcoSpecs are provided in Table 9.1. The EcoSpecs and Thresholds of Potential Concern (TPCs) for each component for the ECs as in Table 9.1 are provided in the sections below.

Table 9.1: Driver and response results for PES, REC and Eco Status for EWR 7.

Driver Components	Component PES	REC	EcoSpecs
Hydrology	**D**	**D**	**D**
Geomorphology	**C**	**C**	**C**
Water quality	**C**	**C**	**C**
Response Components			
Fish	**C**	**C**	**C**
Aquatic invertebrates	**D**	**D**	**D**
Riparian vegetation	**C**	**C**	**C**
EcoStatus	**C**	**C**	**C**

9.3.1 Water quality (Category B)

Landuse in this RU and WQU is protected land or conservation area, i.e. the Kruger National Park. Analysis of data, flow duration curves and consultation with other specialists suggest the following potential water quality issues at EWR 7:

- Increased peripyhyton during low flows.
- Increased SRP during high flow, but unlikely as no agriculture.
- Potentially increased turbidity during very high flows.
- Temperature increases during low flows.
- A drop in oxygen levels during low flows.

Large diurnal temperature differences suggest significant impacts during low flows. Although turbidity levels are related to input from tributaries, high turbidities are of a temporary nature.

Table 9.2 is the PAI rating table for the EWR site, showing the comparative importance of physico-chemical metrics and the contribution of each metric to the water quality condition at the site, while Table 9.3 lists the EcoSpecs and TPC.

Taking into account the ranking, rating and the resultant weighted score the suggested water quality monitoring Eco specs and TPCs for EWR 7 are indicated in Table 9.3. The water quality monitoring should include the following parameters not currently monitored at EWR 7:

- Temperature, dissolved oxygen, turbidity / clarity: particularly important during low flows
- In-stream toxicity: only in response to a biotic trigger
- Chl-a: Periphyton: important as nutrient elevations expected during low flows
- Selected toxics: F and ammonia

Table 9.2: PAI rating table for EWR 7.

SCORING GUIDELINES	EWR 7: Scenario Present				
Physico-chemical Metrics	Rank	%wt	Rating	Weight	Weighted score
pH	5	40	0.50	0.07	0.04
SALTS	2	95	0.50	0.17	0.09
NUTRIENTS	2	95	2.50	0.17	0.43
TEMPERATURE	3	85	2.00	0.15	0.31
TURBIDITY	4	50	1.00	0.09	0.09
OXYGEN	3	85	2.00	0.15	0.31
TOXICS	1	100	0.00	0.18	0.00
TOTALS		550			1.26
PHYSICO-CHEMICAL PERCENTAGE SCORE					74.73
PHYSICO-CHEMICAL CATEGORY					C

Table 9.3: EcoSpecs and TPC table for EWR 7

River	Letaba River: Below Letaba Bridge			
Monitoring Site	B8H028Q01			
EWR Site	7			
EcoSpecs		**TPC**		**Monitoring Frequency**
Inorganic salts	$MgSO_4$	95th percentile of data must be less than the TPC	23 mg/L	Monthly
	Na_2SO_4		20 mg/L	
	$MgCl_2$		30 mg/L	
	$CaCl_2$		57 mg/L	
	NaCl		191 mg/L	
	$CaSO_4$		351 mg/L	
Nutrients	SRP	50th percentile of data must be less than the TPC	0.021 mg/L	Monthly
	TIN		0.070 mg/L	
	pH (pH units)		6.5 to 8.8	

River	Letaba River: Below Letaba Bridge			
Monitoring Site	B8H028Q01			
EWR Site	7			
EcoSpecs		**TPC**		**Monitoring Frequency**
Physical variables	Temperature	95^{th} percentile of data must be less than the TPC	Vary by not more than 2° C	
	Dissolved oxygen		6 – 7 mg/L	
	Turbidity (NTU)		Small change allowed – largely natural and related to natural catchment processes such as rainfall runoff.	
Response variables	Chl-a: periphyton	50^{th} percentile of data must be less than the TPC	21 mg/m^2	Quarterly
	Chl-a: phytoplankton		15 µg/L	
	In-stream toxicity	In-stream toxicity should not occur	Any indication of in-stream toxicity	In response to a biotic trigger
Toxics #	Fluoride	95^{th} percentile of data must be less than the TPC	1500 µg/L	Monthly
	Ammonia		15 µg/L	

Note that current monitoring does not include toxics other than fluoride. As no data exists, background levels of toxics should be assessed and the TPCs adjusted accordingly if required.

9.3.2 Invertebrates

The preliminary EcoSpecs for invertebrates for EWR 7 are indicated in Table 9.4.

Table 9.4: Invertebrate EcoSpecs and Thresholds of Probable Concern (TPC) for EWR 7 (Letaba Bridge), for Category D.

PRELIMINARY EcoSpecs	TPCs
• To ensure that the SASS5 scores and ASPT values occur in the following range: SASS5 score 80 to 140; ASPT 4.0 to 4.5	• The SASS5 score < 85 and ASPT < 4.2.
• To ensure that the MIRAI score is within the range for Category D (ie: 42 to 68).	• The MIRAI score <42.
• To ensure that no group consistently dominates the fauna, defined as D abundance for more than two consecutive surveys.	• Any taxon abundance D' (>1000) in two consecutive surveys. • Thiaridae abundance C' (>100) in two consecutive surveys.
• To maintain suitable conditions for the following flow-dependent species in the SIC biotope: *Elmidae: Abundance ‘B’ *Hydropsychidae - > 2 species: Abundance ‘B’. *Leptophlebiidae Abundance B	• Elmidae absent from two consecutive surveys. • Hydropsychidae less than two species in any one survey. • Leptophlebiidae absent in any one survey.
• To maintain suitable conditions for the following six key taxa:	• Less than four of the six key taxa listed.

PRELIMINARY EcoSpecs	TPCs
*Elmidae *Hydropsychidae *Hydroptilidae *Leptophlebiidae *Corbiculidae *Thiaridae	

9.3.3 Geomorphology

Channel perimeter resistance and Morphological change are the two metrices at EWR 7 that has the highest weighted score and by monitoring for it the active channel at this site will be maintained (Table 9.5).

Table 9.5: Geomorphology EcoSpecs and Thresholds of Probable Concern (TPC) for EWR 7 (Category D).

Channel Perimeter Resistance

METRIC	ECOSPECS	TPCs
Bank (in)stability	Increase the reed fringes along active channel margins to promote a more stable active channel	TPC reached if there is no increase, relative to the 2000 condition of the river, of the length of reed fringes adjacent to the active channel/s at the site.

Morphological Change

METRIC	ECOSPECS	TPCs
HYDRAULIC GEOMETRY		
Reach Type	Maintaining present channel type assemblages	Monitor channel type change. TPC reached if there is a loss of secondary channels in nearby anastomosing channel type reaches *(Assess at 5 year intervals and after any extreme flood or drought events).*

As with EWR 6, channel segments in this area have shown a progressive reduction in the number and extent of active channels, and progressive vegetation encroachment on the macro-channel floor. In many sections the channel patterns have changed from mixed anastomosing to single thread pool-rapid patterns in recent historical times. The 2000 floods caused a reversal of some of these changes, but we anticipate that with the (approximately 38%) reduction in sediment transport capacity because of reduced flows, the pattern is likely to recur in the near future. A loss of multi-channel sections of the river is of high concern because this results in a reduction in instream habitat biodiversity and species richness. Monitoring channel type changes (using aerial photographs) would allow effective assessment of this trend.

Additionally, the restoration of low flows at this site would promote the development of a stabilised active channel through the development of marginal vegetation, specifically reeds. This would allow scouring of the active channel during higher flows (rather than sediment redistribution and infilling if the channel was unconfined/unstable). This would allow for increased instream morphological diversity.

9.3.4 Fish

The rationale for the metric groups, metrics and species for monitoring are specified below:

- Velocity-depth and cover are the most important metrics for EWR 7.
- The spreadsheets were further analysed for cover, flow modification and physico-chemical aspects to select the best indicators for TPCs based on pre-issued guidelines.

Fish EcoSpecs (preferences / intolerances relating to frequency of occurrence) and TPCs are provided in Table 9.6 and Table 9.7.

Table 9.6: Site EWR7 – Fish EcoSpecs Table.

FS			**SD**			**WC**		
SPP	**PREF: FREQ**	**RANK**	**SPP**	**PREF: FREQ**	**RANK**	**SPP**	**PREF:FREQ**	**RANK**
CPAR	0.98	1	BUNI	1	1	BMAR	0.82	1
BMAR	0.88	2	LROS	0.94	2	BAFR	0.8	2
LMOL	0.86	3	BRAD	0.94	2	HVIT	0.784	3
LCYL	0.768	4	BAFR	0.94	2	OMOS	0.78	4
CSWI	0.564	5	OMOS	0.92	5	SINT	0.752	5
AMOS	0.264	6	BMAR	0.88	6	MACU	0.64	6
CPRE	0.196	7	CGAR	0.86	7	MBRE	0.6	7
Subst			SINT	0.8	8	BIMB	0.564	8
SPP	PREF:FREQ	RANK	TREN	0.784	9	BANN	0.564	8
LROS	1	1	BTRI	0.78	10	LCON	0.408	10
CPAR	0.98	2	LRUD	0.752	11	BPAU	0.28	11
LMOL	0.94	3	HVIT	0.752	11			
BMAR	0.9	4	LMOL	0.74	13			
LCYL	0.784	5	MACU	0.688	14			
LRUD	0.752	6	SZAM	0.6	15			
LCON	0.6	7	LCON	0.6	15			
GGIU	0.588	8	BANN	0.6	15			
CSWI	0.588	8	BIMB	0.564	18			
AMOS	0.392	10	MBRE	0.516	19			
AMAR	0.336	11	BTOP	0.396	20			
CPRE	0.196	12	PCAT	0.376	21			
AAEN	0.196	12	AMAR	0.352	22			
			MMAC	0.336	23			
			BPAU	0.312	24			
			AMOS	0.272	25			
			AAEN	0.14	26			

Table 9.7: Site EWR7 – Fish TPCs.

Species	Reference frequency of occurrence	Pres. Observed & habitat derived frequency of occurrence	TPCs % for PES	Motivation
BMAR	5	4	60	Good indicator of low flows and poor water quality (temperature). A minimum of 20 fish should be recorded at every site through surveys of all available habitats using appropriate methods.
CPAR	5	4	70	A good indicator for no flow and phys-chem, and for substrate. A minimum of 10 specimens, should be found at 70% of sites during a survey of FS and FD substrate habitat using a shocker for periods not less than 20 minutes.
HVIT	4	4	52	Flagship species. A good indicator for good water quality and deep water habitats. A minimum of 3 fish should be sampled at 50% sites using appropriate methods which could include: large seine (2 drags), cast net 15 casts or angling techniques (1 rod - 1 hour).

* TPCs are expressed as a percentage within the range associated with the relevant frequency.

9.3.5 Riparian vegetation

The Riparian vegetation EcoSpecs and TPCs for EWR 4 are indicated in Table 9.8.

Table 9.8: Riparian vegetation EcoSpecs and Thresholds of Probable Concern (TPC) for EWR 7.

METRIC GROUP	METRIC	ECOSPECS	TPCs
Marginal zone	Vegetation abundance	▪ Maintain *Phragmites* and hydrophyte fringe along the active channel.	▪ *Phragmites* fringe shrinking and/or becoming more fragmented along the active channel – abundance decreasing from current levels (more baseline data to quantify the existing patchiness)
	Vegetation cover	▪ Maintain *Phragmites* fringe along the active channel ▪ Ideally a cover of greater than 5% but less than 50% required but need more baseline data to quantify the minimum requirement – <u>motivation</u> need to maintain reed habitat for fish and concentration of channel flow but should not exceed 50% cover of the macro-channel floor	▪ *Phragmites* fringe shrinking and/or becoming more fragmented along the active channel ▪ Less than 5% and greater than 50% *Phragmites* cover (*more baseline data is needed to verify these cover values and to quantify the existing cover*) – <u>motivation</u> need to maintain reed habitat for fish and concentration of channel flow but should not exceed 50% cover of the macro-channel floor ▪ Absence of marginal macrophye zone
	Species richness	▪ Maintain a marginal fringe component.	▪ Cover and abundance is more important than number of species
	Species composition	▪ Maintain the *Phragnites* habitat and the marginal hydrophyte zone dominated by *Cyperus marginatus*, *Schoenoplectus*, *Cynodon dactylon* and *Leersia hexandra* – <u>motivation</u> low flows need to be adequate to support these species	▪ Noticeable increase in exotic weedy herbaceous species ▪ Absence of *Phragmites mauritianus* ▪ Absence of *Cyperus marginatus* and/or *Leersia hexandra* and/or *Schoenoplectus* and/or *Cynodon* – <u>motivation</u> low flows need to be adequate to support these species ▪ Absence of *Typha capensis* – <u>motivation</u> low flows need to be adequate to support this species
Lower riparian zone	Vegetation cover	▪ General increase in indigenous riparian tree cover – <u>motivation</u> 2000 floods removed the terraces and most of the lower riparian zone and this is necessary for the re-establishment of this zone	▪ No increase in indigenous riparian tree cover within 5 years
	Species richness	-	-
	Species composition	-	-
	Vegetation structure	-	-
Upper riparian zone	Vegetation cover	▪ Maintain *Combretum microphyllum* population ▪ Maintain *Combretum imberbe* population – <u>motivation</u> typical upper zone species relying on bank storage	▪ Visible decrease in *Combretum microphyllum* cover-abundance ▪ Dying of *Combretum imberbe* adults
	Species richness	-	-

10. CONCLUSIONS

10.1 ECOLOGICAL CATEGORIES AND ECOSPECS

The primary EcoSpecs are the Ecological categories and these are summarized in Table 10.1.

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

Table 10.1: 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**

10.2 BASELINE

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 10.2. 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) and initiate monitoring. This is due to the GAI model only having being developed after the field surveys for this study. A short time on site will be required to assess info requirements for perimeter resistance component of the GAI model.

The existing vegetation survey data needs to be converted to VEGRAI level 4 for EWR sites 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.

10.3 WATER QUALITY MONITORING

The following water quality general procedure should be adopted in selecting water quality variables for Ecological Reserve monitoring:

- Ongoing monitoring and comparison against TPCs in an iterative adaptive management process will indicate whether monitoring of selected variables should be discontinued or the frequency adapted.
- If conditions at the site change (e.g. a pollution event or significant change in land-use) and / or the *site-specific weighted rating* indicate a variable to be of high

significance, more frequent monitoring may be required. Alternatively, if there is little change in a monitored variable, less frequent monitoring can be undertaken.
- The water quality monitoring point to be used for collecting data should be the same site used for setting the water quality baseline. This monitoring point is shown on the EcoSpecs and TPC table per EWR site. The water quality monitoring point should be selected so as to reflect the water quality conditions at the monitoring site.
- Monitoring currently being undertaken by DWAF does not include temperature, dissolved oxygen, Chl-*a*: periphyton, turbidity or toxics (other than fluoride).
- The appropriate set of parameters to be monitored must reflect activities at the site.

The minimal set of parameters for water quality are as follows:

- Physico-chemical variables: 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 a suite of indicator organisms (minimum 3). For site specific details see Table10.1.

Limited information is currently available for toxics, with only fluoride being regularly monitored by DWAF. Note that the TPC for metals such as copper, cadmium and lead is dependent on the hardness of the water. Hardness levels (categories shown below) must therefore be calculated before metal data can be interpreted.

- Soft water: < 60 mg/l $CaCO_3$
- Moderately hard water: 60 – 119 mg/l $CaCO_3$
- Hard water: > 120 mg/l $CaCO_3$

It is important to note that the TPC’s for inorganic salts are derived from a model that coverts the currently monitored organic salts that DWAF’s current monitoring programme collects. In order for aspects to be implemented into the future monitoring programme it is important that further development on how the water quality aspects are derived and integrated into the Reserve process.

10.4 ECOLOGICAL RESERVE MONITORING

The Ecological Reserve monitoring programme will be set according to the guidelines given in Appendix A 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 (ERMDSS, Kleynhans and Louw 2006).

Table 10.2: A summary of the additional work required to establish a baseline monitoring programme.

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: In-stream toxicity: Chl-a: Periphyton, Toxics ammonia, Al and Cu	Data needs to be converted to VEGRAI level 4	No further baseline data needed	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. In-stream 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: In-stream toxicity: Chl-a: Periphyton, Toxics ammonia, Al and Cu			
6		Temperature, dissolved oxygen, turbidity / clarity: In-stream 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					

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APPENDIX A

Ecological Reserve Monitoring: Preliminary Generic guidelines

ECOLOGICAL RESERVE MONITORING: PRELIMINARY GENERIC GUIDELINES

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1 ECOLOGICAL RESERVE MONITORING

1.1 AIM OF THIS DOCUMENT

The determination of EcoSpecs as a component of Resource Quality Objectives (RQO) and the design of an Ecological Reserve Monitoring Programme comprises the final steps of the 8 step RDM procedure. Ecological Reserve Studies therefore should include these steps.

The aim of this document is to

- provide the Rationale on Ecological Reserve Monitoring,
- describe the Ecological Reserve Monitoring Decision Support System (DSS),
- provide an evaluation system to assist in deciding on the suitability of available information as a baseline for monitoring. This can then be used for specific studies to determine the adequacy of all available data and indicate additional information that must be collected to establish a baseline.
- Provide standard survey requirements in terms of frequency, sampling methods, timing etc to be applied during Ecological Reserve Monitoring.
- Provide guidance on the use of the suite of EcoStatus models to set EcoSpecs and Thresholds of Probable Concern (TPC)

It was identified during the Letaba, Komati and Kromme Ecological Reserve Studies that an opportunity existed to initiate the development of approaches associated with EcoSpecs and Ecological Reserve Monitoring. It must therefore be noted that as there was no dedicated project to undertake this, only a first draft was established. Additional work will be required to finalise this document and to refine the Ecological Reserve Monitoring DSS. The Ecological Reserve Monitoring DSS was developed during a Mhlathuze and Thukela Reserve study and requires further refinement.

The document is therefore a first draft of the following processes associated with Ecological Reserve Monitoring:

- Evaluation of suitability of available data for establishing a baseline.
- Ecological Reserve Monitoring DSS.
- Survey requirements for Ecological Reserve Monitoring.
- Determination of EcoSpecs and TPCs.

1.2 OBJECTIVE AND PURPOSE OF ECOLOGICAL RESERVE MONITORING

The word “monitoring” is always used as the descriptor of a specific group of three core, interconnected functions, starting with data acquisition followed by data management & storage and concluding with information generation and dissemination.

The result of the Ecological Reserve determination process encompasses the following (Kleynhans *et al*. 2005):

- Determination of the Present Ecological State (PES) of the resource,
- Formulation of the Recommended Ecological Category (REC),
- Specification of Resource Quality Objectives (RQOs) and,
- Specification of the ecological attributes that would indicate the attainment of the REC.

Following from this, the Ecological Reserve would be implemented and operated to achieve the REC. The basic purpose of Ecological Reserve Monitoring would be to determine if the current management actions are achieving the objective and to serve as a tool for identifying problems in the early stages before it become a crisis (Elzinga et al. 1998).

In terms of Ecological Reserve Monitoring, “monitoring” is defined as the collection and analysis of repeated observations or measurements to evaluate changes in condition and progress toward meeting a management objective (Elzinga et al 1998).

Most monitoring measures the change or condition of the resource and if management objectives are being met, management is considered as effective.

The purpose of the monitoring is to
- determine whether the ecological objectives (in terms of Ecological Categories and EcoSpecs) are being met;
- to identify the possible cause(s) of the problem;
- to determine the required actions according to a Monitoring DSS to be followed if the ecological objectives are not being met.

1.3 PRINCIPLES OF ER MONITORING

Central to the principle of monitoring is the concept of “adaptive management” in which monitoring measures progress toward meeting an objective. This provides the evidence for management change or continuation of current practices (Holling 1978; Ringold et al. 1996; Elzinga et al. 1998).

Steps in the adaptive management process (Based on Elzinga et al. 1998, Fig1.1):
- Objectives are developed to describe the REC;
- Management is designed to meet the objectives, or existing management practices are continued;
- The response of the resource is monitored to determine if the objective has been met; and
- Management is adapted (changed) if objectives are not reached.

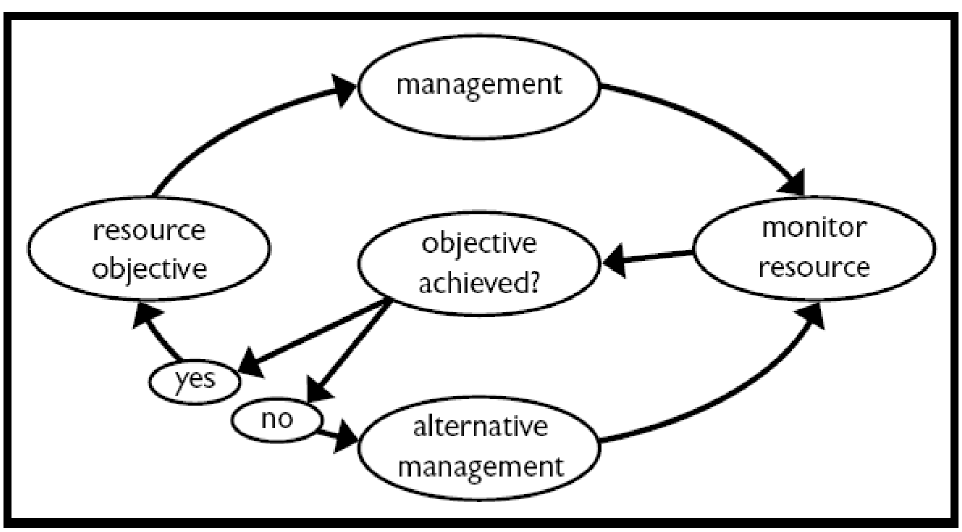

Figure 1.1: The adaptive management cycle. Monitoring provides the critical link between objectives and adaptive (alternative) management (from: Elzinga et al. 1998).

It is also important to consider the “undesirable” adaptive management cycle if monitoring produces inconclusive data (Fig1.2).

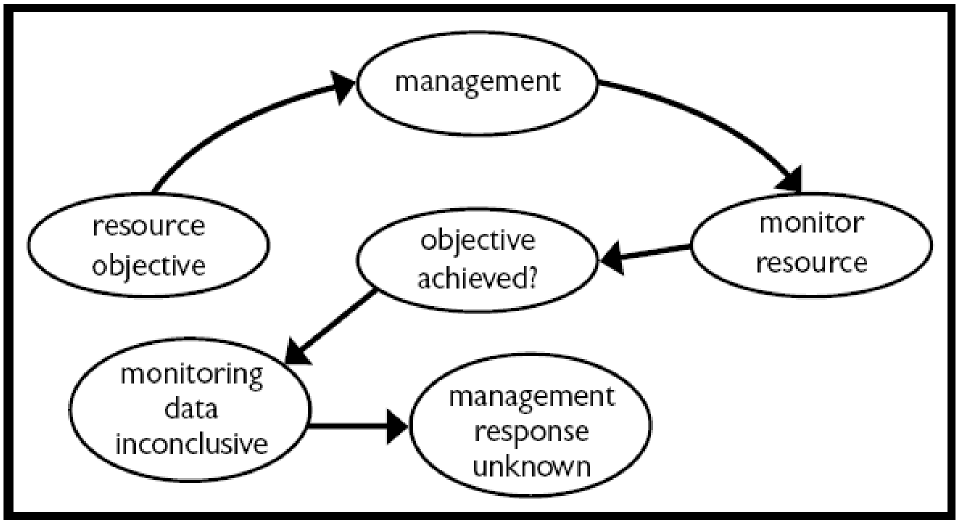

Figure 1.2: Diagram of monitoring that fails to close the adaptive management cycle. Because monitoring data is inconclusive, the management response is unknown and the cycle is unsuccessful (Elzinga et al. 1998).

It is crucial that monitoring be driven by objectives as it forms the foundation of the entire monitoring project (Elzinga et al. 1998):

- The EcoStatus REC represents the overall management objective.
- What is measured, how well it is measured, and how often it is measured are design features that are defined by how an objective is expressed.
- Management is designed to meet the objective.
- Monitoring is designed to determine if the objective is met.

Apart from indicating whether ecological reserve measures were designed and implemented properly and whether the reserve specifications met the objectives, monitoring, when done within the adaptive management framework will give us new insights into ecosystem function and structure. Monitoring should assist in the reexamination of understanding of aquatic and riparian ecosystems, thereby providing information needed to adapt the goals for managing these systems (Kershner 1997).

As with the EcoStatus, the biota, specifically instream, will be the indicators used during monitoring to detect problems. The instream biota (macro-invertebrates in particular) usually respond rapidly to any significant driver changes.

It might however be possible when the expected biological response is highly predictable, to only monitor the drivers, i.e. the existing hydrology and water quality measurements, as well as using remote sensing to indicate large scale catchment changes.

1.4 CONSTRAINTS

The constraints within which the monitoring programme must be designed, i.e. with reference to limited funds, time and human resources, must be considered. Furthermore the traditional way of thinking has been that monitoring is limited to hydrology and water quality. According to the National Water Act (1998), the monitoring practices of DWAF have to be expanded significantly. Procedures and structures to achieve this must be developed. The ER monitoring programme must consider this and make use as much as possible of the RHP (which is already in place) and the hydrology and water quality monitoring.

Sufficient knowledge does not exist to accurately predict the outcome of particular management actions. This relates to data adequacy which refers to the amount of data in terms of spatial and temporal dimensions, as well as the interpretation and insight into the information represented by the data.

1.5 TYPES OF MONITORING

1.5.1 Implementation monitoring

Implementation monitoring assesses whether the activities are carried out as designed. Implementation monitoring can also identify which variables are most likely to be causing a change in the resource, and help eliminate from consideration some potential causes of change (Kershner 1997; Elzinga et al 1998). In terms of the Ecological Reserve this would, inter alia, refer to whether flows are released as was specified for the attainment of a particular REC.

1.5.2 Effectiveness monitoring

It must be determined whether the ecological specifications that were specified were effective in attaining the REC. This is a complex activity and requires understanding of the physical, biological and sometimes the social factors that have an influence on aquatic ecosystems. This understanding is transformed into quantifiable benchmarks, the aim of which is to describe the function of healthy ecosystems. The purpose of effectiveness monitoring is to measure whether objectives (REC) are being achieved by following the particular management scenario (Kershner 1997).

1.5.3 Baseline monitoring

This is the assessment and characterization of existing conditions to provide a standard, or "baseline," against which future change is measured. In this monitoring design a series of measurements are taken prior to the initiation of a management activity and used for comparison (a "baseline") with the series of measurements taken afterward (Elzinga et al. 1998). It may also be important to determine whether the baseline is stable (stationary) or changing in a particular direction. The baseline must be distinguished from the reference which typically would be the natural or unimpacted condition of the system.

1.5.4 Ecological Reserve monitoring

The purpose of this type of monitoring is to measure and determine how the resource is changing over time, i.e. to measure the trend. Trend monitoring can be more rigorously approached by putting it into a management objective. This may mean that the objective will be to keep the resource in a particular REC. If the Ecological Category decreases over a period of time and the cause is unknown, more intensive monitoring or research may be initiated to determine the cause of the decrease. If a cause for decrease is suspected, appropriate management intervention may be indicated (Elzinga et al 1998).

1.6 THE LINK BETWEEN ECOLOGICAL RESERVE MONITORING AND THE RIVER HEALTH PROGRAMME.

The purpose of the RHP is to generate information that can be used for National State of the Rivers reporting. As such the RHP involves the rapid monitoring of a comparatively large number of sites distributed over the catchments of concern. The basis of interpretation of river health is biological responses with limited emphasis on system driver condition. Consequently the cause and effect relationship in terms of driver condition and biological response may be weak (Kleynhans et al. 2005).

The nature of compliance monitoring (i.e. as for the ecological reserve) provide some indication that the intensity of sampling will be higher per site but that there will be less sites monitored as compared to the RHP approach. This is due to the more detailed assessment per site in terms of hydrology, hydraulics, water quality, geomorphology and biological responses. The emphasis would be stronger on quantifiable data to provide a clearer cause and effect relationship between system drivers and biological responses (Kleynhans et al. 2005).

However, the RHP provides a broad scoping level to rapidly assess the health of streams. Where possible and within the correct ecological context, it makes sense to include RHP monitoring sites in the ER monitoring. In addition, the biomonitoring approach level of the RHP can be used in conjunction with Ecological Reserve sites to provide additional information that can be used within an early warning system as well as to be complementary to ecological reserve sites. This may mean that the main stem of a river will be subject to intensive monitoring due to the development taking place (e.g. impoundment), whereas tributaries in a comparatively un-impacted condition may only be subject to RHP-scale monitoring. However, if major changes in the tributary and its catchment take place, it would be prudent to intensify and concentrate monitoring in line with the nature of the disturbance. Contingency plans probably provide the best route to deal with such comparatively unexpected or irregular events.

1.7 ECOSPECS

Ecological specifications (EcoSpecs) were initially developed and specified in terms of the Resource Quality Objectives (RQOs) as per the Resource Directed Measures (RDM). (DWAF 2004)

The purpose of RQOs is the following:

- To establish clear goals relating to the resource quality of the relevant water resources.
- Where resources for instance need a high level of protection, a strict set of objectives that will represent a low risk of damage, will be set.
- There is an implicit understanding that once the management class of a water resource has been decided, the objectives for protection of basic human needs and ecological integrity take precedence in cases where the objectives for other uses, or for impacts, may conflict with the requirements for protection.

The critical components of the RQOs are:

- Requirements for water quantity, stated as flow requirements for a river reach or estuary, and/or water level requirements for standing water or ground water, and/or requirements for groundwater level in order to maintain spring flow and base flow in rivers and other ecological features.
- Requirements for water quality (chemical, physical, and biological characteristics of the water).

- Requirements for habitat integrity, which encompass the physical structure of in-stream and riparian habitats, as well as the vegetation aspects.
- Requirements for biotic integrity that reflect the health, community structure and distribution of aquatic biota. The RQOs must further be quantifiable, measurable, verifiable, and enforceable and ensure protection of all components of the resource, which make up ecological integrity.

EcoSpecs are derived from RQOs and 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.

More specific in terms of biomonitoring for Ecological Reserve purposes is the formulation of biocriteria that are numerical values or narrative statements that define a desired biological condition for a waterbody (Burton and Gerritsen 2003).

1.8 THRESHOLDS OF PROBABLE CONCERN (TPCS)

TPCs are upper and lower levels along a continuum of change in selected environmental indicators. When this level is reached (or when modelling predicts it will be reached), it prompts an assessment of the causes of the extent of the change. The assessment provides the basis for deciding whether management action is needed or recalibrates the TPC. TPCs provide management with strategic goals or endpoints within which to manage the system. They form the basis of an inductive approach to adaptive management, as they are invariably hypotheses of limits of acceptable change in ecosystem structure, function and composition. As such their validity and appropriateness are always open to challenge and they must be adaptively modified as understanding and experience of the system being managed increases" (Rogers & Bestbier 1997).

2 MONITORING BASELINE INFORMATION REQUIREMENTS

2.1 PURPOSE OF THE MONITORING BASELINE

For the purposes of the Ecological Reserve Monitoring, change is measured against a standardised baseline, which indirectly implies a change from reference. However, depending on the situation and circumstances, the reference may also be the baseline.

2.2 BASELINE DEVELOPMENT APPROACH

Before baseline assessment and reserve monitoring is undertaken, it is assumed that the Ecological Reserve has been determined and the following process followed:

- The EcoClassification process has been followed and information is available on the PES, the EIS, the REC and the alternative ECs using the EcoStatus models (Kleynhans et. al 2005).
- The resource has been classified according to the approved system and a Management Class decided on. In the absence of a Classification System, a surrogate system may have been followed to arrive at a preliminary classification and Management Class.
- A decision was taken whether the Reserve requires implementation (i.e. whether there is at times less (than required by the Reserve) water available in the system). This decision must be made to determine whether Ecological Reserve Monitoring is required.
- Sufficient information is available to convert the Management Class to Ecological Categories for all Driver and Response components.
- The ecological responses to the flow scenario selected (output of the Classification System) have been predicted by using the appropriate EcoStatus models (Kleynhans *et al* 2005).

To construct the baseline, existing data must be collated and analyzed to determine its usefulness for inclusion in the baseline. This will allow the identification of data and information gaps that needs to be resolved by undertaking additional surveys. Factors that should be considered in identifying gaps are:

- Location of sites
- Time since last survey
- Purpose of the surveys
- Survey techniques
- Use of EcoStatus suite of model (Kleynhans *et al* 2005)

Depending on the usefulness of this data for constructing a baseline, Ecospecs and TPCs can be formulated on a preliminary basis. When existing data and data collected specifically for baseline purposes have been collated, the Ecospecs and TPCs can be refined. The relative confidence level in the EcoSpecs and TPCs and for each of the Reserve components (driver and responses) must be specified according to a descriptive, numerical scale

2.3 INFORMATION REQUIREMENTS FOR BASELINE

For each of the Reserve components the following must be standardised in terms of information requirements in context of the Resource Unit:

- Number of sites,
- Location of sites

- Number of surveys,
- Time of surveys,
- Sampling techniques
- Analysis methods.

2.3.1 Site selection

(to be completed during the next phase)
Process to select sites in the RHP. Situations when one uses EWR sites and RHP sites. RUs with no sites – need to establish RHP sites

2.3.2 Data sets normally available prior to baseline

For a minimum data set, the assumption is the following (Based on a Rapid III Ecological Reserve determination):

- One survey has been undertaken for fish and invertebrates at one site.
- Hydraulic cross-section has been surveyed.
- The FRAI and MIRAI models were applied.
- No surveys for riparian vegetation, geomorphology, and water quality would be included at this reserve determination level.
- The VEGRAI and GAI would have been run by aquatic ecologist to determine the PES EcoStatus.

The information generated during a PES assessment normally forms part the baseline. Often, the Ecological Reserve Monitoring does not follow immediately after the Ecological Reserve study (i.e. the PES assessment). The longer the time period between the two studies, the less useful the data collated as part of the PES assessment becomes for baseline. Any significant environmental changes that take place after the PES assessment can also result in the PES data not being valid anymore. If no significant environmental changes have taken place, it is assumed that the most recent survey information would probably be valid for at least 2 years. This is a guideline only and the exact site specific situation must be evaluated.

2.3.3 Baseline phase survey requirements

The primary purpose of collecting sufficient data and derive information for the setting the baseline, is to determine if the changes recorded in drivers and biological responses during reserve monitoring, are attributable to Ecological Reserve management (implementation) or are actually natural variation of the system.

Baseline survey phase: Minimum of 1 year

The standard baseline requirements at EWR sites (i.e. sites with hydraulic information and cross-sections) are below. It is assumed that only one EWR site will be selected in the RU.

2.3.2.1 FISH

<u>Fish at EWR sites in Resource Unit</u>

Two fish surveys at
- the end of the dry season (high ecological stress situation)
- the end of the wet season (outside flood condition, e.g. April, May in summer rainfall areas).

Modus operandi during survey will be as described in the RHP site characterization manual (Dallas 2005) and the EcoStatus manual (Kleynhans et al 2005):

- Fish sampling: All velocity-depth should be sampled if possible and as efficient as possible. Fish sampling should be done as prescribed.
- Fish habitat: Relative abundances of velocity-depth classes as well as cover should be rated at each site.

The FRAI should be applied at the end of the baseline survey and driver information should be included in the assessment.

Additional fish sampling sites in the Resource Unit

Sites in addition to the EWR sites may be required to provide a representative picture of the fish assemblage in a Resource Unit. This may be necessary when the fish assemblage in the resource unit is not homogenous (i.e. the Resource Unit may span more than one fish habitat segment), or where the impacts along the resource unit is not homogenous. Two surveys should be conducted for baseline purposes.

Additional fish habitat evaluation sites

Additional fish habitat sites should be evaluated according to the RHP site characterization manual (Dallas 2005).

Where additional macro-invertebrate surveys are conducted, these specialists will rate the fish habitat at these sites according to the described procedures (Dallas 2005).

2.3.2.2 AQUATIC INVERTEBRATES

Aquatic invertebrates at EWR sites in Resource Unit

Three aquatic invertebrate surveys at
- the end of the dry season (high ecological stress situation)
- the end of the wet season (outside flood condition, e.g. April, May in summer rainfall areas).

the middle of the dry season.
Aquatic invertebrate specialist has to also undertake an invertebrate habitat evaluation.
Note: IF the EWR survey fell into one of these times, it does not have to be repeated.

Modus operandi during survey will be as described in the RHP site characterization manual (Dallas 2005) and the EcoStatus manual (Kleynhans et al 2005):

The MIRAI should be applied at the end of the baseline survey and driver information should be included in the assessment.

Additional invertebrate sampling sites in the Resource Unit

Sites in addition to the EWR sites may be required to provide a representative picture of the invertebrate assemblage in a Resource Unit. The number of additional sites will depend on the type of impact. It will mostly be required where habitat differs significantly from the EWR site (i.e. bedrock versus cobble etc). The frequency is the same as at the EWR site as well as the approaches.

2.3.2.3 RIPARIAN ZONE VEGETATION & FLUVIAL GEOMORPHOLOGY

Riparian vegetation surveys at EWR sites in Resource Unit

One survey during the wet season. Actions required during the surveys are according to the VEGRAI manual which will be available end of 2006. Additional to the VEGRAI, flow sensitive species must be indicated on the cross-sections. The survey should be undertaken during the wet season and specifications according to the BBM manual should be undertaken. The VEGRAI should be undertaken at the end of the baseline phase.

Riparian vegetation surveys at additional sites in the RU

Additional sites might be evaluated at a lesser intensity due to practical constraints. This will be specified in the version 2 of the EcoStatus manual. The approach will be according to the EcoStatus manual. The frequency will be one survey during the wet season.

2.3.2.3 WATER QUALITY

- Suitable water quality monitoring point to be used for setting baseline water quality conditions. The water quality monitoring point should be selected so as to reflect the water quality conditions at the monitoring site.
- Appropriate set of monitored parameters to enable setting of a water quality baseline to reflect activities at the site. The minimal set of parameters are as follows:
  - Physico-chemical variables: pH, EC/TDS, DO, temperature, turbidity / water clarity
  - Nutrients: nitrate, nitrate, ammonium and ortho-phosphate

Highly recommended additional variables for setting baseline conditions are the recommended suite of inorganic salts and chlorophyll-a.

Additional variables to monitor are toxicants relevant to the site, e.g. metals ions, pesticides or in-stream toxicity (particularly as a proxy for pesticide contamination).

Where the relevant data are not available, appropriate monitoring should be instituted (e.g. NaCl and in-stream toxicity for pesticide use in an extensive agricultural area).

- Suitable data record in terms of frequency of monitoring. The minimal data record required for setting baseline water quality conditions is at least 24 data points (i.e. fortnightly monitoring over a 1-year period), assuming no other water quality data is available. Should data be available from the same water quality monitoring point as used for assessing the water quality Reserve, use data collected over the preceding 3 years and maintain frequency of monthly monitoring.

Note: Fortnightly monitoring for large catchments is probably only realistic (considering cost implications) if undertaken by DWAF.

2.4 DETERMINING ADEQUACY OF EXISTING DATA

The first step is to collate all data to determine

- where it is available (spatial and temporal context);
- during which season it was collated;
- the techniques used.

2.4.1 Driver: Hydrology

It is accepted that the Reserve flow requirements (in terms of modified flow regime characteristics) were determined from a combination of a natural hydrological signal, the hydraulic characteristics of the site and the ecological specialists' interpretation of the habitat requirements of biota. It is further assumed that the Reserve flow requirements are defined as a set of Reserve assurance rules (frequency of occurrence tables of flow rates or volumes for the different months of a year) and that the future month-by-month, or day-by-day flows that are required will be determined by an equivalent time series of natural flows. In this context 'equivalent' means that the future (used during monitoring) and historical (used during the Reserve determination) natural flow signals should be stationary.

2.4.1.1 QUESTIONS ASSOCIATED WITH THE FUTURE NATURAL FLOW SIGNAL *(the questions below should be addressed in numerical sequence):*

a) Can the historical natural flows that were used during the Reserve determination be extrapolated into the future (during the monitoring period)? What is the level of confidence in this extrapolation?

- Very high
- High
- Moderate
- Low
- Very Low

In many cases, the natural flows that are used for Reserve determinations are simulated (by a rainfall-runoff model) and are based on historical rainfall data as one of the primary model inputs. This question is therefore largely related to whether or not the information is available to generate a stationary rainfall input signal to the hydrological model. In many cases this may not be possible due to the closure of rainfall monitoring stations and in such circumstances it will be necessary to re-calibrate the model with rainfall data that can be expected to be available into the future. Experience suggests that in many areas, obtaining recent rainfall data that has the same characteristics as the data used for most historical rainfall-runoff modelling will be a difficult task. Some recent investigations (Hughes, 2005) have looked into the possibilities of using near-global databases of satellite derived rainfall data, while there are WRC projects that are attempting to combine various sources of rainfall data into a national database of daily rainfall information (see Pegram and Clothier, 1999 and more recent WRC publications).

The level of confidence will be based on the degree of stationarity between the time-series used for the determination and that used for future monitoring. If the level of confidence is less than moderate then re-calibration of the links between natural flow and the Reserve (see question 2) will be required. The methods for determining the degree of stationarity between the two time series will be largely dependent on the flow regime characteristics but could include assessments based on seasonal distribution patterns, flow duration curve similarities, frequency of zero flows, etc.

b) If re-calibration of the model used to simulate natural flows is necessary, will this mean that different time series sequences of Reserve requirements will be generated?

If the answer to this question is yes, it may be necessary to re-calibrate the links between the natural flows and the Reserve flows. In the context of the HFSR method, this will involve re-calibration of the Desktop Reserve model to ensure that the same Reserve flows are generated from a different time-series of natural flow. The re-calibration may be necessary if the level of confidence associated with question 1 is moderate to low. The outcome of the re-calibration should restore the level of confidence (in the expected natural flows generated in future) to at least moderate.

2.4.1.2 QUESTIONS ASSOCIATED WITH FUTURE FLOW OBSERVATIONS:

c) Is there an existing flow gauging station that can be used to measure, or satisfactorily estimate, flow (especially low flow) at the monitoring site?

The answer to this question will depend upon the proximity of the gauge to the site, as well as the 'channel' conditions between the gauge and the site. The relevant 'channel' conditions are associated with the presence or absence of artificial abstractions or return flows, natural flow inputs (tributary flows, ground water inflow and spring seepage) or outputs (ground water outflow and evapotranspiration losses from the water surface or riparian vegetation). The level of confidence will depend upon the accuracy of the gauging station, as well as the accuracy with which additional flow increments or losses can be quantified, especially during low flow periods.

An accuracy of 20% will be required to achieve a confidence rating of moderate:

- Very high
- High
- Moderate
- Low
- Very Low

d) If the answer to the previous question is no, it will be necessary to establish a rated section and continuous (or frequent) water level observations at the site.

The assumption is that there will already be some hydraulic calibrations available (from the Reserve determination) and that these will simply have to be checked and updated. It will also be necessary to determine whether a rated section is likely to be stable enough to provide reasonably accurate flow observations into the future without frequent re-calibration. An expected minimum accuracy of 20% for low flow estimations will be required for a rated section to be considered satisfactory for monitoring purposes. An assessment of the accuracy will need to be undertaken by the hydraulics specialist on the basis of the complexity of the channel reach and the expected stability of the channel cross-section during different flow conditions. For example, sand-bed channels are not expected to be stable during high flows.

2.4.1.3 WHAT IS THE CONFIDENCE IN THE ACCURACY OF LOW FLOW ESTIMATIONS?:

- Very high
- High
- Moderate
- Low
- Very Low

2.4.1.4 ADDITIONAL INVESTIGATIONS AS PART OF ESTABLISHING THE BASELINE.

It is common for monthly natural flow data to be used for the Reserve determination. However, if continuous flow data will be available in the future, it would be very useful to be able to establish the frequency characteristics of run (or spell) durations for specific flow thresholds that will prompt the need for immediate biological surveys and checking for Reserve compliance.

This information cannot be extracted directly from a Reserve determination and will require some additional (although limited) investigations involving one or more biological specialist and a hydrological specialist. The investigation will involve an examination of monthly run characteristics from the same data used for the Reserve determination and some extrapolation to daily run lengths of excessive high ecological stress (or low flows) that might be cause for concern. The confidence levels associated with these investigations will be dependent upon the available understanding of the hydro-ecological dynamics of the system, especially under extreme low flow situations. While the confidence levels are unlikely to be very high in most systems, the information will mostly be used to identify when additional biological monitoring may be required.

The confidence in the accuracy of spell analysis during different seasons must also be assessed.

2.4.2 Driver: Water Quality

The aim is to determine how suitable and reliable (i.e. in terms of confidence) the physico-chemical data is for the interpretation of biological responses and determining whether water quality is a problem. The confidence in the physico-chemical information can be rated as:

- Very high
- High
- Moderate
- Low
- Very Low

This pertains to the following criteria:

- Are there sufficient water quality monitoring stations?

Very high	A water quality monitoring point at the downstream end of every WQSU in the RU
High	A water quality monitoring point at the downstream end of the RU.
Moderate	A water quality monitoring point at the downstream end of at least one of the WQSUs in the RU or in the downstream RU.
Low	A water quality monitoring point in the preceding or upstream RU.
Very Low	No water quality monitoring points in the RU or upstream and downstream RU and information must be derived from either neighbouring catchments or from the biological response and habitat conditions.

- Is there a lack of water quality monitoring close to the monitoring site (assumed to be the EWR site)?

Very high	A water quality monitoring point just above the EWR site.
High	A water quality monitoring point above the EWR site, but at the lower end of the preceding WQSU in the same RU.
Moderate	A water quality monitoring point downstream of the EWR site, but in the same RU.
Low	A water quality monitoring point above the EWR site, but at the lower end of the preceding RU.
Very Low	No water quality monitoring points in the same RU as the EWR site or upstream and downstream RU and information must be derived from either neighbouring catchments or from the biological response and habitat conditions.

- Is the water quality data adequate to derive RC and PES?

Very high	Data from a single monitoring point can be used for both RC and PES.
High	Two different monitoring points are used for RC and PES, with the PES data being from a water quality monitoring point at the lower end of the WQSU.
Moderate	Two different monitoring points are used for RC and PES, with the PES data being from a water quality monitoring point in the upstream or downstream RU.
Moderate/Low	RC data has to be sourced from a tributary or adjacent catchment in the same EcoRegion and similar catchment land-use, although adequate PES data is available. (Moderate / Low depending on the length of the data record used for RC).
Low	No RC data are available (so use benchmark tables), although adequate PES data is available.
Very Low	No RC data is available (so use benchmark tables), and the PES assessment is based on data collected during the study only. (Not relevant to a Rapid Level III assessment).
Very Low	Use of dam data from an **outflow** of a dam in the RU if no other data are available.

Note: Water quality data from points in the dam are only used for interpretation of downstream water quality conditions and not for a present state assessment.

- Is there adequate frequency of water quality monitoring for a present state assessment? The assessment must use data collected from the 5 years preceding the commencement of the study.

Very high	At least 80 data points have been collected over the last 3 years for the main water quality parameters (i.e. pH, EC, full range of inorganic salts*, nutrients (Total Inorganic Nitrogen (TIN) and ortho-phosphate)).
High	At least 60 data points have been collected over a 3 to 5-year period for the main water quality parameters.
Moderate	At least 40 data points have been collected over a 3 to 5-year period for the main water quality parameters.
Low	At least 20 data points have been collected over a 3 to 5-year period for the main water quality parameters.
Very Low	Water quality data collection is limited to the current study only. (Not relevant to a Rapid Level III assessment).

* sodium chloride, magnesium chloride, calcium chloride, magnesium sulphate, sodium sulphate

- Are the appropriate parameters being monitored?

Very high	A full suite of physico-chemical variables have been monitored (incl. DO, temperature, turbidity/water clarity and full range of inorganic salts), including variables required for a full nutrient assessment (i.e. nitrate, nitrate, ammonium for TIN, ortho-phosphate and chl-a) and variables linked to known water quality issues in the RU such as metal contamination by industry (if present) or pesticide use.
High	An extensive suite of physico-chemical variables have been monitored (pH, EC / TDS and incl. inorganic salts), including variables required for an assessment of nutrient status (e.g. nitrate, nitrate, ammonium for TIN and ortho-phosphate).
Moderate	A number of physico-chemical variables (e.g. pH, EC / TDS) have been monitored (excl. all required inorganic salts), including variables required for an assessment of nutrient status (e.g. nitrate, nitrate, ammonium for TIN and ortho-phosphate).
Low	Only limited physico-chemical information, i.e. pH and EC, and nutrient data (some measure of TIN (e.g. nitrate and nitrite) and ortho-phosphate) is available.
Very Low	Only limited physico-chemical information is available, i.e. pH and EC.

- Is there sufficient understanding of point and/or diffuse source impacts?

Very high	Diffuse and point sources of impact have been identified and toxicity information is available e.g. in-stream toxicity tests have been conducted using either site-specific test organisms or a range of standard test organisms (at least fish, *Daphnia* and algal test) and a list of toxicants is available.
High	In-stream toxicity tests (i.e. using receiving water as toxicant) have been conducted using either site-specific test organisms or a range of standard test organisms (at least fish, *Daphnia* and algal test).
Moderate	In-stream toxicity tests (i.e. using receiving water as toxicant) have been conducted using 1 / 2 test organisms.
Low	Diffuse and point sources of impact have been identified (e.g. a list of toxicants is available) but no toxicity information is available.
Very Low	No information is known of point or diffuse sources of impact.

- Based on the above questions, how high is the suitability of and confidence in the water quality data for interpreting biological responses? The link between biological response and water quality condition assume an interpretive and on-site knowledge of the system being evaluated, e.g. size of stream, overhanging and riparian vegetation.

Very high	Adequate chemical (e.g. metals and pH) or toxicity data is available to directly link biological response to water quality condition. (includes DO, temperature, turbidity)
High	An extensive suite of data (including DO, temperature, turbidity and nutrients) are available for a water quality Reserve assessment (see * below) to make a link between biological response and water quality condition.
Moderate	Limited water quality data (e.g. DO, temperature, turbidity and nutrients) to make a link between biological response and water quality data, but mostly due to habitat availability (e.g. levels of turbidity/water clarity and/or periphyton on rocks).
Low	A qualitative assessment can be made to link biological response and water quality condition via habitat availability (e.g. visual assessments of turbidity level and/or periphyton on rocks).
Very Low	No interpretation of biological response can be made from available water quality data or visual assessments, but SASS and/or diatom data can be used to make an assessment of water quality condition.

* An extensive suite of physico-chemical variables have been monitored (pH, EC / TDS and incl. inorganic salts), including variables required for an assessment of nutrient status (e.g. nitrate, nitrate, ammonium for TIN and ortho-phosphate).

General note: Assessment must be evaluated also based on accreditation of specialists. This can only be included if accreditation is available

2.4.3 Driver: Geomorphology

Information required prior to commencement of monitoring process:

1. Geomorphological zonation of stream from source to mouth
2. General catchment information:
    - Catchment size
    - Landuse and landuse history
    - Schematic diagram including positions of sites relative to tributary junctions, towns, major developments (e.g. sewage works), etc. Diagram needn't be to scale.
    - Rainfall record

3. At least one geomorphic assessment (at least for each EWR site, but preferably for reaches in each geomorphic zone) by a specialist. The assessment should preferably comprise an assessment using the GAI as well as additional descriptive data with regards to the following at the EWR sites:
    - Bed material size distribution (quantitative)
    - Date of construction of major impoundments
    - Cross-sectional data (for EWR sites)
    - Flood history, where possible
4. Photographs taken at each site.

The overall purpose would be to estimate the confidence in the geomorphological information and the geomorphological response to hydrological and catchment changes. Data is considered adequate and sufficient to construct a baseline when criteria (in the tables below) are satisfied at a confidence level of at least moderate. The evaluation follows a scale of 1 – 5 described as follows:

- Very high = 1
- High = 2
- Moderate = 3
- Low = 4
- Very Low = 5

This pertains to the following criteria:

- Is sufficient spatial data available?

Very high	EWR site selected is representative of entire RU and additional geomorphological data has been collected within the RU.
High	EWR site selected is representative of entire RU and no additional geomorphological data has been collected within the RU.
Moderate	EWR site selected not representative of entire RU but additional geomorphological data has been collected within the RU.
Low	EWR site selected not representative of entire RU but no additional geomorphological data has been collected within the RU.
Very Low	Incomplete data collection in terms of the GAI at a non-representative site within the RU.

- Is sufficient temporal data available?
  - *Frequency of prior field assessment:* (confidence levels will depend on time scale of catchment changes and channel type).

Very high	More than 15 years with regular (annual) surveys up to present.
High	More than 15 years' worth of irregular survey data
Moderate	More than 5 years but with irregular/limited surveys up to present. Less than 5 years with regular surveys up to present
Moderate to low	Less than 5 years but with irregular/limited surveys up to present.
Low	Once off assessment
Very Low	Desktop data only

- Availability of aerial photographs:

Very high	Series of aerial photographs (i.e. a range of photographs taken over a number of years) available for each geomorphic zone and all sites at a scale large enough to allow observation of channel morphology
High	Series of aerial photographs at a suitable scale available for all sites
Moderate	One set of aerial photographs that covers all sites or a wider coverage at too small a scale
Low	Patchy spatial/temporal photograph coverage at intervals down the length of the stream not including all sites
Very Low	No or very limited coverage of system

- Availability of historical information on landuse and floods:

Very high	100 years of historical record
High	50 years of historical record or up to 100 years of oral catchment history
Moderate	20 years of historical record
Low	Less than 20 years of historical record
Very Low	Modelled historical (observed) record (no gauge in system)

- What assessment method was used?

Very high to high	GAI assessment by geomorphic specialist
Moderate	GAI assessment by non-specialist with relevant training, reviewed by a specialist
Moderate to low	GAI assessment by non-specialist with relevant training
Very Low	Non-standardized assessment method undertaken by non-specialist

2.4.4 Biological Response: Fish

The overall purpose would be to estimate the confidence in the response of the fish assemblage according to driver changes that occur. Data is considered adequate and sufficient to construct a baseline when criteria (in the tables below) are satisfied at a confidence level of at least moderate. The evaluation follows a scale of 1 – 5 described as follows

- Very high = 1
- High = 2
- Moderate = 3
- Low = 4
- Very Low = 5

This pertains to the following criteria:

- Is sufficient spatial data available?

Very high	Data are available for the resource unit at different representative sites
High	Data are only available at the EWR site and it may be representative of the resource unit

Moderate	Data are only available at the EWR site that is not completely representative of the resource unit:
Low	Only incidental data (eg only one survey at the EWR site or more superficial surveys) are available that only pertains to the fish species present in the resource unit
Low	Only derived data are available for the resource unit, but neighbouring rivers have good fish data that appears likely to be applicable to the study area
Very Low	No actual data are available and the neighbouring resource units and rivers also have limited information or are not ecologically comparable to the study area

- Is sufficient temporal data available?

Very high	>15 years ago with regular surveys up to present
Very high to high	> 5 years ago with regular surveys up to present. Depend on time & scale of catchment changes.
	< 5 years ago with regular surveys up to present. Depend on scale of catchment changes.
High - moderate	>15 years ago but with irregular/limited surveys up to present. Depend on time and scale of catchment changes.
	> 5 years ago but with irregular/limited surveys up to present. Depend on time and scale of catchment changes
Moderate - Low	> 5 years ago but with no surveys since. Depend on scale of catchment changes.
	< 5 years ago but with irregular/limited surveys up to present. Depend on scale of catchment changes.
Low	< 5 years ago but with no surveys since. Depend on scale of catchment changes
Low to Very low	> 15 years ago but with no surveys since. Depend on time & scale of catchment changes.

- Interpretive characteristics of ecological data and information in terms of preferences and environmental requirements:

Very high	Excellent information available on all species that represent a wide range of habitat conditions and intolerances.
Very high to high	Excellent information on all species but restricted to a limited range habitat conditions and intolerances.
High to moderate	Good information on all species but restricted to a limited range of habitat conditions and intolerances.
	Excellent information limited to indicator species that represent critical habitats and with high intolerance.
High - Moderate	Good information available on all species that represent a wide range of habitat conditions and intolerances.
Moderate	Good information limited to indicator species that represent critical habitats and with high intolerance
Low	Poor information available on all species that represent a wide range of habitat conditions and intolerances.
Low to Very low	Poor information on all species but restricted to a limited range habitat conditions and intolerances.
	Poor information limited to indicator species that represent critical habitats and with high intolerance.
	Only derived information on closely related species available.

- Environmental changes. This can influence the level of representivity of fish data if significant habitat and catchment changes occurred since the last fish surveys. This relates changes that would influence the system drivers and should also consider non-driver related responses of the native fish assemblage (introduction of non-native species).

NOTE: This only needs to be completed if the criteria described in bold in 2.3.2 are applicable.

Very high - high	No significant changes since the last representative fish surveys. Overall confidence in response of fish
High-moderate-low	Moderately significant changes since the last fish surveys.*
Low to Very Low	Significant changes since last fish surveys:

2.4.5 Biological Response: Invertebrates

The overall purpose would be to estimate the confidence in the response of the invertebrate assemblage according to driver changes that occur. Data is considered adequate and sufficient to construct a baseline when criteria (in the tables below) are satisfied at a confidence level of at least moderate. The evaluation follows a scale of 1 – 5 described as follows

- Very high = 1
- High = 2
- Moderate = 3
- Low = 4
- Very Low = 5

This pertains to the following criteria:

- Is sufficient spatial data available?

Very high	Actual data are available for the resource unit at different representative sites
High	Actual data are only available at the EWR site that may be representative of the resource unit
Moderate	Actual data are only available at the EWR site that is not completely representative of the resource unit
Moderate - Low	Only incidental data are available that only pertains to the invertebrates present in the resource unit
Low	No actual data are available for the resource unit, but neighbouring rivers have good invertebrate data that appears likely to be applicable to the study area
Very Low	No actual data are available and the neighbouring resource units and rivers also have limited information or are not ecologically comparable to the study area

- 2. Is sufficient temporal data available?

Very high	>15 years ago with regular surveys up to present
Very high - high	> 5 years ago with regular surveys up to present. Depend on time & scale of catchment changes.
Very high - high	< 5 years ago with regular surveys up to present. Depend on scale of catchment changes.
High - moderate	>15 years ago but with irregular/limited surveys up to present. Depend on time and scale of catchment changes.
High - Moderate	> 5 years ago but with irregular/limited surveys up to present. Depend on time and scale of catchment changes
Moderate - Low	> 5 years ago but with no surveys since. Depend on scale of catchment changes.
Moderate - Low	< 5 years ago but with irregular/limited surveys up to present. Depend on scale of catchment changes.
Low	< 5 years ago but with no surveys since. Depend on scale of catchment changes
Low - Very low	> 15 years ago but with no surveys since. Depend on time & scale of catchment changes.

- Interpretive characteristics of ecological data and information in terms of preferences and environmental requirements:

Very high	Excellent information available on all taxa that represent a wide range of habitat conditions and intolerances.
Very high - high	Excellent information on all taxa but restricted to a limited range of habitat conditions and intolerances.
High - moderate	Good information on all taxa but restricted to a limited range of habitat conditions and intolerances.
High - moderate	Excellent information limited to indicator taxa that represent critical habitats and with high intolerance.
High - Moderate	Good information available on all taxa that represent a wide range of habitat conditions and intolerances.
Moderate	Good information limited to indicator taxa that represent critical habitats and with high intolerance
Low	Poor information available on all taxa that represent a wide range of habitat conditions and intolerances.
Low - Very low	Poor information on all taxa but restricted to a limited range of habitat conditions and intolerances.
Low - Very low	Poor information limited to indicator taxa that represent critical habitats and with high intolerance.
Very low confidence	Only derived information on closely related taxa available.

2.4.6 Biological Response: Riparian Vegetation

The overall purpose would be to estimate the confidence in the response of the riparian vegetation assemblage according to driver changes that occur. Data is considered adequate and sufficient to construct a baseline when each of the following criteria is satisfied at a confidence level of at least moderate:

- Very high
- High
- Moderate
- Low
- Very Low

This pertains to the following criteria:

- Is sufficient spatial data available?

Very high	Actual data available for the resource unit at different representative (relating to the variety of impacts) sites (including the EWR site)
High	Actual data only available at the EWR site t representative of the RU
Moderate	Actual data only available at the EWR site not completely representative of the RU
Moderate - Low	Only incidental data are available in the RU
Low	No actual data are available for the resource unit, but neighbouring rivers have good fish data that appears likely to be applicable to the study area
Very low	No actual data are available for the resource unit, but neighbouring rivers have good data that appears likely to be applicable to the study area (similar range of impacts)

- Temporal characteristics of data;

Very high	>15 years ago with regular surveys up to present
Very high - high	> 5 years ago with regular surveys up to present. Depend on time & scale of catchment changes.
Very high to high	< 5 years ago with regular surveys up to present. Depend on scale of catchment changes.
High - moderate	>15 years ago but with irregular/limited surveys up to present. Depend on time and scale of catchment changes.
High - Moderate	> 5 years ago but with irregular/limited surveys up to present. Depend on time and scale of catchment changes
Moderate - Low	> 5 years ago but with no surveys since. Depend on scale of catchment changes.
Moderate - Low	< 5 years ago but with irregular/limited surveys up to present. Depend on scale of catchment changes.
Low	< 5 years ago but with no surveys since. Depend on scale of catchment changes
Low - Very low	> 15 years ago but with no surveys since. Depend on time & scale of catchment changes.

- Interpretive characteristics of ecological data and information in terms of preferences and environmental requirements:

Very high	Excellent info on all species that represent a wide range of habitat conditions & intolerances.
Very high - high	Excellent info on all species but restricted to a limited range habitat conditions & intolerances.
High - moderate	Good info on all species but restricted to a limited range of habitat conditions & intolerances.
High - moderate	Excellent info limited to indicator species that represent critical habitats & with high intolerance.
High - Moderate	Good info on all species that represent a wide range of habitat conditions & intolerances.
Moderate	Good info limited to indicator species that represent critical habitats & with high intolerance
Low	Poor info on all species that represent a wide range of habitat conditions & intolerances.
Low - Very low	Poor info on all species but restricted to a limited range habitat conditions & intolerances.
Low - Very low	Poor info limited to indicator species that represent critical habitats & with high intolerance.
Very low	Only derived information on closely related species available.

- Quality and Comprehensiveness of data and quality of assessment? Were assessments done using established indices?

Very high	VEGRAI undertaken by riparian vegetation specialist.
High	VEGRAI undertaken by trained non riparian vegetation specialist and a riparian IHI for the comprehensive reserve has been determined.
High - Moderate	VEGRAI undertaken by trained non-riparian vegetation specialist.
Moderate - Low	Riparian IHI as determined for the Comprehensive Reserve
Low – very low	Riparian IHI determined as for the River Health Programme (site based).

- Evaluation of available aids etc

Very high - high	Range of aerial photographs for each site, land cover, aerial video, good local specialist knowledge.
High	Land cover. limited aerial photographs and aerial video, good local specialist knowledge.
Moderate	Land cover, and good local specialist knowledge.
Low	Land cover, basic local specialist knowledge.
Low – very low	Only land cover available.

- Environmental changes. This can influence the level of representivity of riparian vegetation data if significant habitat and catchment changes occurred since the last vegetation surveys. This relates changes that would influence the system drivers. Confidence considered terms of interpretation of response of riparian vegetation.

NOTE: This only needs to be completed if the criteria described in bold in 2.3.2 are applicable.

Very high - high	No significant changes since the last surveys.
High-moderate-low	Moderately significant changes since the last surveys.
Low to Very Low	Significant changes since last fish surveys:

3 ECOLOGICAL RESERVE MONITORING DSS

STILL TO BE REFINED: INFORMATION BELOW ACCORDING TO THE DSS DEVELOPED AS PART OF THE THUKELA RESERVE STUDY.

3.1 AVAILABLE INFORMATION

Ecological Reserve Monitoring can only be initiated once the Baseline has been formulated at least at a moderate level of confidence for the drivers and the instream biological responses.

Before Ecological Reserve monitoring is undertaken, it is assumed that the Ecological Reserve has been determined and the following process followed:

- The EcoClassification process has been followed and information is available on the PES, the EIS, the REC and the alternative ECs using the EcoStatus models (Kleynhans et. al 2005).
- The resource has been classified according to the approved system and a Management Class decided on. In the absence of a Classification System, a surrogate system may have been followed to arrive at a preliminary classification and Management Class.
- A decision was taken whether the Reserve requires implementation (i.e. whether there is at times less (than required by the Reserve) water available in the system). This decision must be made to determine whether Ecological Reserve Monitoring is required.
- Sufficient information is available to convert the Management Class to Ecological Categories for all Driver and Response components.
- The ecological responses to the flow scenario selected (output of the Classification System) have been predicted by using the appropriate EcoStatus models (Kleynhans et al 2005).

3.2 CONFORMANCE BIOMONITORING DECISION SUPPORT SYSTEM (BIODSS) FOR ASSESSMENT AND MANAGEMENT OF MONITORING DATA AND INFORMATION

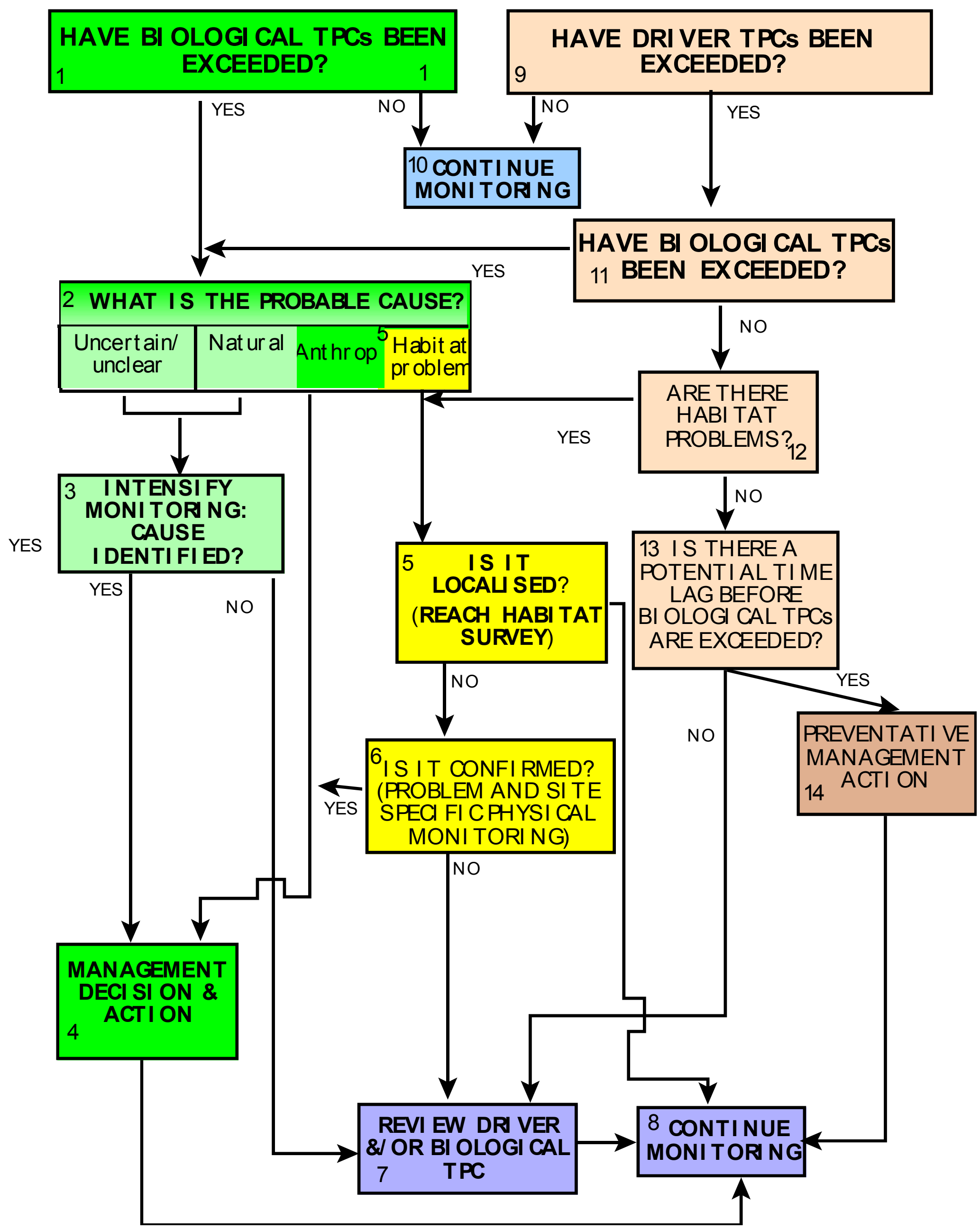

Figure 3.1: Conformance BIODSS

1, 9 & 10: During the long term monitoring, TPCs have to be checked after each survey and analysis. If no TPCs have been exceeded, monitoring will continue.

1, 2, 3, 4, 5, 6, 7 & 8: If the biological TPCs have been exceeded, one has to determine *why*. It could potentially be one of the following:

- Anthropogenic: This could include human use for example such as removal of species, fishing mortality or harvesting. This could also include changes in the catchment due to increased human use. If it is identified as an anthropogenic problem, a management decision and action (Block 4) must be taken and monitoring continues.

- Uncertain/unclear: If this is the case, monitoring should be intensified, TPCs be reviewed and the cause established. If the cause is established, a management decision and action might be required and monitoring should continue. If the cause is not established, it is probably because the driver and or biological TPC is too conservative and must be reviewed. Monitoring must continue after the review.
- Natural: This refers to some natural biological problems such as disease and predation. The sequential process is the same as above.
- Habitat problem: A habitat problem could be evident such as embeddedness of rocks. It must then be established whether this is a localised problem by for example undertaking a reach habitat survey (Block 5). If it is localised, monitoring must continue. If it is not localised, the problem must be confirmed by site specific physical monitoring (Block 6). If it is confirmed, a management decision and action must be undertaken and monitoring must continue. If it is not confirmed, then the driver and or biological TPCs must be reviewed and monitoring must continue (Block 7 and 8).

9, 11, 12: If the driver TPCs have been exceeded, one then has to check whether the response components have reacted to this, i.e. whether the biological TPCs have been exceeded. If the biological TPCs have been exceeded, it must be determined why (block 2 on). If the biological TPCs have NOT been exceeded, one then has to check whether there are habitat problems (block 12). If there are habitat problems, the flow diagram from block 5 must be followed. If there are not habitat problems, one will have to evaluate whether this may be because the response components have not yet indicated a response (block 13). In this case, some preventative management action might be required, and monitoring will continue. If however, there is probably not a potential lag time, the biological or driver TPC must be reviewed and monitoring continued.

3.2.1 The process illustrated as a question-answer system

Assumptions and Principles

It is assumed that baseline requirements for drivers and biological components have been specified in terms of their relation with the REC.

The principles of the Ecological Reserve Monitoring DSS are that normally the system would be followed by starting at step 1. This means that the drivers (at least some of them) would provide a continuous or regular flow of data that may require the immediate (i.e. outside the planned biomonitoring cycle) initiation of biomonitoring if driver TPCs is exceeded. However, if the driver TPCs are not exceeded, but monitoring of biological components according to the frequency and detail prescribed by the monitoring programme is done, these biological results must be assessed on their own by entering the DSS at step 2(b).

1. Have Any of Driver TPCs been exceeded?

Hydrology TPCs
Water Quality TPCs
Geomorphology TPCs :
Instream Habitat TPCs (Instream IHI; Site and reach Habitat attributes – depth, velocity, cover):
Riparian zone TPCs

Yes: Go to 2(a)
No: If biological data is recent: Go to 2(b).
If not, Go to 3.

2(a). Initiate biomonitoring if biological data is not recent: Have Any Biological TPCs been exceeded?
2(b). Assess recent biological data: Have any biological TPCs been exceeded?

Fish TPCs (FAII, indicator spp. and groups):
Invertebrate TPCs (SASS, ASPT, indicator taxa):
Riparian Vegetation TPCs (RVI, indicator taxa):

Yes: Go to 4

3. CONTINUE MONITORING: REGULARLY REVIEW AND REFINE DRIVER AND BIOLOGICAL TPCs (INCLUDING BASELINE).

No: Go to 3

4. Is the Probable Cause of TPC exceedence due to human utilization (e.g., harvesting of fish, i.e. fishing mortality)?

Yes: Go to 13
No: Go to 5

5. Is the Probable Cause of TPC exceedence due to Natural causes?
Yes: Go to 3
No: Go to 6

6. Is the Probable Cause of TPC exceedence due to Water Quality Problems?
Yes: Go to 7
No: Go to 8

7. Are Water Quality problems non-flow related?
Go to 13
No: Go to 14

8. Is the Probable Cause of TPC exceedence due to Habitat Problems?
Yes: Go to 9
No: Go to 12

9. Are Habitat Problems Flow related?
Yes: Go to 13

No: Go to 10

10. Are Habitat Problems non-flow related?
Yes: Go to 13
No: Go to 11

11. Are Habitat Problems Localised?
Yes: Go to 15
No: Go to 16

12. Are the Origin of Biological Symptoms Uncertain/Not Clear?
Yes: Go to 14
No: Go to 4

13.	**MANAGEMENT DECISION AND ACTION: GO TO 3.**

14.	**INTENSIFY MONITORING: HAVE THE CAUSE BEEN IDENTIFIED/ISOLATED?** **Yes: Go to 4** **No: Go to 14**

15.	**UNDERTAKE DETAIL SITE HABITAT SURVEY: GO TO 4**

16.	**UNDERTAKE REACH HABITAT SURVEY: GO TO 4**

Comment [DL1]: Onthou, hierdie verwys na die hele DSS, nie na punt 12 nie. Net hier ingesit sodat gedagtes nie verlore raak nie.

Different levels of EcoStatus determination and different tools for all the components available. It could be possible to link the different levels and tools to the DSS – eg, do monitoring at a specific level of EcoStatus determination. If TPCs are exceeded, then go to next level. This will imply refinement of the DSS.

If, during the above surveys, TPCs are exceeded, the DSS as described in flow diagram 2 (fig ____), needs to be followed. Furthermore, if any major catchment changes or development changes take place, this should lead to the above monitoring to take place immediately, irrespective where one is in the monitoring cycle.

4 GENERIC GUIDELINES FOR ECOLOGICAL RESERVE MONITORING SURVEYS

4.1 HYDROLOGY MONITORING ACTIONS

The main question from a hydrological point of view is whether or not the 'design' (design refers to the flow requirements set at either the EWR workshop or modified and accepted at a later stage) Reserve is being met. The 'design' Reserve can only be determined in relation to the natural flows that would have been expected to occur over the same period (see the section in Chapter 2). The assumption is that the 'design' Reserve for the monitoring period will therefore be generated from estimations of the expected natural flows and the Reserve operating rules.

The monitoring action is therefore to compare the design Reserve with the monitored flows over the period of the evaluation and identify any differences that might be relevant to an evaluation of the biological (and geomorphological) monitoring data (this is comparable to implementation monitoring, cf. section 1.5.1). Additional hydrological monitoring actions may be required to identify potentially critical deficiencies in flow that may lead to biological thresholds being exceeded. An example could be an excessively long period of zero or very low flow that occurs between routine biological monitoring visits.

If flows less than the 'design' Reserve are observed, but the biological monitoring suggests that the ecological objectives are being met, it is possible that the 'design' Reserve is too high and that the Reserve requirements can be adjusted downwards. However, it is important to recognise that short term reductions in flow may not result in immediate negative ecological impacts, but if such reduced flows persist there may be a downward trend in ecological functioning. One of the objectives of the monitoring programme should be to feedback information to the Reserve determination process so that future Reserves can be estimated with greater confidence. The monitoring programme should therefore be designed to answer questions that were not able to be answered during the Reserve determination process and yet are critical to the successful management of the resource. An example is the biological impact of infrequent short periods of zero flow in naturally perennial systems. This type of situation may be unavoidable in highly utilised systems (especially where stream flow reduction activities exist together with high priority run-of-river abstractions). The assumption is often made that this will have a critical impact on the ecological functioning, but in many systems the real impact is uncertain. Monitoring programmes have the potential to resolve such issues and improve the confidence with which Reserve requirements are quantified.

The most difficult aspect of evaluating the biological monitoring data with respect to the monitored flows will always be accounting for the 'recent' history of the flow regime. The effects of 'large' flow events in the recent past are not usually very well understood, but could have a substantial impact on the interpretation of short-term relationships between hydrology and ecological response.

Where a rated section is used for monitoring flows, periodic re-calibration (checking existing calibration points or adding new points to the stage-discharge relationship) will be required.

Where a gauging station is being used to estimate flows at the monitoring site, it will be necessary to periodically gauge flows at the site to check assumptions related to channel gains and/or losses between the monitoring site and the gauge.

4.2 REQUIREMENTS FOR FISH

4.2.1 Monitoring Frequency

Monitoring frequency would be dependant on the sensitivity of the fish assemblage and the level of development of the system. The EIS should be consulted and the risk to the fish should be estimated to arrive at an estimation of vulnerability of the assemblage.

Examples:

- Lower Crocodile East; sensitive species and high level of utilization of the system in terms of quality and quantity. Frequency: 1 X dry season
- Groot Marico, sensitive species and moderate level of utilization in terms of quality and quantity. Frequency: 1 X 3 years
- Lower Thukela, no sensitive species and low level of use in terms of quantity and quality. Frequency. Frequency: 1 X 5 years.
- Kromme , mostly exotic species, medium to high use in terms of quantity and quality. Frequency: 1 X 5 years, but using exotic species as TPCs in terms of indicators of habitat and quantity and quality.

4.2.2 Sampling techniques and assessment methods

Modus operandi during surveys will be as described in the RHP site characterization manual (Dallas 2005) and the EcoStatus manual (Kleynhans *et al* 2005).

At the end of a survey cycle, the FRAI should be applied and all available driver information utilized in this process. If this analysis indicates the exceedence of TPCs, additional sites should be monitored (both fish sampling and fish habitat analysis) to identify the reason and to undertake appropriate management action if the TPC is valid.

4.3 REQUIREMENTS FOR AQUATIC INVERTEBRATES

The monitoring frequency would be dependant on the sensitivity of the invertebrate assemblage and the level of development of the system.

Frequency for sensitive invertebrate assemblage (use combination of SASS, taxa present and ASPT to determine) should be annually (during worst (dry) condition). If the invertebrate assemblage is not sensitive, then the frequency should be once every two years (during worst (dry) condition).

At the end of a survey cycle, the MIRAI should be applied and all available driver information utilized in this process. If this analysis indicates the exceedence of TPCs, additional sites should be monitored (both invertebrate sampling and invertebrate habitat analysis) to identify the reason and to undertake appropriate management action if the TPC is valid.

4.4 REQUIREMENTS FOR RIPARIAN AND FLUVIAL GEOMORPHOLOGY

Due to budget constraints, the riparian and geomorphology specialists are only involved in monitoring when the vegetation and geomorphology TPCs are exceeded. The fish and invertebrate assessors (trained to run VEGRAI and GAI) run these models during every fish and invertebrate sampling survey to check whether TPCs are exceeded. If indications are that they are exceeded, then relevant VEGRAI and GAI specialists must monitor to confirm. If confirmed that they are exceeded, then the Ecological Reserve Monitoring DSS must be followed. During the monitoring by the relevant specialists, the following procedures must be followed.

4.4.1 Geomorphology

If a biological response is detected at a particular site, the following assessment will be undertaken by a geomorphologist:

a) GAI assessment for the site, which will include an assessment of change to

- System connectivity, which includes
  - Hillslope-channel connectivity
  - Upstream-downstream connectivity
  - Within reach connectivity
  - Channel-floodzone connectivity
  - Vertical connectivity
- System inputs (water and sediment)
  - Takes into account landuse changes and status of land degradation in catchment as well as recent floods
- Morphological response to changes in the above

and will take into account the sensitivity of the relevant reach to change based on

- Valley form
- Channel type
- Reach type

b) Quantitative assessment of bed material size distribution for comparison with baseline.

c) Depending on the nature of change/impact, and system connectivity, it may be necessary to assess the sensitivity of downstream reaches to change. If the impact is severe and connectivity is high, change is likely to be reflected downstream of the site. Where possible, an existing downstream site will be used for this assessment. However, if the next downstream site is too far from the site of impact, an additional site may be necessary.

d) Study of aerial photographs if a time series (of aerial photographs) is available and if it is deemed necessary.

Assessments should preferably be carried out in **low to moderate flow conditions** to allow observation of bed material and access to channel.

4.4.2 Riparian vegetation

If a biological response is detected at a particular site, the following assessment will be undertaken by a riparian vegetation specialist:

a) Undertake the VEGRAI.

b) Identify indicator species (flow changes) on the cross-section.

c) Study of aerial photographs if a time series (of aerial photographs) is available and if it is deemed necessary.

4.5 WATER QUALITY

It is a requirement of Ecological Reserve monitoring that data assessment against TPCs be conducted after every monitoring occasion. This task should either be conducted by the responsible DWAF officer or be sub-contracted to an external monitoring team or water quality specialist.

Note that the frequency of monitoring shown on Table 5.1 is a generic guideline to Ecological Reserve monitoring and assumes continued monitoring of all selected variables.

More or less frequent monitoring of a particular variable may be undertaken based on site-specific conditions.

Comment [DL2]: Note: Continuous monitoring at this scale impractical. In die DSS need to specify that some of the monitoring is in reaction to catchment changes etc.

4.6 REQUIREMENTS FOR ECOLOGICAL RESERVE MONITORING WHEN THE RESERVE DOES NOT HAVE TO BE IMPLEMENTED (I.E. FLOW AND QUALITY BETTER THAN REQUIREMENTS)

The situation must be monitored at some level, i.e. first to measure any changes and secondly to determine whether EcoSpecs and associated EWRs were set at the acceptable levels.

A RHP approach is required. The frequency will be as for the requirements set for the RHP assessment. The EWR site has to be included as one of the RHP sites.

5 GUIDELINE TO LINK ECOSTATUS MODEL METRICS TO ECOSPECS AND TPCS

5.1 ASSESSING CONFIDENCE OF ECOSPECS AND TPCS

This will be completed in the next version.

Comment [DL3]: Hier moet ons die benadering verduidelik en spesifiseer (generies, nadat ons dit vir vis gedoen het?)

5.2 SETTING OF ECOSPECS AND TPCS FOR FISH

- Determination of EcoSpecs are based on ecological specifications for different metric groups and metrics.
- Fish EcoSpecs models are used for this purpose. These models are based on the preferences of the indigenous species for velocity-depth classes, cover classes and intolerance for no-flow and modified water quality.
- To achieve this, a list of species for the reference condition is derived based on historical data and expert knowledge. The expected frequency of occurrence of the species in this list are also rated. Where historical information is not sufficient or available to estimate the expected frequency of occurrence, the overall condition of fish habitat as it would be derived to be under reference conditions should be used to estimate frequency of occurrence in a fish habitat segment (FHS), reach or resource unit.
- Frequency of occurrence ratings are based on the following system:
- 0=absent
- 1=present at very few sites (<10%)
- 2=present at few sites (>10-25%)
- 3=present at about >25-50 % of sites
- 4=present at most sites (>50- 75%)
- 5=present at almost all sites (>75%)
- The next step is the compilation of a list of species actually observed in the resource unit. Under certain provisos, species can be added to this list. This refer to ubiquitous species difficult to sample with the sampling equipment used or certain velocity-depth classes (large pools, etc.) not being sampled for whatever reason. Usually species with a wide preference for habitat conditions and tolerant of environmental change would be included here. The observed frequency of occurrence of species is indicated.
- If the sampled fish data are not representative enough to do this (i.e. only one site was sampled), the fish habitat as it is under present conditions as observed at several points in the resource unit should be used to estimate the frequency of occurrence.
- Fish habitat assessment should also be used as an additional source of information. Especially where the number of sites per resource unit is limited to 1 or 2, additional information on habitat condition will contribute in estimating the frequency of occurrence of species in a resource unit. This means that the relative abundance of velocity-depth and cover classes should be assessed visually at several sites and the preferences of species expected in the reach be used to derive the frequency of occurrence of species. Longitudinal geomorphic zonation will also contribute. Driver information relating to flow modification, physico-chemical conditions and migration barriers should be used to provide an overall view of fish species response in terms of frequency of occurrence. The presence of introduced species provide an additional source of information useful to interpret fish assemblage response. As indicated in the EcoStatus manual, habitat integrity should be assessed where driver information is not sufficient (Kleynhans et al 2005).

- It follows that the higher the dependence is on habitat derived species lists and frequency of occurrence, the lower the overall confidence in the assessment would be.
- EcoSpecs (biological criteria) are formulated to describe the REC according to qualitative and quantitative attributes of the fish assemblage. EcoSpecs are based on the principle that any change in the fish assemblage integrity, would be linked to a driver change that would have an influence on fish habitat. In such a situation the FRAI metric group with the highest weight and the metric group indicating most modification would be appropriate starting points. The EcoSpecs model for the selected metric group can then be run for different scenarios of frequency of occurrence for certain species. Again the metric with the highest weight or the metric indicating most modification may be appropriate starting points. The resulting metric values can be fed back into the FRAI model to assess the predicted frequency of occurrence response of the fish assemblage in terms of the index value
- Thresholds of probable concern (TPCs) are meant to provide an early warning that EcoSpecs are in a danger of being exceeded and that the REC may not be achieved or be maintained. This also means that the TPCs may indicate a change before the FRAI is starting to indicate this. TPCs can be formulated in terms of particular metrics that have to be selected based on their information value. The fish assemblage attributes selected as TPCs should be measurable and quantitative as far as possible. The TPC selection process should follow a hierarchical approach where the metric group with the highest weight is selected first, followed by the selection of the metric with the highest weight in the metric group. This metric can be linked to the monitoring of a fish species that provide reliable information in terms of its response to habitat modification. Ideally, a fish species that would be useful as a TPC if it is common, easy to sample and also have a high level of habitat preference (i.e. velocity-depth and cover classes) and is intolerant to various forms of disturbance (i.e. flow modification and water quality modification). It follows that in each metric group, the metric with the highest weight should be linked to a species with such attributes. If this is not possible (e.g. the species may be intolerant but it is naturally rare with a low frequency of occurrence at sites in the resource unit), the metric with the second highest weight should be used. As an alternative, the metric with the highest rating (most modified) can be used and a species selected to represent this.

The following steps are provided as the process to derive EcoSpecs and TPCs from the FRAI ECOSPEC and FRAI EC models

This development to the FRAI models has been made recently with the objective of providing a consistent means of determining, ratings, ranks, weights, EcoSpecs and TPCs. This means that the FRAI as determined for the Komati, Letaba, Kromme and Kat River must be reviewed to allow for the determining of the EcoSpecs and TPCs. The original models and results will be used to calibrate these models.

The process below provides a step by step approach on how to determine the EcoSpecs and TPCs as well as how to update the FRAI. In future the model will be calibrated and some of the steps below will be automated.

5.2.1 Determining EcoSpecs

The FRAI EcoSpec model is applicable to the velocity-depth, flow modification, cover and physico-chemical metric groups. The migration and introduced species metric groups are not part of the FRAI EcoSpec model and are assessed directly within the FRAI model itself.

1. Run the FRAI EcoSpec model on your computer.

2. For species that will occur under reference conditions, provide the frequency of occurrence (0 – 5; the interpretation of the scale is provided in a comment block). The complete list of freshwater species for South Africa is provided and the frequency of occurrence is indicated for the species present in the particular RU for the river being assessed.
3. For species that will occur under present conditions (observed or derived from present habitat conditions and thus expected to be present; habitat conditions must also consider water quality, not just the physical conditions etc.), provide frequency of occurrence (0 – 5).
4. If the REC is different than the PES, the frequency of occurrence of species that you expect to occur under the relevant EC must be indicated in the particular column.
5. Output of EcoSpec model uses the Frequency of Occurrence and the Preferences/Intolerances to provide an INDEX VALUE for the species under all conditions set up under 3 and 4. This is provided for each of the four relevant metric groups as the preferences/intolerances would differ for different metric groups.

THESE INDEX VALUES FOR EACH METRIC GROUP COMPRISE A COMPONENT OF YOUR ECOSPECS. HIERDIE VOORAFGAANDE SIN IS WAT EK OORSPRONKLIK GEHAD HET AS DIE TPCS. NOTE THAT THE FRAI EC MODEL WITH ALL THE RATINGS AND RATED WEIGHTINGS ALSO ACTS AS ECOSPECs.

5.2.2 Converting the FRAI

1. The output of the FRAI EcoSpec model provides the rating, rank and weight to be used in the four relevant metric groups of the FRAI EC model
2. Copy the rating, rank and weight to the relevant metrics and metric groups of the FRAI EC model.
3. Evaluate the calculated rating rank and weight in the FRAI EC model and, adjust these results where necessary. If these are adjusted, motivations are required. The other option is to re-evaluate the frequency of occurrence. In the FRAI EcoSpec model.
4. If not similar to the results generated during the EcoClassification, adjust if you can motivate, otherwise discuss implications with study leader.

5.2.3 Setting the TPC

Note: For practical reasons, only key species will be selected for monitoring purposes and interpretation of monitoring results. TPCs will only be formulated for these species. The process below provides guidance for selecting the key species and setting the TPCs for these.

1. To select suitable species for monitoring, select the species with the highest index value under reference conditions (preference or intolerance X reference frequency/25) in the FRAI EC model for each of the metric under each of the four metric groups (this will be automated)
2. Consult the FRAI EC model to determine which metric group has the highest rated weighting.
3. Use this metric group and determine which metric/s has/ve the highest rated weighting.
4. Considering the FRAI EcoSpec Model, evaluate whether the species with highest index value under reference conditions have a sufficiently high frequency of occurrence to include in monitoring.
5. For those species, set a % frequency within the present (observed) frequency of occurrence range associated with the 0 – 5 scale to act as the TPC.

THE TPCS ARE THEREFORE EXPRESSED AS A PERCENTAGE WITHIN THE RANGE ASSOCIATED WITH THE RELEVANT FREQUENCY OF OCCURRENCE SCORE UNDER PRESENT (OR REC) CONDITIONS.

5.2.4 Approach for sites dominated by alien species

To be completed in the next version.

Comment [DL4]: Approach possibly based on ecological requirements of exotic species and/or general fish habitat evaluation. Inverts will play a bigger role, Frequency of monitoring of fish lower.

5.3 SETTING OF ECOSPECS AND TPCS FOR AQUATIC INVERTEBRATES

This is a preliminary method to use specifically for the Kromme, Letaba, Komati and Kat rivers. It is foreseen that a method similar to that followed for the fish will be developed. This method will include a model that can be used to derive the EcoSpecs and TPCs. This model will only be included in the next version of the manual.

The method will be explained using an example

Use the MIRAI model for the REC to select the relevant metrics to use for setting EcoSpecs and TPCs

INVERTEBRATE EC METRIC GROUP		WEIGHTED SCORE OF GROUP	RANK OF METRIC	%WEIGHT FOR METRIC
FLOW MODIFICATION	FM	19.3944	1	100
HABITAT	H	18.0224	2	90
WATER QUALITY	WQ	12.3264	3	70
CONNECTIVITY & SEASONALITY	CS	17.9012	1	100
				360
INVERTEBRATE EC		67.6444		
INVERTEBRATE EC CATEGORY		C		

>89=A; 80-89=B; 60-79=C; 40-59=D; 20-39=E; <20=F

The first EcoSpec would be related to the actual category for invertebrates. For this example the EcoSpec would be to keep the invertebrates within a C category. This would translate to keeping the MIRAI within the percentage range for a C category (62- 78). The TPC related to this EcoSpec would then be if the MIRAI percentage drops to below 63%.

The next EcoSpec, in this instance is related to connectivity and seasonality. In this example only the seasonality is relevant.

Based on observed and derived data, with reference to migration and seasonality, how did the following change?	RATING	WEIGHT	WEIGHTED SCORE	RANKING OF METRICS	% Weight
Impact on distribution of migratory taxa		0.00	0.00		
Impact on abundance and/or frequency of occurrence of migratory taxa		0.00	0.00		

Impact on occurrence of taxa with seasonal distribution	1	0.56	0.56	1	100
Impact on abundance and/or frequency of occurrence of taxa with seasonal distribution	1	0.44	0.44	2	80

Summer taxa

Taxon	Ref abun	Ref freq	8/12/2004	2/3/2005	Frequency
Belostomatidae	A	25%			
Sphaeridae	A	25%			
Potamonautidae	B	75%	B		50%
Physidae	A	25%			
Planorbinae	A	25%			
Gerridae	A	25%			
Atyidae	B	100%	A	A	100%
Trichorythidae	B	25%			
Gyrinidae	B	100%	A		50%
Coenagrionidae	B	25%			
Ceratopogonidae	A	50%	1		50%
Ancylidae	A	25%			

In the MIRAI model the reference conditions are specified according to each taxon's expected abundance (on the logarithmic scale used for the SASS protocol) as well as how often (frequency) each taxon would be expected to occur. The frequency of occurrence takes into account both spatial and temporal distribution. The abundance and frequency for the different categories are included in the MIRAI model as well. The abundances and frequency of the taxa for the category under consideration is used to set the Ecospecs and corresponding TPCs.

An example of EcoSpecs and the corresponding TPCs for addressing the summer taxa would be:

PRELIMINARY ECOSPECs	TPCs
• To maintain suitable conditions for summer taxa: o Atyidae: occurring at an A abundance in >80% of summer samples o Gyrinidae occurring at an A abundance in >50% of summer samples	o Atyidae absent from three consecutive summer surveys. o Gyrinidae absent from two consecutive summer surveys,

In this example Flow Modification metric group was ranked the highest and will be considered next. One would then look at the flow modification metric group to determine which of the flow metrics would be relevant to use for setting EcoSpecs.

FLOW MODIFICATION METRICS. **WITH REFERENCE TO VELOCITY PREFERENCES, WHAT ARE THE CHANGES TO THE FOLLOWING OBSERVED OR EXPECTED TO BE?**	**RATING**	**WEIGHT**	**WEIGHTED SCORE**	**RANKING OF METRICS**	**% Weight**
Presence of taxa with a preference for very fast flowing water	1	0.14	0.14	3	80
Abundance and/or frequency of occurrence of taxa with a preference for very fast flowing water	0.5	0.13	0.06	4	70
Presence of taxa with a preference for moderately fast flowing water	0.5	0.18	0.09	1	100
Abundance and/or frequency of occurrence of taxa with a preference for moderately fast flowing water	0.5	0.17	0.09	2	95
Presence of taxa with a preference for slow flowing water	2	0.14	0.29	3	80
Abundance and/or frequency of occurrence of taxa with a preference for slow flowing water	0.5	0.13	0.06	4	70
Presence of taxa with a preference for standing water	1	0.05	0.05	5	30
Abundance and/or frequency of occurrence of taxa with a preference for standing water	1.5	0.05	0.08	5	30

In this example the taxa with a preference for moderately fast flowing water (0.3-0.6 m/s) would be the most relevant to set EcoSpecs for this site.

Taxon	**Ref abun**	**Ref freq**	**9/6/2004**	**16/9/2004**	**8/12/2004**	**2/3/2005**	**Frequency**	**0.3-0.6**
Elmidae	B	50%	A				25	4
Naucoridae	A	80%						3
Gomphidae	A	80%		A			25	3
Libellulidae	B	25%						3
Hydraenidae	A	<10%						3
Leptoceridae	B	25%						3
Heptageniidae	A	25%						3

An example of EcoSpecs and the corresponding TPCs for addressing this group of taxa would be:

PRELIMINARY ECOSPECs	**TPCs**
• To maintain suitable conditions for the following taxa preferring moderately fast flowing water: o Elmidae occurring at an A abundance in >20% of samples o Gomphidae: occurring at an A abundance in >20% of samples	o Elmidae absent from three consecutive surveys. o Gomphidae absent from three consecutive surveys,

Habitat also plays an important role in maintaining the Invertebrate assemblage in a certain condition. One would then look at the Habitat modification metrics:

HABITAT MODIFICATION METRICS. WITH REFERENCE TO INVERTEBRATE HABITAT PREFERENCES, WHAT ARE THE CHANGES TO THE FOLLOWING OBSERVED OR EXPECTED TO BE?	RATING	WEIGHT	WEIGHTED SCORE	RANKING OF METRICS	%WEIGHT
Has the occurrence of invertebrates with a preference for bedrock/boulders changed relative to expected?	0.5	0.01	0.01	5	10
Has the abundance and/or frequency of occurrence of any of the taxa with a preference for bedrock/boulders changed?	0.5	0.01	0.01	5	10
Has the occurrence of invertebrates with a preference for loose cobbles changed relative to expected?	2.5	0.15	0.37	1	100
Has the abundance and/or frequency of occurrence of any of the taxa with a preference for loose cobbles changed?	1	0.15	0.15	1	100
Has the occurrence of invertebrates with a preference for vegetation changed relative to expected?	2	0.14	0.28	2	95
Has the abundance and/or frequency of occurrence of any of the taxa with a preference for vegetation changed?	2	0.14	0.28	2	95
Has the occurrence of invertebrates with a preference for sand, gravel or mud changed relative to expected?	0.5	0.07	0.04	4	50
Have the abundance of any of the taxa with a preference for sand, gravel or mud changed relative to expected?	1	0.07	0.07	4	50
Has the occurrence of invertebrates with a preference for the water column or water surface changed relative to expected?	0.5	0.12	0.06	3	80
Has the abundance and/or frequency of occurrence of any of the taxa with a preference for the water column/water surface changed?	1	0.12	0.12	3	80

In this example the loose cobbles would have to be maintained to ensure that the Invertebrates stay in a C category. Certain key taxa (Hydropsychidae & Simuliidae) occurring in the cobble biotope can be selected to set EcoSpecs for habitat conditions

Taxon	Ref abun	Ref freq	9/6/2004	16/9/2004	8/12/2004	2/3/2005	Frequency	COBBLES
Hirudinea	A			A	A	A	75	4
Empididae	A							4
Elmidae	B		A				25	4
Perlidae	A							4
Heptageniidae	A							4
Athericidae	A			A	A		50	4
Philopotamidae	A							4
Libellulidae	B							4
Chlorocyphidae	A							4
Aeshnidae	A							3
Leptophlebiidae	B			A			25	3
Hydropsychidae 1sp			A	A	B	A	100	3
Hydropsychidae 2spp	B							3
Simuliidae	B		A	A	C	B	100	3
Ecnomidae	A							3

An example of EcoSpecs and TPCs to address the Habitat would be:

PRELIMINARY ECOSPECs	TPCs
• To maintain suitable conditions for the following taxa in the Cobble biotope: • Hydropsychidae occurring at an A abundance • Simuliidae occurring at a B abundance	o Hydropsychidae absent from consecutive surveys. o Simuliidae absent from any survey.

The Physico Chemical Parameters (Water Quality) is also an important factor in determining the invertebrate EC.

WATER QUALITY METRICS. WITH REFERENCE TO WATER QUALITY REQUIREMENTS, WHAT ARE THE CHANGES TO THE FOLLOWING OBSERVED OR EXPECTED TO BE?	RATING	WEIGHT	WEIGHTED SCORE	RANKING OF METRICS	% WEIGHT
Have the number of taxa with a high requirement for unmodified physico-chemical conditions changed?	2	0.07	0.1429	4	60
Have the abundance and/or frequency of occurrence of the taxa with a high requirement for unmodified physico-chemical conditions changed?	2	0.07	0.1429	4	60
Have the number of taxa with a moderate requirement for unmodified physico-chemical conditions changed?	1.5	0.10	0.1518	3	95
Have the abundance and/or frequency of occurrence of the taxa with a moderate requirement for modified physico-chemical conditions changed?	1.5	0.10	0.1518	3	95
Have the number of taxa with a low requirement for unmodified physico-chemical conditions changed?	2	0.11	0.2143	2	90
Have the abundance and/or frequency of occurrence of the taxa with a low requirement for unmodified physico-chemical conditions changed?	1.5	0.11	0.1607	2	90
Have the number of taxa with a very low requirement for unmodified physico-chemical conditions changed?	0.5	0.10	0.0506	3	85
Have the abundance and/or frequency of occurrence of the taxa with a very low requirement for unmodified physico-chemical conditions changed?	1	0.10	0.1012	3	85
How does the total SASS score differ from expected?	3	0.12	0.3571	1	100
How does the total ASPT score differ from expected?	3	0.12	0.3571	1	100

SASS and ASPT is always a good measure of Water Quality impacts and can easily be used to set EcoSpecs and TPCs.

Taxon	Ref SASS	9/6/2004	16/9/2004	8/12/2004	2/3/2005
SASS	120	57	70	72	35
No of taxa		12	13	15	8
ASPT	6	4.8	5.4	4.8	4.4

An example of EcoSpecs and TPCs using SASS5 and ASPT is presented in the table below:

PRELIMINARY ECOSPECs	TPCs
• To ensure that the SASS5 scores and ASPT values occur in the following range: SASS5 score 35 to 75; ASPT 4.5 to 5.5	• The SASS5 score < 40 and ASPT < 4.5.

In addition to these specific Ecospecs and TPCs, other factors can also be taken into account to ensure a healthy Invertebrate composition. Examples of other EcoSpecs and TPCs to address factors such as diversity and composition are indicated in the table below:

PRELIMINARY ECOSPECs	TPCs
• To ensure that no group consistently dominates the fauna, defined as D abundance for more than two consecutive surveys.	• Any taxon abundance 'D' (>1000) in two consecutive surveys.
• To maintain suitable conditions for the following seven key taxa: • Chironomidae • Atyidae • Gyrinidae • Caenidae • Baetidae 2spp • Simuliidae • Hydropsychidae	• Less than five of the seven key taxa listed.

5.4 SETTING OF ECOSPECS AND TPCS FOR RIPARIAN VEGETATION

This process is a preliminary method to use specifically for the Kromme, Letaba, Komati and Kat Rivers as the VEGRAI was not yet developed prior to these studies. A model with many of the characteristics of the VEGRAI that is now being developed was used (riparian vegetation response model) and EcoSpecs and TPCs must be derived using this model. The process below provides some guidelines. Depending on the level of data or field observations, the relevant riparian vegetation specialist could further develop these approaches.

The following steps are provided as a guideline.

1. Within each metric group (riparian vegetation zone), focus on Abundance and Cover metrics as these will be the easiest to measure during monitoring.
2. Refer to the Riparian vegetation response model for the REC to determine the rating provided for the abundance and cover metrics.
3. Provide some means of quantifying the rating. For example, the key/dominant/sensitive/indicator species can be identified and a range of % occurrence under the REC conditions can be provided. This would comprise the EcoSpec.
4. If a similar quantifying process can be followed for any other importance metrics, provide this.
5. In the example (point 3 above), the TPC would then constitute a percentage point within the expected or observed range that could trigger a specific monitoring action. For example, if Phragmites were one of the species assessed and the rating was defined as a percentage occurrence of between 20 and 40 %, then the TPCs could be set at 35% (to address a possible increase of Phragmites due for example to increased and steady

base flows) and at 25% (to address a possible decrease of Phragmites due to for example physical removal or decrease of base flows).

6. During the monitoring phase, the monitoring could focus on the metric group which has the highest weighted rating only and specific metrics only that are easy to monitor. This decision is however made during the design of the actual monitoring programme.

5.5 SETTING OF ECOSPECS AND TPCS FOR WATER QUALITY

TPCs are presented as a percentile of the data record for each water quality EcoSpec, as shown on Table 5.1. Note that the data assessment against the selected TPC must be calculated using data from the monitoring point used for baseline monitoring, but always update and use the last 3 years of data or a minimum of 60 data points, or data collected during baseline monitoring.

Table 5.1 Ecospecs and related TPCs for Ecological Reserve monitoring

Ecospec	Frequency of monitoring	TPC
Inorganic salts i.e. sodium chloride, magnesium chloride, calcium chloride, magnesium sulphate, sodium sulphate	Monthly	95^{th} percentile of data must be less than the boundary value for the relevant category
Nutrients i.e. TIN and SRP (ortho-phosphate), chlorophyll-a	Monthly for nutrients, and quarterly for chl-a	50^{th} percentile of data must be less than the boundary value for the relevant category
System variables i.e. pH, EC/TDS, DO, temperature, turbidity/water clarity	Monthly	95^{th} percentile of data must be less than the boundary value for the relevant category for EC/TDS, temperature, DO and turbidity / water clarity
Toxic substances	Monthly	95^{th} percentile of data must be less than the boundary value for the relevant category
In-stream toxicity	At times of known impact (e.g. pesticide use), or in response to a biotic trigger, but at least twice per year	Any indication of in-stream toxicity

5.5.1 Selection of variables for site-specific Ecological Reserve monitoring

This section of the document aims to assist in targeting water quality variables and monitoring effort for site-specific Ecological Reserve monitoring purposes. The *rank* and related *%wt* columns determine the significance or contribution of the water quality variable to the overall water quality category of the site (and is therefore site-specific). The following procedure should be adopted in selecting variables for Ecological Reserve monitoring:

- 1. Water quality metrics (see Table 5.2) with a rank of 1 or 2 (therefore with a high contribution to overall water quality category) should be monitored according to the frequency shown in Table 5.1.
- 2. Ongoing monitoring and comparison against TPCs in an iterative adaptive management process will indicate whether monitoring of selected variables should be discontinued or the frequency adapted.
- 3. If conditions at the site (e.g. a pollution event or significant change in land-use) and / or the *site-specific weighted rating* (see PAI table, Table 5. 2) indicates the variable to be of high significance, more frequent monitoring may be required. Alternatively, if there is little change in a monitored variable, less frequent monitoring can be undertaken.

Table 5.2 An example of a PAI table (note that the *weighted rating* column is normally hidden in the Excel spreadsheet)

PHYSICO-CHEMICAL EC					
Physico-chemical Metrics	**Rating**	**Rank**	**%wt**	**WEIGHTED RATING**	**CONFIDENCE**
pH	0.00	3	40	0.00	
SALTS	1.50	2	80	1.20	
NUTRIENTS	3.00	2	80	2.40	
TEMPERATURE	1.00	1	100	1.00	
TURBIDITY	1.00	2	80	0.80	
OXYGEN	1.00	1	100	1.00	
TOXICS	0.00	1	100	0.00	
TOTALS		7.00		18.29	
PHYSICO-CHEMICAL			81.71		
PHYSICO-CHEMICAL CATEGORY			**B**		
BOUNDARY CATEGORY			**B/C**		

5.6 SETTING ECOSPECS AND TPCS FOR GEOMORPHOLOGY

- Inspect final GAI worksheet and identify metrics which are having, and in the future may have, the greatest impact on the Ecological Category. This is often the metric with the highest weighted score.

- The generic way in which Ecospecs will be set for each metric is as set out below. Each table represents one of the four main system components, namely Reach Sediment Balance, Channel Perimeter Resistance, System Connectivity and Morphological Change.

A. Reach Sediment Balance

Metric	Way in which Ecospecs will be expressed and set	Way in which TPCs will be set
Change in sediment supply	▪ % of upstream catchment affected by gully erosion. ▪ % bank length of upstream channel reach affected by bank erosion. ▪ Estimated % of sediment trapped by upstream dams/weirs.	▪ Depending on erodibility and land use of catchment, a threshold % increase in erosion will be set. ▪ Depending on nature and erodibility of banks, a threshold % increase in erosion will be set. ▪ In setting these TPCs, the nature of the system should be considered. If the system is supply limited, probable concern will decrease as dams/weirs reach their capacity to trap sediment. If the system is transport limited, concern will increase as dams reach their sediment holding capacity.
Change to magnitude and frequency of flood events	▪ % of catchment affected by impoundment. ▪ Change to magnitude (Q) and frequency of flood events.	▪ Depends on nature of system. Small, more arid systems are more dependant on floods for geomorphological change (Baker, 1977). Threshold %s will be set accordingly. ▪ According to natural flow regime, thresholds for concern will be set in terms of both decreases and increases in flood magnitude and frequency.

B. Channel Perimeter Resistance

Metric	Way in which Ecospecs will be expressed	Way in which TPCs will be set
Bed Mobility	▪ Bed material size distribution. ▪ Degree of embeddedness. ▪ Degree of armouring of bed. ▪ Degree of imbrication of bed.	▪ Depending on dominant geomorphological processes, channel type and habitat requirements, threshold % for each size fraction will be set. ▪ Depending on channel type and habitat requirements, threshold degrees of embeddedness will be set. ▪ Depending on channel type and habitat requirements, threshold degrees of bed armouring will be set. ▪ Depending on channel type and habitat requirements, threshold degrees of imbrication will be set.
Bank (in)stability	▪ % Length of bank slumping. ▪ Change in bank angle. ▪ Degree of protection given by vegetation cover.	▪ Depending on nature and erodibility of banks, a threshold % increase in bank slumping will be set. ▪ Threshold change in angle will be set depending on dominant geomorphic processes and nature of bank. ▪ Threshold degree of decrease in vegetation cover in terms of both rooting and canopy cover.
Bar (in)stability	▪ Bar material size distribution. ▪ Degree of protection given by vegetation cover.	▪ Depending on dominant geomorphological processes, channel type and habitat requirements, threshold % for each size fraction will be set. ▪ Threshold degree of decrease in vegetation cover in terms of rooting and canopy cover.
Floodzone (in)stability	▪ Degree of protection given by vegetation cover. ▪ Sediment volume added or removed (e.g. sediment mining) since last survey.	▪ Threshold degree of decrease in vegetation cover in terms of rooting and canopy cover. ▪ Depending on channel type and habitat requirements, threshold volumes will be set in terms of sediment addition and removal.

C. System Connectivity

Metric	Way in which Ecospec will be expressed	Way in which TPCs will be set
Inter-system connectivity	▪ % Q added to or removed from system by interbasin transfer.	▪ According to natural flow regime, thresholds for concern will be set in terms of both decreases and increases in flood magnitude and frequency.
Hillslope-channel connectivity	▪ Degree of catchment hardening. ▪ Drainage density (ratio).	▪ Bar material size distribution. ▪ Degree of protection given by vegetation cover.
Upstream-downstream connectivity	▪ Number of dams, weirs, causeways, bridges and landslides upstream of site. ▪ % Catchment runoff impounded.	▪ In setting these TPCs, the nature of the system should be considered. Depending on the size of the upstream catchment, TPCs may be set in terms of total dam/weir volume or in terms of the number of obstructions upstream of the study reach. ▪ Depends on nature of system. Small, more arid systems are more dependant on floods for geomorphological change (Baker, 1977). Threshold %s will be set accordingly.
Within reach connectivity	▪ Number of weirs, causeways and bridges in reach.	▪ Depending on the length of the reach and/or the size of the channel, TPCs may be set in terms of total dam/weir volume or in terms of the number of obstructions in the reach.
Channel-floodzone connectivity	▪ Magnitude and frequency of flow events that overtop channel banks.	▪ According to natural flow regime, thresholds for concern will be set in terms of both decreases and increases in flood magnitude and frequency.
Vertical connectivity	▪ Degree of channel bed armouring.	▪ Depending on channel type and habitat requirements, threshold degrees of bed armouring will be set.

D. Morphological Change

Metric	Way in which Ecospec will be expressed	Way in which TPCs will be set
SUBSTRATE CHANGES		
Channel Bed	▪ Bed material size distribution.	▪ Depending on dominant geomorphological processes, channel type and habitat requirements, threshold % for each size fraction will be set.
Bars	▪ Bar material size distribution.	▪ Depending on dominant geomorphological processes, channel type and habitat requirements, threshold % for each size fraction will be set.
Channel Bank	▪ Bank material size distribution.	▪ Depending on dominant geomorphological processes, channel type and habitat requirements, threshold % for each size fraction will be set.
Flood zone sediments	▪ Flood zone material size distribution.	▪ Depending on dominant geomorphological processes, channel type and habitat requirements, threshold % for each size fraction will be set.
HYDRAULIC GEOMETRY		
Reach Type	▪ Ratio of riffle/rapid length to pool length. ▪ Type of hydraulic control (material size distribution in relation to flow/ stream power).	▪ TPC will be set as a ratio dependent on the trajectory of change and the channel type. ▪ Threshold is state change expressed in terms of relative mobility of the hydraulic control.
Cross-section Shape	▪ Channel width. ▪ Channel depth. ▪ Width-depth ratio.	▪ Depending on channel type, trajectory of change and habitat requirements TPCs in terms of actual channel dimensions will be set. ▪ Depending on channel type, trajectory of change and habitat requirements TPCs in terms of actual channel dimensions will be set. ▪ Depending on channel type, trajectory of change and habitat requirements TPCs in terms of actual channel dimensions will be set.
Secondary Channels	▪ Number of channels.	▪ Depending on channel type and habitat requirements, TPCs will be set in terms of the number of channels found in a reach.
Channel Roughness	▪ Channel sinuosity. ▪ Bed material size distribution.	▪ Depending on channel type, valley form, and trajectories of change, TPCs for sinuosity will be expressed as ratios (stream length/valley length). ▪ Depending on dominant geomorphological processes, channel type and habitat requirements, threshold % for each size fraction will be set.

5.7 DETERMINING HYDROLOGICAL TPCS FOR LOW FLOWS BASED ON POTENTIAL INSTREAM BIOTA RESPONSE: FISH EXAMPLE

- Use the fish stress excel table where the habitat stress, species stress and duration is determined and tabled.
- Copy the spreadsheet and adjust the duration sheet.
- Use column A to K as is.
- Combine the two columns representing the percentages for the wet and dry durations for the REC and illustrate the durations, indicating the season in column L.
- Add a column M called: Continuous days.
- Add a column N called: Ecological motivation.
- Delete all other columns to the right.

- Complete column M and N using the ecological motivation for the specified duration supplied in either the original spreadsheet or in MS Word format in the EWR report.
- AN EXAMPLE IS PROVIDED BELOW (Table 5.3).

Completing column M and N

When setting the DURATIONS during the original workshop, these durations represented the % time at which stress conditions can occur due to the duration of particular flows. These durations do not necessarily refer to a continuous period of time during which a particular flow would occur. Duration represent the total time that a particular flow would occur during a number of years and this may be continuous or discontinuous.

Specific important/key stresses that may only occur for the specified % during the record may however occur continuously over a number of days. This continuous stress conditions may be ecologically intolerable for the particular EC, depending on the length of time it happens continuously as well as the season during which it occurs.

If, during monitoring, a gauging station with a continuous recorder is available, these continuous periods (days) with a particular flow can be monitored and could act as a hydrological TPC which would initiate certain biological monitoring. Continuous periods of specific flow (and associated stress) can also be modelled to provide spell or run analysis. I.e. how often does a certain specified flow occur continuously for a specified number of days in a specific season? To undertake this analysis, the hydrologist would require the spells (continuous period length) from the ecologist, i.e. flow and number of successive days during which flow would be at or below a particular level. Aspects that could be considered to provide these (in column M and N) are the following:

- Maintenance flows/stress duration (dry season): Usually the assumption is that the flows specified for the lowest flow month (dry season) could occur continuously for the dry season, i.e. 90 days. If however these flows exceeded 90 days, however, any continuation of these flows into the wetter seasons could represent a problem. Therefore, if these flows occur for a certain period of time in the wetter months, this could be problematic from an ecological point of view.
- Maintenance flow/stress duration (wet season): Continuous flows, even those specified, in the wet season could also be problematic as the assumption would be that floods are occurring at certain times. A continuous set of flows will therefore represent a problem as it might indicate that floods will not be happening. This could be a natural situation due to a drought situation, or physical manipulation such as increased dams in the area or incorrect operation.
- Droughts: Continuous periods of drought could result in higher stress than expected. Ecological motivations could be set up for the maximum allowed number of days that these conditions could happen continuously in a specific season.

Table 5.3 Example of the Excel spreadsheet

Flow-Depth Response index	HABITAT ABUNDANCE AND				SPECIES STRESS	FLOW	CRIT STRESS	Requirements	Continuous No Days	Ecological Motivations
	FD	FS	SD	SS						
0	3	1	5	5	0	3.00	2			
1					1		2.8	30%: Wet season maintenance		
2					2		3.5	30%: Dry season maintenance		
3					3	0.78	4.5			
4	1	1	5	5	4		5.5			
5					5		6	10% Wet season drought		
6					6	0.38	7	10 % Dry season drought		
7	0	0	5	5	7		7.5			
8					8	0.12	8			
9					9		9			
10	0	0	5	5	10		10			

6 REFERENCES

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APPENDIX B

The Generic Range of possible EcoSpecs and TPCs for Geomorphology

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B1. Reach Sediment Balance

Metric	Way in which EcoSpecs will be expressed and set	Way in which TPCs will be set
Change in sediment supply	▪ % of upstream catchment affected by gully erosion. ▪ % bank length of upstream channel reach affected by bank erosion. ▪ Estimated % of sediment trapped by upstream dams/weirs.	▪ Depending on erodibility and land use of catchment, a threshold % increase in erosion will be set. ▪ Depending on nature and erodibility of banks, a threshold % increase in erosion will be set. ▪ In setting these TPCs, the nature of the system should be considered. If the system is supply limited, probable concern will decrease as dams/weirs reach their capacity to trap sediment. If the system is transport limited, concern will increase as dams reach their sediment holding capacity.
Change to magnitude and frequency of flood events	▪ % of catchment affected by impoundment. ▪ Change to magnitude (Q) and frequency of flood events.	▪ Depends on nature of system. Small, more arid systems are more dependant on floods for geomorphological change (Baker, 1977). Threshold %s will be set accordingly. ▪ According to natural flow regime, thresholds for concern will be set in terms of both decreases and increases in flood magnitude and frequency.

B2. Channel Perimeter Resistance

Metric	Way in which EcoSpecs will be expressed	Way in which TPCs will be set
Bed Mobility	▪ Bed material size distribution. ▪ Degree of embeddedness. ▪ Degree of armouring of bed. ▪ Degree of imbrication of bed.	▪ Depending on dominant geomorphological processes, channel type and habitat requirements, threshold % for each size fraction will be set. ▪ Depending on channel type and habitat requirements, threshold degrees of embeddedness will be set. ▪ Depending on channel type and habitat requirements, threshold degrees of bed armouring will be set. ▪ Depending on channel type and habitat requirements, threshold degrees of imbrication will be set.
Bank (in)stability	▪ % Length of bank slumping. ▪ Change in bank angle. ▪ Degree of protection given by vegetation cover.	▪ Depending on nature and erodibility of banks, a threshold % increase in bank slumping will be set. ▪ Threshold change in angle will be set depending on dominant geomorphic processes and nature of bank. ▪ Threshold degree of decrease in vegetation cover in terms of both rooting and canopy cover.
Bar (in)stability	▪ Bar material size distribution. ▪ Degree of protection given by vegetation cover.	▪ Depending on dominant geomorphological processes, channel type and habitat requirements, threshold % for each size fraction will be set. ▪ Threshold degree of decrease in vegetation cover in terms of rooting and canopy cover.
Floodzone (in)stability	▪ Degree of protection given by vegetation cover. ▪ Sediment volume added or removed (e.g. sediment mining) since last survey.	▪ Threshold degree of decrease in vegetation cover in terms of rooting and canopy cover. ▪ Depending on channel type and habitat requirements, threshold volumes will be set in terms of sediment addition and removal.

B3. System Connectivity

Metric	Way in which EcoSpecs will be expressed	Way in which TPCs will be set
Inter-system connectivity	▪ % Q added to or removed from system by interbasin transfer.	▪ According to natural flow regime, thresholds for concern will be set in terms of both decreases and increases in flood magnitude and frequency.
Hillslope-channel connectivity	▪ Degree of catchment hardening. ▪ Drainage density (ratio).	▪ Bar material size distribution. ▪ Degree of protection given by vegetation cover.
Upstream-downstream connectivity	▪ Number of dams, weirs, causeways, bridges and landslides upstream of site. ▪ % Catchment runoff impounded.	▪ In setting these TPCs, the nature of the system should be considered. Depending on the size of the upstream catchment, TPCs may be set in terms of total dam/weir volume or in terms of the number of obstructions upstream of the study reach. ▪ Depends on nature of system. Small, more arid systems are more dependant on floods for geomorphological change (Baker, 1977). Threshold %s will be set accordingly.
Within reach connectivity	▪ Number of weirs, causeways and bridges in reach.	▪ Depending on the length of the reach and/or the size of the channel, TPCs may be set in terms of total dam/weir volume or in terms of the number of obstructions in the reach.
Channel-floodzone connectivity	▪ Magnitude and frequency of flow events that overtop channel banks.	▪ According to natural flow regime, thresholds for concern will be set in terms of both decreases and increases in flood magnitude and frequency.
Vertical connectivity	▪ Degree of channel bed armouring.	▪ Depending on channel type and habitat requirements, threshold degrees of bed armouring will be set.

B4. Morphological Change

Metric	Way in which Ecospec will be expressed	Way in which TPCs will be set
SUBSTRATE CHANGES		
Channel Bed	▪ Bed material size distribution.	▪ Depending on dominant geomorphological processes, channel type and habitat requirements, threshold % for each size fraction will be set.
Bars	▪ Bar material size distribution.	▪ Depending on dominant geomorphological processes, channel type and habitat requirements, threshold % for each size fraction will be set.
Channel Bank	▪ Bank material size distribution.	▪ Depending on dominant geomorphological processes, channel type and habitat requirements, threshold % for each size fraction will be set.
Flood zone sediments	▪ Flood zone material size distribution.	▪ Depending on dominant geomorphological processes, channel type and habitat requirements, threshold % for each size fraction will be set.
HYDRAULIC GEOMETRY		
Reach Type	▪ Ratio of riffle/rapid length to pool length. ▪ Type of hydraulic control (material size distribution in relation to flow/ stream power).	▪ TPC will be set as a ratio dependent on the trajectory of change and the channel type. ▪ Threshold is state change expressed in terms opf relative mobility of the hydraulic control.
Cross-section Shape	▪ Channel width. ▪ Channel depth. ▪ Width-depth ratio.	▪ Depending on channel type, trajectory of change and habitat requirements TPCs in terms of actual channel dimensions will be set. ▪ Depending on channel type, trajectory of change and habitat requirements TPCs in terms of actual channel dimensions will be set. ▪ Depending on channel type, trajectory of change and habitat requirements TPCs in terms of actual channel dimensions will be set.
Secondary Channels	▪ Number of channels.	▪ Depending on channel type and habitat requirements, TPCs will be set in terms of the number of channels found in a reach.
Channel Roughness	▪ Channel sinuosity. ▪ Bed material size distribution.	▪ Depending on channel type, valley form, and trajectories of change, TPCs for sinuosity will be expressed as ratios (stream length/valley length). ▪ Depending on dominant geomorphological processes, channel type and habitat requirements, threshold % for each size fraction will be set.