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Work Package 5:

Assessment of Environmental Flow Requirements

Environmental Flow Requirements
Volume 2

December 2010

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SUPPORT TO PHASE 2 OF THE ORASECOM BASIN-WIDE INTEGRATED WATER RESOURCES MANAGEMENT PLAN

Work Package 5:

Assessment of Environmental Flow Requirements

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ABBREVIATIONS AND ACRONYMS

AEC	Alternative Ecological Category
ASPT	Average Score Per Taxon
BEC	Baseline Ecological Category
CD: RDM	Chief Directorate: Resource Directed Measures
CEC	Classification Ecological Category
CEV	Chronic Effects Value
CPUE	Catch per Unit Effort
DAP	Diatom Assessment Protocol
D:RQS	Directorate: Resource Quality Services
DSS	Decision Support System
DWA	Department of Water Affairs
DWAF	Department of Water Affairs and Forestry
EC	Ecological Category
EC	Electrical Conductivity
EIS	Ecological Importance and Sensitivity
ERM	Ecological Resource Monitoring
EFR	Ecological Flow Requirements
EWRM	Ecological Water Resource Monitoring
F/VFF	Fast/ Very Fast Flow
FCS	Fast over Coarse Substrate
FD	Fast deep
FDI	Flow Dependent macroinvertebrate
FF	Fast Flow
FRAI	Fish Response Assessment Index
FROC	Fish Frequency of Occurrence
FS	Fast shallow
GAI	Geomorphology Assessment Index
MAR	Mean Annual Runoff
MCB	Macro Channel Bank
MIRAI	Macro Invertebrate Assessment Index
MV	Marginal Vegetation
MVI	Marginal Vegetation Macroinvertebrate
NAEHMP	National Aquatic Ecosystem Health Monitoring Programme
nMAR	Natural mean annual runoff
MRU	Management resource unit
ORASECOM	Orange-Senq River Commission
PES	Present Ecological State

Quat	Quaternary catchment
RDM	Resource Directed Measures
R-DRAM	Rapid Diatom Assessment Method
REC	Recommended Ecological Category
RHAM	Rapid Habitat Assessment Method
RHP	River Health Programme
RQO	Resource Quality Objective
SANParks	South African National Parks
SASS5	South African Scoring System version 5
scs	Slow over Coarse Substrate
SD	Slow deep
spp	Species
SPI	Specific Pollution sensitivity Index
SRP	Soluble Reactive Phosphate
SS	Slow shallow
TEACHA	Tool for Ecological Aquatic Chemical Habitat Assessment
TIN	Total Inorganic Nitrogen
ToR	Terms of Reference
TPC	Threshold of Potential Concern
TWQR	Target Water Quality Range
VEGRAI	Riparian Vegetation Response Assessment Index
VFCS	Very Fast over Coarse Substrate
Wat Qual	Water quality
WMA	Water Management Area
WMS	Water Management System

1 APPROACH

This chapter is modified from DWAF, 2009a and DWA (2010).

1.1 BACKGROUND TO ECOLOGICAL WATER RESOURCES Monitoring IN SOUTH AFRICA

The National Water Act (NWA, Act No. 36 of 1998) requires the establishment of a national monitoring system that must provide for the collection of appropriate data and information necessary to assess water resources. Such a system must collect relevant information that contributes to the management of the resource in a desirable ecological condition by providing information on:

- Compliance with Resource Quality Objectives (RQOs). This relates to Ecological Reserve Monitoring (ERM) following on from the specification of Ecological Water Requirements (EFRs). The EFR process results in an extensive amount of data at a relatively limited number of sites that can be used to determine if the Recommended Ecological Category (REC) generated during the study per EFR site is achieved.
- The health of aquatic ecosystems. This relates to the National Aquatic Ecosystem Health Monitoring Programme (NAEHMP) and in this particular situation, to the River Health Programme (RHP) (a sub-component of the NAEHMP). The RHP is primarily aimed at providing information on the health or integrity of rivers based on biological responses for national state-of-the-rivers reporting and as input to resource management at a large number of sites.

Initially an Ecological Reserve Monitoring programme was developed that would run separately to the River Health Programme (RHP). However, the implications of simultaneously operating two separate ecological monitoring programmes have serious resource implications. To mitigate this and still maintain an operational ecological monitoring programme that provides useful management information, integration of the ERM and RHP within an adaptive management approach is proposed (Kleynhans *et al*., 2009). **This forms the basis of the integrated Ecological Water Resource Monitoring (EWRM) approach**.

1.1.1 Ecological monitoring

Ecological monitoring is the collection and analysis of repeated observations or measurements **to evaluate changes in the condition of the resource and the progress towards meeting the management objective (Elzinga *et al*., 1998)**. In terms of EWRM, it is the measurement of EcoSpecs (ecological specifications) to determine if the Ecological Category (EC) is attained (Kleynhans *et al.,* 2009). EWRM operates within the following concepts (based on Elzinga *et al*., 1998):

- The reference condition which is the natural or unimpaired condition of the system.
- The monitoring baseline which is a series of measurements taken before the initiation of the impact or management activity and used for comparison with the series of measurements taken afterward.
- Response monitoring occurs at a particular detail, frequency and intensity as guided by the Ecological Importance and Sensitivity (EIS) of the resource. Response monitoring results are evaluated by analysis within a management objective framework. This allows measurement of how the resource is changing over time, i.e. to measure the trend.

- 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). This would, inter alia, refer to whether flows are released as was specified for the attainment of a particular Ecological Category.
- Effectiveness monitoring measures whether the Ecological Category in terms of EcoSpecs) are attained by following the particular management scenario (Kershner, 1997).

If the Ecological Category (EC) 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).

1.1.2 EcoSpecs and Thresholds of Potential Concern

EWRM should be undertaken within a structured Decision Support System (DSS) framework following the principles of Adaptive Management. The purpose of the DSS system is to provide a decision framework within which monitoring results can be interpreted in terms of the attainment of objectives set for the condition and integrity of the resource. This relates directly to EcoSpecs and Thresholds of Potential Concern (TPCs) (Rogers and Bestbier, 1997) formulated to assess attainment of an Ecological Category. Conclusions emanating from the DSS will provide guidance on the management of the resource (Cormier and Suter, 2008).

1.2 ECOSPECS AND TPCs

EcoSpecs and TPCs are described in the Table 1.1 below.

Table 1.1 Purposes and principles of EcoSpecs and TPCs (from DWA, 2009a)

ECOSPECS	TPCs
PURPOSES	
During EFR studies, EcoSpecs are developed and specified per the EcoClassification process (Kleynhans and Louw, 2007). This encompasses biological specifications or Biocriteria that are numerical values or narrative statements that define a desired biological condition for a waterbody (Burton and Gerritsen, 2003). A certain level of habitat integrity (specified as Habitat criteria) is required to attain a particular biological condition for a water body. EcoSpecs then indicates the ecological detail that characterizes the EC. To establish clear goals relating to the ecological 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. 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	TPCs indicate the values around the EcoSpecs that, if being approached would initiate more detailed investigation or even management action. TPCs are based on the acceptance that there is uncertainty as to accuracy or validity of EcoSpecs i.e. is deviation from EcoSpecs due to natural variation, sampling error, etc. In the context of EWRM, TPCs are regarded as early warning indicators of potential change from a particular EC to another (lower) EC.

ECOSPECS	TPCs
SA) in cases where the objectives for other uses, or for impacts, may conflict with the requirements for protection.	
PRINCIPLES	
EcoSpecs must be quantifiable, measurable, verifiable and enforceable and ensure protection of all components of the resource, which make up ecological integrity. The critical components of the EcoSpecs include: Requirements for water quantity. Flow requirements for a river reach, estuary, and/or water level requirements for standing water or ground water are included. Groundwater level requirements to maintain spring and base flow in rivers and other ecological features are also considered. Biocriteria and Habitat criteria that are derived from EcoSpecs are clear and measurable specifications of ecological attributes (flow, physico-chemical attributes and biological integrity that reflect the health, community structure and distribution of aquatic biota). EcoSpecs therefore define the EC.	TPCs are upper and lower levels along a continuum of change in selected environmental indicators and are used and interpreted according to the following guidelines (Rogers and Bestbier, 1997): When a TPC level is reached (or when modelling predicts it will be reached), it prompts an assessment of the causes of the extent of the change. Assessment of the causes provides the basis for deciding whether management actions are needed or if the TPC needs to be recalibrated. TPCs provide management with strategic goals or endpoints within which to manage the system. TPCs form the basis of an inductive approach to adaptive management, and are invariably hypotheses of limits of acceptable change in ecosystem structure, function and composition. The validity and appropriateness of TPCs are always open to challenge and they must be adaptively modified as understanding and experience of the system being managed increases. It follows that more detailed monitoring surveys would increase the confidence in the validity of a TPC (i.e. narrow the uncertainty). This principle is built into the DSS by considering different levels of monitoring surveys.

1.3 APPROACH FOR APPLYING THE PRINCIPLES OF EWRM, ECOSPECS AND TPCS WITHIN THIS STUDY

The principles and conceptual approaches to EWRM have been under development since 2006 (DWAF, 2006). However, very few monitoring approaches have been tested and an appropriate DSS is still being developed. Proper testing within an adaptive management framework can only be done if EWRM is implemented for ecological flow requirements.

EWRM operates within the following concepts (based on Elzinga *et al*., 1998):

- The reference condition is the natural or unimpaired condition of the system.
- The monitoring baseline is a series of measurements taken before the initiation of the impact or management activity and is used for comparison with the series of measurements taken after the management activity. If the Present ecological State (PES) of the resource is unimpaired (natural), the reference will also be the baseline.
- It is important to assess whether there is a trend in the baseline, i.e. is it stationary or changing in a particular direction at the time when it is determined.
- This is the standard (“benchmark”) against which future deviations can be compared.

Therefore the PES of the system must be determined prior to management interventions. The PES will then serve as the baseline ecological state from which all changes can be measured and evaluated. i.e.:

PES = BASELINE = BASELINE ECOLOGICAL CATEGORY (BEC)

Management actions are designed to maintain, or attain (if different from the PES) the REC. These management actions relate to the management objectives which are described in terms of the flow and quality (water quality) EcoSpecs. Additional land use objectives may also be described if non-flow related aspects are contributing to the PES of the system.

Different flow regimes are identified for a range of ECs (referred to as EFR scenarios). These serve as the flow EcoSpecs for different ECs. Water quality EcoSpecs are finalized during the EcoSpec phase of the study. Once a decision is made on which future EC the river will be managed for, the EcoSpecs associated with this scenario are used to describe the management objectives for the system.

Therefore one must clearly distinguish between setting management objectives in terms of the drivers to achieve/maintain certain Ecological Categories, and defining EcoSpecs for the biophysical responses that describe the Ecological Categories.

In essence, during an EFR study, flow requirements (i.e. the main driver) that could result in a certain ecological state are defined through an Ecological Category. **These flow requirements inform the management objectives supported by the other driver component**s. Note that the word 'could' is used as the biological responses to driver conditions are all predicted and must be tested through monitoring.

Monitoring the ecological responses will test the predictions made during an EFR study. It furthermore will test whether adjustments to the EcoSpecs and TPCs are required and whether the overall management objective in terms of the REC is being achieved. It is therefore crucial that monitoring be driven by objectives as it forms the foundation of a monitoring project (cf. Elzinga *et al*., 1998).

1.4 FOCUS AND APPROACH FOR THE ORANGE EFR SITES (written by D Louw)

Reference conditions, the Present Ecological State (PES), the Recommended Ecological Category (REC) and Alternative Ecological Categories (AECs) have been determined for each EFR site and are described in Volume 1. **This information provides the broad level of EcoSpecs for the biophysical components addressed during EcoClassification. The next step is therefore the finalization of detailed EcoSpecs and TPCs for the baseline, i.e. the BEC, for the biological response indicators, water quality and geomorphology.** These objectives are used during monitoring, as monitoring is aimed at determining changes from the baseline or present state, irrespective of the management category. Measurement against EcoSpecs and TPCs will therefore indicate whether the BEC is being maintained, improved, or degrading. Note that TPCs are set so as to indicate the probability or relative risk of moving from the BEC or present state to a lower category. Management actions to prevent this degradation should then be defined and implemented.

The concepts of the EcoSpecs and TPCs are described in a hypothetical example (Figure 2.3) where the PES (BEC) is a C and the REC a B.

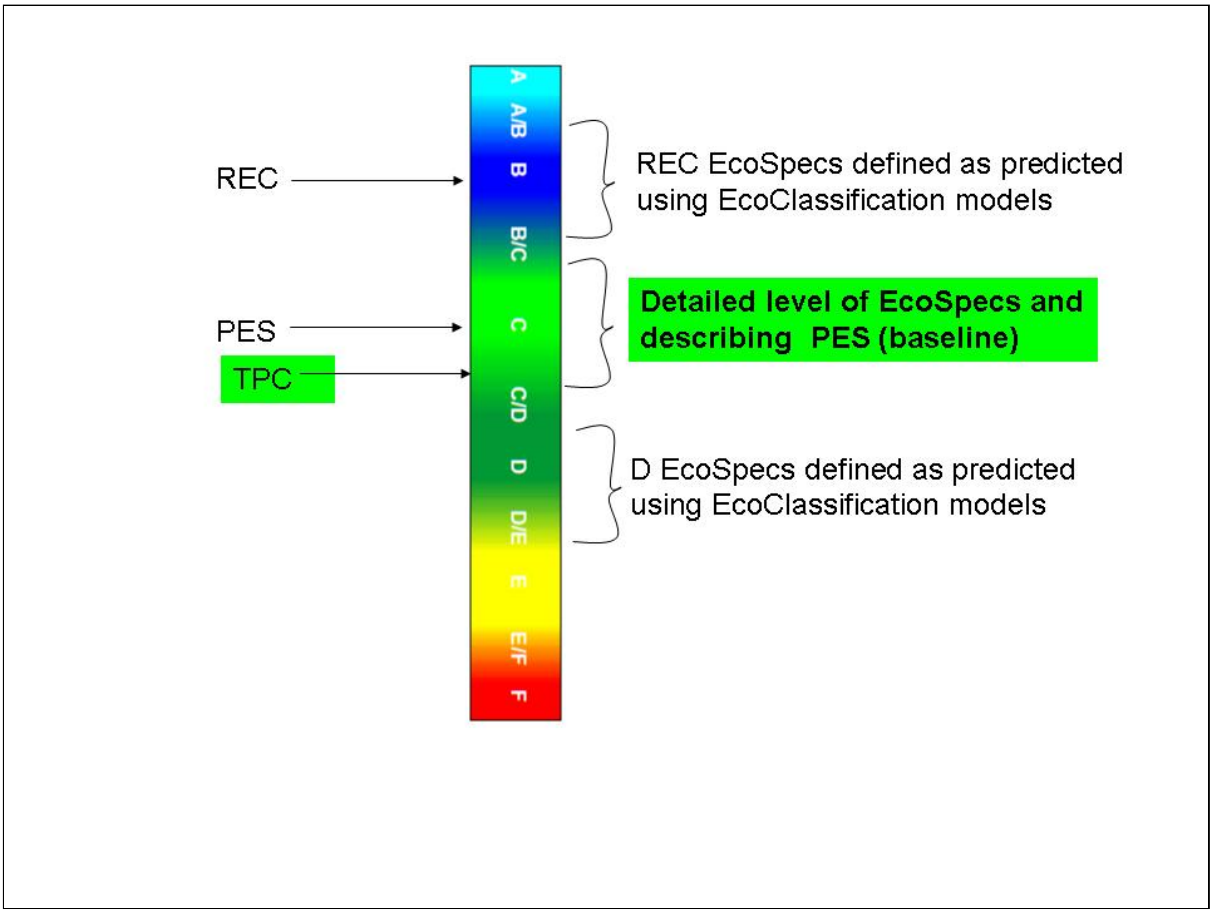

Figure 1.1 Example showing how the relationship between the EcoSpecs, TPCs and ECs

1.5 ISSUES AND CONSTRAINTS

- This study is the first EFR study on the Orange River (specifically lower) that is based on comprehensive field data.
- As such, no EFR has been implemented.
- No regular monitoring in terms of EWRM or the RHP has been undertaken.
- No Rapid Habitat Assessment Monitoring (RHAM) has been undertaken for the Orange River as it was not part of the ToR.
- In summary, no proper EWRM programme has been implemented on the Orange River, or for that case, anywhere in the catchment countries.
- No EWRM DSS exists as a framework within which EcoSpecs and TPCs can be set for the Orange River.
- Monitoring activities have previously been initiated without an integrated structure. This includes a current ORASECOM monitoring project to conduct a baseline biomonitoring exercise, which includes specialists from the EFR study. The biomonitoring exercise will focus only on data collection, while the EFR study will provide EcoSpec and TPC data. These data can then be evaluated within an EWRM DSS and used for decision-making regarding the operation of the system.

2 METHODOLOGY

This section describes the methods and data that were used to identify metrics and TPCs to determine the EcoSpecs and TPCs for the different Reserve components.

2.1 GEOMORPHOLOGY

Authored by MW Rountree

2.1.1 Background to geomorphological monitoring

River monitoring is required to assess the efficacy of the requested flows for the environment. Monitoring should thus be focussed on those descriptors of the system that are sensitive to flow alterations. Instream biota are thus generally the fastest responders to flow conditions, with riparian vegetation and geomorphology indicating longer term trends of flow and floods. Geomorphology thus responds to long term flow patterns and would be slow to react to recently imposed flow changes, so this makes it an excellent indicator of changes in longer term flow patters (such as altered floods) but a poor indicator of intra-annual flow changes.

Monitoring using geomorphology is also constrained at the sites since the geomorphological condition can be affected by both the upstream flow alterations as well as adjacent landuse activities. Thus there may not always be simple cause-effect relationships between geomorphological descriptors and flow conditions, and one should be aware of possible changes to river geomorphology that are not directly flow related. Additionally, antecedent events such as large natural flood events may temporarily create apparently undesirable changes that are not directly related to the provision of EFR flows at a site. Monitoring of the geomorphological conditions must therefore take into account:

- The number and size of recent floods; and
- The impacts of catchment and riparian landuse on the site.

These complexities make the interpretation of geomorphological monitoring data difficult and a somewhat specialist endeavour. However, monitoring of at least the gross morphology of EFR sites is possible with increasing ease through free aerial photographic and high resolution satellite imagery such as is available through Google Earth.

A monitoring framework that takes the above into account has been developed for the Orange EFR sites. Basic monitoring of gross morphology of all sites is recommended since this is a cheap monitoring option that can be used to indicate the impact of floods (generally reduced in this system) and long term flow patterns on gross habitat diversity of the riparian zone. This monitoring only needs to be undertaken at 5 year intervals. For sites that are more sensitive or at risk, more detailed monitoring of the EFR site that includes field-based instream surveys is recommended.

The descriptors selected for monitoring were chosen based on their assumed potential to indicate responses to flow changes. Four categories of descriptors were identified:

- Hydrology.
- Reach-based river planform and morphological features.
- Channel morphology at the site; and
- Low flow season bed sediment composition.

Hydrology is obviously the most basic of the descriptors and should always be monitored to evaluate the delivery of the prescribed EFRs, including the associated floods.

The latter three descriptors represent increasingly fine temporal and spatial scale responders to flow changes. Reach-based planform monitoring (from aerial photographs or Google Earth imagery) is recommended for all sites, with monitoring of the other descriptors only recommended at those sites where the instream habitat conditions are sensitive to flow changes and at risk from further upstream catchment issues and flow changes.

2.1.2 EcoSpecs and sensitivity of the EFR sites

EcoSpecs are intended to provide the quantifiable and enforceable descriptors of geomorphological condition as they pertain to the ecological objectives or Ecological Condition for a river reach or site. In the case of geomorphology there is seldom a record of high resolution, small spatial data for describing the Reference or current (baseline) condition of the site and trends of change; nor high resolution detailed data recording the natural rates and ranges of change.

In South Africa extensive historical aerial photographic analysis for numerous river reach types has documented their respective rates and ranges of change (c.f. Parsons *et al*., 2006; Rountree *et al*., 2004; Rountree *et al*., 2001, and numerous EFR studies). This information has been used to guide the estimates for the metrics.

At each EFR site therefore there is usually a broad conceptual understanding of the Reference condition morphology and likely rates and ranges of changes of that state derived from:

- Expert knowledge of the area;
- The historical aerial photographic record of the site and
- The reach (channel) type sensitivity to change.

Thus ***EcoSpecs for geomorphology***, described below for each of the EFR sites, ***tend to be based on expert assumptions of the likely acceptable range of change for a variety of metrics*** for a specific site.

However the large spatial and long-term temporal scale of this understanding is largely mismatched with the relatively short-term, small site specific scale of monitoring for EcoSpecs. Monitoring for geomorphological indicators is therefore usually recommended at much longer intervals (5 to 10 years) than for more rapidly responding instream biota. This is because the geomorphology is responding to longer term flow changes and irregular floods rather than rapidly responding to intra-annual flow conditions and specific frequent flow events as is the case for fish and aquatic invertebrates.

The Orange River and its tributaries can generally be described as supply (sediment) limited systems, in that there is more streampower available to erode than there is sediment available to be moved. The rivers have eroded down to an underlying bedrock base in many places and consequently the morphologies of these rivers are resilient to moderate increases or decreases in overall flow. Notable exceptions are EFR C5 (Upper Caledon) which is a largely alluvial site, and EFR M8 which is a very low energy, alluvial wetland system.

For all other sites however, the rates and ranges of morphological adjustment that can be expected are likely to be relatively small due to the low slopes and resistant (often bedrock-controlled) nature of the bed and banks of the river reaches. In most cases therefore, monitoring of geomorphological condition can be undertaken at relatively long intervals and at fairly large scales to identify trends in the reach planforms.

For sites that are more sensitive or more at risk to rapid changes in morphology, more detailed EcoSpecs and TPCs have been generated for the hydrology, bed material composition and EFR site morphology metrics. These metrics were identified based on metrics that are critical and rapidly responding and which are:

- Relevant for assessing and monitoring the condition of the river geomorphology, and/or represent critical habitats for instream biota; and
- Feasible and cost-effective to collect as part of a monitoring programme.

Hydrology requirements were however covered by the flow EcoSpecs provided as the EFRs for the EFR sites. EcoSpecs and TPCs were set based on a field and desktop assessment of the site visit undertaken during the low flow season in 2010. The 2010 condition thus represents the Baseline Ecological Condition for the sites.

2.2 WATER QUALITY

Authored by P-A Scherman

2.2.1 Approach

Note that the water quality assessment included the use of biotic response data, i.e. diatoms and chlorophyll-a (periphyton and phytoplankton), as well as physico-chemical data. This document also assumes that the monitoring baseline has been set for the sites and that all evaluations are therefore relative to knowledge of the natural state of the catchment.

The approach followed for each site was therefore as follows:

- EcoSpecs, i.e. water quality specifications or objectives for the Recommended Ecological Category (REC) and/or Present Ecological State (PES), were set for physico-chemical parameters and response indicators. Although macroinvertebrate and fish data were evaluated in the water quality assessment, they were not used to set the EC but rather to assess the accuracy of the water quality category.
- Quality EcoSpecs are therefore related to attaining the recommended water quality category of the overall REC, and are presented as the range that each variable should be in to maintain the required category for that variable.
- TPCs were set to monitor deterioration from present state (i.e. the BEC) per variable. TPCs are presented as 95^{th} percentiles, i.e. values not to be exceeded more than 5% of the time, for inorganic salts, physical variables and toxics; and 50^{th} percentiles for nutrients, i.e. Total Inorganic Nitrogen (TIN), Soluble Reactive Phosphorous (SRP) or ortho-phosphate and chlorophyll-a (chl-a). The TPC ranges are defined by the upper boundary of the PES category and 80% thereof for the lower boundary, e.g. if a B category for a PES EcoSpec is < 15 mg/L, the associated TPC would be 12 – 15 mg/L.
- It is recommended that monitoring for salts rely on the EcoSpec and TPC for Electrical Conductivity. Although EcoSpecs and TPCs are also provided for integrated salts, the use of TEACHA to produced integrated salts is recommended only when the TPC for Electrical Conductivity is exceeded. Should the TPC for any integrated salt be exceeded, consult a water quality specialist and check the validity of the EcoSpec and TPC by running TEACHA on the

data used to determine the PES. If necessary, adjust the boundary for the EcoSpec and TPC for the relevant salt.

- Use of diatom data: The following diatom data was received from the diatomologist for the study, Ms Shael Koekemoer – an ecological category for diatoms, the SPI rating, water quality conditions indicated by her results (as shown on the table below), and detailed information regarding the diatom community structure and water quality state it indicates.

Sample	pH	Trophy	Salinity	Oxygen	Nitrogen metabolism	SPI	EC
EFR K7	Alkaliphilous	Eutrophic	Fresh-brackish	Continuously high	Elevated	12.6	C

It should be noted that diatom data provides useful information on pollution events. Data should be interpreted together with long-term water quality data, which incorporates deviation from natural. Note that due to the paucity of diatom data, reference condition data are not normally available.

Note: Percentiles should be calculated within the framework of the current assessment method (DWAF, 2008), i.e. using the PES monitoring point as shown on the table for the relevant EFR site, and the most recent 3 to 5 years of data, equivalent to a minimum of 60 data points. Data used from the DWA gauging weir must be requested from DWA's Water Management System's (WMS) database. Toxics data used for the assessment (Appendix C – Volume 3) should be used to develop a database of information for these variables, as they are generally not monitored by DWA.

NB: Quality EcoSpecs are therefore related to attaining the water quality category of the overall REC or PES, and are presented as the range that each variable should be in to maintain the required category for that variable. The category specified per variable, and the composition of categories for all variables, will depend on the drivers of water quality per site.

2.3 DIATOMS

Authored by S Koekemoer. Method developed by S Koekemoer.

Until recently diatom community analyses have not been included in biomonitoring programmes due to lack of expertise in the identification of these organisms, a lack of standard protocols for sampling and data generation and perceived difficulties in the general use of this group (Taylor, 2004; Bate *et al*., 2002). The Diatom Assessment Protocol (DAP) Toolkit, developed during 2006 consists of a suite of tools necessary for the practical use and application of diatoms in biomonitoring in South Africa.

In 2005, diatoms were successfully used for the first time as one of the biological indicators for the State of the Rivers Report (RHP, 2005) on the Crocodile (West) and Marico catchments due to the above-mentioned research (Taylor *et al*., 2007a; De la Rey *et al*., 2008). European based indices and specifically the Specific Pollution Index (SPI) (Coste in CEMAGREF, 1982) index were applied during the diatom assessments to provide a quantitative numerical reflection of water quality as well as to classify the rivers and streams in a particular water quality class.

IMPORTANT NOTE:

Currently there are no methods developed specifically for deriving EcoSpecs and TPCs for diatoms, although some developmental work has been produced over the past three years. Therefore it is very important to note that the approach and method provided in this document has not been tested and should be viewed as experimental. The methods outlined below are based on the DAP and should be used by an diatomologist with experience in detailed diatom analysis as outlined in Taylor *et al*. (2007b) specifically relating to biomonitoring.

Software used for the determination of EcoSpecs and TPCs as well as generating diatom index scores at the sites was OMNIDIA (Lecointe *et al*., 1993). The OMNIDIA software (Lecointe *et al*., 1993) was developed for the purpose of including and calculating diatom indices in studies relating to water quality. It is the most widely used and preferred data base in South Africa and version 5.3 was used during this study.

2.3.1 Approach

Within the context of this study diatoms should be used as a **WATER QUALITY SCREENING TOOL** to indicate if:

- A particular physico-chemical metric needs further monitoring to assess the cause of the extent of the change.
- Management action is needed.
- The TPC for the particular metric needs recalibration.

For diatoms to function as an effective water quality screening tool the results generated should:

- Provide information on diatoms as an additional response variable to compliment the physico-chemical driver component of the monitoring programme.
- Provide additional information and interpretive results, especially at sites were physico-chemical data availability was poor or of low confidence.
- Give an indication of the current pollution levels at a monitoring site according to the defined water quality class limits of the Specific Pollution sensitivity Index (SPI).

EcoSpecs and TPCs were derived from class values provided in OMNIDIA (Lecointe *et al*., 1993), according to the Van Dam *et al*. (1994) ecological classification which is based on the preferences of 948 freshwater and brackish water diatom species in terms of pH, nitrogen, oxygen, salinity, humidity, saprobity and trophic state. Saprobity rankings were based on Van Dam *et al*. (1994) and Taylor *et al*. (2007c). The physico chemical metrics included in the approach is:

- pH
- Salinity
- Nutrients
- Oxygen
- Organics.

Most of the indices included in OMNIDIA were designed to evaluate at least one of these metrics and there is good information available on the relationship between these metrics and diatom based water quality indices as well as the tolerance limits of diatom species for the different metrics. The selected metrics also provides the necessary information for additional input to the physico-chemical driver component within the monitoring programme (Dr Scherman; *Pers. Comm*.)

The classification of ecological indicators and class ranking based on van Dam *et al*. (1994) is provided in Table 2.1.

Table 2.1 Description of the Ecological Classification and interpretation of the class rankings according to Van Dam et al. (2004)

Metric and rank	Classification of Ecological Indicators: Description			
pH				
1	Acidobiontic	Optimal occurrence at pH <5.5		
2	Acidophilous	Mainly occurring at pH <7		
3	Circumneutral	Mainly occurring at pH values about 7		
4	Alkaliphilous	Mainly occurring at pH >7		
5	Alkalibiontic	Exclusively occurring at pH >7		
6	Indifferent	No apparent optimum		
Salinity				
		Cl- (mg l-1)	Salinity (‰)	Cond. mS/m
1	Fresh	<100	<0.2	<3
2	Fresh-brackish	<500	<0.9	<139
3	Brackish-fresh	500-1000	0.9 - 1.8	139 - 277
4	Brackish	1000-5000	1.8 - 9.0	277 - 1385
Oxygen requirements				
1	Continuously high	~100% saturation		
2	Fairly high	>75% saturation		
3	Moderate	>50% saturation		
4	Low	>30% saturation		
5	Very low	~10% saturation		
Nitrogen uptake mechanism				
1	Nitrogen autotrophic - sensitive	Tolerating very small concentrations of organically bound nitrogen		
2	Nitrogen autotrophic - tolerant	Tolerating elevated concentrations of organically bound nitrogen		
3	Nitrogen heterotrophic - facultative	Needing periodically elevated concentrations of organically bound nitrogen		
4	Nitrogen heterotrophic - obligatory	Needing continuously elevated concentrations of organically bound nitrogen		
Saprobity				
1	Unpolluted to slightly polluted	BOD <2, O_2 deficit <15% (oligosaprobic)		
2	Moderately polluted	BOD <4, O_2 deficit <30% (β-mesosaprobic)		
3	Critical level of pollution	BOD <7 (10), O_2 deficit <50% (β-ά-mesosaprobic)		
3	Strongly polluted	BOD <13, O_2 deficit <75% (ά-mesosaprobic)		
4	Very heavily polluted	BOD <22, O_2 deficit <90% (ά-meso-polysaprobic)		
5	Extremely polluted	BOD >22, O_2 deficit >90% (polysaprobic)		

2.3.2 EcoSpecs and TPCs derived for this study

A summary of the diatom results as well as the physico-chemical EC for the EFR sites are provided below in Table 2.1.

Table 2.2 Diatom and physico-chemical results

EFR site	Site name	River	SPI score	Class	Category	Physico-chemical EC
ORANGE RIVER MAIN STEM						
EFR O1	Hopetown	Orange	15.7	Good quality	B	D
EFR O2	Boegoeberg	Orange	13.4	Good quality	B	C
EFR O3	Augrabies	Orange	13.3	Moderate quality	B/C	C
EFR O4	Vioolsdrift	Orange	11.4	Moderate quality	C	C/D
ORANGE RIVER TRIBUTARIES						
EFR C5	Upper Caledon	Caledon	14.2	Good quality	B	B/C
EFR C6	Lower Caledon	Caledon	19.2	Good quality	B (C)*	C
EFR K7	Lower Kraai	Kraai	12.6	Moderate quality	C	B/C
EFR M8	Molopo wetlands	Molopo	<16.8	Good quality	A/B	B

* See discussion in respective chapter.

Based on the diatom and physico-chemical ECs at the sites, EcoSpecs and TPCs were set for the PES, based on professional judgement and included an analysis of the diatom communities of the different samples taken at the sites as well as sites within the different reaches of the study area. EcoSpecs and TPCs were derived for B and C EC diatom based water quality respectively and is provided in Tables 2.3 and 2.4.

These class ranking values are estimated per physico-chemical metric and reflect the prevailing conditions as determined by the diatom community. General guidelines are provided per site which provides information on specific species which would influence the overall SPI score as well as pollution related events which would lead to an increase in these species. Although there are many species that could lead to a change in community composition and ultimately deteriorated SPI scores, the species included in the guidelines are species that occurred frequently in the samples (2005, 2008 – 2010) and are specifically good indicators of deteriorated water quality conditions.

Table 2.3 EcoSpecs and TPCs for a B EC

Physico-chemical metric	EcoSpecs	Class rank*	TPC
pH	6 - 8 Circumneutral.	3	≥2; ≤4

Salinity	Fresh brackish (100 - 500 µS/cm).	2	<2
Oxygen	Fairly high saturation (<75% saturation)	≤2	≤3
Nutrients	Slightly elevated concentrations of organically bound nitrogen.	1-2	≤2
Organics	β-mesosaprobic: BOD_5 < 4mg/l, O_2 deficit <30%.	2	<2
SPI score	≤13.3 - ≥16.8.	B EC	≥ 13.3

Table 2.4 EcoSpecs and TPCs for a C EC

Physico-chemical metric	EcoSpecs	Class rank*	TPC
pH	6 - 8	3	≥2; ≤4
Salinity	Fresh brackish (100 - 500 µS/cm)	2	<2
Nutrients	Slightly elevated concentrations of organically bound nitrogen.	2-3	≤3
Oxygen	Moderate saturation (<50% saturation)	≤3	≤4
Organics	β-ά-mesosaprobic: BOD_5 < 7 (10) mg/l, O_2 deficit <50% (Critical level of pollution)	3	<3
	ά-mesosaprobic: BOD5 < 13mg/l, O2 deficit <75% (Strongly polluted)		
SPI Score	9.2 – 12.8	C EC	≥ 9

2.4 RIPARIAN VEGETATION

Authored by J Mackenzie. Method developed by J Mackenzie.

2.4.1 Method

The following vegetation components, when assessed together and compared to reference conditions, satisfactorily describe the overall state of any riparian site: exotic invasion, terrestrialisation, general vegetation structure as shown by proportions of riparian woody species, reeds and non-woody species (grasses, sedges and dicotyledonous forbs). Please note EcoSpecs (and hence TPCs) are based on hypotheses and these need to be refined, most likely through a DSS. All components are estimated aerial cover (%) as this facilitates ease and speed of assessments.

2.4.2 Exotic invasion

Ecological specifications were set for the proportion of exotic species invading the riparian zone (Table 2.5). Values were tested by assessing a number of existing sites where exotic aerial cover data were available. Values of perennial exotic species aerial cover (%) in Table 2.5 were used to assess all sites on the Orange, Caledon, Kraai and Molopo since the reference percentage cover of exotics is not expected to change for different sites or different systems and is therefore robust enough to transfer across sites.

Table 2.5 Hypothesis on which EcoSpecs for exotic perennial species occurrence in the riparian zone is based

Ecological Class	% Aerial Cover (Perennial Exotics)
A	0
A/B	1 - 5
B	5 - 10
B/C	10 - 15
C	15 - 20
C/D	20 - 30
D	30 - 50
D/E	50 - 60
E	60 - 70
E/F	70 - 80
F	> 80

2.4.3 Terrestrialisation

The occurrence of terrestrial species in the riparian zone is based on the phenomenon that terrestrial species occur naturally in the riparian zone (to greater or lesser degrees depending on vegetation biomes), but are reduced in cover and abundance by increased flooding disturbance. Because the focus is on woody terrestrial species and the sites occur in Nama-karoo, Desert or Grassland biomes, expected cover is low since the upland species pool able to contribute is sparse, succulent, grass or scrub. Table 2.6 outlines an hypothesis for EcoSpecs for the occurrence of terrestrial woody species in the riparian.

Table 2.6 Hypothesis for EcoSpecs concerning terrestrialisation of the riparian zone

Ecological Class	Marginal Zone	Lower Zone	Upper Zone
A	0	0	0 - 5
A/B	0	0	5 - 10
B	0	0	10 - 15
B/C	0	1 - 5	15 - 20
C	0	5 - 10	20 - 30
C/D	0	10 - 15	30 - 40
D	1 - 5	15 - 20	40 - 50
D/E	5 - 10	20 - 30	50 - 60
E	10 - 15	30 - 40	60 - 70
E/F	15 - 20	40 – 50	70 - 80
F	> 20	> 50	> 80

2.4.4 Indigenous riparian woody cover

The proportion of woody riparian species in the riparian zone is not as easily transferrable to different sites and rivers as is exotic and terrestrial vegetation. The sites that have been selected in the Orange catchment fall into different biomes: Grasslands (EFR C5, C6, K7, M8), Nama-Karoo (EFR O2 and O3), Desert (EFR O4), and some occur close to the Ecotone between Savanna and Nama-Karoo (EFR O1). Sites EFR O1, O2, O3 and O4 however, occur in azonal vegetation units (Lower and Upper Gariep Alluvial Vegetation), which can be treated similarly in terms of expected proportions of riparian woody cover. The hypothesis for sites in Lower and Upper Gariep Alluvial vegetation is based on the occurrence of riparian woody dominant species characteristic of these vegetation units, and on a dynamic whereby riparian vegetation will always tend towards increased woody cover with diminishing non-woody cover (including reeds), this being "reset" by large flood events. "Reset" here refers to the removal of woody plants by floods, the resulting open space being available for quick colonising non-woody species (including reeds). The hypothesis assumes that if woody cover increases beyond a given value and remains high, that the flooding regime has been changed so that large floods are smaller or less frequent. Because flooding frequency and disturbance decreases up the bank, the expected cover of riparian woody species will increase. Tables 2.7 and 2.8 outlines a basic expected pattern of riparian woody cover, but is general in nature and has been changed slightly where necessary to more realistically reflect site characteristics when setting EcoSpecs and TPCs for each site (see EcoSpec and TPC detail below).

Table 2.7 General Hypothesis for EcoSpecs concerning indigenous riparian woody cover (% aerial cover) for sites in Upper or Lower Gariep Alluvial Vegetation

Class	Marginal Zone		Lower Zone		Upper Zone		MCB[1]	
A	10-30		10-20		30-50		70-80	
A/B		30-40		20-40	20-30	50-60	60-70	80-90
B	5-10	40-60	5-10	40-50	10-20	60-70	40-60	>90
B/C		60-70				70-80	20-40	
C	1-5	70-80	<5	50-60	5-10	80-90	10-20	
C/D							<10	
D	0	>80		60-70	<5	>90		
D/E								
E				70-80				
E/F								
F				>80				

[1] Macro Channel Bank

Table 2.8 Hypotheses for EcoSpecs concerning indigenous riparian woody cover (% aerial cover) for sites in the Grassland Biome (such as EFR C5)

Class	Marginal Zone		Lower Zone		Upper Zone		MCB	
A	10-20		10-20		<5		0	
A/B	5-10		5-10					
B		20-30		20-30		5-10		1-10
B/C	1-5		1-5					
C	0	30-40	0	30-40		10-25		10-20

Class	Marginal Zone		Lower Zone		Upper Zone		MCB	
C/D								
D		>40		>40		25-60		20-50
D/E								
E						>60		>50
E/F								
F								

2.4.5 Phragmites (Reeds) cover

For sites occurring in Lower or Upper Gariep Alluvial Vegetation (EFR O1 to 4), this hypothesis is based on the expectation that reeds should always be components of marginal and lower zone vegetation (Table 2.9), that their unchecked increase in aerial cover is a change away from reference, and that their occurrence in the upper zone should be low. The hypothesis assumes that reeds will colonise open alluvium (similar to the pioneer species concept) created by floods, and will increase in cover until slowly replaced by woody vegetation as shading occurs. A natural flow regime will create a patch mosaic of woody vs. reeded areas, thus a mix is always expected (in the absence of very infrequent extreme events): an increase in reed cover beyond a specified value is seen to be a loss of riverine diversity and as such will begin to reduce the EC. For sites that occur in the Grassland Biome (such as EFR C5), reeds are frequently not expected, even though they may be found.

Table 2.9 Hypotheses for EcoSpecs concerning Phragmites (Reed) cover (% aerial cover) for sites in Upper or Lower Gariep Alluvial Vegetation

Class	Marginal Zone		Lower Zone		Upper Zone	
A	10-20		10-20		<5	
A/B		20-30		20-30		
B	<10	30-40	<10	30-40		5-10
B/C						
C		40-50		40-50		10-20
C/D						
D		50-60		50-60		20-30
D/E						
E		60-80		60-80		30-40
E/F						
F		>80		>80		>40

2.5 FISH

Authored: P Kotze and A Deacon

EcoSpec and TPC results are provided in an MS Excel format (Fish EcoSpec & TPCs) for the relevant site, which includes methodology and supporting data and information for future reference, especially during application of TPCs after monitoring. This data will be provided electronically.

The approach for determining EcoSpecs and TPCs and the use of the electronic spreadsheet (Fish EcoSpec & TPC) are described in sheet 1 of the Excel spreadsheet in a step-wise manner. These steps are listed below (Bold typeface) and further explained below.

Step 1: Populate spreadsheet with relevant data: Import information from FRAI model (PES and REC) into relevant sheets (sheet 5 to 10) and follow the instructions at the top of each spreadsheet.

Step 2: Selection of indicator taxa for different metrics (worksheet 2-EcoSpecs&TPCs): Select indicator taxa for each metric (in worksheet 2-EcoSpecs&TPCs, column C) using sheets 7 to 10 and referring to sheet 5 to determine whether a species was sampled at the relevant EFR site (only use species known to occur at the site for the purpose of site-specific EcoSpecs and TPCs). Use one or two of the highest ranked species (present at site) and list them in Column C (2-EcosSpecs&TPCs worksheet).

The selection of indicator taxa for each metric is done using the 'monitoring indicator' sheet in the Fish Response Assessment Index (FRAI) model for each EFR site/reach. This sheet calculates an indicator value per species for different variables (such as fast shallow habitats, cover type, etc.) based on the reference Frequency Of Occurrence (FROC) and relative intolerance rating of the species. Based on the indicator value determined by the model, species are ranked (manually for each metric/variable) in order of importance to serve as indicator for a specific variable. The two highest ranked species that are known to occur at the EFR site was generally used as the indicator taxa for the specific metric. If there were uncertainty about the presence of an optimal indicator species (ranked 1 and 2) at a site, or if the species occurred in too low abundance and sampling may therefore be coincidental, these species were excluded and replaced by lower ranked indicator taxa at the site. The two highest ranked indicator species for each metric was used as indicators for reach (automated in Excel spreadsheet) by default. This should be edited should a species expected under natural conditions is thought to not be present in the reach under present conditions.

Step 3: Describing EcoSpecs and setting TPCs in sheet 2-EcoSpecs&TPCs: Describe PES EcoSpecs and TPCs for each metric per site and reach (columns D,E,F & I), and EcoSpec for the REC (reach only) (column J). This should be done using the spatial and temporal1 FROC as well as relative abundance information in the worksheet labeled 5-FROC.

Site versus reach EcoSpec assessment

Fish EcoSpecs and TPCs are described for each fish metric, differentiating between reach and EFR site where applicable. This was done due to the fact that the PES is determined for an entire reach within which the EFR site falls, while fish sampling is however often conducted only at the EFR site, and therefore merits site-specific EcoSpecs and TPCs. EcoSpecs were therefore described for the site to reflect the PES (baseline), while broad EcoSpecs were also given for the reach should detailed monitoring be performed where more than one site is sampled in the reach. EcoSpecs were also described for the reach in terms of the REC (if different from PES), providing a broad description of the expected change in FROC of selected species that would result in the attainment of (improvement towards) the REC.

[1] Spatial FROC: presence of fish species at different sites within a reach or in different units/areas at a site (as used in FRAI).
Temporal FROC: Presence of species over time at a specific site (such as EFR site).
Relative abundance/Catch per Unit Effort (CPUE): Calculated only for electro-fishing in number of individuals/minute (can be done for per site and per species) (if available for many surveys, use lowest observed CPUE to set TPCs).

Once site-specific EcoSpecs were described, TPCs were then derived for each of the selected metrics for the EFR site, giving measurable biotic TPCs for fish as well as conceptual habitat TPC. The biotic (fish) TPCs described for the site should enable the detection of deterioration at the site that may result in a deterioration of the PES towards a lower category (deterioration). The EcoSpecs described for the reach should provide an indication of conditions when the PES is reaching the REC.

Spatial and temporal FROC of species, as well as their relative abundance (catch per unit effort) were used as units for the different variables or metrics. The calculation of the FROC and relative abundance is based on the results gained during the baseline (generally EFR) surveys, and sometimes also on other available data (important to note that EcoSpecs and TPCs should reflect the PES) and therefore historic data should be used with care in cases where changes could have occurred since the surveys were conducted. The use of data from other sites in a reach must also be applied with circumspection as it may not reflect the species composition and relative abundances of the specific EFR site. It is imperative to note that the recommended values given as TPCs should be tested and refined over time as more information becomes available. This is however the best available information at present and should serve as a good starting point.

Step 4: Ranking metrics: Based on metric group weight (Sheet 6), professional judgment and considering the probability that the metric will indicate deterioration, rank metrics in sheet "EcoSpecs & TPCs" in order of the most sensitive metric expected to detect change (rated 1) to less sensitive to detect change.

Various metrics were selected that would allow the use of fish to determine changes, specifically deterioration in biotic integrity of the aquatic ecosystem. A metric is a measurable component of biological systems, which show an empirical change in value along a gradient of human disturbance (USEPA, 1998). By default, various relevant metrics used in the FRAI model (such as FS habitats, overhanging vegetation, etc.) were selected.

The different metrics were then ranked, based on FRAI metric group weighting, relative intolerance or sensitivity of the species and professional judgment, as an indication of the expected sensitivity (value) of the metric to detect change. All metrics should be used when monitoring a system, as different indicator species may detect different impacts or changes. The purpose of the ranking of metrics is to provide a rough estimate of metrics most probable (most sensitive) to detect deterioration (species being generally intolerant to changes in their environment should theoretically react earlier to changes/deterioration than more tolerant species, although a more tolerant species will react to a specific impact that may not be detected by more intolerant species). Therefore, aalthough different indicator species may indicate different changes, the ranking aims to highlight which metrics is most likely to be the early indicators of change at the site/reach.

Step 5: Complete sheet 3 - Monitoring requirements

Recommendations were also made regarding monitoring requirements taking into consideration the Ecological Importance and Sensitivity metric - rare and endangered and unique fish species at the site. The monitoring recommendations included aspects such as frequency of monitoring, optimal sampling season, location (where and which habitats to focus on) as well as sampling techniques (including recommended effort that should be applied). The monitoring recommendation should also be verified and adapted over time once more information becomes available. It is of critical importance that the follow-up monitoring should be conducted during the same season as when baseline surveys were conducted, or TPCs should be refined for the specific season of the monitoring. The closer the flow (discharge) between monitoring and baseline survey, the more comparable the results and the more likely changes can be detected (it will exclude natural seasonal and habitat differences at the site, which is coupled with natural variation in fish diversity and abundance at the site).

When a TPC for a certain metric is reached, it must first be established whether that specific habitat type (such as SD, water column, overhanging vegetation) has been sampled adequately, to exclude the possibility that the TPC was reached as a result of lack of sampling effort. This would therefore mean that sampling should be done when conditions are optimal. Indicator species can be identified before the actual survey at a site and sampling can then be aimed at specific habitats using the most appropriate sampling method that would give the highest probability of the indicator species being sampled if present. The most preferred sampling method for monitoring purposes is electro-fishing, as this method is very effective in especially flow sensitive habitats (Fast Shallow (FS)) as well as other shallow marginal habitats (such as undercut banks and overhanging vegetation). This method may also be the most reliable of all methods to calculate relative abundance of a species (CPUE). For the purpose of setting EcoSpecs and TPCs during this study, relative abundance was only determined using electro-fishing data and it was expressed as individuals per minute. Electro-fishing however does not have to be the only sampling method applied during the monitoring phase, as sampling methods should be determined by the indicator species, habitat composition, human resources and time availability.

Unfortunately due to factors such as cost efficiency, safety at site (presence of crocodiles and hippos) a range of sampling methods can sometimes not be applied. Under such circumstances, the TPCs should be evaluated with caution, considering only those metrics that reflect habitats and species that could be sampled efficiently.

2.6 MACROINVERTEBRATES

Authored: R Palmer

The approach used in this report to define EcoSpecs and TPCs for macroinvertebrates was to define simple rules that could be applied consistently at all sites, and to select metrics based on information that can be readily derived from standard invertebrate biomonitoring data. The EcoSpecs and TPCs recommended here may need to be modified as more biomonitoring data becomes available. Four components were considered, namely 1) SASS scores, 2) MIRAI, 3) Indicator Taxa and 4) Overall Compliance.

- ***SASS Scores***. A hypothetical list of taxa expected to occur under natural conditions was compiled for each EFR site. The list was based on professional judgement and available biomonitoring data for the area. Invertebrate taxa expected to occur at each site with more than 80% probability under natural conditions were used to generate a likely minimum SASS Total Score and ASPT for natural conditions (Category A). These scores were then used to generate likely site-specific scores for the remaining five categories (B to E), based on the percentage deviation from natural, as indicated in the table below. The likely scores were used as default values for defining ecological categories, based on SASS Total Scores and ASPT. The TPCs for SASS5 Total Scores were set 5% higher than the lower boundary of the relevant

PES band, while the TPCs for ASPT were set 2% higher than the lowest boundary of the relevant band.

- ***MIRAI.*** The standard MIRAI system was used to generate PES bands, as indicted in the table below. The TPCs were set 5% higher than the lower boundary of the relevant PES band.

Category	Description	SASS Score (% Total)	ASPT (% Total)	MIRAI Score (%)
A	Natural.	>90	>95	>90
B	Largely Natural.	80-89	90-95	80-89
C	Moderately Modified.	60-79	85-89	60-79
D	Largely Modified.	40-59	80-84	40-59
E	Seriously Modified.	20-39	75-79	20-39
F	Critically Modified.	<20	<75	<20

- ***Indicator Taxa.*** Invertebrate taxa that have been recorded as common or abundant at, or near, each EFR site, and which are sensitive to changes in flow and/or deterioration in water quality, were considered as potential indicators. The selection of indicator taxa was based on recent biomonitoring data collected at or nearby each EFR site. Nearby sites were usually located within the same quaternary catchment as the EFR site. The list was reduced to a six taxa, based on their sensitivity to water quality deterioration.

- Tricorythid mayflies were identified as suitable indicator taxa because they are sensitive to flow and water quality deterioration. However, the abundance of these mayflies is usually low during winter, so surveys conducted during winter that fail to record them should not trigger TPCs. This applies to most sites, but not to the lower Orange at EFR O4, where winter water temperature is expected to be high enough for larval numbers not to drop significantly.

The following criteria were used to define TPCs for indicator taxa:

- any one indicator taxon absent for two or more consecutive surveys, except for very common taxa, such as Baetidae and Hydropsychidae, which are expected to always be present, and;
- more than 50% of the indicator taxa absent on any one survey (i.e. three or more out of six).

- ***Overall TPC Compliance.*** Ten EcoSpecs were selected as suitable monitoring indicators at each site, each with specific TPCs, as explained above. A 70% compliance to the specific TPCs on any one survey was considered acceptable, so the overall TPC for the site should be triggered only when three or more specific TPCs are non-compliant. Full compliance with all ten TPCs on any one monitoring survey is unlikely because of natural variability of river systems

The most useful sources of information for this report were the following:

- Data collected during the EFR site visits; April to June 2010.
- Data extracted from the National River Health Database (DWA 2010).
- Relevant biomonitoring reports.
-

2.7 RIVERINE FAUNA: ECOLOGICAL WATER RESOURCES MONITORING: AUGRABIES FALLS AND RICHTERSVELD NATIONAL PARKS

Authored: A Deacon

The conservation ethic is reflected as follows in the vision for Augrabies: “Augrabies Falls National Park seeks to conserve the unique landscape, features (cultural, biological and scenic) and the biodiversity characteristic of the Gariep centre with its associated processes as part of the regional landscape, for the appreciation and benefit of present and future generations”.

No previous detailed surveys on the riverine faunal were conducted in the two National Parks, a tested EcoSpecs could not be developed during the workshop. This section will strive to establish a prototype that will be tested as a monitoring project in the different parks by the SANParks researchers.

At the same time, TPCs will be developed for the proposed monitoring programme. TPCs indicate the values around the EcoSpecs that, if being approached would initiate more detailed investigation or even management action. In the context of EWRM, TPCs are regarded as early warning indicators of potential change from a particular EC to another (lower) EC.

During the Orange River Environmental Flow Requirement workshop, the following Present Ecological State (discussed in Section 2.8.1 – 2.8.4) was defined for the Riverine Fauna at the EFR O3 - Augrabies site. This PES is depending strongly on the status of the Riparian Vegetation as a driver of habitat and the Fish integrity as a supportive system (food):

2.7.1 Habitat present

Cobble beaches, grazing lawns, backwaters, intact riparian zone, reed beds and some mud flats are present. Shallow backwater habitats consisting of overhanging and emergent vegetation, inhabited with fish as a food source are also present. A riparian band in the area is annually inundated by high floods which forms a very important migration corridor for most of the riverine faunal species present in the area.

2.7.2 Aquatic and semi-aquatic species

Flow alteration impacts on the food source (abundance of fish) of piscivorous species while lower flows eliminate associated deep pool habitat (overhanging vegetation for kingfishers; emerging vegetation for warblers, weavers and moorhen) and slower backwater habitats (ducks, coots, storks).

2.7.3 Marginal habitat species

Flow alteration (decreased flooding regime) has resulted in reduced mudflat and alluvial sandbar habitat as a result of the marginal zone being vegetated with reeds and hygrophilous shrubs leading to a decrease in waders (sandpipers, plovers) and open habitat animals (plovers, geese) while species that use sand bars and sandbanks lose digging substrate (monitors, bee-eaters, martins).

2.7.4 Riparian species

The riparian vegetation habitats on the upper zones have not changed much, as most of the divers structured riparian are still intact and provides refuge, shelter, breeding and feeding habitats, and a migration route. Some trampling and grazing will affect shelter for smaller species (shrews, frogs).

The floodplain habitat (alluvial floodplain channels and associated vegetation) includes the upper and lower riparian zone.

Reasoning for the fish and riparian vegetation PES were used to derive the main impacts on the riverine fauna which is provided in Table 2.10.

Table 2.10 PES causes and sources – Riparian fauna

Causes	Sources
Changing inundation levels leads to deteriorated marginal habitats as marginal zones are invaded by reeds and shrubs; reducing open shore habitats (mudflat and alluvial sandbanks) which serve as habitat for waders.	Loss of frequency and magnitude of larger floods. Loss of zero flows which did occur naturally.
Reduced abundance in piscivorous species - Reduction in fish abundance (due to reduction of habitat) as a food base for piscivorous species.	Substantial decreased floods from Natural and somewhat elevated low flows than Natural. Unnatural changes in flows due to periodic releases and stream regulation by dams has a lag effect on seasonality. Small and medium floods are heavily impacted due to large dams.

In order to identify metrics and TPCs to determine the EcoSpecs and TPCs for the different Reserve components, the following steps were taken:

Step 1: Species lists (see 5.6.1 – 5.6.3) of potential riverine fauna in the study area are compiled using Species Atlases, museum records and distribution maps.

Step 2: All expected riverine faunal species are then grouped according to the following broad habitat assemblages for either breeding or feeding, or both:

- Aquatic and semi-aquatic species – Dependant on instream associated aquatic habitats
- Muddy and alluvial edges of wetlands, shallow wadeable edges - dependant on marginal habitats
- Riparian species - Dependant on habitats provided in the upper zones, especially woody vegetation

Step 3: Finer detailed aspects of breeding- and feeding habitat are then compiled as set out below and each animal is positioned according to these parameters:

Feeding habitat	Breeding habitat
Habitat with fish	High trees in water
River backwater	High trees in riparian
Pools/slow flow	Reed beds

Feeding habitat	Breeding habitat
Rapids, riffles, fast flows	Islands
Shallow marginal habitat emergent	Over-hanging trees
Sand bars	Sand bars
Open shores	Open shores
Reed beds	Vertical sand banks
	Cliff / Outcrop
	Grass or sedges
	Hole in ground
	Floating vegetation
	Terrestrial shrubs
	Terrestrial trees

Step 4: **The PES results** generated during the EFR process, and the habitats listed in Step 3 (above), are rated based on the probability of being affected by the current trend (causes and sources), where ratings range from “most probable of being affected” to “least probable of being affected”. The habitat “Most probable of being affected” according to the “PES priority rating” will carry the most weight in determining the indicator animal species.

Step 5: The next step is to evaluate the importance of the animal as an indicator species. This is done by linking a “sensitivity value” to an “abundance value” to derive a score indicating the potential of the species that is the best indicator species. The “sensitivity value” and “abundance value” are based on the following criteria:

Sensitivity value	Abundance value
The tolerance level of fauna to changes:	The abundance level of a species:
5 = Very sensitive 3 = Sensitive 1 = Tolerant	5 = Common 3 = Less common 1 = Rare

Thus: “Sensitivity value” + “Abundance value” = “Indicator value” (importance as an indicator - score between 1 and 25). In the event of a number of species receiving equal scores, the “Sensitivity value” will be the overriding factor.

Step 6: For each of the habitat assemblages (see Step 2), all the expected species are ranked according to their indicator value and the five highest ranked species are then used as indicator species per habitat assemblage in the monitoring processes. Should there be a number of species with equal scores, the fauna utilizing habitats mentioned in Step 4, will carry more weight (in order of the habitat ranking) in determining the indicator species.

Step 7: Seven to ten species per habitat assemblages should be attempted. The scope of species should be maximised by ensuring a wide spread over different sub-categories of habitat and animal groups (e.g.: 6 bird spp., 2 mammal spp and 2 herpetofaunal spp.). Migratory species are sub-optimal.

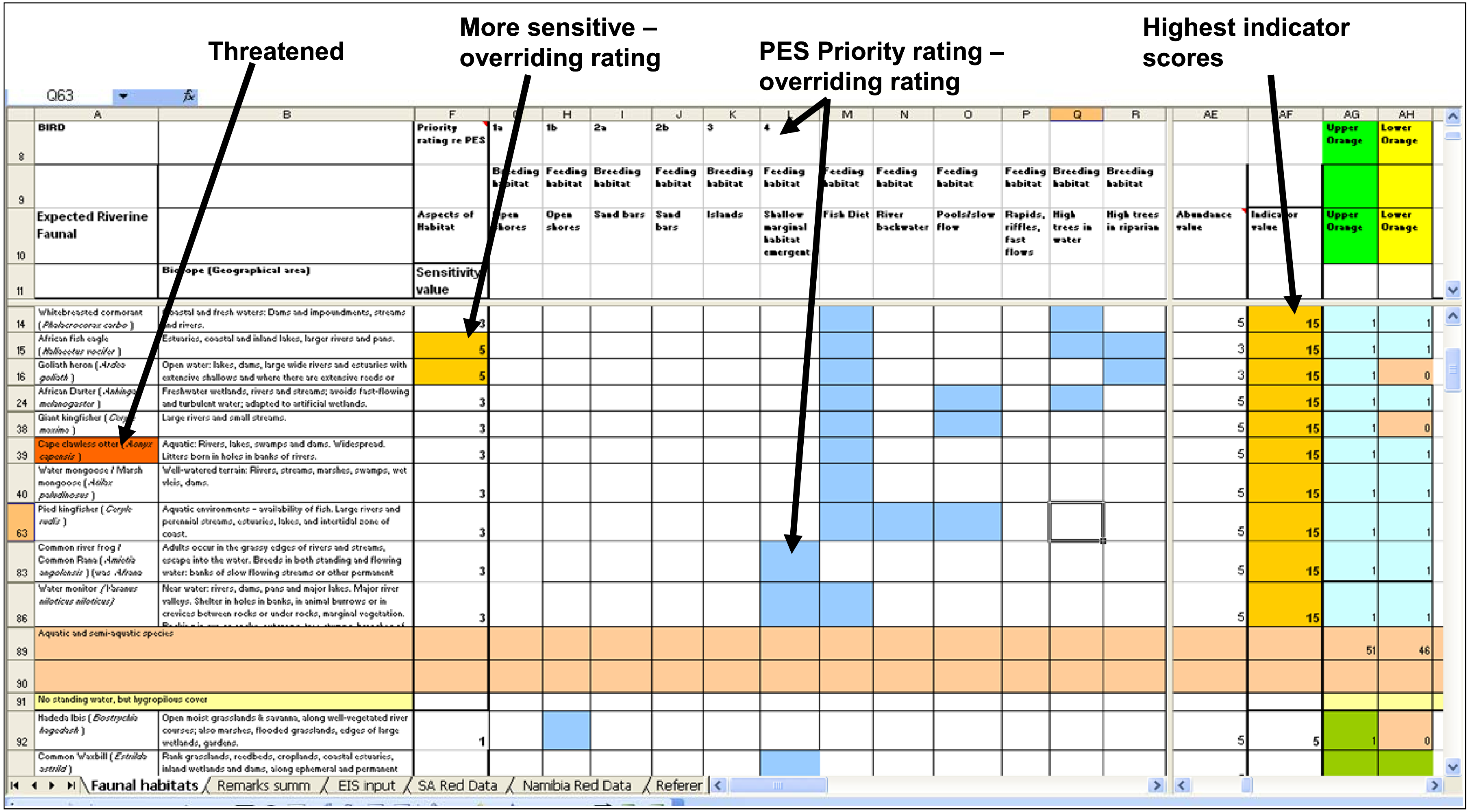

Figure 2.1 Data input and rating sheet

Table 2.11 EcoSpecs and TPCs relating to Riverine Fauna data (Unknown = will be established with the baseline survey)

Metric	Indicator spp.	Monitoring REACH		
		ECOSPECS	**TPC (Biotic)**	**TPC (Habitat – feeding and breeding)**
Species richness.	All indigenous species.	*Unknown* expected indigenous animal species to be observed (as per monitoring baseline survey).	Less than *Unknown* species observed during a survey when habitat can be surveyed efficiently.	Fish TPC regarding "Relative abundance" reached and/or any of the Vegetation cover TPCs reached.
Relative abundance.	All indigenous species.	Number of riverine animals observed during baseline survey.	Relative abundance of less than *Unknown* individual per hectare observed in the reach (during same season as baseline data) when habitat can be surveyed efficiently using the same methods.	Fish TPC regarding "Relative abundance" reached and/or any of the Vegetation cover TPCs reached.
Alien animal species.	Any alien/introduced spp.	*Unknown* number of alien species.	Increase in the number of alien species (> *Unknown* species during any survey) **OR** increased relative abundance of *Unknown* species.	N/A
Aquatic and semi-aquatic species – Dependant on instream associated aquatic habitats	Group 1 (See Table 5.6.1)	The Group 1 assemblage observed *Unknown*% of the time per species during the surveys (or signs of them) at a relative abundance per species of > *Unknown* individual/survey.	The Group 1 assemblage present less than *Unknown*% of time (not observed during any survey) **AND/OR** decrease in relative abundance per species of < *Unknown* individual/survey.	Reduced abundance in fish stock for piscivorous species (relate to fish TPC) and/or the reduction in shallow marginal habitat due to reed and shrub encroachment (relate to vegetation TPC).
Muddy and alluvial edges of wetlands, shallow wadeable edges - Dependant on marginal habitats	Group 2 (See Table 5.6.2)	The Group 2 assemblage observed *Unknown*% of the time per species during the surveys (or signs of them) at a relative abundance per species of > *Unknown* individual/survey.	The Group 2 assemblage present less than *Unknown*% of time (not observed during any survey) **AND/OR** decrease in relative abundance per species of < *Unknown* individual/survey.	The reduction in marginal habitat and lower zone due to reed and shrub encroachment (relate to vegetation TPC).
Riparian species - Dependant on habitats provided in the upper zones, especially woody vegetation	Group 3 (See Table 5.6.3)	The Group 3 assemblage observed *Unknown*% of the time per species during the surveys (or signs of them) at a relative abundance per species of > *Unknown* individual/survey.	The Group 3 assemblage present less than *Unknown*% of time (not observed during any survey) **AND/OR** decrease in relative abundance per species of < *Unknown* individual/survey.	The change in riparian structure due to invading *Prosopis;* over-utilization due to trampling and browsing of large herbivores; desiccation due to lowered base flows.

3 EFR O1 – HOPETOWN (ORANGE RIVER)

A summary of the site EcoClassification results are provided below (Volume 1: EFR).

3.1 ECOCLASSIFICATION SUMMARY OF EFRO1

EFR 01 (HOPETOWN)

EIS: MODERATE

The highest scoring metrics are instream and riparian rare and endangered biota, unique riparian biota, instream biota intolerant to flow changes, taxon richness of riparian biota, critical riparian habitat and refugia and riparian migration corridor.

PES: C

The major issues that have caused the change from reference conditions are the releases for hydropower, barrier effects of the dams, water quality problems and the destruction of and removal of vegetation on floodplains for agriculture. The dominant factor seems to be the hydro-electric releases.

Driver Components	PES	TREND
IHI HYDROLOGY	E	
WATER QUALITY	D	
GEOMORPHOLOGY	C/D	-
INSTREAM IHI	D/E	
RIPARIAN IHI	C	
Response Components	**PES**	**TREND**
FISH	C/D	0
MACRO INVERTEBRATES	C	0
INSTREAM	C	0
RIPARIAN VEGETATION	B/C	0
RIVERINE FAUNA	C	0
ECOSTATUS	C	0
EIS	MODERATE	

EcoSpecs and TPCs for EFR O1 are provided for the different components in Section 3.2 to 3.7

3.2 GEOMORPHOLOGY

3.2.1 Site Description and focus of TPCs

This is a braided reach of the river, with well-vegetated islands between the distributary channels, and large riffle areas in the active channels. Present Day MAR is about half of the virgin MAR and overall flood sizes and frequencies are highly reduced relative to natural conditions. This has caused an increase in the area of bars and islands and the progressive stabilisation of the sedimentary features by vegetation. Scouring events across these bars are too infrequent and small to keep sedimentary and vegetation encroachment in check. To maintain the PES, the growth and stabilisation of bars would need to be kept in check.

3.2.2 EcoSpecs and TPCs relating to GAI monitoring data

Descriptor	Motivation for Monitoring
Reach morphology: Area of in-channel bars and islands	At this site, under Reference Condition fewer bars and islands existed, and these were more mobile than the present condition. To maintain the PES, no further expansion of bars and islands in the reach should occur. The presence of bars indicates the reduced mobilisation of the river bed and banks, and increasingly vegetated state reduces opportunities for species requiring high flood disturbance frequencies (refer to Appendix E – Volume 3).

Descriptor	Motivation for Monitoring	
	TPC:	Any increase in the area of alluvial bars in the reach relative to the 2010 level.
	Approach:	Aerial photographic or Google Earth imagery analysis of the site.
	Frequency:	Every 5 years

3.3 WATER QUALITY

3.3.1 EcoSpecs relating to water quality

River: Orange		EFR O1, Hopetown
Water quality metrics		**EcoSpecs: PES**
Inorganic salts*	$MgSO_4$	The 95th percentile of the data must be ≤ 16 mg/L.
	Na_2SO_4	The 95th percentile of the data must be ≤ 20 mg/L.
	$MgCl_2$	The 95th percentile of the data must be ≤ 15 mg/L.
	$CaCl_2$	The 95th percentile of the data must be ≤ 21 mg/L.
	NaCl	The 95th percentile of the data must be ≤ 45 mg/L.
	$CaSO_4$	The 95th percentile of the data must be ≤ 351 mg/L.
Physical variables	EC	The 95th percentile of the data must be ≤ 30 mS/m.
	pH	The 5th percentile of the data must range from 6.5 to 8.0, and the 95th percentile from 8.0 to 8.8
	Temperature	Serious changes to temperature regime occur most of the time, with fluctuations of more than 4°C.
	Dissolved oxygen	The 5th percentile of the data must be ≥ 4 mg/L. Large fluctuations in oxygen levels are evident.
	Turbidity	Vary by a small amount from the natural turbidity range; minor silting of instream habitats acceptable.
Nutrients	TIN	The 50th percentile of the data must be ≤ 0.7 mg/L
	PO_4 – P	The 50th percentile of the data must be ≤ 0.025 mg/L.
Response variables	Chl – a phytoplankton	The 50th percentile of the data must be ≤ 20 mg/L.
	Chl - a periphyton	The 50th percentile of the data must be ≤ 21 mg/m^2.
	Toxics	The 95th percentile of the data must be within the Chronic Effects Value (CEV) as stated in DWAF (1996) #

* To be generated using TEACHA when the TPC for EC is exceeded or salt pollution is expected.

#: Although category boundaries exist in the Water quality Reserve manual (DWAF, 2008) for a number of toxicants, adherence to the CEV (DWAF, 1996) is recommended for the present state. Data collection and testing will need to be undertaken to assess the suitability of these objectives.

3.3.2 TPCs relating to water quality data

River: Orange		EFR O1, Hopetown
Water quality metrics		TPCs
Inorganic salts*	$MgSO_4$	The 95th percentile of the data is 13 – 16 mg/L.
	Na_2SO_4	The 95th percentile of the data is 16 – 20 mg/L.
	$MgCl_2$	The 95th percentile of the data is 12 – 15 mg/L.
	$CaCl_2$	The 95th percentile of the data is 17 – 21 mg/L.
	NaCl	The 95th percentile of the data is 36 – 45 mg/L.
	$CaSO_4$	The 95th percentile of the data is 280 – 351 mg/L.
Physical variables	EC	The 95th percentile of the data is < 30 mS/m.
	pH	The 5th percentile of the data is <6.7 and >7.8, and the 95th percentile is <8.2 and >8.6
	Temperature	Rely on biotic response data to evaluate whether the TPC for temperature is being reached. Moderately temperature sensitive species at lower abundances and frequency.
	Dissolved oxygen	The 5th percentile of the data is < 4.2 mg/L.
	Turbidity	Silting of habitats. Check biotic response for habitat-related changes.
Nutrients	TIN	The 50th percentile of the data must be 0.56 – 0.7 mg/L
	PO_4 – P	The 50th percentile of the data must be 0.02 – 0.025 mg/L
Response variables	Chl - a phytoplankton	The 50th percentile of the data must be 16 – 20 µg/L.
	Chl - a periphyton	The 50th percentile of the data must be 17 – 21 mg/m^2.
	Toxics	An impact is expected if the 95th percentile of the data exceeds the Target Water Quality Range (TWQR) as stated in DWAF (1996).

* To be generated using TEACHA when the TPC for EC is exceeded or salt pollution is expected.

The presence of upstream instream dams has had large impacts on water quality in terms of changing conditions from the reference state, particularly for temperature. Seasonal fluctuations have been severely impacted on, so that although overall present state for water quality seems acceptable, changes from the natural state have been severe. Elevated nutrients from farming also impact on the water quality state.

3.4 DIATOMS

Physico-chemical metric	EcoSpecs	Class rank	TPC	PES
pH	6 - 8 Circumneutral.	3	≥2; ≤4	3
Salinity	Fresh brackish (100 - 500 µS/cm).	2	<2	1
Oxygen	Fairly high saturation (<75% saturation)	≤2	≤3	1
Nutrients	Slightly elevated concentrations of organically bound nitrogen.	1-2	≤2	1
Organics	β-mesosaprobic: BOD_5 < 4mg/l, O_2 deficit <30%.	1-2	<2	1

SPI score	≤13.3 - ≥16.8.	B EC	≥ 13.3	15.7 (B)

Physico-chemical data indicates fluctuating temperature and oxygen levels and toxicants and the EC is a D. Class limits fall with the defined TPC ranges set for a B PES as the SPI scores of the sites within this reach all fluctuated within a B EC (2008 - 2010). An increase in GOMS[2], EOMI, and SSEM (more than 2% of the total count (400)) will be due to organic pollution resulting in deterioration of the oxygen, organics, and nutrient metrics, and impact on the overall integrity of the diatom community. A check should be done for valve deformities with every count as this is indicative of metal contamination. An increase in species which have an affinity for calcium-based salinity should be noted.

3.5 RIPARIAN VEGETATION

3.5.1 EcoSpec and TPC description relating to VEGRAI monitoring data: PES and REC

PES	Assessed Component	Zone Assessed	EcoSpec (for PES)	TPC (for PES)	Baseline (measured value,% cover) / Note
B/C	Exotic Invasion (perennial exotics)	Riparian zone	Maintain exotic species cover between 10-15%	An increase in exotic species cover above 15%	VEGRAI recorded 0% (marginal zone), 5% (lower zone), 5% (upper zone) and 5% (MCB)
	Terrestrialisation	Marginal Zone	Maintain an absence of terrestrial species	An occurrence of terrestrial species	0
		Lower Zone	Maintain cover of terrestrial species at 5% or less	An increase above 5% of terrestrial species cover	5
		Upper Zone	Maintain terrestrial species cover between 15 and 20%	An increase above 20% of terrestrial species cover	10% (8% on upper zone features and 10% on MCB)
	Indigenous Riparian Woody Cover	Marginal Zone	Maintain riparian woody species cover between 5 and 70%	An increase above 70% cover, OR a decrease below 5% cover	5
		Lower Zone	Maintain riparian woody species cover between 10 and 50%	An increase above 50% cover, OR a decrease below 10% cover	30
		Upper Zone	Maintain riparian woody species cover between 10 and 50%	An increase above 50% cover, OR a decrease below 10% cover	26
		MCB	Maintain riparian woody species cover between 30 and 60%	An increase above 60% cover, OR a decrease below 30% cover	38

2 Species abbreviations are listed in Appendix B, Volume 3.

PES	Assessed Component	Zone Assessed	EcoSpec (for PES)	TPC (for PES)	Baseline (measured value,% cover) / Note
	Phragmites australis (reed) cover	Marginal Zone	Maintain reed cover between 40 and 60%	An increase in reed cover above 60% OR a decrease below 20%	85
		Lower Zone	Maintain reed cover between 40 and 60%	An increase in reed cover above 60% OR a decrease below 20%	40

3.5.2 EcoSpecs and TPCs summary relating to VEGRAI monitoring data

Colour coding in the table below refers to:

EcoSpec	TPC	Baseline (measured)	PES B/C

Class	Perennial Exotics	Reeds	Riparian Woody	Terrestrialisation
Lower Zone				
A	0	20 - 30	10-20	0
A/B	1-5		20-40	0
B	5-10	40 - 60	40-60; 5-10	0
B/C	10-15		60-70	0
C	15-20	10-20: 60-80	70-80; 1-5	0
C/D	20-30		0	0
D	30-50	>80		1-5
D/E	50-60			5-10
E	60-70	<10		10-15
E/F	70-80			15-20
F	>80			>20
Middle Zone				
A	0	20 - 30	20-40	0
A/B	1-5			0
B	5-10	40 - 60	10-20; 40-50	0
B/C	10-15			1-5
C	15-20	10-20: 60-80	5-10; 50-60	5-10
C/D	20-30			10-15
D	30-50	>80	<5; 60-70	15-20
D/E	50-60			20-30
E	60-70	<10	70-80	30-40
E/F	70-80			40-50
F	>80		>80	>50
Upper Zone				
A	0		20-40	0-5

A/B		1-5									5-10	
B		5-10						10-20; 40-50			10-15	
B/C		10-15									15-20	
C		15-20						5-10; 50-60			20-30	
C/D		20-30									30-40	
D		30-50						<5; 60-70			40-50	
D/E		50-60									50-60	
E		60-70						70-80			60-70	
E/F		70-80									70-80	
F		>80						>80			>80	
Upper Zone (MCB)												
A								40-50				
A/B												
B								30-40; 50-60				
B/C												
C								20-30; 60-70				
C/D												
D								10-20; 70-80				
D/E												
E								5-10; 80-90				
E/F												
F								<5; >90				

3.6 FISH

EcoSpecs and TPCs are provided for FRAI data in Section 3.6.1. The spatial FROC of EFR O1 is provided in Section 3.6.2 and indicates the FROC under reference, PES and REC conditions as well as TPCs for baseline (PES) conditions.

3.6.1 EcoSpecs and TPCs relating to FRAI data: PES and REC

Rank	Metric	Indicator spp.	PES/REC					AEC↑
			EFR SITE			REACH		REACH
			ECOSPECS	TPC (Biotic)	TPC (Habitat)	Indicator spp.	TPC (Biotic)	ECOSPECS
1	Species richness	all indigenous species	Six (6) of the expected (under reference conditions) 11 indigenous fish species were sampled during the baseline	Less than 5 fish species sampled during a survey when habitat can be sampled efficiently.	Loss in diversity, abundance and condition of velocity-depth categories and cover features.	All indigenous species	Baseline (PES) FRAI score of 58% (C/D) calculated for the reach. Any decreased FROC in reach of especially ASCL, BAEN,	An improvement from PES FROC in the reach for especially BANO, BPAU, BKIM and LUMB should

			(EFR) survey.				BKIM and BTRI (refer to sheet 5-FROC: Table 2) OR FRAI scores decreasing below 57.4% (category D).	be indicative of reaching/maintaining the REC (refer to 5-FROC sheet for more detail).
2	Relative abundance	n/a	During baseline (EFR) surveys fish were sampled at 0.5 individuals per minute (ind/min) using a SAMUS electrofisher during wading. Relative abundance was very low.	Relative abundance of less than 0.4 individual per minute sampled at the site (during same season as baseline data) when habitat can be sampled efficiently and using comparable method.	N/a	N/a	N/a	
7	Alien fish species	any alien/introduced spp.	No alien fish species sampled at site during recent surveys	Presence of any alien/introduced fish species at site during any survey.	N/A	Any alien/introduced spp.	CCAR and MSAL previously sampled in reach. Presence of any additional alien/introduced species.	
3	FD Habitats, substrate, flow dependance (flow alteration) and water column	BAEN, LCAP	The two indicator species of this metric group, BAEN and LCAP, were sampled at the site during the baseline EFR surveys. BAEN and LCAP were present at relative abundance of 0.01 indiv/min.	BAEN and /or LCAP absent during any survey OR present at relative abundance of <0.1 ind/min.	Reduced suitability (abundance & quality) of FD habitats (i.e. decreased flows, increased zero flows), Increased sedimentation of riffle/rapid substrates, excessive algal growth on substrates. Reduction in suitability of water column (i.e. increased sedimentation of pools).	BAEN LCAP	Any decreased FROC in reach of BAEN and LCAP (refer to sheet 5-FROC, column F: Table 2)	

4	FS habitats,	BAEN, ASCL	The two indicator species of this metric group, BAEN and ASCL were sampled at the site during the baseline EFR surveys. BAEN was present at relative abundance of 0.01 indiv/min and ASCL at 0.06 ind/min.	BAEN and/or ASCL absent during any survey OR present at relative abundance of <0.1 ind/min for BAEN and <0.05 ind/min for ASCL.	Reduced suitability (abundance & quality) of FS habitats (i.e. decreased flows, increased zero flows),	BAEN	ASCL	Any decreased FROC in reach of BAEN and ASCL (refer to sheet 5-FROC, column F: Table 2)	
3	Substrate, SD habitats	BAEN, LCAP	The two indicator species of this metric group, BAEN (in the absence of LUMB at site) and LCAP, were sampled at the site during the baseline EFR surveys. BAEN and LCAP were present at relative abundance of 0.01 indiv/min.	BAEN and/or LCAP absent during any survey OR present at relative abundance of <0.1 ind/min.	Increased sedimentation of riffle/rapid substrates, excessive algal growth on substrates. Reduced suitability of SD habitats (i.e. increased flows in dry season, alteration in seasonality, sedimentation of pools).	LCAP	LUMB	Any decreased FROC in reach of LCAP & LUMB (refer to sheet 5-FROC, column F: Table 2)	
3	Water quality intolerance	BAEN, LCAP	In the absence of BKIM (not sampled at site), the two most appropriate indicator species of this metric group at the site is BAEN and LCAP. BAEN and LCAP were present at relative abundance of 0.01 indiv/min.	BAEN and/or LCAP absent during any survey OR present at relative abundance of <0.1 ind/min.	Decreased water quality.	BKIM		Any decreased FROC in reach of BKIM (refer to sheet 5-FROC, column F: Table 2)	

5	SS habitats	PPHI, TSPA	In the absence of CGAR & BANO at the site (not sampled during baseline EFR survey), the most appropriate indicators of this metric is PPHI and TSPA. PPHI was present at relative abundance of 0.2 indiv/min and TSPA at 0.01 ind/min.	PPHI and/or TSPA absent during any survey OR present at relative abundance of <0.1.5 ind/min for PPHI and <0.01 ind/min for TSPA	Significant change in SS habitat suitability (i.e. increased flows, altered seasonality, increased sedimentation of slow habitats).	CGAR	BANO	Any decreased FROC in reach of CGAR & BANO (refer to sheet 5-FROC, column F: Table 2)	
5	Overhanging vegetation	PPHI, TSPA	The most appropriate indicators of this metric is PPHI and TSPA. PPHI was present at relative abundance of 0.2 indiv/min and TSPA at 0.01 ind/min.	PPHI and/or TSPA absent during any survey OR present at relative abundance of <0.1.5 ind/min for PPHI and <0.01 ind/min for TSPA	Significant change in overhanging vegetation habitats (to be quantified with RHAM)	PPHI	TSPA	Any decreased FROC in reach of PPHI & TSPA (refer to sheet 5-FROC, column F: Table 2)	
4	Undercut banks	ASCL, PPHI	The most appropriate indicators of this metric is PPHI and ASCL. PPHI was present at relative abundance of 0.2 indiv/min and ASCL at 0.06 ind/min.	PPHI and/or TSPA absent during any survey OR present at relative abundance of <0.15 ind/min for PPHI and <0.01 ind/min for TSPA	Significant change in undercut bank habitats.	ASCL	PPHI	Any decreased FROC in reach of ASCL & PPHI (refer to sheet 5-FROC, column F: Table 2)	

6	Instream vegetation	TSPA	In the absence of BPAU & BANO at the site (not sampled during baseline EFR survey), the most appropriate indicator of this metric is TSPA. TSPA was present at relative abundance of 0.01 ind/min.	TSPA absent during any survey OR present at relative abundance of <0.01 ind/min.	Significant change in overhanging vegetation habitats.	BPAU	TSPA	Any decreased FROC in reach of BPAU & TSPA (refer to sheet 5-FROC, column F: Table 2)	

3.6.2 Spatial FROC under reference, PES and REC conditions and TPCs for baseline (PES) conditions

Species (Abbr.)	Scientific names: Reference species (Introduced species excluded)	Spatial FROC			
		REFERENCE (A)	PES/REC (C)		AEC up (B)
		Reference FROC	EC: Observed and habitat derived FROC	FROC TPC	Expected/derived FROC
ASCL*	AUSTROGLANIS SCLATERI (BOULENGER, 1901)	3	2	1	2
BAEN*	LABEOBARBUS AENEUS (BURCHELL, 1822)	5	4	3	4
BANO	BARBUS ANOPLUS WEBER, 1897	3	0.5	0	1
BKIM	LABEOBARBUS KIMBERLEYENSIS GILCHRIST & THOMPSON, 1913	3	1	0	2
BPAU	BARBUS PALUDINOSUS PETERS, 1852	3	1	0	2
BTRI*	BARBUS TRIMACULATUS PETERS, 1852	3	2	1	3
CGAR	CLARIAS GARIEPINUS (BURCHELL, 1822)	4	2	1	3
LCAP*	LABEO CAPENSIS (SMITH, 1841)	5	4	3	4
LUMB	LABEO UMBRATUS (SMITH, 1841)	5	2	1	3
PPHI*	PSEUDOCRENILABRUS PHILANDER (WEBER, 1897)	3	2.5	1.5	2.5
TSPA*	TILAPIA SPARRMANII SMITH, 1840	3	2	1	2

* sampled at site during EFR survey

3.7 MACROINVERTEBRATES

3.7.1 SASS Data

Available SASS5 data collected at or near Site EFR O1 are summarised as follows:

Site	Date	SASS Score	ASPT	No. of Taxa	Reference
D3ORAN-HOPET	11-Oct-2004	20	4.0	5	Ramogale Sekwele (River Health Database)
D3ORAN-HOPET	7-Mar-2005	98	5.4	18	Ramogale Sekwele (River Health Database)
D3ORAN-HOPET	25-Nov-2005	90	5.3	17	Ramogale Sekwele (River Health Database)
EWR O1	2-Jun-2010	128	6.1	21	This study

The very low score recorded in October 2004 is likely to have been caused by short-term water level fluctuations from releases from Vanderkloof Dam

3.7.2 Indicator Taxa

The following macroinvertebrate taxa, arranged in order of decreasing sensitivity to water quality deterioration were selected as monitoring indicators for EFR O1.

	Flow				Substrate					Wat Qual		
	Standing (<0.1 m/s)	Slow (0.1-0.3 m/s)	Mod (0.3-0.6 m/s)	Fast (>0.6 m/s)	Hard	Boulders/Bedrock	Loose Cobble	Veg	Sand, Gravel, Mud	High (SASS>11)	Mod (SASS 7-10)	Low (SASS 4-6)
Heptageniidae (Flathead mayflies)		•	•	•		•	●	•		**13**		
Baetidae (>2 spp)	•	•	●	●	•	•	●	•	•		**10**	
Leptophlebiidae (Prongills)	•	●	•		•	•	●	•	●		**9**	
Tricorythidae (Stout crawlers)			•	●	•	●	●	•			**9**	
Ancylidae	•	•	•	•	•	•	•	•				**6**
Leptoceridae	•	●	•					●				**6**

• = Partial Preference ● = Strong Preference

3.7.3 EcoSpecs and TPCs

EcoSpecs and TPCs for the PES and REC (C EC) at EFR O1 are provided below.

ECOSPECS	TPCs
SASS5 Score between 150 and 169.	SASS5 Score < 105.
ASPT between 5.9 and 6.2.	ASPT < 6.0
MIRAI Score between 60% and 79%.	MIRAI Score < 63%.
At least 50% indicator taxa present.	Three or more Indicator Taxa absent.
Indicator Taxa	

Heptageniidae present.	Heptageniidae absent on two or more consecutive surveys.
Baetidae >2 spp.	Baetidae < 2 spp on any one survey.
Leptophlebiidae present.	Leptophlebiidae absent on two or more consecutive surveys.
Tricorythidae present (except winter).	Tricorythidae absent on two or more consecutive surveys.
Ancylidae present.	Ancylidae absent on two or more consecutive surveys.
Leptoceridae present.	Leptoceridae absent on two or more consecutive surveys.

4 EFR 02 – BOEGOEBERG (ORANGE RIVER)

A summary of the site EcoClassification results are provided below (Volume 1: EFR).

4.1 ECOCLASSIFICATION SUMMARY OF EFRO2

EFR 02 (BOEGOEBERG)

EIS: HIGH

Highest scoring metrics are instream and riparian rare/endangered biota, unique riparian biota, instream biota intolerant to flow, taxon richness of riparian biota, diversity of riparian habitat types, critical riparian habitat, refugia, migration corridor.

PES: C

Loss of frequency of large floods, agricultural return flows, higher low flows than natural in the dry season, drought and dry periods, decreased low flows at other times, release of sediment, presence of alien fish species and barrier effects of dams.

REC: B/C

Instream improvement was not possible due to constraints and no EFR will be set for REC.

AEC D (instream)

Decreased low flows in the wet and dry season. Decreased floods, Decreased dilution resulting in worse water quality. Reduced low flows will result in less light penetration which will result in algal and benthic growth.

Driver Components	PES	TREND	REC	AEC↓
IHI HYDROLOGY	E			
WATER QUALITY	C		C	D
GEOMORPHOLOGY	C	0	C	C
INSTREAM IHI	C/D			
RIPARIAN IHI	B/C			
Response Components	**PES**	**TREND**	**REC**	**AEC↓**
FISH	C	0	C	D
MACRO INVERTEBRATES	C	0	C	D
INSTREAM	C	0	C	D
RIPARIAN VEGETATION	B	0	A/B	B/C
RIVERINE FAUNA	C	0	B	C
ECOSTATUS	C	0	B/C	C
EIS	HIGH			

EcoSpecs and TPCs for EFR O2 are provided for the different components in Section 4.2 to 4.6.

4.2 GEOMORPHOLOGY

4.2.1 Site Description and focus of TPCs

This bedrock anastomosing reach has well-vegetated bedrock core bars and islands between the distributary channels, and large bedrock riffle areas in the active channels. Distributaries are generally stable with reach planforms controlled by local weaknesses in the underlying geology (Tooth and McCarthy, 2004). Anastomosing reaches of rivers have been shown to be relatively stable over long periods; being only 'reset' or scoured across the entire macro-channel flood by extremely large, infrequent ("catastrophic') flood events (Rountree *et al*, 2001, Rountree and Rogers, 2004). Therefore very large floods are required to maintain these reaches. The Present Day sediment loads, flood sizes and flood frequencies are highly reduced – even floods up to the 1:10 year event may be attenuated in the upstream dams. The key issue for this site is the loss of large floods that scour and maintain the distributary channels and beds and prevent encroachment of vegetation in to the channels and over time this may lead to abandonment of secondary channels and loss of backwaters.

4.2.2 EcoSpecs and TPCs relating to GAI monitoring data

Descriptor	Motivation for Monitoring	
Reach morphology: Area of islands	The reduced size and frequency of floods at this site allow for the growth of islands from deposition and vegetation encroachment in to the channel due to reduced scouring events. This can cause a loss of instream habitat area. To maintain the PES, no expansion of the islands in the reach should occur (refer to Appendix E – Volume 3).	
	TPC:	Any increase in the area of islands in the reach from the 2010 level.
	Approach:	Aerial photographic or Google Earth imagery analysis of the site.
	Frequency:	Every 5 years
Reach morphology: Number of active distributary channels	Reduced flood sizes and frequency are inhibiting the scour and maintenance secondary distributary channels. This can lead to the abandonment of secondary channels which reduces in-channel habitat area and diversity and exposes island biota (e.g. nesting birds) to terrestrial predators.	
	TPC:	Any decrease in the length of active distributary channels in the reach from the 2010 level.
	Approach:	Aerial photographic or Google Earth imagery analysis of the site.
	Frequency:	Every 5 years

4.3 WATER QUALITY

4.3.1 EcoSpecs relating to water quality

River: Orange		EFR O2, Boegoeberg
Water quality metrics		**EcoSpecs: PES**
Inorganic salts*	$MgSO_4$	The 95th percentile of the data must be ≤ 16 mg/L.
	Na_2SO_4	The 95th percentile of the data must be ≤ 20 mg/L.
	$MgCl_2$	The 95th percentile of the data must be ≤ 15 mg/L.
	$CaCl_2$	The 95th percentile of the data must be ≤ 21 mg/L.
	NaCl	The 95th percentile of the data must be ≤ 45 mg/L.
	$CaSO_4$	The 95th percentile of the data must be ≤ 351 mg/L.
Physical variables	EC	The 95th percentile of the data must be ≤ 55 mS/m.
	pH	The 5th percentile of the data must range from 6.5 to 8.0, and the 95th percentile from 8.0 to 8.8
	Temperature	Moderate to large changes to temperature regime occur frequently, with fluctuations of 2 to 4°C.
	Dissolved oxygen	The 5th percentile of the data must be ≥ 6.5 mg/L. Some concerns about dissolved oxygen, with only some oxygen sensitive species present.
	Turbidity	Vary by a small amount from the natural turbidity range; minor silting of instream habitats acceptable.

River: Orange		EFR O2, Boegoeberg
Water quality metrics		EcoSpecs: PES
Nutrients	TIN	The 50th percentile of the data must be ≤ 0.25 mg/L
	PO_4 – P	The 50th percentile of the data must be ≤ 0.025 mg/L.
Response variables	Chl – a phytoplankton	The 50th percentile of the data must be ≤ 20 mg/L ♦
	Chl – a periphyton	The 50th percentile of the data must be ≤ 21 mg/m² ♦
	Toxics	The 95th percentile of the data must be within the Chronic Effects Value (CEV) as stated in DWAF (1996) #

* To be generated using TEACHA when the TPC for EC is exceeded or salt pollution is expected. Should the TPC for any integrated salt be exceeded, consult a water quality specialist and check the validity of the EcoSpec and TPC by running TEACHA on the data used to determine the PES. If necessary, adjust the boundary for the EcoSpec and TPC for the relevant salt.
#: Although category boundaries exist in the Water quality Reserve manual (DWAF, 2008) for a number of toxicants, adherence to the CEV (DWAF, 1996) is recommended for the present state. Data collection and testing will need to be undertaken to assess the suitability of these objectives.
♦: low confidence. EcoSpec and TPC boundaries may need adjusting as data become available.

4.3.2 PCs relating to water quality data

River: Orange		EFR O2, Boegoeberg
Water quality metrics		TPCs
Inorganic salts*	$MgSO_4$	The 95th percentile of the data is 13 – 16 mg/L.
	Na_2SO_4	The 95th percentile of the data is 16 – 20 mg/L.
	$MgCl_2$	The 95th percentile of the data is 12 – 15 mg/L.
	$CaCl_2$	The 95th percentile of the data is 17 – 21 mg/L.
	NaCl	The 95th percentile of the data is 36 – 45 mg/L.
	$CaSO_4$	The 95th percentile of the data is 280 – 351 mg/L.
Physical variables	EC	The 95th percentile of the data is 44 – 55 mS/m.
	pH	The 5th percentile of the data is <6.7 and >7.8, and the 95th percentile is <8.2 and >8.6
	Temperature	Rely on biotic response data to evaluate whether the TPC for temperature is being reached. Most highly temperature sensitive species are in lower abundances and frequency of occurrence than expected for reference.
	Dissolved oxygen	The 5th percentile of the data is < 6.7 mg/L.
	Turbidity	Silting of habitats. Check biotic response for habitat-related changes.
Nutrients	TIN	The 50th percentile of the data must be 0.2 – 0.25 mg/L
	PO_4 – P	The 50th percentile of the data must be 0.02 – 0.025 mg/L
Response variables	Chl - a phytoplankton	The 50th percentile of the data must be 16 – 20 µg/L ♦

River: Orange		EFR O2, Boegoeberg
Water quality metrics		**TPCs**
	Chl - a periphyton	The 50[th] percentile of the data must be 17 – 21 mg/m^2 ♦
	Toxics	An impact is expected if the 95[th] percentile of the data exceeds the Target Water Quality Range (TWQR) as stated in DWAF (1996).

* To be generated using TEACHA when the TPC for EC is exceeded or salt pollution is expected. Should the TPC for any integrated salt be exceeded, consult a water quality specialist and check the validity of the EcoSpec and TPC by running TEACHA on the data used to determine the PES. If necessary, adjust the boundary for the EcoSpec and TPC for the relevant salt.

♦: low confidence. EcoSpec and TPC boundaries may need adjusting as data become available.

Land-use is agricultural, resulting in some toxicant and nutrient loading expected. The upstream dams still have some impact in terms of temperature.

4.4 DIATOMS

Physico-chemical metric	EcoSpecs	Class rank	TPC	PES
pH	6 - 8 Circumneutral.	3	≥2; ≤4	4
Salinity	Fresh brackish (100 - 500 µS/cm).	2	<2	2
Oxygen	Fairly high saturation (<75% saturation)	≤2	≤3	1
Nutrients	Slightly elevated concentrations of organically bound nitrogen.	1-2	≤2	2
Organics	β-mesosaprobic: BOD_5 < 4mg/l, O_2 deficit <30%.	1-2	<2	2
SPI score	≤13.3 - ≥16.8.	B EC	≥ 13.3	13.4 (B)

Physico-chemical data indicates an increase in sulphide and chloride levels from Reference Conditions and the EC is a C. The data indicates that toxicants may also be problematic. Class limits fall within the defined TPC ranges set for a B PES as the SPI scores of the sites within MRU D up to EFR 2 all fluctuated within a B EC (2008 - 2010). Below EFR 2 the EC deteriorated. An increase in GOMS, especially GPAR; CPLA, CPLE and *Nitzschia* species (more than 5% of the total count (400)) will be due to increased nutrient levels and organic pollution and result in deterioration in oxygen, organics, and nutrient metrics, and impact on the overall integrity of the diatom community. A check should be done for valve deformities with every count as this is indicative of metal contamination. An increase in species which have an affinity for calcium-based salinity should be noted.

4.5 RIPARIAN VEGETATION

4.5.1 EcoSpec and TPC description relating to VEGRAI monitoring data: PES and REC

PES	REC	Assessed Component	Zone Assessed	EcoSpec (for PES)	TPC (for PES)	EcoSpec (for REC or AEC up)	Baseline (measured value,% cover) / Note
B	A/B	Exotic Invasion (perennial exotics)	Riparian zone	Maintain exotic species cover below 10%	An increase in exotic species cover above 10%	Maintain exotic species cover below 5%	VEGRAI recorded 0% (marginal zone), 3% (lower zone), 9% (upper zone), 7% (MCB) and 10% (floodplain or macro terrace): overall weighted mean of 8%
		Terrestrialisation	Marginal Zone	Maintain an absence of terrestrial species	An occurrence of terrestrial species	Maintain an absence of terrestrial species	0
			Lower Zone	Maintain an absence of terrestrial species	An occurrence of terrestrial species	Maintain an absence of terrestrial species	0
			Upper Zone	Maintain terrestrial species cover between 10 and 15%	An increase above 15% of terrestrial species cover	Maintain terrestrial species cover between 5 and 10%	10
			MCB	Maintain terrestrial species cover between 10 and 15%	An increase above 15% of terrestrial species cover	Maintain terrestrial species cover between 5 and 10%	10
		Indigenous Riparian Woody Cover	Marginal Zone	Maintain riparian woody species cover between 5% and 60%	An increase in riparian woody species cover above 60% OR a decrease below 5%	Maintain riparian woody species cover between 10% and 40%	45
			Lower Zone	Maintain riparian woody species cover between 5% and 50%	An increase in riparian woody species cover above 50% OR a decrease below 5%	Maintain riparian woody species cover between 20% and 40%	15
			Upper Zone	Maintain riparian woody	An increase in riparian woody	Maintain riparian woody	36

				species cover between 10% and 50%	species cover above 50% OR a decrease below 10%	species cover between 20% and 40%	
			MCB	Maintain riparian woody species cover between 30% and 60%	An increase in riparian woody species cover above 60% OR a decrease below 30%	Maintain riparian woody species cover between 40% and 50%	50
		Phragmites australis (reed) cover	Marginal Zone	Maintain reed cover less than 40%	An increase in reed cover above 40%	Maintain reed cover between 20% and 30%	13
			Lower Zone	Maintain reed cover less than 40%	An increase in reed cover above 40%	Maintain reed cover between 20% and 30%	18

4.5.2 EcoSpecs and TPCs summary relating to VEGRAI monitoring data

Colour coding in the table below refers to:

EcoSpec	TPC	Baseline (measured)	PES B	REC A/B

Class		Perennial Exotics			Terrestrialisation			Riparian Woody			Reeds	
Middle Zone												
A		0			0			10-30			10-20	
A/B		1-5			0			30-40			20-30	
B		5-10			0			40-60; 5-10			<10; 30-40	
B/C		10-15			0			60-70				
C		15-20			0			70-80; 1-5			40-50	
C/D		20-30			0							
D		30-50			1-5			>80; 0			50-60	
D/E		50-60			5-10							
E		60-70			10-15						60-80	
E/F		70-80			15-20							
F		>80			>20						>80	
Lower Zone												
Class		Perennial Exotics			Terrestrialisation			Riparian Woody			Reeds	
A		0			0			10-20			10-20	
A/B		1-5			0			20-40			20-30	
B		5-10			0			5-10; 40-50			<10; 30-40	

Class	Perennial Exotics	Terrestrialisation	Riparian Woody	Reeds
B/C	10-15	1-5		
C	15-20	5-10	<5; 50-60	40-50
C/D	20-30	10-15		
D	30-50	15-20	60-70	50-60
D/E	50-60	20-30		
E	60-70	30-40	70-80	60-80
E/F	70-80	40-50		
F	>80	>50	>80	>80
Upper Zone				
A	0	0-5	20-40	
A/B	1-5	5-10		
B	5-10	10-15	10-20; 40-50	
B/C	10-15	15-20		
C	15-20	20-30	5-10; 50-60	
C/D	20-30	30-40		
D	30-50	40-50	<5; 60-70	
D/E	50-60	50-60		
E	60-70	60-70	70-80	
E/F	70-80	70-80		
F	>80	>80	>80	
Upper Zone (MCB)				
A	0	0-5	40-50	
A/B	1-5	5-10		
B	5-10	10-15	30-40; 50-60	
B/C	10-15	15-20		
C	15-20	20-30	20-30; 60-70	
C/D	20-30	30-40		
D	30-50	40-50	10-20; 70-80	
D/E	50-60	50-60		
E	60-70	60-70	5-10; 80-90	
E/F	70-80	70-80		
F	>80	>80	<5; >90	

4.6 FISH

EcoSpecs and TPCs are provided for FRAI data in Section 4.6.1. The spatial FROC of EFR O2 is provided in Section 4.6.2 and indicates the FROC under reference, PES and REC conditions as well as TPCs for baseline (PES) conditions.

4.6.1 EcoSpecs and TPCs relating to FRAI data: PES and REC

RANK	METRIC	Indicator SPP.	PES					REC
			EFR SITE			REACH		REACH
			ECOSPECS	TPC (Biotic)	TPC (Habitat)	Indicator SPP.	TPC (Biotic)	ECOSPECS
1	Species richness	all indigenous species	Eight (8) of the expected (under reference conditions) 11 indigenous fish species were sampled during the baseline (EFR) survey.	Less than (<) 6 fish species sampled during a survey when habitat can be sampled efficiently.	Loss in diversity, abundance and condition of velocity-depth categories and cover features.	All indigenous species	Baseline (PES) FRAI score of 67% (C) calculated for the reach. Any decreased FROC in reach of especially ASCL, BAEN, BKIM and BTRI (refer to sheet 5-FROC: Table 2) OR FRAI scores decreasing below 62.02% (category C/D).	An improvement from PES FROC in the reach for especially BANO, BKIM and LUMB should be indicative of reaching/maintaining the REC (refer to 5-FROC sheet for more detail).
2	Relative abundance	n/a	During baseline (EFR) surveys fish were sampled at 2.35 individuals per minute using a SAMUS electrofisher during wading. Relative abundance was very low.	Relative abundance of less than (<) 2 individual per minute sampled at the site (during same season as baseline data) when habitat can be sampled efficiently and using comparable method.	N/a	N/a	N/a	
7	Alien fish species	any alien/introduced spp.	Three alien species, namely CCAR, GAFF & CIDE sampled at site during baseline EFR survey.	Presence of any additional alien/introduced species.	N/A	Any alien/introduced spp.	CCAR, GAFF & CIDE previously sampled in reach. Presence of any additional alien/introduced species.	
3	FD Habitats, substrate, Flow dependant spp (flow alteration), SD habitats & water column.	BAEN, LCAP	The two indicator species of this metric group, BAEN and LCAP, were sampled at the site during the baseline EFR surveys. BAEN was relatively scarce (0.03 ind/min) while LCAP was more abundant at 0.8 indiv/min.	BAEN and/or LCAP absent during any survey OR present at relative abundance of <0.03 ind/min for BAEN or <0.5 ind/min for LCAP.	Reduced suitability (abundance & quality) of FD habitats (i.e. decreased flows, increased zero flows), increased sedimentation of riffle/rapid substrates, excessive algal growth on substrates. Reduced suitability of SD habitats (i.e. increased flows in dry season, alteration in seasonality, sedimentation of pools). Reduction in suitability of water column (i.e. increased sedimentation of pools)	BAEN LCAP	Any decreased FROC in reach of BAEN and LCAP (refer to sheet 5-FROC, column F: Table 2)	

RANK	METRIC	Indicator SPP.	PES						REC
			EFR SITE			REACH			REACH
			ECOSPECS	TPC (Biotic)	TPC (Habitat)	Indicator SPP.		TPC (Biotic)	ECOSPECS
4	FS habitats,	BAEN, ASCL	The two indicator species of this metric group, BAEN and ASCL were sampled at the site during the baseline EFR surveys. Both these species were scarce at the site, with BAEN being present at relative abundance of 0.03 indiv/min and ASCL at 0.02 ind/min.	BAEN and/or ASCL absent during any survey OR present at relative abundance of <0.03 ind/min for BAEN and <0.02 ind/min for ASCL.	Reduced suitability (abundance & quality) of FS habitats (i.e. decreased flows, increased zero flows),	BAEN	ASCL	Any decreased FROC in reach of BAEN and ASCL (refer to sheet 5-FROC, column F: Table 2)	
3	Water quality intolerance,	BAEN, LCAP	In the absence of BKIM (not sampled at site during baseline EFR survey) the two indicator species of this metric group is BAEN and LCAP. Both were sampled at the site during the baseline EFR surveys. BAEN was relatively scarce (0.03 ind/min) while LCAP was more abundant at 0.8 indiv/min.	BAEN and/or LCAP absent during any survey OR present at relative abundance of <0.03 ind/min for BAEN or <0.5 ind/min for LCAP.	Decreased water quality.	BKIM		Any decreased FROC in reach of BKIM (refer to sheet 5-FROC, column F: Table 2)	
6	SS habitats, Overhanging vegetation	BPAU, PPHI	The most appropriate indicators of this metric is PPHI and BPAU. PPHI was present at relative abundance of 0.03 indiv/min and BPAU at 0.02 ind/min.	PPHI and/or BPAU absent during any survey OR present at relative abundance of <0.03 ind/min for PPHI and <0.02 ind/min for BPAU	Significant change in SS habitat suitability (i.e. increased flows, altered seasonality, increased sedimentation of slow habitats).Significant change in overhanging vegetation habitats	BPAU	PPHI	Any decreased FROC in reach of BPAU & PPHI (refer to sheet 5-FROC, column F: Table 2)	
5	Undercut banks	ASCL, PPHI	The most appropriate indicators of this metric is PPHI and ASCL PPHI was present at relative abundance of 0.03 indiv/min and ASCL at 0.02 ind/min.	PPHI and/or ASCL absent during any survey OR present at relative abundance of <0.03 ind/min for PPHI and <0.02 ind/min for ASCL	Significant change in undercut bank habitats	ASCL	PPHI	Any decreased FROC in reach of ASCL & PPHI (refer to sheet 5-FROC, column F: Table 2)	

RANK	METRIC	Indicator SPP.	PES: EFR SITE: ECOSPECS	PES: EFR SITE: TPC (Biotic)	PES: EFR SITE: TPC (Habitat)	PES: REACH: Indicator SPP.		PES: REACH: TPC (Biotic)	REC: REACH: ECOSPECS
6	Instream vegetation	BPAU, TSPA	The most appropriate indicators of this metric is TSPA and BPAU. TSPA was present at relative abundance of 0.08 indiv/min and BPAU at 0.02 ind/min.	TSPA and/or BPAU absent during any survey OR present at relative abundance of <0.08 ind/min for TSPA and <0.02 ind/min for BPAU	Significant change in overhanging vegetation habitats.	BPAU	TSPA	Any decreased FROC in reach of BPAU & TSPA (refer to sheet 5-FROC, column F: Table 2)	

4.6.2 Spatial FROC under reference, PES and REC conditions and TPCs for baseline (PES) conditions

	Species (Abbr.)	Scientific names: Reference species (Introduced species excluded)	Spatial FROC: REFERENCE (A): Reference FROC	Spatial FROC: PES/REC (C): EC: Observed and habitat derived FROC	Spatial FROC: PES/REC (C): FROC TPC	Spatial FROC: AEC up (B): Expected/derived FROC
INDIGENOUS	ASCL*	AUSTROGLANIS SCLATERI (BOULENGER, 1901)	3	2	1	2
	BAEN*	LABEOBARBUS AENEUS (BURCHELL, 1822)	5	4	3	4
	BANO	BARBUS ANOPLUS WEBER, 1897	2	0.5	0	1
	BKIM	LABEOBARBUS KIMBERLEYENSIS GILCHRIST & THOMPSON, 1913	3	1.5	0.5	2
	BPAU*	BARBUS PALUDINOSUS PETERS, 1852	4	3.5	2.5	3.5
	BTRI*	BARBUS TRIMACULATUS PETERS, 1852	3	2.5	1.5	2.5
	CGAR*	CLARIAS GARIEPINUS (BURCHELL, 1822)	3	2.5	1.5	2.5
	LCAP*	LABEO CAPENSIS (SMITH, 1841)	5	4.5	3.5	4.5
	LUMB	LABEO UMBRATUS (SMITH, 1841)	3	0.5	-0.5	1.5
	PPHI*	PSEUDOCRENILABRUS PHILANDER (WEBER, 1897)	3	2.5	1.5	2.5
	TSPA*	TILAPIA SPARRMANII SMITH, 1840	2	1.5	0.5	1.5
ALIEN	CCAR*	CYPRINUS CARPIO LINNAEUS, 1758				
	GAFF*	GAMBUSIA AFFINIS (BAIRD & GIRARD, 1853)				
	CIDE*	CTENOPHARYNGODON IDELLA (VALENCIENNES, 1844)				

* sampled at site during baseline EFR survey

4.7 MACROINVERTEBRATES

4.7.1 SASS Data

Available SASS5 data collected at or near Site EFR O2 are summarised as follows:

Site	Date	SASS Score	ASPT	No. of Taxa	Reference
D7ORAN-PRIES	12-Oct-2004	62	5.2	12	Ramogale Sekwele (River Health Database)
D7ORAN-PRIES	8-Mar-2005	118	5.9	20	Ramogale Sekwele (River Health Database)
D7ORAN-GROBL	8-Mar-2005	91	5.7	16	Ramogale Sekwele (River Health Database)
D7ORAN-GROBL	24-Nov-2005	106	6.2	17	Ramogale Sekwele (River Health Database)
D7ORAN-PRIES	25-Nov-2005	115	5.2	22	Ramogale Sekwele (River Health Database)
EWR O2	31-May-2010	116	5.8	20	This study

4.7.2 Indicator Taxa

The following macroinvertebrate taxa, arranged in order of decreasing sensitivity to water quality deterioration were selected as monitoring indicators for EFR O2.

	Flow				Substrate					Wat Qual		
	Standing (<0.1 m/s)	Slow (0.1-0.3 m/s)	Mod (0.3-0.6 m/s)	Fast (>0.6 m/s)	Hard	Boulders/Bedrock	Loose Cobble	Veg	Sand, Gravel, Mud	High (SASS>11)	Mod (SASS 7-10)	Low (SASS 4-6)
Baetidae (>2 spp)	•	•	●	●	•	•	●	•	•		**10**	
Leptophlebiidae (Prongills)	•	●	•		•	•	●	•	●		**9**	
Tricorythidae (Stout crawlers)			•	●	•	●	●	•			**9**	
Atyidae (Freshwater shrimps)		•						●			**8**	
Hydropsychidae (2 spp)			•	●	•	●	•					**6**
Gomphidae		●							●			**6**

• = Partial Preference ● = Strong Preference

4.7.3 EcoSpecs and TPCs

EcoSpecs and TPCs for the PES at EFR O2 are provided below.

ECOSPECS	TPCs
SASS5 Score between 143 and 161.	SASS5 Score < 150.
ASPT between 5.9 and 6.3.	ASPT < 6.1.
MIRAI Score between 60% and 79%.	MIRAI Score < 63%.
At least 50% indicator taxa present.	Three or more Indicator Taxa absent.
Indicator Taxa	
Baetidae >2 spp.	Baetidae < 2 spp on any one survey.

Leptophlebiidae present.	Leptophlebiidae absent on two or more consecutive surveys.
Tricorythidae present (except winter).	Tricorythidae absent on two or more consecutive surveys.
Atyidae present.	Atyidae absent on two or more consecutive surveys.
Hydropsychidae present.	Hydropsychidae absent on two or more consecutive surveys.
Gomphidae present.	Gomphidae absent on two or more consecutive surveys.

5 EFR O3 – AUGRABIES (ORANGE RIVER)

A summary of the site EcoClassification results are provided below (Volume 1: EFR).

5.1 ECOCLASSIFICATION SUMMARY OF EFRO3

EFR O3 (AUGRABIES)

EIS: HIGH

Highest scoring metrics are instream and riparian rare/endangered biota, unique instream and riparian biota, taxon richness of riparian biota, diversity of riparian habitat types, critical riparian habitat, refugia, migration corridor, National Park

PES: C

Decreased frequency of large floods. Agricultural return flows, agricultural activities and associated water quality impacts. Higher low flows than natural in the dry season, drought and dry periods. Decreased low flows at other times. Presence of alien fish species and barrier effects of dams and alien vegetation. Decreased sedimentation (lack of large floods and upstream dams).

REC: B

Reinstate droughts (i.e., lower flows than present during the drought season).Improved (higher) wet season base flows. Clear vegetation aliens which will improve the vegetation condition in the marginal and lower zones. Improved agricultural practices.

AEC: D

Increased agriculture with associated impacts on water quality and decreased wet season base flows. Decreased floods. Increased vegetation aliens.

Driver Components	PES	TREND	REC	AEC↓
IHI HYDROLOGY	E			
WATER QUALITY	C		C	D
GEOMORPHOLOGY	C	0	C	C-
INSTREAM IHI	D			
RIPARIAN IHI	C/D			
Response Components	**PES**	**TREND**	**REC**	**AEC↓**
FISH	C	0	B	D
MACRO INVERTEBRATES	C	0	B	D
INSTREAM	C	0	B	D
RIPARIAN VEGETATION	B/C	-	B	C
RIVERINE FAUNA	C	0	B	C
ECOSTATUS	C	0	B	C*
EIS	HIGH			

* The focus for setting EFRs will be on the instream EC of a D

EcoSpecs and TPCs for EFR O3 are provided for the different components in Section 5.2 to 5.6.

5.2 GEOMORPHOLOGY

5.2.1 Site Description and focus of TPCs

The morphology of this pool riffle and rapid reach is stable due to the high degree of bedrock control. Present Day flows in this section are less than half of the virgin MAR due to very large upstream dams and extensive abstractions. Flood sizes and frequencies are highly reduced. Dams trap sediments, but some flush through bottom releases. This however should occur during high flow periods in order to allow for dilution of the accumulated sediments and prevent habitat smothering and fish kills. Embeddedness of the gravels and cobbles is a risk for the site due to high fines loads but reduced large sediment sizes (due to trapping in the dams), and could lead to degraded in-channel habitat.

5.2.2 EcoSpecs and TPCs relating to GAI monitoring data

Descriptor	Motivation for Monitoring	
Reach morphology	The site is very stable due to a high degree of bedrock control. This means the morphology is insensitive to flow changes and thus and no TPCs linked to the gross morphology of the site have been recommended (refer to Appendix E – Volume 3).	
	TPC:	n/a
	Approach:	
	Frequency:	
In-channel morphology: Bed sediment size distribution	Reduced flood sizes and frequency are reducing bed scour and removal of accumulated fines deposits. This may lead to embeddedness of the larger sediments and smothering by fines materials which will reduce in-channel habitat condition.	
	TPCs:	Fines (silts and sands) should not comprise more than 10% of the bed sediment in the active channel. Gravels and small cobbles (5-100mm) should comprise at least 50% of the bed sediment in the active channel.
	Approach:	Resurvey of the bed sediment at the EFR cross-section site during the low flow season.
	Frequency:	Every 2-5 years

5.3 WATER QUALITY

5.3.1 EcoSpecs relating to water quality

River: Orange		EFR O3, Augrabies
Water quality metrics		EcoSpecs: PES
Inorganic salts*	$MgSO_4$	The 95th percentile of the data must be ≤ 16 mg/L.
	Na_2SO_4	The 95th percentile of the data must be ≤ 20 mg/L.
	$MgCl_2$	The 95th percentile of the data must be ≤ 15 mg/L.
	$CaCl_2$	The 95th percentile of the data must be ≤ 21 mg/L.
	NaCl	The 95th percentile of the data must be ≤ 45 mg/L.
	$CaSO_4$	The 95th percentile of the data must be ≤ 351 mg/L.
Physical variables	EC	The 95th percentile of the data must be ≤ 55 mS/m.
	pH	The 5th percentile of the data must range from 6.5 to 8.0, and the 95th percentile from 8.0 to 8.8
	Temperature	Some minor man-made changes to the river but no known changes to the natural temperature regime.
	Dissolved oxygen	The 5th percentile of the data must be ≥ 8 mg/L.

River: Orange		EFR O3, Augrabies
Water quality metrics		**EcoSpecs: PES**
	Turbidity	Vary by a small amount from the natural turbidity range; minor silting of instream habitats acceptable.
Nutrients	TIN	The 50th percentile of the data must be ≤ 0.25 mg/L
	PO_4 – P	The 50th percentile of the data must be ≤ 0.125 mg/L.
Response variables	Chl – a phytoplankton	The 50th percentile of the data must be ≤ 20 mg/L ♦
	Chl – a periphyton	The 50th percentile of the data must be ≤ 21 mg/m^2 ♦
	Toxics	The 95th percentile of the data must be within the Chronic Effects Value (CEV) as stated in DWAF (1996) #

* To be generated using TEACHA when the TPC for EC is exceeded or salt pollution is expected. Should the TPC for any integrated salt be exceeded, consult a water quality specialist and check the validity of the EcoSpec and TPC by running TEACHA on the data used to determine the PES. If necessary, adjust the boundary for the EcoSpec and TPC for the relevant salt.

#: Although category boundaries exist in the Water quality Reserve manual (DWAF, 2008) for a number of toxicants, adherence to the CEV (DWAF, 1996) is recommended for the present state. Data collection and testing will need to be undertaken to assess the suitability of these objectives.

♦: low confidence. EcoSpec and TPC boundaries may need adjusting as data become available.

5.3.2 TPCs relating to water quality data

River: Orange		EFR O3, Augrabies
Water quality metrics		**TPCs**
Inorganic salts*	$MgSO_4$	The 95th percentile of the data is 13 – 16 mg/L.
	Na_2SO_4	The 95th percentile of the data is 16 – 20 mg/L.
	$MgCl_2$	The 95th percentile of the data is 12 – 15 mg/L.
	$CaCl_2$	The 95th percentile of the data is 17 – 21 mg/L.
	NaCl	The 95th percentile of the data is 36 – 45 mg/L.
	$CaSO_4$	The 95th percentile of the data is 280 – 351 mg/L.
Physical variables	EC	The 95th percentile of the data is 44 – 55 mS/m.
	pH	The 5th percentile of the data is <6.7 and >7.8, and the 95th percentile is <8.2 and >8.6
	Temperature	Rely on biotic response data to evaluate whether the TPC for temperature is being reached. Some highly temperature sensitive species are at lower abundances and frequency of occurrence than expected for reference.
	Dissolved oxygen	The 5th percentile of the data is < 8.2 mg/L.
	Turbidity	Silting of habitats. Check biotic response for habitat-related changes.
Nutrients	TIN	The 50th percentile of the data must be 0.2 – 0.25 mg/L

River: Orange		EFR O3, Augrabies
Water quality metrics		**TPCs**
	PO_4 – P	The 50th percentile of the data must be 0.06 – 0. 075 mg/L **
Response variables	Chl - a phytoplankton	The 50th percentile of the data must be 16 – 20 µg/L ♦
	Chl - a periphyton	The 50th percentile of the data must be 17 – 21 mg/m^2 ♦
	Toxics	An impact is expected if the 95th percentile of the data exceeds the Target Water Quality Range (TWQR) as stated in DWAF (1996).

* To be generated using TEACHA when the TPC for EC is exceeded or salt pollution is expected. Should the TPC for any integrated salt be exceeded, consult a water quality specialist and check the validity of the EcoSpec and TPC by running TEACHA on the data used to determine the PES. If necessary, adjust the boundary for the EcoSpec and TPC for the relevant salt.

♦: low confidence. EcoSpec and TPC boundaries may need adjusting as data become available.

**: Although the upper boundary for the relevant phosphate category is 0.125 mg/L, the TPC has been set at 0.075 mg/L as the PES measurements (50th percentile) were 0.029 mg/L (i.e. a recalibrated A/B category).

There is some indication of elevated nutrient levels throughout the reach; probably due to intensive agricultural activities in the area. The presence of toxic algae has been reported in the Lower Orange River passing Upington, as well as intermittently high concentrations of some metals, i.e. Al, Cd, Cu and Pb, in the Upington and Neusberg weir area.

5.4 DIATOMS

Physico-chemical metric	EcoSpecs	Class rank	TPC	PES
pH	6 - 8	3	≥2; ≤4	4
Salinity	Fresh brackish (100 - 500 µS/cm)	2	<2	2
Nutrients	Slightly elevated concentrations of organically bound nitrogen.	2-3	≤3	2
Oxygen	Moderate saturation (<50% saturation)	≤3	≤4	3
Organics	β-ά-mesosaprobic: BOD_5 < 7 (10) mg/l, O_2 deficit <50% (Critical level of pollution)	3	<3	2
	ά-mesosaprobic: BOD5 < 13mg/l, O2 deficit <75% (Strongly polluted)	3		
SPI Score	9.2 – 12.8	C EC	≥ 9	13.3 (B/C)

Physico-chemical data indicates that nutrients are elevated at times and that toxicants may be problematic. The EC was a C EC for EFR O3. Although the diatom based PES is a B/C the community indicated an increase in organic pollution and, based on the diatom results of this site and other sites within MRU E the community is more representative of a c EC. Therefore the EcoSpecs and TPCs was set at a C EC. With increased nutrients, organics and salinity from agriculture, CPLA and ESBM which are already dominating the community and further increases in valve counts APED, *Nitzschia* species including NIFR; CDUB, RUNI and TPSN will result in the deterioration of most metrics leading to a deteriorated EC. A check should be done for valve deformities with every count as this is indicative of metal contamination. An increase in species which have an affinity for calcium-based salinity should be noted.

5.5 RIPARIAN VEGETATION

5.5.1 EcoSpec and TPC description relating to VEGRAI monitoring data: PES and REC

PES	REC	Assessed Component	Zone Assessed	EcoSpec (for PES)	TPC (for PES)	EcoSpec (for REC or AEC up)	Baseline (measured value,% cover) / Note
B/C	B	Exotic Invasion (perennial exotics)	Riparian zone	Exotic species cover less than 15%	An increase in exotic species cover above 15%	Exotic species cover less than 10%	VEGRAI recorded 0% marginal zone, <10% (lower zone), <15% (upper zone); < 10% Upper MCB.
		Terrestrialisation	Marginal Zone	The absence of terrestrial woody species	A presence of terrestrial woody species	The absence of terrestrial woody species	0
			Lower Zone	Maintain terrestrial woody species cover less than 5%	An increase in terrestrial woody species cover above 5%	The absence of terrestrial woody species	0
			Upper Zone + MCB	Maintain terrestrial woody species cover less than 20%	An increase in terrestrial woody species cover above 20%	Terrestrial woody cover between 10 and 15%	3
		Indigenous Riparian Woody Cover	Marginal Zone	Indigenous riparian woody cover between 5 - 60%	A decrease in riparian woody species cover below 5% OR an increase above 60%	Indigenous riparian woody cover between 5 and 40%	8
			Lower Zone	Indigenous riparian woody cover between 10 - 50%	A decrease in riparian woody species cover below 10% OR an increase above 50%	Indigenous riparian woody cover between 10 and 50%	10
			Upper Zone	Indigenous riparian woody cover between 30 - 70%	A decrease in riparian woody species cover below 30% OR an increase above 70%	Indigenous riparian woody cover between 30 and 70%	41

			MCB	Indigenous riparian woody cover above 40%	A decrease in riparian woody species cover below 40%	Indigenous riparian woody cover above 40%	42
		Phragmites (reed) cover	Marginal Zone	Reed cover below 40%	An increase in reed cover above 40%	Reed cover below 40%	30
			Lower Zone	Reed cover below 40%	An increase in reed cover above 40%	Reed cover below 40%	7

5.5.2 EcoSpecs and TPCs summary relating to VEGRAI monitoring data

Colour coding in the table below refers to:

EcoSpec	TPC	Baseline (measured)	PES B/C	REC B

Class	Perennial Exotics	Reeds	Riparian Woody	Terrestrial Woody
Marginal Zone				
A	0	10 - 20	10-20	0
A/B	1-5	20 - 30	20-40	0
B	5-10	<10; 30-40	5-10	0
B/C	10-15		40-60	1-5
C	15-20	40-50	60 - 70; 1-5	5-10
C/D	20-30			10-15
D	30-50	50-60	70-80; 0	15-20
D/E	50-60			20-30
E	60-70	60-80	> 80	30-40
E/F	70-80			40-50
F	>80	> 80		>50
Lower Zone				
A	0	10 - 20	20-40	0
A/B	1-5	20 - 30		0
B	5-10	<10; 30-40	10-20; 40-50	1-5
B/C	10-15			5-10
C	15-20	40-50	5-10; 50-60	10-15
C/D	20-30			15-20
D	30-50	50-60	<5; 60-70	20-30
D/E	50-60			30-40
E	60-70	60-80	70-80	40-50
E/F	70-80			50-60
F	>80	> 80	>80	>60
Upper Zone				
A	0		40-60	0-10
A/B	1-5			10-20

Class	Perennial Exotics	Reeds	Riparian Woody	Terrestrial Woody
B	5-10		30-40; 60-70	20-30
B/C	10-15			30-40
C	15-20		20-30; 70-80	40-50
C/D	20-30			50-60
D	30-50		10-20; 80-90	60-70
D/E	50-60			70-80
E	60-70		< 10; > 90	80-90
E/F	70-80			>90
F	>80			
Upper Zone (MCB)				
A	0		60-80	0-10
A/B	1-5			10-20
B	5-10		40-60; >80	20-30
B/C	10-15			30-40
C	15-20		20-40	40-50
C/D	20-30			50-60
D	30-50		10-20	60-70
D/E	50-60			70-80
E	60-70		< 10	80-90
E/F	70-80			>90
F	>80			

5.6 RIVERINE FAUNA

5.6.1 Group 1 species identified as most appropriate indicator species being dependant on instream associated aquatic habitats

Species	Present per survey	Individual numbers
Whitebreasted cormorant (*Phalacrocorax carbo*)	(The species being accounted for in all the surveys / number of surveys) Unknown	Unknown
African Darter (*Anhinga melanogaster*)	Unknown	Unknown
Giant kingfisher (*Ceryle maxima*)	Unknown	Unknown
Cape clawless otter (*Aonyx capensis*)	Unknown	Unknown
Water mongoose (*Atilax paludinosus*)	Unknown	Unknown
Pied kingfisher (*Ceryle rudis*)	Unknown	Unknown
Common river frog (*Amietia angolensis*)	Unknown	Unknown
monitor (*Varanus niloticus niloticus*)	Unknown	Unknown
African fish eagle (*Haliaeetus vocifer*)	Unknown	Unknown
Goliath heron (*Ardea goliath*)	Unknown	Unknown

5.6.2 Group 2 species identified as most appropriate indicator species being dependant on marginal habitats

Species	Present per survey	Individual numbers
Hadeda Ibis (*Bostrychia hagedash*)	(The species being accounted for in all the surveys / number of surveys) Unknown	Unknown
Comm Common Waxbill (*Estrilda astrild*)	Unknown	Unknown
Blackheaded heron (*Ardea melanocephala*)	Unknown	Unknown
Threebanded plover (*Charadrius tricollaris*)	Unknown	Unknown
Common Greenshank (*Tringa nebularia*)	Unknown	Unknown
Wood sandpiper (*Tringa glareola*)	Unknown	Unknown
Common sandpiper (*Actitis hypoleucos*)	Unknown	Unknown
Marsh sandpiper (*Tringa stagnatilis*)	Unknown	Unknown
Avocet /Pied Avocet (*Recurvirostra avosetta*)	Unknown	Unknown
Black-winged stilt (*Himantopus himantopus*)	Unknown	Unknown

5.6.3 Group 3 species identified as most appropriate indicator species being dependant on habitats provided in the upper zones, especially woody vegetation

Species	Present per survey	Individual numbers
Redeyed Dove (*Streptopelia semitorquata*)	(The species being accounted for in all the surveys / number of surveys) Unknown	Unknown
Fairy Flycatcher *(Stenostira scita)*	Unknown	Unknown
Karoo Scrub-Robin *(Cercotrichas coryphaeus)*	Unknown	Unknown
Vervet monkey (*Cercopithecus aethiops*)	Unknown	Unknown
Small-spotted genet (*Genetta genetta*)	Unknown	Unknown
White-backed Mousebird *(Colius colius)*	Unknown	Unknown
Karoo thrush (*Turdus smithi*)	Unknown	Unknown
Cape Robin *(Cossypha caffra)*	Unknown	Unknown
Pririt Batis *(Batis pririt)*	Unknown	Unknown
Orange river white-eye (*Zosterops pallidus*)	Unknown	Unknown

5.7 FISH

EcoSpecs and TPCs are provided for FRAI data in Section 5.7.1. The spatial FROC of EFR O3 is provided in Section 5.7.2 and indicates the FROC under reference, PES and REC conditions as well as TPCs for baseline (PES) conditions.

5.7.1 EcoSpecs and TPCs relating to FRAI data: PES and REC

Rank	Metric	Indicator spp.	PES					REC
			EFR SITE			REACH		REACH
			ECOSPECS	TPC (Biotic)	TPC (Habitat)	Indicator SPP.	TPC (Biotic)	ECOSPECS
1	Species richness	all indigenous species	Eight (8) of the expected (under reference conditions) 12 indigenous fish species were sampled during the baseline (EFR) survey.	Less than 7 fish species sampled during a survey when habitat can be sampled efficiently.	Loss in diversity, abundance and condition of velocity-depth categories and cover features.	All indigenous species	Baseline (PES) FRAI score of 77% (high C) calculated for the reach. Any decreased FROC in reach of especially ASCL, BAEN, BHOS, BKIM and BTRI (refer to sheet 5-FROC: Table 2) OR FRAI scores decreasing below 68.4% low C).	An improvement from PES FROC in the reach for especially ASCL, BAEN, BHOS, BKIM & BPAU should be indicative of reaching/maintaining the REC (refer to 5-FROC sheet for more detail).
2	Relative abundance	n/a	During baseline (EFR) surveys fish were sampled at 0.7 individuals per minute using a SAMUS electrofisher (wading and from boat). Relative abundance was very low.	Relative abundance of less than 0.5 individual per minute sampled at the site (during same season as baseline data) when habitat can be sampled efficiently and using comparable method.	N/a	N/a	N/a	
9	Alien/introduced fish species	any alien/introduced spp.	One indigenous introduced fish species (OMOS) was sampled at the site during the baseline EFR survey at 0.12 ind/min.	Present of any additional alien/introduced species at site, or OMOS present at relative abundance > 0.2 ind/min.	N/A	Any alien/introduced spp.	CCAR, GAFF and introduced OMOS previously sampled in reach. Presence of any additional alien/introduced species.	

Rank	Metric	Indicator spp.	PES						REC
			EFR SITE			REACH			REACH
			ECOSPECS	TPC (Biotic)	TPC (Habitat)	Indicator SPP.		TPC (Biotic)	ECOSPECS
3	FD Habitats, substrate, Flow dependant spp (flow alteration),	BAEN, LCAP	The two indicator species of this metric group, BAEN and LCAP, were sampled at the site during the baseline EFR surveys. BAEN was present at 0.1 ind/min while LCAP was present at 0.2 indiv/min.	BAEN and/or LCAP absent during any survey OR present at relative abundance of <0.05 ind/min for BAEN or <0.1 ind/min for LCAP.	Reduced suitability (abundance & quality) of FD habitats (i.e. decreased flows, increased zero flows), increased sedimentation of riffle/rapid substrates, excessive algal growth on substrates, Increased sedimentation of riffle/rapid substrates, excessive algal growth on substrates.	LCAP	BAEN	Any decreased FROC in reach of LCAP and BAEN (refer to sheet 5-FROC, column F: Table 2)	
3	FS habitats,	BAEN, BKIM	The two indicator species of this metric group, BAEN and BKIM were sampled at the site during the baseline EFR surveys. BAEN was present at 0.1 ind/min while BKIM was very scarce at 0.01 indiv/min.	BAEN absent during any survey , BKIM absent during 2 consecutive surveys (>50% of time) OR BAEN present at relative abundance of <0.05 ind/min.	Reduced suitability (abundance & quality) of FS habitats (i.e. decreased flows, increased zero flows), [To be quantified with RHAM]	BAEN	BKIM	Any decreased FROC in reach of BAEN and BKIM (refer to sheet 5-FROC, column F: Table 2)	
3	Water quality intolerance,	BKIM, LCAP	The two indicator species of this metric group, BKIM and LCAP, were sampled at the site during the baseline EFR surveys. BKIM was very scarce at 0.01 ind/min while LCAP was present at 0.2 indiv/min.	LCAP absent during any survey, BKIM absent during 2 consecutive surveys (>50% of time) OR present at relative abundance of <0.1 ind/min for LCAP.	Decreased water quality	BKIM	LCAP	Any decreased FROC in reach of BKIM & LCAP (refer to sheet 5-FROC, column F: Table 2)	
4	SD habitats	LCAP, CGAR	The two indicator species of this metric group, CGAR and LCAP, were sampled at the site during the baseline EFR surveys. BKIM was very scarce at 0.01 ind/min while LCAP was present at 0.2 indiv/min.	LCAP absent during any survey, CGAR absent during 2 consecutive surveys (>50% of time) OR present at relative abundance of <0.1 ind/min for LCAP.	Reduced suitability of SD habitats (i.e. increased flows in dry season, alteration in seasonality, sedimentation of pools).	LCAP	CGAR	Any decreased FROC in reach of LCAP & CGAR (refer to sheet 5-FROC, column F: Table 2)	

Rank	Metric	Indicator spp.	PES						REC
			EFR SITE			REACH			REACH
			ECOSPECS	TPC (Biotic)	TPC (Habitat)	Indicator SPP.		TPC (Biotic)	ECOSPECS
5	Water column	MBRE, BAEN	The two indicator species of this metric BAEN and MBRE were sampled at the site during the baseline EFR surveys. BAEN was present at 0.1 ind/min while MBRE was very scarce at 0.18 indiv/min.	BAEN and/or MBRE absent during any survey OR present at relative abundance of <0.05 ind/min for BAEN or <0.15 ind/min for LCAP.	Reduction in suitability of water column (i.e. increased sedimentation of pools)	MBRE	BAEN	Any decreased FROC in reach of MBRE & BAEN (refer to sheet 5-FROC, column F: Table 2)	
6	SS habitats	PPHI, MBRE	The two indicator species of this metric PPHI and MBRE were sampled at the site during the baseline EFR surveys. PPHI was present at 0.03 ind/min while MBRE was very scarce at 0.18 indiv/min.	PPHI and/or MBRE absent during any survey OR present at relative abundance of <0.01 ind/min for PPHI or <0.15 ind/min for MBRE.	Significant change in SS habitat suitability (i.e. increased flows, altered seasonality, increased sedimentation of slow habitats).	PPHI	MBRE	Any decreased FROC in reach of PPHI & MBRE (refer to sheet 5-FROC, column F: Table 2)	
7	Overhanging vegetation	PPHI, BPAU	The two indicator species of this metric PPHI and BPAU (in the absence of TSPA at the site) were sampled at the site during the baseline EFR surveys. PPHI was present at 0.03 ind/min while BPAU was very scarce at 0.01 indiv/min.	PPHI and/or BPAU absent during any survey OR present at relative abundance of <0.01 ind/min for PPHI or <0.01 ind/min for BPAU	Significant change in overhanging vegetation habitats (e.g. Overgrazing, vegetation removal, alien vegetation encroachment, erosion).	PPHI	TSPA	Any decreased FROC in reach of PPHI & TSPA (refer to sheet 5-FROC, column F: Table 2)	
8	Undercut banks	PPHI	With ASCL not sampled at the EFR site during the baseline survey, PPHI is the only indicator species of this metric. PPHI was present at 0.03 ind/min.	PPHI absent during any survey OR present at relative abundance of <0.01 ind/min for PPHI.	Significant change in undercut bank habitats (e.g. bank erosion, reduced flows)	PPHI	ASCL	Any decreased FROC in reach of PPHI & ASCL (refer to sheet 5-FROC, column F: Table 2)	
8	Instream vegetation	BPAU	With TSPA not sampled at the EFR site during the baseline survey, BPAU is the only indicator species of this metric. BPAU was very scarce at 0.01 indiv/min.	BPAU absent during any survey OR present at relative abundance of <0.01 ind/min for BPAU	Significant change in instream vegetation (e.g. Flow modification, water quality deterioration, esp increased turbidity).	TSPA	BPAU	Any decreased FROC in reach of TSPA & BPAU (refer to sheet 5-FROC, column F: Table 2)	

5.7.2 Spatial FROC under reference, PES and REC conditions and TPCs for baseline (PES) conditions

	Species (Abbr.)	Scientific names: Reference species (Introduced species excluded)	Spatial FROC			
			REFERENCE (A)	PES/REC (C)		AEC up (B)
			Reference FROC	EC: Observed and habitat	FROC TPC	Expected/ derived FROC

				derived FROC		
INDIGENOUS	ASCL	AUSTROGLANIS SCLATERI (BOULENGER, 1901)	2	1	0	1.5
	BAEN*	LABEOBARBUS AENEUS (BURCHELL, 1822)	4	3	2	3.5
	BHOS	BARBUS HOSPES BARNARD, 1938	3	1.5	0	2
	BKIM*	LABEOBARBUS KIMBERLEYENSIS GILCHRIST & THOMPSON, 1913	3	2	1	2.5
	BPAU*	BARBUS PALUDINOSUS PETERS, 1852	3	2	1	2.5
	BTRI*	BARBUS TRIMACULATUS PETERS, 1852	3	2.5	1.5	2.5
	CGAR*	CLARIAS GARIEPINUS (BURCHELL, 1822)	4	3.5	2.5	3.5
	LCAP*	LABEO CAPENSIS (SMITH, 1841)	5	4	3	4
	LUMB	LABEO UMBRATUS (SMITH, 1841)	1	0.5	0	0.5
	MBRE*	MESOBOLA BREVIANALIS (BOULENGER, 1908)	4	3.5	2.5	3.5
	PPHI*	PSEUDOCRENILABRUS PHILANDER (WEBER, 1897)	4	3	2	3
	TSPA	TILAPIA SPARRMANII SMITH, 1840	4	3	2	3
INTRO1	OMOS*	OREOCHROMIS MOSSAMBICUS (PETERS, 1852)				

* Sampled at EFR site during baseline survey (June 2010)

1 Introduced species

5.8 MACROINVERTEBRATES

5.8.1 SASS Data

Available SASS5 data collected at or near Site EFR O3 are summarised as follows:

Site	Date	SASS Score	ASPT	No. of Taxa	Reference
D7ORAN-NEUSB	13-Oct-2004	53	5.3	10	Ramogale Sekwele (River Health Database)
D8ORAN-BLOUP	13-Oct-2004	59	4.9	12	Ramogale Sekwele (River Health Database)
D8ORAN-BLOUP	20-Apr-2005	75	5.8	13	Ramogale Sekwele (River Health Database)
D8ORAN-ONSEE	20-Apr-2005	55	3.7	15	Ramogale Sekwele (River Health Database)
D7ORAN-NEUSB	23-Nov-2005	106	5.3	20	Ramogale Sekwele (River Health Database)
D8ORAN-BLOUP	23-Nov-2005	113	5.1	22	Ramogale Sekwele (River Health Database)
D8ORAN-ONSEE	23-Nov-2005	88	4.9	18	Ramogale Sekwele (River Health Database)
EWR O3	29-May-2010	133	6.7	20	This study

5.8.2 Indicator Taxa

The following macroinvertebrate taxa, arranged in order of decreasing sensitivity to water quality deterioration were selected as monitoring indicators for EFR O3.

	Flow				Substrate					Wat Qual		
	Standing (<0.1 m/s)	Slow (0.1-0.3 m/s)	Mod (0.3-0.6 m/s)	Fast (>0.6 m/s)	Hard	Boulders/Bedrock	Loose Cobble	Veg	Sand, Gravel, Mud	High (SASS>11)	Mod (SASS 7-10)	Low (SASS 4-6)
Baetidae (>2 spp)	•	•	●	●	•	•	●	•	•		**10**	
Leptophlebiidae (Prongills)	•	●	•		•	•	●	•	●		**9**	
Tricorythidae (Stout crawlers)			•	●	•	●	●	•			**9**	
Atyidae (Freshwater shrimps)		•						●			**8**	
Elmidae (Riffle beetles)			•	●		●	•	•			**8**	
Leptoceridae	•	●	•					●				**6**

• = Partial Preference ● = Strong Preference

5.8.3 EcoSpecs and TPCs

EcoSpecs and TPCs for the PES at EFR O3 are provided below.

ECOSPECS	TPCs
SASS5 Score between 143 and 161.	SASS5 Score < 150.
ASPT between 5.9 and 6.3.	ASPT < 6.1.
MIRAI Score between 60% and 79%.	MIRAI Score < 63%.
At least 50% indicator taxa present.	Three or more Indicator Taxa absent.
Indicator Taxa	
Baetidae >2 spp.	Baetidae < 2 spp on any one survey.
Leptophlebiidae present.	Leptophlebiidae absent on two or more consecutive surveys.
Tricorythidae present (except winter).	Tricorythidae absent on two or more consecutive surveys.
Atyidae present.	Atyidae absent on two or more consecutive surveys.
Elmidae present.	Elmidae absent on two or more consecutive surveys.
Leptoceridae present.	Leptoceridae absent on two or more consecutive surveys.

6 EFR O4 – VIOOLSDRIFT ORANGE RIVER

A summary of the site EcoClassification results are provided below (Volume 1: EFR).

6.1 ECOCLASSIFICATION SUMMARY OF EFRO4

EFR O4 (VIOOLSDRIF)

EIS: HIGH

Highest scoring metrics are instream and riparian rare/endangered biota, unique instream and riparian biota,, migration corridor, National Park

PES: B/C

Decreased frequency of large floods. Agricultural return flows and mining activities – water quality problems. Higher low flows than natural in the dry season, drought and dry periods. Decreased low flows at other times. Presence of alien fish species and barrier effects of dams. Decreased sedimentation due to lack of large floods and upstream dams. Alien vegetation and fish.

REC:

Improved (higher) wet season base flows. Clear vegetation aliens – will improve the vegetation condition in the marginal and lower zones. Control grazing and trampling

AEC:

Increased mining with associated impacts on water quality and decreased wet season base flows. Decreased floods. Increased vegetation aliens (esp. *Prosopis* sp.). Habitat loss for a large percentage of time due to decreased flows. Vegetation: Increased sedges due to increased sedimentation

Driver Components	PES	Trend	REC	AEC↓
IHI HYDROLOGY	D			
WATER QUALITY	C/D		C/D	D
GEOMORPHOLOGY	C	0	C	C
INSTREAM IHI	D			
RIPARIAN IHI	D			
Response Components	**PES**	**Trend**	**REC**	**AEC↓**
FISH	C	0	B/C	D
MACRO INVERTEBRATES	C	0	B/C	D
INSTREAM	C	0	B/C	D
RIPARIAN VEGETATION	C	-	B	C/D
RIVERINE FAUNA	C	-	B/C	C/D
ECOSTATUS	C	-	B/C	D
EIS	HIGH			

EcoSpecs and TPCs for EFR O4 are provided for the different components in Section 6.2 to 6.6.

6.2 GEOMORPHOLOGY

6.2.1 Site Description and focus of TPCs

The historical aerial photographic record indicates that small (bedrock core) bars within this pool rapid/riffle reach are becoming slightly more extensive and increasingly vegetated, probably due to the very reduced floods. The present MAR is about one third of the virgin MAR. The key issues for this site are the degradation of the channel bed and bars due to reduced scouring floods. The condition of this site is important since it provides an indication of the flows and floods being provided to the downstream Ramsar wetland at the mouth.

6.2.2 EcoSpecs and TPCs relating to GAI monitoring data

Descriptor	Motivation for Monitoring	
Reach morphology: Area of and vegetation cover on bars	The reduced size and frequency of floods at this site allow for the growth of bars from deposition and vegetation encroachment in to the channel due to reduced scouring events. This can cause a loss of instream habitat area and reduce sediment delivery downstream as the bars become increasingly stable. To maintain the PES, no expansion of the islands in the reach should occur. (refer to Appendix E – Volume 3).	
	TPCs:	Any increase in the area of bars in the reach from the 2010 level Any increased extent of vegetation on the bars in the reach from the 2010 level
	Approach:	Aerial photographic or Google Earth imagery analysis of the site.
	Frequency:	Every 5 years
In-channel morphology: Bed sediment size distribution	Reduced flood sizes and frequency are reducing bed scour and removal of accumulated fines deposits. This may lead to smothering of the larger sediments by fines materials which will reduce in-channel habitat condition.	
	TPCs:	Fines (silts and sands) should not comprise more than 60% of the bed sediment in the active channel. Gravels and small cobbles (5-100 mm) should comprise at least 30% of the bed sediment in the active channel.
	Approach:	Resurvey of the bed sediment at the EFR cross-section site during the low flow season.
	Frequency:	Every 2-5 years

6.3 WATER QUALITY

6.3.1 EcoSpecs relating to water quality

River: Orange		EFR O4, Vioolsdrift
Water quality metrics		**EcoSpecs: PES**
Inorganic salts*	$MgSO_4$	The 95th percentile of the data must be ≤ 16 mg/L.
	Na_2SO_4	*Calculate if TPC for EC exceeded.*
	$MgCl_2$	The 95th percentile of the data must be ≤ 15 mg/L.
	$CaCl_2$	The 95th percentile of the data must be ≤ 21 mg/L.
	NaCl	*Calculate if TPC for EC exceeded.*
	$CaSO_4$	The 95th percentile of the data must be ≤ 351 mg/L.
Physical variables	EC	The 95th percentile of the data must be ≤ 85 mS/m.
	pH	The 5th percentile of the data must range from 6.5 to 8.0, and the 95th percentile from 8.0 to 8.8
	Temperature	Large changes to temperature regime occur most of the time, with fluctuations of no more than 4°C.
	Dissolved oxygen	The 5th percentile of the data must be ≥ 6 mg/L.

River: Orange		EFR O4, Vioolsdrift
Water quality metrics		**EcoSpecs: PES**
	Turbidity	Vary by a small amount from the natural turbidity range; minor silting of instream habitats acceptable.
Nutrients	TIN	The 50th percentile of the data must be ≤ 0.25 mg/L
	$PO_4 - P$	The 50th percentile of the data must be ≤ 0.125 mg/L.
Response variables	Chl – a phytoplankton	The 50th percentile of the data must be ≤ 20 mg/L ♦
	Chl – a periphyton	The 50th percentile of the data must be ≤ 84 mg/m^2 ♦
	Toxics	The 95th percentile of the data must be within the Chronic Effects Value (CEV) as stated in DWAF (1996) #

* To be generated using TEACHA when the TPC for EC is exceeded or salt pollution is expected. Should the TPC for any integrated salt be exceeded, particularly Na_2SO_4 and NaCl in this instance consult a water quality specialist and check the validity of the EcoSpec and TPC by running TEACHA on the data used to determine the PES. If necessary, adjust the boundary for the EcoSpec and TPC for the relevant salt.

#: Although category boundaries exist in the Water quality Reserve manual (DWAF, 2008) for a number of toxicants, adherence to the CEV (DWAF, 1996) is recommended for the present state. Data collection and testing will need to be undertaken to assess the suitability of these objectives.

♦: low confidence. EcoSpec and TPC boundaries may need adjusting as data become available.

6.3.2 TPCs relating to water quality data

River: Orange		EFR O4, Vioolsdrift
Water quality metrics		**TPCs**
Inorganic salts*	$MgSO_4$	The 95th percentile of the data is 13 – 16 mg/L.
	Na_2SO_4	*Set TPC once EcoSpec has been calculated, as required.*
	$MgCl_2$	The 95th percentile of the data is 12 – 15 mg/L.
	$CaCl_2$	The 95th percentile of the data is 17 – 21 mg/L.
	NaCl	*Set TPC once EcoSpec has been calculated, as required.*
	$CaSO_4$	The 95th percentile of the data is 280 – 351 mg/L.
Physical variables	EC	The 95th percentile of the data is > 75 (present state) and < 85 mS/m ***
	pH	The 5th percentile of the data is <6.7 and >7.8, and the 95th percentile is <8.2 and >8.6
	Temperature	Rely on biotic response data to evaluate whether the TPC for temperature is being reached.
	Dissolved oxygen	The 5th percentile of the data is < 6.2 mg/L.
	Turbidity	Silting of habitats. Check biotic response for habitat-related changes.
Nutrients	TIN	The 50th percentile of the data must be 0.2 – 0.25 mg/L
	$PO_4 - P$	The 50th percentile of the data must be 0.06 – 0. 075 mg/L **
Response variables	Chl - a	The 50th percentile of the data must be 16 – 20 µg/L♦

River: Orange		**EFR O4, Vioolsdrift**
Water quality metrics		**TPCs**
	phytoplankton	
	Chl - a periphyton	The 50th percentile of the data must be 67 – 84 mg/m^2 ♦
	Toxics	An impact is expected if the 95th percentile of the data exceeds the Target Water Quality Range (TWQR) as stated in DWAF (1996).

* To be generated using TEACHA when the TPC for EC is exceeded or salt pollution is expected. Should the TPC for any integrated salt be exceeded, consult a water quality specialist and check the validity of the EcoSpec and TPC by running TEACHA on the data used to determine the PES. If necessary, adjust the boundary for the EcoSpec and TPC for the relevant salt.

♦: low confidence. EcoSpec and TPC boundaries may need adjusting as data become available.

**: Although the upper boundary for the relevant phosphate category is 0.125 mg/L, the TPC has been set at 0.075 mg/L as the PES measurements (50th percentile) were 0.026 mg/L (i.e. a C/D category).

***: TPC assigned based on expert judgement due to the small margin between present state and the upper limit of the category.

There is an increase in salinity and nutrients along the reaches of the lower Orange River due to a cumulative effect of irrigation return flows (although limited agriculture in the immediate area) and evaporative losses along the river. The concentration of some metals was reported to be intermittently high at Pella and Vioolsdrift – some evidence of these elevations was seen, although data is very limited. Various incidents suggest toxic events in the river, so the exceedance of TPCs for toxics should be carefully monitored.

6.4 DIATOMS

Physico-chemical metric	EcoSpecs	Class rank	TPC	PES
pH	6 - 8	3	≥2; ≤4	5*
Salinity	Fresh brackish (100 - 500 µS/cm)	2	<2	3
Nutrients	Slightly elevated concentrations of organically bound nitrogen.	2-3	≤3	2
Oxygen	Moderate saturation (<50% saturation)	≤3	≤4	3
Organics	β-ά-mesosaprobic: BOD$_5$ < 7 (10) mg/l, O$_2$ deficit <50% (Critical level of pollution) ά-mesosaprobic: BOD5 < 13mg/l, O2 deficit <75% (Strongly polluted)	3	<3	3
SPI Score	9.2 – 12.8	C EC	≥ 9	11.4 (C)

* The PES exceeds the TPC currently.

Physico-chemical data indicates that phosphates are elevated and metal concentrations have been reported to be intermittently high at Pella and Vioolsdrift. The biological water quality was a C EC for EFR O4 as was the overall assessment of MRU F and the EcoSpecs and TPCs were set at a C EC. Currently ESBM, CPLA and CDUB are dominant and an increase in nutrients and organics levels during reduced flow periods will lead to deterioration in most metrics. Organic pollution is problematic at this site, as indicated by the dominant species. A check should be done for valve deformities with every count as this is indicative of metal contamination. An increase in species which have an affinity for calcium-based salinity should be noted. COSS occurs at 2% dominance and was recorded for the first time during 2010. The presence of this species should be monitored to ascertain if the presence of this species is due to the hot springs found in the area or due to increased salinity levels due to agricultural return flows.

6.5 RIPARIAN VEGETATION

6.5.1 EcoSpec and TPC description relating to VEGRAI monitoring data: PES and REC

PES	REC	Assessed Component	Zone Assessed	EcoSpec (for PES)	TPC (for PES)	EcoSpec (for REC or AEC up)	Baseline (measured value,% cover) / Note
C	B	Exotic Invasion (perennial exotics)	Riparian zone	Maintain exotic species cover below 20%	An increase in exotic species cover above 20%	Maintain exotic species cover below 10%	ranged from 0 on marginal zone to 13 on upper zone
		Terrestrialisation	Marginal Zone	Maintain an absence of terrestrial species	An occurrence of terrestrial species	Maintain an absence of terrestrial species	0
			Lower Zone	Maintain cover of terrestrial species at 10% or less	An increase above 10% of terrestrial species cover	Maintain an absence of terrestrial species	0
			Upper Zone	Maintain cover of terrestrial species at 30% or less	An increase above 30% of terrestrial species cover	Maintain cover of terrestrial species at 15% or less	0
			MCB	Maintain cover of terrestrial species at 30% or less	An increase above 30% of terrestrial species cover	Maintain cover of terrestrial species at 15% or less	3
		Indigenous Riparian Woody Cover	Marginal Zone	Maintain indigenous riparian woody cover between 1 and 80%	An increase in riparian woody species cover above 80% OR an absence of riparian woody species	Maintain indigenous riparian woody cover between 5 and 60%	3
			Lower Zone	Maintain indigenous riparian woody cover below 60%	An increase in riparian woody species cover above 60%	Maintain indigenous riparian woody cover between 5 and 50%	10
			Upper Zone	Maintain indigenous	An increase in riparian woody	Maintain indigenous	9

PES	REC	Assessed Component	Zone Assessed	EcoSpec (for PES)	TPC (for PES)	EcoSpec (for REC or AEC up)	Baseline (measured value,% cover) / Note
				riparian woody cover between 5 and 90%	species cover above 90% OR a decrease below 5%	riparian woody cover between 10 and 70%	
			MCB	Maintain indigenous riparian woody cover above 10%	A decrease in riparian woody cover below 10%	Maintain indigenous riparian woody cover above 40%	43
		Phragmites (reed) cover	Marginal Zone	Maintain reed cover below 50%	An increase in reed cover above 50%	Maintain reed cover below 40%	30
			Lower Zone	Maintain reed cover below 50%	An increase in reed cover above 50%	Maintain reed cover below 40%	20

6.5.2 EcoSpecs and TPCs summary relating to VEGRAI monitoring data

Colour coding in the table below refers to:

EcoSpec	TPC	Baseline (measured)	PES C	REC B

Class	Perennial Exotics	Reeds	Riparian Woody	Terrestrial Woody
Marginal Zone				
A	0	10-20	10-30	0
A/B	1-5	20-30	30-40	0
B	5-10	<10; 30-40	40-60; 5-10	0
B/C	10-15		60-70	0
C	15-20	40-50	70-80; 1-5	0
C/D	20-30			0
D	30-50	50-60	>80; 0	1-5
D/E	50-60			5-10
E	60-70	60-80		10-15
E/F	70-80			15-20
F	>80	>80		>20
Lower Zone				
A	0	10-20	10-20	0
A/B	1-5	20-30	20-40	0
B	5-10	<10; 30-40	5-10; 40-50	0
B/C	10-15			1-5
C	15-20	40-50	<5; 50-60	5-10
C/D	20-30			10-15

Class	Perennial Exotics	Reeds	Riparian Woody	Terrestrial Woody
D	30-50	50-60	60-70	15-20
D/E	50-60			20-30
E	60-70	60-80	70-80	30-40
E/F	70-80			40-50
F	>80	>80	>80	>50
Upper Zone				
A	0		30-50	0-5
A/B	1-5			5-10
B	5-10		10-20; 60-70	10-15
B/C	10-15			15-20
C	15-20		5-10; 80-90	20-30
C/D	20-30			30-40
D	30-50		<5; >90	40-50
D/E	50-60			50-60
E	60-70			60-70
E/F	70-80			70-80
F	>80			>80
Upper Zone (MCB)				
A	0		70-80	0-5
A/B	1-5		60-70; 80-90	5-10
B	5-10		40-60; >90	10-15
B/C	10-15		20-40	15-20
C	15-20		10-20	20-30
C/D	20-30		<10	30-40
D	30-50			40-50
D/E	50-60			50-60
E	60-70			60-70
E/F	70-80			70-80
F	>80			>80

6.6 RIVERINE FAUNA

See Chapter 5 sub-section 5.6

6.7 FISH

EcoSpecs and TPCs are provided for FRAI data in Section 6.7.1. The spatial FROC of EFR O4 is provided in Section 6.7.2 and indicates the FROC under reference, PES and REC conditions as well as TPCs for baseline (PES) conditions.

6.7.1 EcoSpecs and TPCs relating to FRAI data: PES and REC

Rank	metric	Indicator spp.	PES					REC
			EFR SITE			REACH		REACH
			ECOSPECS	TPC (Biotic)	TPC (Habitat)	Indicator spp.	TPC (Biotic)	ECOSPECS
1	Species richness	all indigenous species	Ten (10) of the expected (under reference conditions) 12 indigenous fish species were sampled during the baseline (EFR) survey.	Less than 8 fish species sampled during a survey when habitat can be sampled efficiently.	Loss in diversity, abundance and condition of velocity-depth categories and cover features.	All indigenous species	Baseline (PES) FRAI score of 65% (C) calculated for the reach. Any decreased FROC in reach of especially ASCL, BAEN, BHOS, BKIM and BTRI (refer to sheet 5-FROC: Table 2) OR FRAI scores decreasing below 62.02% (C/D).	An improvement from PES FROC in the reach for especially BAEN, BHOS, BKIM, BPAU & BTRI should be indicative of reaching/maintaining the REC (refer to 5-FROC sheet for more detail).
2	Relative abundance	n/a	During baseline (EFR) surveys fish were sampled at 3.5 individuals per minute using a SAMUS electrofisher (wading and from boat). Overall relative abundance was high.	Relative abundance of less than 2.5 individual per minute sampled at the site (during same season as baseline data) when habitat can be sampled efficiently and using comparable method.	N/a	N/a	N/a	
8	Alien fish species	any alien/introduced spp.	One indigenous introduced fish species (OMOS) and one alien (CCAR) were sampled at the site during the baseline EFR survey. OMOS was recorded at 0.2 ind/min, while CCAR was scarce at 0.02 ind/min.	Present of any additional alien/introduced species at site, or OMOS present at relative abundance > 0.25 ind/min and CCAR >0.1 ind/min.	N/A	Any alien/ introduced spp.	Increase in the number of alien species (>2 species in reach) OR presence of any alien species other than CCAR & OMOS.	
3	FD Habitats, substrate, Flow dependant spp (flow alteration), SD habitats,	BAEN, LCAP	The two indicator species of this metric group, BAEN and LCAP, were sampled at the site during the baseline EFR surveys. BAEN was present at 0.2 ind/min while LCAP was present at 1 indiv/min.	BAEN and/or LCAP absent during any survey OR present at relative abundance of <0.1 ind/min for BAEN or <0.7 ind/min for LCAP.	Reduced suitability (abundance & quality) of FD habitats (i.e. decreased flows, increased zero flows), increased sedimentation of riffle/rapid substrates, excessive algal growth on substrates, Increased sedimentation of riffle/rapid substrates, excessive algal growth on substrates.	BAEN; LCAP	Any decreased FROC in reach of BAEN and LCAP (refer to sheet 5-FROC, column F: Table 2)	

Rank	metric	Indicator spp.	PES						REC
			EFR SITE			REACH			REACH
			ECOSPECS	TPC (Biotic)	TPC (Habitat)	Indicator spp.		TPC (Biotic)	ECOSPECS
3	FS habitats,	BAEN, BKIM	The two indicator species of this metric group, BAEN and BKIM were sampled at the site during the baseline EFR surveys. BAEN was present at 0.2 ind/min while BKIM was very scarce at 0.01 indiv/min.	BAEN absent during any survey OR BKIM absent during 2 consecutive surveys (>50% of time) AND/OR BAEN present at relative abundance of <0.1 ind/min.	Reduced suitability (abundance & quality) of FS habitats (i.e. decreased flows, increased zero flows).	BAEN	BKIM	Any decreased FROC in reach of BAEN and BKIM (refer to sheet 5-FROC, column F: Table 2)	
3	Water quality intolerance,	BKIM, LCAP	The two indicator species of this metric group, BKIM and LCAP, were sampled at the site during the baseline EFR surveys. BKIM was very scarce at 0.01 ind/min while LCAP was abundant at 1 indiv/min.	LCAP absent during any survey, BKIM absent during 2 consecutive surveys (>50% of time) OR present at relative abundance of <0.7 ind/min for LCAP.	Decreased water quality	BKIM	LCAP	Any decreased FROC in reach of BKIM & LCAP (refer to sheet 5-FROC, column F: Table 2)	
4	Water column	BAEN, MBRE	The two indicator species of this metric BAEN and MBRE were sampled at the site during the baseline EFR surveys. BAEN was present at 0.2 ind/min while MBRE was abundant at 1 indiv/min.	BAEN and/or MBRE absent during any survey OR present at relative abundance of <0.1 ind/min for BAEN or <0.7 ind/min for MBRE	Reduction in suitability of water column (i.e. increased sedimentation of pools)	BAEN	MBRE	Any decreased FROC in reach of BAEN & MBRE (refer to sheet 5-FROC, column F: Table 2)	
6	SS habitats , overhanging vegetation	PPHI, TSPA	The two indicator species of this metric PPHI and TSPA were sampled at the site during the baseline EFR surveys. PPHI was present at 0.02 ind/min while TSPA was very scarce at 0.24 indiv/min.	PPHI and/or TSPA absent during any survey OR present at relative abundance of <0.01 ind/min for PPHI or <0.15 ind/min for TSPA.	Significant change in SS habitat suitability (i.e. increased flows, altered seasonality, increased sedimentation of slow habitats). Significant change in overhanging vegetation habitats.	PPHI	TSPA	Any decreased FROC in reach of PPHI & TSPA (refer to sheet 5-FROC, column F: Table 2)	
7	Undercut banks	PPHI	With ASCL not sampled at the EFR site during the baseline survey, PPHI is the only indicator species of this metric. PPHI was present at 0.02 ind/min.	PPHI absent during any survey OR present at relative abundance of <0.01 ind/min for PPHI.	Significant change in undercut bank habitats (e.g. bank erosion, reduced flows)	PPHI	ASCL	Any decreased FROC in reach of PPHI & ASCL (refer to sheet 5-FROC, column F: Table 2)	

Rank	metric	Indicator spp.	PES						REC
			EFR SITE			REACH			REACH
			ECOSPECS	TPC (Biotic)	TPC (Habitat)	Indicator spp.		TPC (Biotic)	ECOSPECS
5	Instream vegetation	BPAU, TSPA	The two indicator species of this metric BPAU and TSPA were sampled at the site during the baseline EFR surveys. BPAU was present at 0.02 ind/min while TSPA was very scarce at 0.24 indiv/min.	BPAU and/or TSPA absent during any survey OR present at relative abundance of <0.01 ind/min for BPAU or <0.15 ind/min for TSPA.	Significant change in overhanging vegetation habitats.	BPAU	TSPA	Any decreased FROC in reach of BPAU & TSPA (refer to sheet 5-FROC, column F: Table 2)	

6.7.2 Spatial FROC under reference, PES and REC conditions and TPCs for baseline (PES) conditions

	Species (Abbr.)	Scientific names: Reference species (Introduced species excluded)	Spatial FROC			
			REFERENCE (A)	PES/REC (C)		AEC up (B)
			Reference FROC	EC: Observed and habitat derived FROC	FROC TPC	Expected/ derived FROC
INDIGENOUS	BPAU*	BARBUS PALUDINOSUS PETERS, 1852	4	3	2	3.5
	BTRI*	BARBUS TRIMACULATUS PETERS, 1852	4	3	2	3.5
	CGAR*	CLARIAS GARIEPINUS (BURCHELL, 1822)	4	3.5	2.5	3.5
	LCAP*	LABEO CAPENSIS (SMITH, 1841)	5	4	3	4.5
	LUMB	LABEO UMBRATUS (SMITH, 1841)	1	0.5	0	0.5
	MBRE*	MESOBOLA BREVIANALIS (BOULENGER, 1908)	4	3.5	2.5	3.5
	PPHI*	PSEUDOCRENILABRUS PHILANDER (WEBER, 1897)	4	3	2	3.5
	TSPA*	TILAPIA SPARRMANII SMITH, 1840	4	3	2	3.5
ALIEN	CCAR*	CYPRINUS CARPIO LINNAEUS, 1758				
	OMOS*	OREOCHROMIS MOSSAMBICUS (PETERS, 1852)				

* Sampled at site during EFR survey

6.8 MACROINVERTEBRATES

6.8.1 SASS Data

Available SASS5 data collected at or near Site EFR O4 are summarised as follows:

Site	Date	SASS Score	ASPT	No. of Taxa	Reference
D8ORAN-SENDU	13-Jan-2004	146	5.8	25	Rob Palmer (River Health Database)
D8ORAN-SENDD	14-Jan-2004	98	5.4	18	Rob Palmer (River Health Database)
D8ORAN-PELLA	14-Oct-2004	34	5.7	6	Ramogale Sekwele (River Health Database)
D8ORAN-RICHT	18-Apr-2005	33	4.7	7	Ramogale Sekwele (River Health Database)
D8ORAN-PELLA	19-Apr-2005	38	4.8	8	Ramogale Sekwele (River Health Database)
D8ORAN-GOODH	19-Apr-2005	28	4	7	Ramogale Sekwele (River Health Database)
D8ORAN-VIOOL	19-Apr-2005	44	4.9	9	Ramogale Sekwele (River Health Database)
D8ORAN-RICHT	21-Nov-2005	115	5.5	21	Ramogale Sekwele (River Health Database)
D8ORAN-GOODH	22-Nov-2005	63	5.7	11	Ramogale Sekwele (River Health Database)
D8ORAN-VIOOL	22-Nov-2005	62	4.8	13	Ramogale Sekwele (River Health Database)
EWR O4	26-May-2010	96	6.0	16	This study

6.8.2 Indicator Taxa

The following macroinvertebrate taxa, arranged in order of decreasing sensitivity to water quality deterioration were selected as monitoring indicators for EFR O4.

	Flow				Substrate					Wat Qual		
	Standing (<0.1 m/s)	Slow (0.1-0.3 m/s)	Mod (0.3-0.6 m/s)	Fast (>0.6 m/s)	Hard	Boulders/Bedrock	Loose Cobble	Veg	Sand, Gravel, Mud	High (SASS>11)	Mod (SASS 7-10)	Low (SASS 4-6)
Perlidae (Stoneflies)			•	●		•	●			**12**		
Baetidae (>2 spp)	•	•	●	●	•	•	●	•	•		**10**	
Tricorythidae (Stout crawlers)			•	●	•	●	●	•			**9**	
Atyidae (Freshwater shrimps)		•						●			**8**	
Elmidae (Riffle beetles)			•	●		●	•	•			**8**	
Hydropsychidae (2 spp)			•	●	•	●	•					**6**

• = Partial Preference ● = Strong Preference

6.8.3 EcoSpecs and TPCs

EcoSpecs and TPCs for the PES at EFR O4 are provided below.

ECOSPECS	TPCs
SASS5 Score between 143 and 161.	SASS5 Score < 150
ASPT between 5.9 and 6.3.	ASPT < 6.1.
MIRAI Score between 60% and 79%.	MIRAI Score < 63%.
At least 50% indicator taxa present.	Three or more Indicator Taxa absent.
Indicator Taxa	
Perlidae present.	Perlidae absent on two or more consecutive surveys.
Baetidae >2 spp.	Baetidae < 2 spp on any one survey.

Tricorythidae present.	Tricorythidae absent on two or more consecutive surveys.
Atyidae present.	Atyidae absent on two or more consecutive surveys.
Elmidae present.	Elmidae absent on two or more consecutive surveys.
Hydropsychidae present.	Hydropsychidae absent on two or more consecutive surveys.

7 EFR C5 – UPPER CALEDON

A summary of the site EcoClassification results are provided below (Volume 1: EFR).

7.1 ECOCLASSIFICATION SUMMARY OF EFR C5

<table>
<tr><th colspan="2">EFR C5 (UPPER CALEDON)</th></tr>
<tr><td>EIS: LOW.
Highest scoring metrices are rare and endangered riparian species, instream biota's taxon richness, and sensitive instream habitat (to flow changes).

PES: C/D
Grazing and trampling, bank erosion, sedimentation, exotic vegetation and fish species.

REC:C/D
EIS is low - provides no motivation for improvement. The problems are also all non-flow related.

AEC ↓: D
Decreased flows due to increased abstraction. Reduced dilatation - impact temperature and oxygen. Increased sedimentation (continued erosion). Habitat loss for a large percentage of time. Vegetation – increased sedges due to increased sedimentation</td>
<td>
<table>
<tr><th>Driver Components</th><th>PES</th><th>Trend</th><th>AEC↓</th></tr>
<tr><td>IHI HYDROLOGY</td><td>A/B</td><td></td><td></td></tr>
<tr><td>DIATOMS</td><td>B</td><td></td><td></td></tr>
<tr><td>WATER QUALITY</td><td>B/C</td><td></td><td>C</td></tr>
<tr><td>GEOMORPHOLOGY</td><td>C</td><td>-</td><td>C/D</td></tr>
<tr><th>Response Components</th><th>PES</th><th>Trend</th><th>AEC↓</th></tr>
<tr><td>FISH</td><td>D</td><td>0</td><td>E</td></tr>
<tr><td>MACRO INVERTEBRATES</td><td>C</td><td>0</td><td>C/D</td></tr>
<tr><td>INSTREAM</td><td>D</td><td>0</td><td>D</td></tr>
<tr><td>RIPARIAN VEGETATION</td><td>C</td><td>0</td><td>C</td></tr>
<tr><td>ECOSTATUS</td><td>C/D</td><td></td><td>D</td></tr>
<tr><td>INSTREAM IHI</td><td colspan="3">B/C</td></tr>
<tr><td>RIPARIAN IHI</td><td colspan="3">C</td></tr>
<tr><td>EIS</td><td colspan="3">LOW</td></tr>
</table>
</td></tr>
</table>

EcoSpecs and TPCs for EFR C5 are provided for the different components in Section 7.2 to 7.6.

7.2 GEOMORPHOLOGY

7.2.1 Site Description and focus of TPCs

Degradation of the site is not as a result of flow alterations but instead primarily attributed to intensive grazing and trampling of the banks and the high sediment loads (sands and fines) being introduced from the upstream hillslopes and associated drainage lines. All the instream biotic indicators demonstrate the problems of increased sedimentation in the active channel - smothering of gravels and cobbles has converted extensive sections of the reach to a sandbed channel.

The river here is too small to make use of large-scale historical aerial photography for monitoring purposes and the focus of geomorphological monitoring is thus field-based at the site scale.

7.2.2 EcoSpecs and TPCs relating to GAI monitoring data: PES

Descriptor	Motivation for Monitoring
In-channel morphology:	Elevated sediment inputs from the catchment due to widespread degradation and vegetation removal are smothering larger gravel and cobble bed elements. This will lead to smothering of

Descriptor	Motivation for Monitoring	
Bed sediment size distribution	the larger sediments by fines materials which will reduce in-channel habitat condition.	
	TPCs:	Gravels and larger bed elements (>5mm) should comprise more than 30% of the bed sediment in the active channel. Cobbles (>100mm) should comprise at least 10% of the bed sediment in the active channel.
	Approach:	Resurvey of the bed sediment in the active channel during the low flow season. Area to be sampled is from the EFR cross-section upstream for approximately100 metres mapping out in-channel bed sediment deposits.
	Frequency:	Every 2-5 years
Channel morphology: Bed and bank stability	Denudation of the banks from intensive grazing and trampling have destabilised the banks, and high sediment loads have created relatively unstable lower banks. A reduced grazing pressure is required to allow revegetation of the banks so that the fines load within the active channel can begin to reduce and enable improved instream habitat conditions. Further widening of the channel is undesirable.	
	TPCs:	Any further widening of the active channel or macro-channel banks
	Approach:	Resurvey of the cross-section at the EFR site
	Frequency:	Every 5 years

7.3 WATER QUALITY

7.3.1 EcoSpecs relating to water quality: PES

River: Caledon		EFR C5, Upper Caledon
Water quality metrics		EcoSpecs: PES
Inorganic salts*	$MgSO_4$	The 95th percentile of the data must be ≤ 16 mg/L.
	Na_2SO_4	The 95th percentile of the data must be ≤ 20 mg/L.
	$MgCl_2$	The 95th percentile of the data must be ≤ 15 mg/L.
	$CaCl_2$	The 95th percentile of the data must be ≤ 21 mg/L.
	NaCl	The 95th percentile of the data must be ≤ 45 mg/L.
	$CaSO_4$	The 95th percentile of the data must be ≤ 351 mg/L.
Physical variables	EC	The 95th percentile of the data must be ≤ 55 mS/m.
	pH	The 5th percentile of the data must range from 6.5 to 8.0, and the 95th percentile from 8.0 to 8.8
	Temperature	Natural temperature regime.
	Dissolved oxygen	The 5th percentile of the data must be ≥ 8 mg/L.
	Turbidity	Moderate changes to the catchment land-use have resulted in fluctuating unnaturally high sediment loads and high turbidity levels.
Nutrients	TIN	The 50th percentile of the data must be ≤ 0.25 mg/L
	PO_4 – P	The 50th percentile of the data must be ≤ 0.125 mg/L
Response variables	Chl – a	The 50th percentile of the data must be ≤ 10 mg/L

River: Caledon		EFR C5, Upper Caledon
Water quality metrics		**EcoSpecs: PES**
	phytoplankton	
	Chl - a periphyton	The 50th percentile of the data must be ≤ 21 mg/m^2
	Toxics	The 95th percentile of the data must be within the Chronic Effects Value (CEV) as stated in DWAF (1996) #

* To be generated using TEACHA when the TPC for EC is exceeded or salt pollution is expected. Should the TPC for any integrated salt be exceeded, consult a water quality specialist and check the validity of the EcoSpec and TPC by running TEACHA on the data used to determine the PES. If necessary, adjust the boundary for the EcoSpec and TPC for the relevant salt. This is particularly relevant as salinities are naturally elevated.

#: Although category boundaries exist in the Water quality Reserve manual (DWAF, 2008) for a number of toxicants, adherence to the CEV (DWAF, 1996) is recommended for the present state. Data collection and testing will need to be undertaken to assess the suitability of these objectives.

7.3.2 TPCs relating to water quality data

River: Caledon		EFR C5, Upper Caledon
Water quality metrics		**TPCs**
Inorganic salts*	$MgSO_4$	The 95th percentile of the data is 13 – 16 mg/L.
	Na_2SO_4	The 95th percentile of the data is 16 – 20 mg/L.
	$MgCl_2$	The 95th percentile of the data is 12 – 15 mg/L.
	$CaCl_2$	The 95th percentile of the data is 17 – 21 mg/L.
	NaCl	The 95th percentile of the data is 36 – 45 mg/L.
	$CaSO_4$	The 95th percentile of the data is 280 – 351 mg/L.
Physical variables	EC	The 95th percentile of the data is 44 – 55 mS/m.
	pH	The 5th percentile of the data is <6.7 and >7.8, and the 95th percentile is <8.2 and >8.6
	Temperature	Rely on biotic response data to evaluate whether the TPC for temperature is being reached. Some highly temperature sensitive species in lower abundance and frequency of occurrence than expected for reference.
	Dissolved oxygen	The 5th percentile of the data is < 8.2 mg/L.
	Turbidity	Increases in siltation beyond a 95th percentile of 30 mg/L to be accompanied by checks on biotic response, particularly macroinvertebrates, for habitat-related changes.♦
Nutrients	TIN	The 50th percentile of the data must be 0.2 – 0.25 mg/L
	PO_4 – P	The 50th percentile of the data must be 0.06 – 0.075 mg/L**
Response variables	Chl - a phytoplankton	The 50th percentile of the data must be 8 – 10 µg/L.
	Chl - a	The 50th percentile of the data must be 17 – 21 mg/m^2.

River: Caledon		EFR C5, Upper Caledon
Water quality metrics		**TPCs**
	periphyton	
	Toxics	An impact is expected if the 95th percentile of the data exceeds the Target Water Quality Range (TWQR) as stated in DWAF (1996).

* To be generated using TEACHA when the TPC for EC is exceeded or salt pollution is expected, and TPCs adjusted where required.

♦: low confidence. EcoSpec and TPC boundaries may need adjusting as data become available.

**: Although the upper boundary for the relevant phosphate category is 0.125 mg/L, the TPC has been set at 0.075 mg/L as the PES measurements (50th percentile) were 0.039 mg/L (i.e. a recalibrated B/C category).

The Lesotho Lowlands area upstream of the Caledon River is susceptible to erosion and due to poor land management the Caledon River transports large sediment loads. Despite being a naturally highly turbid system, some of the highest sediment yields in SA are to be found within the Caledon River system (Rooseboom, 1992).

7.4 DIATOMS

Physico-chemical metric	EcoSpecs	Class rank	TPC	PES
pH	6 - 8 Circumneutral.	3	≥2; ≤4	4
Salinity	Fresh brackish (100 - 500 µS/cm).	2	<2	2
Oxygen	Fairly high saturation (<75% saturation)	≤2	≤3	2
Nutrients	Slightly elevated concentrations of organically bound nitrogen.	1-2	≤2	2
Organics	β-mesosaprobic: BOD_5 < 4mg/l, O_2 deficit <30%.	1-2	<2	2
SPI score	≤13.3 - ≥16.8.	B EC	≥ 13.3	14.2 (B)

Physico-chemical data indicates elevated phosphate levels and the EC was set at a B/C. Class limits fall within the defined TPC ranges set for a B PES as the SPI scores of the sites within this reach all fluctuated within a B EC (2008 - 2010). Currently the dominant species, NDIS, RUNI, GOMS and CPLA are indicative of periodically elevated organics, salinity and nutrient levels. An increase in GOMS, EOMI, and SSEM (more than 2% of the total count (400)) will be due to organic pollution resulting in deterioration of the oxygen, organics, and nutrient metrics, and impact on the overall integrity of the diatom community. A check should be done for valve deformities with every count as this is indicative of metal contamination. An increase in species which have an affinity for calcium-based salinity should be noted.

7.5 RIPARIAN VEGETATION

7.5.1 EcoSpec and TPC description relating to VEGRAI monitoring data: PES and REC

PES	REC	Assessed Component	Zone Assessed	EcoSpec (for PES)	TPC (for PES)	EcoSpec (for REC or AEC up)	Baseline (measured value,% cover) / Note
C	B/C	Exotic Invasion (perennial exotics)	Riparian Zone	Exotic species cover less than 20%	An increase in exotic species cover above 20%	Exotic species cover less than 15%	Data show 10% cover by exotic perennial species on the marginal; 20% in lower zone and 14% for upper zone.
		Terrestrialisation	Marginal Zone	The absence of terrestrial woody species	The presence of terrestrial woody species	The absence of terrestrial woody species	0
			Lower Zone	Terrestrial woody cover less than 10%	An increase in terrestrial woody species cover >10%	The terrestrial woody species less than 5%	5
			Upper Zone	Terrestrial woody cover less than 15%	An increase in terrestrial woody species cover >15%	Terrestrial woody cover less than 10%	7
		Indigenous Riparian Woody Cover	Marginal & Lower Zones	Indigenous riparian woody cover less than 40%	A decrease in riparian woody cover below 1% OR an increase above 40%	Indigenous riparian woody cover between 1and 5%	Marginal 8; Lower 8
		Non-woody Indigenous Cover (sedges)	Marginal and Lower Zone	Sedge cover between 10% and 80%	A decrease in sedge cover below 10% OR an increase above 80%	Sedge cover increase > 10% and a decrease in 60%	Marginal 30; Lower 20 and Upper 5 for sedge cover - decision is to split the two dominant Non-woody Indigenous plant species into grasses and sedges with the sedges in the marginal and lower zone dominant and the grasses in the upper zone dominant
		Non-woody Indigenous Cover (grasses)	Upper Zone	Grass cover above 30%	Grass cover less than 30%	Grass cover above 40%	Marginal 15; Lower 60 and Upper 75 for grass cover - decision is to split the two dominant Non-woody Indigenous plant species into grasses and sedges with the sedges in the lower zone dominant and the grasses in the upper zone dominant

PES	REC	Assessed Component	Zone Assessed	EcoSpec (for PES)	TPC (for PES)	EcoSpec (for REC or AEC up)	Baseline (measured value,% cover) / Note
		Phragmites (reed) cover	Riparian Zone	The absence of reeds	The presence of reeds	The absence of reeds	0

7.5.2 EcoSpecs and TPCs summary relating to VEGRAI monitoring data

Colour coding in the table below refers to:

EcoSpec	TPC	Baseline (measured)	PES C	REC B/C

Class	Perennial Exotics	Sedges		Riparian Woody		Terrestrial Woody
Marginal Zone						
A	0	20-60		10-20		0
A/B	1-5			5-10		0
B	5-10	10-20			20-30	0
B/C	10-15			1-5		0
C	15-20		60-80	0	30-40	0
C/D	20-30	< 10				0
D	30-50		> 80		>40	1-5
D/E	50-60					5-10
E	60-70					10-15
E/F	70-80					15-20
F	>80					>20
Lower Zone						
A	0	20-60		10-20		0
A/B	1-5			5-10		0
B	5-10	10-20			20-30	0
B/C	10-15			1-5		1-5
C	15-20		60-80	0	30-40	5-10
C/D	20-30	< 10				10-15
D	30-50		> 80		>40	15-20
D/E	50-60					20-30
E	60-70					30-40
E/F	70-80					40-50
F	>80					>50
Upper Zone						
A	0	> 70				0
A/B	1-5	60-70				0
B	5-10	50-60				1-5
B/C	10-15	40-50				5-10
C	15-20	30-40				10-15

Class	Perennial Exotics	Sedges	Riparian Woody	Terrestrial Woody
C/D	20-30			15-20
D	30-50	20-30		20-30
D/E	50-60			30-40
E	60-70	10-20		40-50
E/F	70-80			50-60
F	>80	<10		>60

7.6 FISH

EcoSpecs and TPCs are provided for FRAI data in Section 7.6.1. The spatial FROC of EFR C5 is provided in Section 7.6.2 and indicates the FROC under reference, PES and REC conditions as well as TPCs for baseline (PES) conditions.

7.6.1 EcoSpecs and TPCs relating to FRAI data: PES and REC

Rank	Metric	Indicator spp.	PES					REC
			EFR SITE			REACH		REACH
			ECOSPECS	TPC (Biotic)	TPC (Habitat)	Indicator spp.	TPC (Biotic)	ECOSPECS
1	Species richness	all indigenous species	Only one (1) of the expected (under reference conditions) 4 indigenous fish species were sampled during the baseline (EFR) survey.	Less than 1 fish species sampled during a survey when habitat can be sampled efficiently.	Loss in diversity, abundance and condition of velocity-depth categories and cover features.	All indigenous species	Baseline (PES) FRAI score of 43% (D) calculated for the reach. Any further decreased FROC in reach of BAEN & BANO (refer to sheet 5-FROC: Table 2) OR FRAI scores decreasing below 42.01%. (D/E).	An improvement from PES FROC in the reach for BAEN and BANO, and the return of LCAP and ACL should be indicative of reaching/maintaining the REC (refer to 5-FROC sheet for more detail).
2	Relative abundance	n/a	During baseline (EFR) surveys fish were very scarce at the site, sampled at 0.02 individuals per minute using a SAMUS electrofisher (wading).	Relative abundance of less than 0.02 individual per minute sampled at the site (during same season as baseline data) when habitat can be sampled efficiently and using comparable method.	N/a	N/a	N/a	
4	Alien fish species	any alien /introduced spp.	No alien fish species were sampled at EFR site during baseline survey.	Presence of any alien fish species during a survey.	N/A	Any alien/introduced spp.	Increase in the number of alien species (>2 species in reach) OR presence of any alien species other than MSAL & STRU.	

Rank	Metric	Indicator spp.	PES						REC
			EFR SITE			REACH			REACH
			ECOSPECS	TPC (Biotic)	TPC (Habitat)	Indicator spp.		TPC (Biotic)	ECOSPECS
3	FD Habitats, Flow dependant spp (flow alteration), substrate, water column	BAEN	BAEN was the only fish species sampled at the site during the EFR baseline survey. It was very scarce, sampled at 0.02 ind/min.	Absence of BAEN during any survey, or being present at <0.02 ind/min.	Reduced suitability (abundance & quality) of FD habitats, flow modification and reduced availability of water column (i.e. decreased flows, increased zero flows, sedimentation of pools).	BAEN	(LCAP)	Any decreased FROC in reach of BAEN (refer to sheet 5-FROC, column F: Table 2) (LCAP expected to be have been lost in reach)	
3	FS habitats,	BAEN			Reduced suitability (abundance & quality) of FS habitats (i.e. decreased flows, increased zero flows), [To be quantified with RHAM]	BAEN	(LCAP)	Any decreased FROC in reach of BAEN (refer to sheet 5-FROC, column F: Table 2) (LCAP expected to be have been lost in reach)	
3	Water quality intolerance, SD habitats.	BAEN			Decreased water quality (construction of dams that influence temperature and oxygen regime, pollution, etc.). Reduced suitability of SD habitats (i.e. increased flows in dry season, alteration in seasonality, sedimentation of pools).	BANO	(LCAP)	Any decreased FROC in reach of BANO (refer to sheet 5-FROC, column F: Table 2) (LCAP expected to be have been lost in reach)	
6	SS habitats , overhanging vegetation & instream vegetation.	(BANO)	None of the indicator taxa of these metrics were sampled at the EFR site during the baseline EFR survey. If these species are sampled at the site in future, TPCs should be determined.		Significant change in SS habitat suitability (i.e. increased flows, altered seasonality, increased sedimentation of slow habitats). Significant change in instream and overhanging vegetation habitats.	BANO		Any decreased FROC in reach of BANO (refer to sheet 5-FROC, column F: Table 2)	
5	Undercut banks	(ASCL)			Significant change in undercut bank habitats.	ASCL		In the absence of ASCL in the reach, there are no indicators of this metric available.	

7.6.2 Spatial FROC under reference, PES and REC conditions and TPCs for baseline (PES) conditions

	Species	Scientific names: Reference species	Spatial FROC

	(Abbr.)	(Introduced species excluded)	REFERENCE	PES/REC (C)		AEC up (B)
			Reference FROC	EC: Observed and habitat derived FROC	FROC TPC	Expected/ derived FROC
INDIGENOUS	BANO	BARBUS ANOPLUS WEBER, 1897	4	2	1	3
	BAEN*	LABEOBARBUS AENEUS (BURCHELL, 1822)	4	3	2	4
	LCAP	LABEO CAPENSIS (SMITH, 1841)	4	0	0	3
	ASCL	AUSTROGLANIS SCLATERI (BOULENGER, 1901)	2	0	0	1

* Sampled at EFR site during baseline survey (June 2010)

7.7 MACROINVERTEBRATES

7.7.1 SASS Data

Available SASS5 data collected at or near Site EFR C5 are summarised as follows:

Site	Date	SASS Score	ASPT	No. of Taxa	Reference
Clean Stream EWR3	16-Sep-2003	106	5.3	20	Niehaus and Kotze (2003)
Clean Stream EWR3	17-Sep-2003	89	4.5	20	Niehaus and Kotze (2003)
EWR C5	22-Jun-2010	97	5.7	17	This study

7.7.2 Indicator Taxa

The following macroinvertebrate taxa, arranged in order of decreasing sensitivity to water quality deterioration were selected as monitoring indicators for EFR C5.

	Flow				Substrate					Wat Qual		
	Standing (<0.1 m/s)	Slow (0.1-0.3 m/s)	Mod (0.3-0.6 m/s)	Fast (>0.6 m/s)	Hard	Boulders/Bedrock	Loose Cobble	Veg	Sand, Gravel, Mud	High (SASS>11)	Mod (SASS 7-10)	Low (SASS 4-6)
Heptageniidae (Flathead mayflies)		•	•	•		•	●	•		**13**		
Baetidae (>2 spp)	•	•	●	●	•	•	●	•	•		**10**	
Leptophlebiidae (Prongills)	•	●	•		•	•	●	•	●		**9**	
Gomphidae		●							●			**6**
Ancylidae	•	•	•	•	•	•	•	•				**6**
Simuliidae (Blackflies)		•	●	●	●	●	●	●				**5**

• = Partial Preference ● = Strong Preference

7.7.3 EcoSpecs and TPCs

EcoSpecs and TPCs for the PES at EFR C5 are provided below.

ECOSPECS	TPCs
SASS5 Score between 150 and 169.	SASS5 Score < 158.
ASPT between 5.9 and 6.2.	ASPT < 6.0
MIRAI Score between 60% and 79%.	MIRAI Score < 63%.
At least 50% indicator taxa present.	Three or more Indicator Taxa absent.
Indicator Taxa	
Heptageniidae present.	Heptageniidae absent on two or more consecutive surveys.
Baetidae >2 spp.	Baetidae < 2 spp on any one survey.
Leptophlebiidae present.	Leptophlebiidae absent on two or more consecutive surveys.
Gomphidae present.	Gomphidae absent on two or more consecutive surveys.
Ancylidae present.	Ancylidae absent on two or more consecutive surveys.
Simuliidae present.	Simuliidae absent on two or more consecutive surveys.

8 EFR C6 – LOWER CALEDON

A summary of the site EcoClassification results are provided below (Volume 1: EFR).

8.1 ECOCLASSIFICATION SUMMARY OF EFR C6

EFR C6 (LOWER CALEDON)

EIS: LOW

The highest scoring matrices are rare and endangered riparian species.

PES:C

Sedimentation (bank erosion), significantly reduced base flows, alien fish species.

REC:C

EIS is low - provides no motivation for improvement.

AEC ↑: B/C

Bottom releases must take place during the wet season and not during low flow conditions. Low flows must be improved. No zero flows or limited duration

Driver Components	PES	Trend	AEC↑
IHI HYDROLOGY	E		
DIATOMS	C		
WATER QUALITY	C		C(+)
GEOMORPHOLOGY	C/D	0	C
Response Components	**PES**	**Trend**	**AEC↑**
FISH	D	0	C
MACRO INVERTEBRATES	D	0	C
INSTREAM	D	0	C
RIPARIAN VEGETATION	B	0	B
ECOSTATUS	C		B/C
INSTREAM IHI	E		
RIPARIAN IHI	B/C		
EIS	LOW		

EcoSpecs and TPCs for EFR C6 are provided for the different components in Section 8.2 to 8.6.

8.2 GEOMORPHOLOGY

8.2.1 Site Description and focus of TPCs

The sediment load from this catchment is naturally high but is elevated due to clearing for cultivation on soils that are naturally easily erodible. It is also possible that at very high flood flows this is site is in the backup of the Gariep Dam. The elevated sediment loads have caused sedimentation of the lower riparian zone and smothering of the instream habitats, resulting in reduction in deep pools and gravels within the channel.

8.2.2 EcoSpecs and TPCs relating to GAI monitoring data: PES

Descriptor	Motivation for Monitoring	
In-channel morphology: Bed sediment size distribution	Elevated sediment inputs from the catchment are smothering larger (gravel) and bedrock bed elements, causing a reduction in in-channel habitat diversity.	
	TPCs:	Fines (silts and fine sands <1mm) should comprise not more than 60% of the bed sediment in the active channel. Gravels and small cobbles (10-100mm) should comprise at least 20% of the bed sediment in the active channel.

	Approach:	Resurvey of the bed sediment at the EFR cross-section site during the low flow season.
	Frequency:	Every 2-5 years
Channel morphology: Aggradation	Elevated sediment inputs from the catchment are potentially reducing channel depth. Infilling of the channel will result in loss of bedrock areas and deepwater habitats, and smothering of marginal habitats, and is therefore undesirable from a habitat diversity perspective.	
	TPCs:	Any bed elevation (aggradation) of the active channel relative to the 2010 condition.
	Approach:	Resurvey of the cross-section at the EFR site
	Frequency:	Every 5 years

Figure 8.1 The bed at this site is being smothered by fines deposits. This is reducing inchannel habitat diversity.

8.3 WATER QUALITY

8.3.1 EcoSpecs relating to water quality: PES

River: Caledon		EFR C6, Lower Caledon
Water quality metrics		**EcoSpecs: PES**
Inorganic salts*	$MgSO_4$	The 95th percentile of the data must be ≤ 16 mg/L.
	Na_2SO_4	The 95th percentile of the data must be ≤ 20 mg/L.
	$MgCl_2$	The 95th percentile of the data must be ≤ 15 mg/L.
	$CaCl_2$	The 95th percentile of the data must be ≤ 21 mg/L.
	NaCl	The 95th percentile of the data must be ≤ 45 mg/L.
	$CaSO_4$	The 95th percentile of the data must be ≤ 351 mg/L.
Physical variables	EC	The 95th percentile of the data must be ≤ 55 mS/m.
	pH	The 5th percentile of the data must range from 6.5 to 8.0, and the 95th percentile from 8.0 to 8.8

River: Caledon		EFR C6, Lower Caledon
Water quality metrics		**EcoSpecs: PES**
	Temperature	Some minor man-made changes to the river but no known changes to the natural temperature regime.
	Dissolved oxygen	The 5th percentile of the data must be ≥ 7 mg/L.
	Turbidity	Large changes to the catchment land-use have resulted in unnaturally high sediment loads and high turbidity levels most of the time. Large silt loads lead to a serious reduction in habitat.
Nutrients	TIN	The 50th percentile of the data must be ≤ 0.7 mg/L
	$PO_4 – P$	The 50th percentile of the data must be ≤ 0.125 mg/L.
Response variables	Chl – a phytoplankton	The 50th percentile of the data must be ≤ 10 mg/L
	Chl – a periphyton	The 50th percentile of the data must be ≤ 21 mg/m^2
	Toxics	The 95th percentile of the data must be within the Chronic Effects Value (CEV) as stated in DWAF (1996) #

* To be generated using TEACHA when the TPC for EC is exceeded or salt pollution is expected. Should the TPC for any integrated salt be exceeded, consult a water quality specialist and check the validity of the EcoSpec and TPC by running TEACHA on the data used to determine the PES. If necessary, adjust the boundary for the EcoSpec and TPC for the relevant salt.

#: Although category boundaries exist in the Water quality Reserve manual (DWAF, 2008) for a number of toxicants, adherence to the CEV (DWAF, 1996) is recommended for the present state. Data collection and testing will need to be undertaken to assess the suitability of these objectives.

♦: low confidence. EcoSpec and TPC boundaries may need adjusting as data become available.

8.3.2 TPCs relating to water quality data

River: Caledon		EFR C6, Lower Caledon
Water quality metrics		**TPCs**
Inorganic salts*	$MgSO_4$	The 95th percentile of the data is 13 – 16 mg/L.
	Na_2SO_4	The 95th percentile of the data is 16 – 20 mg/L.
	$MgCl_2$	The 95th percentile of the data is 12 – 15 mg/L.
	$CaCl_2$	The 95th percentile of the data is 17 – 21 mg/L.
	NaCl	The 95th percentile of the data is 36 – 45 mg/L.
	$CaSO_4$	The 95th percentile of the data is 280 – 351 mg/L.
Physical variables	EC	The 95th percentile of the data is 44 – 55 mS/m
	pH	The 5th percentile of the data is <6.7 and >7.8, and the 95th percentile is <8.2 and >8.6
	Temperature	Rely on biotic response data to evaluate whether the TPC for temperature is being reached. Some highly temperature sensitive species are at lower abundances and frequency of occurrence than expected for reference.
	Dissolved	The 5th percentile of the data is < 7.2 mg/L.

River: Caledon		EFR C6, Lower Caledon
Water quality metrics		**TPCs**
	oxygen	
	Turbidity	Increases in siltation beyond a 95th percentile of 1 000 mg/L to be accompanied by checks on biotic response, particularly macroinvertebrates, for habitat-related changes. ♦
Nutrients	TIN	The 50th percentile of the data must be 0.55 – 0.7 mg/L
	PO_4 – P	The 50th percentile of the data must be 0.06 – 0.075 mg/L **
Response variables	Chl - a phytoplankton	The 50th percentile of the data must be 8 – 10 µg/L ♦
	Chl - a periphyton	The 50th percentile of the data must be 17 – 21 mg/m^2 ♦
	Toxics	An impact is expected if the 95th percentile of the data exceeds the Target Water Quality Range (TWQR) as stated in DWAF (1996).

* To be generated using TEACHA when the TPC for EC is exceeded or salt pollution is expected. Should the TPC for any integrated salt be exceeded, consult a water quality specialist and check the validity of the EcoSpec and TPC by running TEACHA on the data used to determine the PES. If necessary, adjust the boundary for the EcoSpec and TPC for the relevant salt.

♦: low confidence. EcoSpec and TPC boundaries may need adjusting as data become available.

**: Although the upper boundary for the relevant phosphate category is 0.125 mg/L, the TPC has been set at 0.075 mg/L as the PES measurements (50th percentile) were 0.037 mg/L (i.e. a recalibrated B/C category).

Turbidities are particularly high in this stretch of the river, with the impact of the dam shown in changing temperature and oxygen levels.

8.4 DIATOMS

Physico-chemical metric	EcoSpecs	Class rank	TPC	PES
pH	6 - 8	3	≥2; ≤4	4
Salinity	Fresh brackish (100 - 500 µS/cm)	2	<2	2
Nutrients	Slightly elevated concentrations of organically bound nitrogen.	2-3	≤3	2
Oxygen	Moderate saturation (<50% saturation)	≤3	≤4	1
Organics	β-ά-mesosaprobic: BOD_5 < 7 (10) mg/l, O_2 deficit <50% (Critical level of pollution)	3	<3	2
	ά-mesosaprobic: BOD5 < 13mg/l, O2 deficit <75% (Strongly polluted)			
SPI Score	9.2 – 12.8	C EC	≥ 9	19.2 (A)

Physico-chemical data indicates that nutrients are elevated at times and that toxicants may be problematic and there are great fluctuations in turbidity in this system. The EC was a C EC for EFR C6 in MRU D. The diatom based PES is an A due to the high abundance of ACHS species in the sample and species diversity was low. This assessment appears not to be a true reflection of conditions at the site, and long-term monitoring will provide more accurate results. The EcoSpecs and TPCs for EFR C6 were set at a C EC and care should be taken to collect samples at the lowest possible flow. An increase in nutrient and organics will lead to an increase in species for an affinity for these conditions and would include: CPLA, NTPT, CPLE MAPE, NANT, *Nitzschia* species and NDIS. An increase in species which have an affinity for calcium-based salinity should be noted. A check should be done for valve deformities with every count as this is indicative of metal contamination. An increase in species which have an affinity for calcium-based salinity should be noted.

8.5 RIPARIAN VEGETATION

8.5.1 EcoSpec and TPC description relating to VEGRAI monitoring data: PES and REC

PES	REC	Assessed Component	Zone Assessed	EcoSpec (for PES)	TPC (for PES)	EcoSpec (for REC or AEC up)	Baseline (measured value,% cover) / Note
B	B	Exotic Invasion (perennial exotics)	Riparian zone	Exotic species cover less than 10%	An increase in exotic species cover above 10%	Exotic species cover less than 10%	no perennial exotics were observed in any zones
		Terrestrialisation	Marginal Zone	Maintain an absence of terrestrial woody species	A presence of terrestrial woody species	Maintain an absence of terrestrial woody species	0
			Lower Zone	Maintain an absence of terrestrial woody species	A presence of terrestrial woody species	Maintain an absence of terrestrial woody species	0
			Upper Zone	Maintain terrestrial woody cover below 15%	An increase in terrestrial woody cover above 15%	Maintain terrestrial woody cover below 15%	2
			MCB	Maintain terrestrial woody cover below 15%	An increase in terrestrial woody cover above 15%	Maintain terrestrial woody cover below 15%	10
		Indigenous Riparian Woody Cover	Marginal Zone	Maintain woody riparian cover between 5 and 60%	An increase in riparian woody species cover above 60% OR a decrease below 5%	Maintain woody riparian cover between 5 and 60%	6
			Lower Zone	Maintain woody riparian cover between 5 and 50%	An increase in riparian woody species cover above 50% OR a decrease below 5%	Maintain woody riparian cover between 5 and 50%	7
			Upper Zone	Maintain woody riparian cover between 10 and 70%	An increase in riparian woody species cover above 70% OR a decrease below 10%	Maintain woody riparian cover between 10 and 70%	6
			MCB	Maintain woody riparian cover above 40%	A decrease in riparian woody species cover below 40%	Maintain woody riparian cover above 40%	50
		Phragmites (reed) cover	Riparian zone	Maintain reed cover below 40%	An increase in reed cover above	Maintain reed cover below 40%	reed cover was below 20% for

					40%		marginal, lower and upper zones (MCB excluded from EcoSpec since reeds are not expected in the zone)

8.5.2 EcoSpecs and TPCs summary relating to VEGRAI monitoring data

Colour coding in the table below refers to:

EcoSpec	TPC	Baseline (measured)	PES B	REC B

Class	Perennial Exotics	Reeds		Riparian Woody		Terrestrialisation
Marginal Zone						
A	0	10-20		10-30		0
A/B	1-5		20-30		30-40	0
B	5-10	<10	30-40	5-10	40-60	0
B/C	10-15				60-70	0
C	15-20		40-50	1-5	70-80	0
C/D	20-30					0
D	30-50		50-60	0	>80	1-5
D/E	50-60					5-10
E	60-70		60-80			10-15
E/F	70-80					15-20
F	>80		>80			>20
Lower Zone						
A	0	10-20		10-20		0
A/B	1-5		20-30		20-40	0
B	5-10	<10	30-40	5-10	40-50	0
B/C	10-15					1-5
C	15-20		40-50	<5	50-60	5-10
C/D	20-30					10-15
D	30-50		50-60		60-70	15-20
D/E	50-60					20-30
E	60-70		60-80		70-80	30-40
E/F	70-80					40-50
F	>80		>80		>80	>50
Upper Zone						
A	0	10-20		30-50		0-5
A/B	1-5		20-30	20-30	50-60	5-10
B	5-10	<10	30-40	10-20	60-70	10-15
B/C	10-15			5-10	70-80	15-20
C	15-20		40-50	<5	80-90	20-30

Class	Perennial Exotics	Reeds		Riparian Woody		Terrestrialisation
C/D	20-30					30-40
D	30-50		50-60		>90	40-50
D/E	50-60					50-60
E	60-70		60-80			60-70
E/F	70-80					70-80
F	>80		>80			>80
Upper Zone (MCB)						
A	0			70-80		0-5
A/B	1-5			60-70	80-90	5-10
B	5-10			40-60	>90	10-15
B/C	10-15			20-40		15-20
C	15-20			10-20		20-30
C/D	20-30			<10		30-40
D	30-50					40-50
D/E	50-60					50-60
E	60-70					60-70
E/F	70-80					70-80
F	>80					>80

8.6 FISH

EcoSpecs and TPCs are provided for FRAI data in Section 8.6.1. The spatial FROC of EFR C6 is provided in Section 8.6.2 and indicates the FROC under reference, PES and REC conditions as well as TPCs for baseline (PES) conditions.

8.6.1 EcoSpecs and TPCs relating to FRAI data: PES and REC

Rank	Metric	Indicator spp.	EFR SITE			REACH		REACH
			ECOSPECS	TPC (Biotic)	TPC (Habitat)	Indicator spp.	TPC (Biotic)	ECOSPECS
1	Species richness	all indigenous species	Only three (3) of the expected (under reference conditions) 8 indigenous fish species were sampled during the baseline (EFR) survey.	Less than 2 fish species sampled during a survey when habitat can be sampled efficiently.	Loss in diversity, abundance and condition of velocity-depth categories and cover features.	All indigenous species	Baseline (PES) FRAI score of 55% (D) calculated for the reach. Any decreased FROC in reach of especially ASCL, BAEN, BKIM & LCAP (refer to sheet 5-FROC: Table 2) OR FRAI scores decreasing below 50%.	An improvement from PES FROC in the reach for especially ASCL, BANO & BKIM should be indicative of reaching/maintaining the REC (refer to 5-FROC sheet for more detail).
2	Relative abundance	n/a	During baseline (EFR) surveys fish were sampled at 0.7 individuals per minute using a SAMUS electrofisher (wading).	Relative abundance of less than 0.5 individual per minute sampled at the site (during same season as baseline data) when habitat can	N/a	N/a	N/a	

Rank	Metric	Indicator spp.	EFR SITE: ECOSPECS	EFR SITE: TPC (Biotic)	EFR SITE: TPC (Habitat)	REACH: Indicator spp.		REACH: TPC (Biotic)	REACH: ECOSPECS
				be sampled efficiently and using comparable method.					
6	Alien fish species	any alien/ introduced spp.	No alien fish species were sampled at EFR site during baseline survey.	Presence of any alien fish species during a survey.	N/A	Any alien/introduced spp.		Increase in the number of alien species (>4 species in reach) OR presence of any alien species other than CCAR, MSAL, STRU & OMYK .	
3	FD Habitats, Flow dependant spp (flow alteration), water column	LCAP, BAEN	The two indicator species of this metric group, BAEN and LCAP, were sampled at the site during the baseline EFR surveys. BAEN was recorded at 0.16 ind/min while LCAP was abundant at 0.56 indiv/min.	BAEN and/or LCAP absent during any survey OR present at relative abundance of <0.1 ind/min for BAEN or <0.4 ind/min for LCAP.	Reduced suitability (abundance & quality) of FD habitats, flow modification and reduced availability of water column (i.e. decreased flows, increased zero flows, sedimentation of pools).	LCAP	BAEN	Any decreased FROC in reach of LCAP and BAEN (refer to sheet 5-FROC, column F: Table 2)	
3	FS habitats,	LCAP, BAEN			Reduced suitability (abundance & quality) of FS habitats (i.e. decreased flows, increased zero flows),	BAEN	ASCL	Any decreased FROC in reach of ASCL and BAEN (refer to sheet 5-FROC, column F: Table 2)	
3	Substrate	LCAP, BAEN			Increased sedimentation of riffle/rapid substrates, excessive algal growth on substrates.	LCAP	LUMB	Any decreased FROC in reach of LCAP and LUMB (refer to sheet 5-FROC, column F: Table 2)	
3	Water quality intolerance,	LCAP, BAEN			Decreased water quality (as indicated by PAI, RHAM visual, or water quality assessments)	BKIM	LCAP	Any decreased FROC in reach of LCAP and BKIM (refer to sheet 5-FROC, column F: Table 2)	
4	SD habitats	CGAR, LCAP	The two indicator species of this metric group, CGAR and LCAP, were sampled at the site during the baseline EFR surveys. CGAR was very scarce, recorded at 0.01 ind/min while LCAP was abundant at 0.56 indiv/min.	LCAP absent during any survey OR CGAR absent during 2 consecutive surveys (<50% of time) OR LCAP present with relative abundance of <0.4 ind/min.	Reduced suitability of SD habitats (i.e. increased flows in dry season, alteration in seasonality, sedimentation of pools).	CGAR	LCAP	Any decreased FROC in reach of LCAP and CGAR (refer to sheet 5-FROC, column F: Table 2)	

Rank	Metric	Indicator spp.	EFR SITE: ECOSPECS	EFR SITE: TPC (Biotic)	EFR SITE: TPC (Habitat)	REACH: Indicator spp.		REACH: TPC (Biotic)	REACH: ECOSPECS
5	SS habitats	CGAR	CGAR was very scarce during the baseline EFR survey, recorded at 0.01 ind/min.	CGAR absent during 2 consecutive surveys (<50% of time)	Significant change in SS habitat suitability (i.e. increased flows, altered seasonality, increased sedimentation of slow habitats).	BANO	CGAR	Any decreased FROC in reach of BANO & CGAR (refer to sheet 5-FROC, column F: Table 2)	
9	Overhanging vegetation	(BPAU)	None of the indicator taxa of these metrics were sampled at the EFR site during the baseline EFR survey. If these species are sampled at the site in future, TPCs should be determined.		Significant change in overhanging vegetation habitats.	BPAU		Any decreased FROC in reach of BPAU (refer to sheet 5-FROC, column F: Table 2)	
7	Undercut banks	(ASCL)			Significant change in undercut bank habitats.	ASCL		Any decreased FROC in reach of ASCLT (refer to sheet 5-FROC, column F: Table 2)	
8	Instream vegetation	(BPAU, BANO)			Significant change in instream vegetation habitats.	BPAU	BANO	Any decreased FROC in reach of BPAU & BANO (refer to sheet 5-FROC, column F: Table 2)	

8.6.2 Spatial FROC under reference, PES and REC conditions and TPCs for baseline (PES) conditions

	Species (Abbr.)	Scientific names: Reference species (Introduced species excluded)	Spatial FROC: REFERENCE (A)			
				PES/REC (C)		AEC up (B)
			Reference FROC	EC: Observed and habitat derived FROC	FROC TPC	Expected/ derived FROC
INDIGENOUS	ASCL	AUSTROGLANIS SCLATERI (BOULENGER, 1901)	3	1	0	**1.5**
	BANO	BARBUS ANOPLUS WEBER, 1897	4	1	0	**2**
	BAEN*	LABEOBARBUS AENEUS (BURCHELL, 1822)	4	3	2	3
	BPAU	BARBUS PALUDINOSUS PETERS, 1852	4	3	2	3
	BKIM	LABEOBARBUS KIMBERLEYENSIS GILCHRIST & THOMPSON, 1913	3	1	0	**1.5**
	CGAR*	CLARIAS GARIEPINUS (BURCHELL, 1822)	5	3	2	3
	LCAP*	LABEO CAPENSIS (SMITH, 1841)	5	4	3	4
	LUMB	LABEO UMBRATUS (SMITH, 1841)	4	2	1	2

* Sampled at EFR site during baseline survey (June 2010)

8.7 MACROINVERTEBRATES

8.7.1 SASS Data

Available SASS5 data collected at or near Site EFR C6 are summarised as follows:

Site	Date	SASS5 Score	ASPT	No. of Taxa	Reference
D2CALE-WELBE	7-Dec-2000	38	6	6.3	Marie Watson (River Health Database)
D2CALE-WELBE	15-Feb-2001	18	3	6	Marie Watson (River Health Database)
D2CALE-WELBE	13-Mar-2001	29	7	4.1	Marie Watson (River Health Database)
D2CALE-WELBE	7-Jun-2001	23	5	4.6	Marie Watson (River Health Database)
D2CALE-WELBE	7-Aug-2001	31	5	6.2	Marie Watson (River Health Database)
D2CALE-WELBE	11-Sep-2001	12	1	12	Marie Watson (River Health Database)
D2CALE-WELBE	17-Oct-2001	15	3	5	Marie Watson (River Health Database)
D2CALE-WELBE	9-Oct-2002	9	2	4.5	Marie Watson (River Health Database)
D2CALE-WELBE	27-Nov-2002	18	3	6	Marie Watson (River Health Database)
D2CALE-WELBE	5-Feb-2003	5	1	5	Marie Watson (River Health Database)
D2CALE-WELBE	8-Oct-2003	29	8	3.6	Marie Watson (River Health Database)
D2CALE-WELBE	12-May-2004	10	3	3.3	Marie Watson (River Health Database)
D2CALE-WELBE	11-Jan-2005	22	4	5.5	Marie Watson (River Health Database)
EWR C6	23-Jun-2010	52	5.2	10	This study

8.7.2 Indicator Taxa

The following macroinvertebrate taxa, arranged in order of decreasing sensitivity to water quality deterioration were selected as monitoring indicators for EFR C6.

	Flow				Substrate					Wat Qual		
	Standing (<0.1 m/s)	Slow (0.1-0.3 m/s)	Mod (0.3-0.6 m/s)	Fast (>0.6 m/s)	Hard	Boulders/Bedrock	Loose Cobble	Veg	Sand, Gravel, Mud	High (SASS>11)	Mod (SASS 7-10)	Low (SASS 4-6)
Baetidae (>2 spp)	●	●	⬤	⬤	●	●	⬤	●	●		**10**	
Leptophlebiidae (Prongills)	●	⬤	●		●	●	⬤	●	⬤		**9**	
Tricorythidae (Stout crawlers)			●	⬤	●	⬤	⬤	●			**9**	
Gomphidae		⬤							⬤			**6**
Simuliidae (Blackflies)		●	⬤	⬤	⬤	⬤	⬤	⬤				**5**
Hydropsychidae (1 sp)			●	⬤	●	⬤	●					**4**

● = Partial Preference ⬤ = Strong Preference

8.7.3 EcoSpecs and TPCs

EcoSpecs and TPCs for the PES at EFR C6 are provided below.

ECOSPECS	TPCs
SASS5 Score between 68 and 90.	SASS5 Score < 71.
ASPT between 5.0 and 5.3.	ASPT < 5.1.
MIRAI Score between 40% and 59%.	MIRAI Score < 44%.
At least 50% indicator taxa present.	Three or more Indicator Taxa absent.
Indicator Taxa	
Baetidae >2 spp.	Baetidae < 2 spp on any one survey.
Leptophlebiidae present.	Leptophlebiidae absent on two or more consecutive surveys.
Tricorythidae present (except winter).	Tricorythidae absent on two or more consecutive surveys.
Gomphidae present.	Gomphidae absent on two or more consecutive surveys.
Simuliidae present.	Simuliidae absent on two or more consecutive surveys.
Hydropsychidae present.	Hydropsychidae absent on two or more consecutive surveys.

9 EFR K7 – LOWER KRAAI

A summary of the site EcoClassification results are provided below (Volume 1: EFR).

9.1 ECOCLASSIFICATION SUMMARY OF EFR K7

EFR K7 (KRAAI)

EIS: MODERATE

The highest scoring matrix was Unique Riparian biota.

PES: C

Reduced base flows, exotic vegetation and fish species, grazing and trampling, bank erosion.

REC: C

The EIS is moderate which does not provide motivation for improvement.

AEC↓: C

Increased abstraction; more frequent zero flows .Negative impact on water quality. Decrease in small floods (e.g. by an increase of dams in the tributaries).Slightly higher sedimentation in areas.

AEC↑: B

Decreased abstraction (higher base flows) and no zero flows. Improved water quality. Alien vegetation should be cleared.

Driver Components	PES	Trend	AEC↓	AEC↑
IHI HYDROLOGY	A/B			
DIATOMS	C			
WATER QUALITY	B/C		C	A/B
GEOMORPHOLOGY	A/B	0	B/C	A/B
Response Components	**PES**	**Trend**	**AEC↓**	**AEC↑**
FISH	C	0	D	B
MACRO INVERTEBRATES	C	0	D	B
INSTREAM	C	0	D	B
RIPARIAN VEGETATION	C	-	C-	B/C
ECOSTATUS	C		C	B
INSTREAM IHI	B/C			
RIPARIAN IHI	C			
EIS	MODERATE			

EcoSpecs and TPCs for EFR 21 are provided for the different components in Section 9.2 to 9.6.

9.2 GEOMORPHOLOGY

9.2.1 Site Description and focus of TPCs

The morphology of this cobble/gravel pool-riffle reach is dynamic but stable in the long term. Cobbles and gravels are mobile and there is no embeddedness at the site. There is no evidence of excessive fines in the active channel. The site is considered to be close to the Reference Condition.

9.2.2 EcoSpecs and TPCs relating to GAI monitoring data: PES

Descriptor	Motivation for Monitoring
Reach morphology: Vegetation cover on bars	The bars at this site are dynamic sedimentary deposits and are naturally unvegetated. Any vegetation encroachment on the bars (by indigenous or exotic vegetation) will cause stabilisation of the bars and incision of the active channels and armouring of the bed. This would be an unnatural and undesirable direction of change for the reach. To maintain the PES, no stabilisation (vegetation colonisation) of the bars should occur.

Descriptor	Motivation for Monitoring	
	TPCs:	Any increase in the area of vegetation on bars within the reach relative to 2010
	Approach:	Aerial photographic or Google Earth imagery analysis of the site.
	Frequency:	Every 5 years
In-channel morphology: Bed sediment size distribution	At present the bed sediments are mobile (i.e. no embeddedness) and in-channel habitats have lots of interstitial spaces. Monitoring is focussed on maintaining these good quality inchannel habitat conditions.	
	TPCs:	Fines (sands up to 1mm) should not comprise more than 10% of the bed sediment in the active channel. Gravels and small cobbles (10-100mm) should comprise at least 80% of the bed sediment in the active channel.
	Approach:	Resurvey of the bed sediment at the EFR cross-section site.
	Frequency:	Every 2-5 years

Figure 9.1 This pool-riffle reach comprises mobile well-sorted cobble and gravel beds. The reach is considered to be close to the Reference conditions.

9.3 WATER QUALITY

9.3.1 EcoSpecs relating to water quality: PES

River: Kraai		EFR K7
Water quality metrics		**EcoSpecs: PES**
Inorganic salts*	$MgSO_4$	The 95th percentile of the data must be ≤ 16 mg/L.
	Na_2SO_4	The 95th percentile of the data must be ≤ 20 mg/L.
	$MgCl_2$	The 95th percentile of the data must be ≤ 15 mg/L.
	$CaCl_2$	The 95th percentile of the data must be ≤ 21 mg/L.
	NaCl	The 95th percentile of the data must be ≤ 45 mg/L.
	$CaSO_4$	The 95th percentile of the data must be ≤ 351 mg/L.
Physical variables	EC	The 95th percentile of the data must be ≤ 45 mS/m (A/B category).

River: Kraai		EFR K7
Water quality metrics		**EcoSpecs: PES**
	pH	The 5th percentile of the data must range from 6.5 to 8.0, and the 95th percentile from 8.0 to 8.8
	Temperature	Natural temperature regime.
	Dissolved oxygen	The 5th percentile of the data must be ≥ 8 mg/L.
	Turbidity	Vary by a small amount from the natural turbidity range; minor silting of instream habitats acceptable.
Nutrients	TIN	The 50th percentile of the data must be ≤ 0.25 mg/L
	PO_4 – P	The 50th percentile of the data must be ≤ 0.125 mg/L.
Response variables	Chl – a phytoplankton	The 50th percentile of the data must be ≤ 10 mg/L
	Chl – a periphyton	The 50th percentile of the data must be ≤ 21 mg/m^2 ♦
	Toxics	The 95th percentile of the data must be within the Chronic Effects Value (CEV) as stated in DWAF (1996) #

* To be generated using TEACHA when the TPC for EC is exceeded or salt pollution is expected.

#: Although category boundaries exist in the Water quality Reserve manual (DWAF, 2008) for a number of toxicants, adherence to the CEV (DWAF, 1996) is recommended for the present state. Data collection and testing will need to be undertaken to assess the suitability of these objectives.

♦: low confidence. EcoSpec and TPC boundaries may need adjusting as data become available.

9.3.2 TPCs relating to water quality data

River: Kraai		EFR K7
Water quality metrics		**TPCs**
Inorganic salts*	$MgSO_4$	The 95th percentile of the data is 13 – 16 mg/L.
	Na_2SO_4	The 95th percentile of the data is 16 – 20 mg/L.
	$MgCl_2$	The 95th percentile of the data is 12 – 15 mg/L.
	$CaCl_2$	The 95th percentile of the data is 17 – 21 mg/L.
	NaCl	The 95th percentile of the data is 36 – 45 mg/L.
	$CaSO_4$	The 95th percentile of the data is 280 – 351 mg/L.
Physical variables	EC	The 95th percentile of the data is 35 – 44 mS/m.
	pH	The 5th percentile of the data is <6.7 and >7.8, and the 95th percentile is <8.2 and >8.6
	Temperature	Rely on biotic response data to evaluate whether the TPC for temperature is being reached. Temperature sensitive species present in abundances and frequencies of occurrence as expected for reference.
	Dissolved oxygen	The 5th percentile of the data is < 8.2 mg/L.
	Turbidity	Check biotic response for habitat-related changes, although not

River: Kraai		EFR K7
Water quality metrics		**TPCs**
		anticipated.
Nutrients	TIN	The 50th percentile of the data must be 0.2 – 0.25 mg/L
	PO_4 – P	The 50th percentile of the data must be 0.06 – 0.075 mg/L **
Response variables	Chl - a phytoplankton	The 50th percentile of the data must be 8 – 10 µg/L
	Chl - a periphyton	The 50th percentile of the data must be 17 – 21 mg/m^2 ♦
	Toxics	An impact is expected if the 95th percentile of the data exceeds the Target Water Quality Range (TWQR) as stated in DWAF (1996).

* To be generated using TEACHA when the TPC for EC is exceeded or salt pollution is expected.

♦: low confidence. EcoSpec and TPC boundaries may need adjusting as data become available.

**: Although the upper boundary for the relevant phosphate category is 0.125 mg/L, the TPC has been set at 0.075 mg/L as the PES measurements (50th percentile) were 0.033 mg/L (i.e. a recalibrated A category).

Although nutrient data appear to be low, diatoms indicate some nutrients and organics in the system, probably related to farming activities.

9.4 DIATOMS

Physico-chemical metric	EcoSpecs	Class rank	TPC	PES
pH	6 - 8	3	≥2; ≤4	4
Salinity	Fresh brackish (100 - 500 µS/cm)	2	<2	2
Nutrients	Slightly elevated concentrations of organically bound nitrogen.	2-3	≤3	1
Oxygen	Moderate saturation (<50% saturation)	≤3	≤4	1
Organics	β-ά-mesosaprobic: BOD_5 < 7 (10) mg/l, O_2 deficit <50% (Critical level of pollution)	3	<3	2
	ά-mesosaprobic: BOD5 < 13mg/l, O2 deficit <75% (Strongly polluted)			
SPI Score	9.2 – 12.8	C EC	≥ 9	12.6 (C)

Physico-chemical data indicates that toxicants may be problematic especially aluminium and the EC was set at a C EC. Class limits fall within the defined TPC ranges set for a C PES as the SPI scores of the sites within MRU C fluctuated between a B/C and C/D EC (2008 - 2010). As there is evidence of periodic elevated levels of organics, an increase in this variable along with nutrients and salinity levels will result in increases in CPLA and CPED along with GOMS. NDIS and Nitzschia species are dominant at the moment, but an increased dominance of these species will bring about a deteriorated SPI score. An increase of species preferring elevated organics e.g. MAPE, NERI and RCUR should be noted as this will affect the SPI scores negatively. A check should be done for valve deformities with every count as this is indicative of metal contamination.

9.5 RIPARIAN VEGETATION

9.5.1 EcoSpec and TPC description relating to VEGRAI monitoring data: PES and REC

PES	REC	Assessed Component	Zone Assessed	EcoSpec (for PES)	TPC (for PES)	EcoSpec (for REC or AEC up)	Baseline (measured value,% cover) / Note
C	B/C	Exotic Invasion (perennial exotics)	Riparian zone	Maintain perennial exotic species cover below 20%	An increase in exotic species cover above 20%	Maintain perennial exotic species cover below 15%	VEGRAI recorded data: 0% (marginal zone); 5% (lower zone); 42% (upper zone); 23% (MCB)
		Terrestrialisation	Marginal Zone	Maintain an absence of terrestrial woody species	A presence of terrestrial woody species	Maintain an absence of terrestrial woody species	0
			Lower zone	Maintain terrestrial woody species cover below 10%	An increase in woody terrestrial species cover above 10%	Maintain terrestrial woody species cover below 5%	0
			Upper Zone & MCB	Maintain terrestrial woody species cover below 30%	An increase in woody terrestrial species cover above 30%	Maintain terrestrial woody species cover below 20%	5
		Indigenous Riparian Woody Cover	Marginal Zone	Maintain a presence of riparian woody species, but also an aerial cover of not more than 80%	An absence of riparian woody species OR an increase in cover above 80%	Maintain woody riparian cover between 5 and 70%	18
			Lower Zone	Maintain woody riparian cover below 60%	An increase in woody riparian cover above 60%	Maintain riparian woody species cover between 5 and 50%	21
			Upper Zone	Maintain woody riparian cover below 90%	An increase in woody riparian cover above	Maintain riparian woody species	31

					90%	cover between 5 and 80%	
			MCB	Maintain woody riparian cover above 10%	A decrease in riparian woody species cover below 10%	Maintain woody riparian cover above 20%	33
		Phragmites (reed) cover	Marginal Zone	Maintain reed cover below 50%	An increase in reed cover above 50%	Maintain reed cover below 40%	0
			Lower Zone	Maintain reed cover below 50%	An increase in reed cover above 50%	Maintain reed cover below 40%	0
			Upper Zone	Maintain reed cover below 50%	An increase in reed cover above 50%	Maintain reed cover below 40%	19

9.5.2 EcoSpecs and TPCs summary relating to VEGRAI monitoring data

Colour coding in the table below refers to:

EcoSpec	TPC	Baseline (measured)	PES C	REC B/C

Class	Perennial Exotics	Reeds		Riparian Woody		Terrestrialisation
Marginal Zone						
A	0	10-20		10-30		0
A/B	1-5		20-30		30-40	0
B	5-10	<10	30-40	5-10	40-60	0
B/C	10-15				60-70	0
C	15-20		40-50	1-5	70-80	0
C/D	20-30					0
D	30-50		50-60	0	>80	1-5
D/E	50-60					5-10
E	60-70		60-80			10-15
E/F	70-80					15-20
F	>80		>80			>20
Lower Zone						
A	0	10-20		10-20		0
A/B	1-5		20-30		20-40	0
B	5-10	<10	30-40	5-10	40-50	0
B/C	10-15					1-5

Class	Perennial Exotics	Reeds		Riparian Woody		Terrestrialisation
C	15-20		40-50	<5	50-60	5-10
C/D	20-30					10-15
D	30-50		50-60		60-70	15-20
D/E	50-60					20-30
E	60-70		60-80		70-80	30-40
E/F	70-80					40-50
F	>80		>80		>80	>50
Upper Zone						
A	0	<20		30-50		0-5
A/B	1-5		20-30	20-30	50-60	5-10
B	5-10		30-40	10-20	60-70	10-15
B/C	10-15			5-10	70-80	15-20
C	15-20		40-50	<5	80-90	20-30
C/D	20-30					30-40
D	30-50		50-60		>90	40-50
D/E	50-60					50-60
E	60-70		60-80			60-70
E/F	70-80					70-80
F	>80		>80			>80
Upper Zone (MCB)						
A	0			70-80		0-5
A/B	1-5			60-70	80-90	5-10
B	5-10			40-60	>90	10-15
B/C	10-15			20-40		15-20
C	15-20			10-20		20-30
C/D	20-30			<10		30-40
D	30-50					40-50
D/E	50-60					50-60
E	60-70					60-70
E/F	70-80					70-80
F	>80					>80

9.6 FISH

EcoSpecs and TPCs are provided for FRAI data in Section 9.6.1. The spatial FROC of EFR K7 is provided in Section 9.6.2 and indicates the FROC under reference, PES and REC conditions as well as TPCs for baseline (PES) conditions.

9.6.1 EcoSpecs and TPCs relating to FRAI data: PES and REC

Rank	Metric	Indicator spp.	PES: EFR SITE: ECOSPECS	PES: EFR SITE: TPC (Biotic)	PES: EFR SITE: TPC (Habitat)	PES: REACH: Indicator spp.	PES: REACH: TPC (Biotic)	REC: REACH: ECOSPECS
1	Species richness	all indigenous species	Only two (2) of the expected (under reference conditions) 7 indigenous fish species were sampled during the baseline (EFR) survey.	Less than 2 fish species sampled during a survey when habitat can be sampled efficiently.	Loss in diversity, abundance and condition of velocity-depth categories and cover features.	All indigenous species	Baseline (PES) FRAI score of 74% (high C) calculated for the reach. Any decreased FROC in reach of especially ASCL, BAEN, BKIM & LCAP (refer to sheet 5-FROC: Table 2) OR FRAI scores decreasing below 66% (low C).	An improvement from PES FROC in the reach for especially ASCL, BAEN, BKIM, LCAP, LUMB, CGAR should be indicative of reaching/maintaining the REC (refer to 5-FROC sheet for more detail).
2	Relative abundance	n/a	During baseline (EFR) surveys fish were sampled at 0.8 individuals per minute using a SAMUS electrofisher (wading).	Relative abundance of less than 0.5 individual per minute sampled at the site (during same season as baseline data) when habitat can be sampled efficiently and using comparable method.	N/a	N/a	N/a	
4	Alien fish species	any alien/ introduced spp.	No alien fish species were sampled at EFR site during baseline survey.	Presence of any alien fish species during a survey.	N/A	Any alien/ introduced spp.	Increase in the number of alien species (>4 species in reach) OR presence of any alien species other than CCAR, MSAL, STRU & OMYK .	
3	FD Habitats, Flow dependant spp (flow alteration), water column	BAEN, LCAP	The two indicator species of this metric group, BAEN and LCAP, were sampled at the site during the baseline EFR surveys. BAEN was abundant, recorded at 0.7 ind/min while LCAP was present at 0.1 indiv/min.	BAEN and/or LCAP absent during any survey OR present at relative abundance of <0.5 ind/min for BAEN or <0.05 ind/min for LCAP.	Reduced suitability (abundance & quality) of FD habitats, flow modification and reduced availability of water column (i.e. decreased flows, increased zero flows, sedimentation of pools).	BAEN, LCAP	Any decreased FROC in reach of BAEN and LCAP (refer to sheet 5-FROC, column F: Table 2)	
3	FS habitats				Reduced suitability (abundance & quality) of FS habitats (i.e. decreased flows, increased zero flows),	BAEN, BKIM	Any decreased FROC in reach of BAEN and BKIM (refer to sheet 5-FROC, column F: Table 2)	
3	Substrate				Increased sedimentation of riffle/rapid substrates, excessive algal growth on substrates.	LCAP, LUMB	Any decreased FROC in reach of LUMB and LCAP (refer to sheet 5-FROC, column F: Table 2)	

Rank	Metric	Indicator spp.	PES						REC
			EFR SITE			REACH			REACH
			ECOSPECS	TPC (Biotic)	TPC (Habitat)	Indicator spp.		TPC (Biotic)	ECOSPECS
3	Water quality intolerance				Decreased water quality	BKIM	LCAP	Any decreased FROC in reach of BKIM and LCAP (refer to sheet 5-FROC, column F: Table 2)	
3	SD habitats				Reduced suitability of SD habitats (i.e. increased flows in dry season, alteration in seasonality, sedimentation of pools).	LUMB	CGAR	Any decreased FROC in reach of LUMB & CGAR (refer to sheet 5-FROC, column F: Table 2)	
6	SS habitats	(BANO, CGAR)	None of the indicator taxa of these metrics were sampled at the EFR site during the baseline EFR survey. If these species are sampled at the site in future, TPCs should be determined.		Significant change in SS habitat suitability (i.e. increased flows, altered seasonality, increased sedimentation of slow habitats).	BANO	CGAR	Any decreased FROC in reach of BANO & CGAR (refer to sheet 5-FROC, column F: Table 2)	
7	Overhanging vegetation, instream vegetation.	(BANO)			Significant change in instream and overhanging vegetation habitats.	BANO		Any decreased FROC in reach of BANO (refer to sheet 5-FROC, column F: Table 2)	
5	Undercut banks	(ASCL)			Significant change in undercut bank habitats.	ASCL		Any decreased FROC in reach of ASCL (refer to sheet 5-FROC, column F: Table 2)	

9.6.2 Spatial FROC under reference, PES and REC conditions and TPCs for baseline (PES) conditions

	Species (Abbr.)	Scientific names: Reference species (Introduced species excluded)	Spatial FROC			
			REFERENCE	PES/REC (C)		AEC up (B)
			Reference FROC	EC: Observed and habitat derived FROC	FROC TPC	Expected/ derived FROC
INDIGENOUS	ASCL	AUSTROGLANIS SCLATERI (BOULENGER, 1901)	2	1	0	1.5
	BANO	BARBUS ANOPLUS WEBER, 1897	4	2	1	2
	BAEN*	LABEOBARBUS AENEUS (BURCHELL, 1822)	5	4	3	4.5
	BKIM	LABEOBARBUS KIMBERLEYENSIS GILCHRIST & THOMPSON, 1913	3	2	1	2.5
	CGAR	CLARIAS GARIEPINUS (BURCHELL, 1822)	5	4	3	5

	LCAP*	LABEO CAPENSIS (SMITH, 1841)	5	4	3	4.5
	LUMB	LABEO UMBRATUS (SMITH, 1841)	5	4	3	4.5

* Sampled at EFR site during baseline survey (June 2010)

9.7 MACROINVERTEBRATES

9.7.1 SASS Data

Available SASS5 data collected at or near Site EFR K7 are summarised as follows:

Site	Date	SASS5 Score	ASPT	No. of Taxa	Reference
EWR K7	24-Jun-2010	81	6.2	13	This study

9.7.2 Indicator Taxa

The following macroinvertebrate taxa, arranged in order of decreasing sensitivity to water quality deterioration were selected as monitoring indicators for EFR K7.

	Flow				Substrate					Wat Qual		
	Standing (<0.1 m/s)	Slow (0.1-0.3 m/s)	Mod (0.3-0.6 m/s)	Fast (>0.6 m/s)	Hard	Boulders/Bedrock	Loose Cobble	Veg	Sand, Gravel, Mud	High (SASS>11)	Mod (SASS 7-10)	Low (SASS 4-6)
Perlidae (Stoneflies)			•	●		•	●			**12**		
Baetidae (>2 spp)	•	•	●	●	•	•	●	•	•		**10**	
Leptophlebiidae (Prongills)	•	●	•		•	•	●	•	●		**9**	
Elmidae (Riffle beetles)			•	●		●	•	•			**8**	
Gomphidae		●							●			**6**
Caenidae (Squaregills)	•	●				•	●	•	•			**6**

• = Partial Preference ● = Strong Preference

9.7.3 EcoSpecs and TPCs

EcoSpecs and TPCs for the PES at EFR K7 are provided below.

ECOSPECS	TPCs
SASS5 Score between 98 and 111.	SASS5 Score < 103.
ASPT between 5.6 and 5.9.	ASPT < 5.7.
MIRAI Score between 60% and 79%.	MIRAI Score < 63%.
At least 50% indicator taxa present.	Three or more Indicator Taxa absent.

Indicator Taxa	
Perlidae present.	Perlidae absent on two or more consecutive surveys.
Baetidae >2 spp.	Baetidae < 2 spp on any one survey.
Leptophlebiidae present.	Leptophlebiidae absent on two or more consecutive surveys.
Elmidae present.	Elmidae absent on two or more consecutive surveys.
Gomphidae present.	Gomphidae absent on two or more consecutive surveys.
Caenidae present.	Caenidae absent on two or more consecutive surveys.

10 EFR M8 – MOLOPO WETLANDS

A summary of the site EcoClassification results are provided below (Volume 1: EFR).

10.1 ECOCLASSIFICATION SUMMARY OF EFR M8

EFR M8 (MOLOPO WETLANDS)

EIS: HIGH

Wetland is a unique habitat in this dry region. Highest scoring matrix were Rare and endangered vegetation types; Unique fish and invertebrate species, Critical habitat and refuge and a Proclaimed area.

PES: C

Pesticide spraying. Backup effect from poorly designed road crossings. Burning of reeds. Alien fish species

REC: B

As the EIS is HIGH, the REC is an improvement of the PES.

1. Driver Components	PES	REC
IHI HYDROLOGY	D/E	
DIATOMS	A/B	A/B
WATER QUALITY	B	B
GEOMORPHOLOGY	B	B
Response Components	**PES**	**REC**
FISH	C	B
MACRO INVERTEBRATES	C	B
INSTREAM	C	B
RIPARIAN VEGETATION	C/D	B/C
ECOSTATUS	C	B
WETLAND IHI	D	C
LARGER WETLAND / MRU ECOSTATUS	C	B

EcoSpecs and TPCs for EFRM8 are provided for the different components in Section 10.2 to 10.6.

10.2 WETLAND CONDITION

10.2.1 Site Description of the site

The Molopo wetland is a groundwater dependent wetland system, with flow arising from the eyes (springs) that emerge from the underlying dolomitic geology. Large abstractions at the eye have dramatically reduced flows in the lower wetland areas, whilst small weirs and dams have had an impact on the water distribution across the wetland surface. The reduced flows and trapping of water in impoundments has reduced the extent of and duration of wetting within the wetland. To improve the PES, more water needs to be permitted to flow through the impoundments to the downstream wetland reaches. This can be achieved by lowering the road crossings.

10.2.2 Monitoring to maintain the PES

No monitoring of wetland condition is recommended at the EFR cross-section site. The cross-section (EFR site) is within an impoundment created by an elevated road crossing and this has created shallow dam conditions that are not representative of the reach, nor ideal wetland conditions.

Monitoring of the wetland should be conducted at the resource unit scale (Management Resource Unit A for this area) and specifically should be focussed on the wetland area downstream of the road crossing near the EFR site. The objective of such monitoring is to ensure that the downstream wetland areas are at least maintained, but ideally improved and expanded. Monitoring of the wetland condition can take place through one of two ways:

- Remote sensing methods: The permanently wet wetland area could be monitored with remotely sensed imagery to identify the extent of permanently wet areas and ensure that these are at least maintained at the 2010 levels, but ideally that the area is increased through implementation of one of the scenarios identified in this study to improve overall condition of the resource (through lowering of the culverts). Some LandSat imagery is freely available, and other high resolution imagery is also available to some government departments, so such a monitoring programme could be very economical.
- On-site monitoring: On-site monitoring could be undertaken during the heights of both the wet and dry seasons on an annual basis. T he monitoring would be undertaken to ensure that:
  - The permanent wetland soils remain saturated in the wet season and moist in the dry season;
  - That the area of wetland is maintained, but ideally increased, downstream of the road crossing; and
  - That the habitat quality (indicated by vegetation composition and stature) be maintained or improved.

A monitoring programme for the above would need to be developed since baseline data to address the above were not collected as part of the routine EFR assessment.

Table 10.1 Reduced flows in to the wetland and disturbance within the wetland has reduced the area of reeds and other natural vegetation between 1943 and the present day

10.2.3 Recommendations to improve PES through on-site remediation

The condition of the wetland has declined in part through reduced flows. Water is diverted from the upstream areas for the city of Mafikeng, and this abstraction is not likely to be decreased.

However remediation of the wetland can be achieved through addressing non-flow related impacts at the site and in the reach. The following recommendations are made for improving the condition of the upper Molopo wetland:

- ***Culverts and the road crossing should be lowered*** to allow more water to flow to the downstream wetland areas. At present the evapotranspiration losses from the impoundment areas created by the road crossing are reducing the water available for the downstream wetland areas. We estimated that:
    - lowering the current road crossing by 1.2 metres would increase flows to the downstream wetland by 35%.
    - lowering the current road crossing by 2 metres would increase flows to the downstream wetland by 56%; and
    - lowering the current road crossing down to the original channel bed level would increase flows to the downstream wetland by 63%.

These increased flows will allow for rewetting of desiccated wetland areas and therefore improve the ecological condition of the reach.

- ***Spraying of the reeds should not be permitted***. The reed spraying kills the reeds and creates more open water which favours invasive predatory fish species.
- ***Burning and grazing*** ... See 10.5.

10.3 WATER QUALITY

Due to the lack of understanding linking concentrations of chemical constituents (both in the water column and in the substrate) to ecological response, it is not possible to provide prescriptive water quality ecological specifications for wetlands. Several approaches were suggested during the 2009/2010 WRC study on developing a Rapid Reserve method for wetlands. Information contained in this section is therefore taken from Malan et al. (2010).

10.3.1 Narrative ecological specifications

For example, "*Phragmites/Typha* (or other problematic plant) should not extend more than a given percentage area of the open water surface".
Or,
"the wetland should remain in the same trophic state or ecological category".

10.3.2 Ecological specifications can be set using biological response (diatom) data

Changes in ecological category indicate a modification of diatom community composition which is usually accompanied by a change in water quality. These changes (both in category and community composition) can be used to directly track/indicate water quality impacts. Linkages between the diatom (SPI) score, general water quality condition and EC can be found in the Section 10.4.

10.3.3 Evaluating water quality consequences of scenarios for wetlands

The following issues can be considered when evaluating scenarios, with potential impacts considered through biological response indicators (Malan *et al*., 2010):

- A *reduction* in water volume: This may result in changed hydroperiod, reduction in the dilution capacity, and an increase in residence time of the water.
- An *increase* in water volume: This may lead to a change in hydroperiod, decreased salinity, decreased residence time and consequent changes in biotic character. The quality of the increased volume of water should also be considered. Although more water can lead to higher dilution of contaminants, higher volumes of poor quality water can also increase levels of pollutants.
- Alterations to nutrient loads (P and N): This may result in external and internal eutrophication (Boers *et al*., 2006). Internal eutrophication occurs when previously unavailable nutrients become liberated from the wetland substrate due to changes in physico-chemical conditions (e.g. due to changes in hydrology).
    - N in organic matter can be liberated when water levels drop, the substrate becomes aerated and decomposition rates increase.
    - P can be liberated when naturally fluctuating water levels are stabilized, for example, by the construction of a dam or weir. The substrate then becomes anaerobic and chemically-bound P may be released from the sediments into the water column.
    - P availability to plants may be increased when surface water rich in sulphates and chlorides is supplied to wetlands. Sulphates may be reduced to sulphides, which precipitate with iron. This can lead to the release of P into the water column (Batchelor, Wetland Consulting Services, pers. comm. 2008).

10.4 DIATOMS

Physico-chemical metric	EcoSpecs	Class rank	TPC	PES
pH	6 - 8 Circumneutral.	3	≥2; ≤4	3

Salinity	Fresh brackish (100 - 500 µS/cm).	2	<2	2
Oxygen	Fairly high saturation (<75% saturation)	≤2	≤3	1-2
Nutrients	Slightly elevated concentrations of organically bound nitrogen.	1-2	≤2	1-2
Organics	β-mesosaprobic: BOD_5 < 4mg/l, O_2 deficit <30%.	1-2	<2	2
SPI score	≤13.3 - ≥16.8.	B EC	≥ 13.3	14.2 (B)

There was very limited physico-chemical data for this reach and the data indicates that nutrients are elevated at times and that toxicants are present due to spaying. Farming and spillage of chemicals are also problematic in this specific study area. The EC was a B EC for EFR M8. The diatom assessment for the Molopo wetland was based on samples collected from EFR M8 during April 2010 at three sites. Data showed high SPI scores indicating Very good water quality (i.e. an A/B category). Oxygen levels were high and nutrient and organic levels were low. However, confidence in the assessment was low as no seasonal data were available. The EcoSpecs and TPCs were set at a B EC. It is suggested that three samples are taken at the sites identified during the EFR study. It is expected that there will be a wide range of species are present due to the range of impacts and therefore specific species cannot be identified. An increase in indicator species with an affinity for critical pollution levels should be noted and a check should be done for valve deformities with every count as this is indicative of metal contamination.

10.5 RIPARIAN VEGETATION

10.5.1 EcoSpec and TPC description relating to VEGRAI monitoring data: PES and REC

PES	REC	Assessed Component	Zone Assessed	EcoSpec (for PES)	TPC (for PES)	EcoSpec (for REC or AEC up)	Baseline (measured value,% cover) / Note
A	A	*Phragmites* (reed) cover	Upper Wetland	Maintain reed cover between 80 and 90%	An increase in reed cover above 90% OR a decrease below 80%	Maintain reed cover between 80 and 90%	90
		Exotic Invasion (perennial exotics)		Maintain an absence of perennial exotic species	A presence of perennial exotic species	Maintain an absence of perennial exotic species	2
D	C	*Phragmites* (reed) cover	Lower Wetland	Maintain reed cover above 20%	A decrease in reed cover below 20%	Maintain reed cover above 40%	25
		Exotic Invasion (perennial exotics)		Maintain perennial exotic species cover below 50%	An increase in cover of perennial exotic species above 50%	Maintain perennial exotic species cover below 20%	7

10.5.2 EcoSpecs and TPCs summary relating to VEGRAI monitoring data

Colour coding in the table below refers to:

EcoSpec	TPC	Baseline (measured)	PES C/D	REC B/C

Class	Perennial Exotics			Reeds			
Upper Wetland							
A		0			80-90		
A/B		1-5					
B		5-10			60-80	>90	
B/C		10-15					
C		15-20			40-60		
C/D		20-30					
D		30-50			20-40		
D/E		50-60					
E		60-70			<20		
E/F		70-80					
F		>80					
Lower Wetland							
A		0			80-90		
A/B		1-5					
B		5-10			60-80	>90	
B/C		10-15					
C		15-20			40-60		
C/D		20-30					
D		30-50			20-40		
D/E		50-60					
E		60-70			<20		
E/F		70-80					
F		>80					

10.6 FISH

EcoSpecs and TPCs are provided for FRAI data in Section 10.6.1. The spatial FROC of EFR M8 is provided in Section 10.6.2 and indicates the FROC under reference, PES and REC conditions as well as TPCs for baseline (PES) conditions.

10.6.1 EcoSpecs and TPCs relating to FRAI data: PES and REC

Rank	Metric	Indicator spp.	PES					REC
			EFR SITE			REACH		REACH
			ECOSPECS	TPC (Biotic)	TPC (Habitat)	Indicator spp.	TPC (Biotic)	ECOSPECS

Rank	Metric	Indicator spp.	PES					REC
			EFR SITE			REACH		REACH
			ECOSPECS	TPC (Biotic)	TPC (Habitat)	Indicator spp.	TPC (Biotic)	ECOSPECS
1	Species richness	all indigenous species	Three (3) of the expected (under reference conditions) 6 indigenous fish species were sampled during the baseline (EFR) survey.	Less than 3 indigenous fish species sampled during a survey when habitat can be sampled efficiently.	Loss in diversity, abundance and condition of velocity-depth categories and cover features.	All indigenous species	Baseline (PES) FRAI score of 64% (C) calculated for the reach. Any decreased FROC in reach of especially BBRI, BPAL and BPAU (if they are present) (refer to sheet 5-FROC: Table 2) OR FRAI scores decreasing below 62% (category C/D).	An improvement from PES FROC in the reach for especially BPAL, BBRI and BPAU should be indicative of reaching/maintaining the REC (refer to 5-FROC sheet for more detail).
2	Relative abundance	n/a	During baseline (EFR) surveys fish were sampled at 0.25 individuals per minute (ind/min) using a SAMUS electrofisher during wading. Relative abundance was generally very low.	Relative abundance of less than 0.2 individual per minute sampled at the site (during same season as baseline data) when habitat can be sampled efficiently and using comparable method.	N/a	N/a	N/a	
3	Alien fish species	any alien /introduced spp.	One alien fish species (MSAL) sampled during baseline EFR survey at relative abundance of 0.01 ind/min.	Presence of any alien/introduced fish other than MSAL or increase in relative abundance of MSAL > 0.03 ind/min.	N/A	Any alien/ introduced spp.	CCAR and MSAL previously sampled in reach. Presence of any additional alien/introduced species.	
n/a	FD Habitats, FS habitats	None	No species expected under natural or present condition are considered indicators of FD and FS habitats					
n/a	Substrate	(BPAL)	None of the indicator taxa of these metrics were sampled at the EFR site during the baseline EFR survey. If these species are sampled at the site in future, TPCs should be determined.		Decrease in substrate quality (sedimentation, excessive algal growth, etc.)	(BPAL)	Uncertain about the presence of these species in reach. If still present, any decreased in its FROC (refer to sheet 5-FROC, column F: Table 2)	
n/a	Flow dependance (flow alteration)	(BBRI)			Flow modification (e.g. water abstraction, dams, etc).	(BBRI)		
n/a	Water column	(BPAU)			Reduced suitability of water column (i.e. decreased flows, increased zero flows, sedimentation of pools).	(BPAU)		

Rank	Metric	Indicator spp.	PES						REC
			EFR SITE			REACH			REACH
			ECOSPECS	TPC (Biotic)	TPC (Habitat)	Indicator spp.		TPC (Biotic)	ECOSPECS
n/a	Water quality intolerance,	(BBRI, BPAL)			Decreased water quality.	BPAL	BBRI		
7	SD habitats	CGAR	In the absence of BPAU at the site (not sampled during baseline survey), CGAR is the best indicator of this metric. CGAR was very scarce during the baseline, sampled at 0.01 ind/min.	Absence of CGAR for two consecutive surveys (>50% of time)	Reduced suitability of SD habitats (i.e. increased flows in dry season, alteration in seasonality, sedimentation of pools).	(BPAL)			
4	SS habitats, overhanging vegetation	PPHI, TSPA	The most appropriate indicators of this metric are PPHI and TSPA. PPHI was present at relative abundance of 0.08 indiv/min and TSPA at 0.15 ind/min.	PPHI and/or TSPA absent during any survey OR present at relative abundance of <0.05 ind/min for PPHI and <0.1 ind/min for TSPA	Significant change in SS habitat suitability (i.e. increased flows, altered seasonality, increased sedimentation of slow habitats). Significant change in overhanging vegetation habitats	PPHI	TSPA	Any decreased FROC in reach of PPHI & TSPA (refer to sheet 5-FROC, column F: Table 2)	
6	Undercut banks	PPHI	In the absence of BBRI at the site (not sampled during baseline EFR survey), the most appropriate indicator of this metric is PPHI. PPHI was present at relative abundance of 0.08 ind/min.	PPHI absent during any survey OR present at relative abundance of <0.1 ind/min.	Significant change in undercut bank habitats.	PPHI	BBRI	Any decreased FROC in reach of PPHI (and BBRI if present) (refer to sheet 5-FROC, column F: Table 2)	
5	Instream vegetation	TSPA	In the absence of BPAU at the site (not sampled during baseline EFR survey), the most appropriate indicator of this metric is TSPA. TSPA was present at relative abundance of 0.15 ind/min.	TSPA absent during any survey OR present at relative abundance of <0.1 ind/min.	Significant change in overhanging vegetation habitats.	TSPA	BPAU	Any decreased FROC in reach of BPAU (if present in reach) & TSPA (refer to sheet 5-FROC, column F: Table 2)	

10.6.2 Spatial FROC under reference, PES and REC conditions and TPCs for baseline (PES) conditions

	Species (Abbr.)	Scientific names: Reference species (Introduced species excluded)	Spatial FROC			
			REFERENCE (A)	PES/REC (C)		AEC up (B)
			Reference FROC	EC: Observed and habitat derived FROC	FROC TPC	Expected/ derived FROC
INDIGENOUS	BPAL	BARBUS PALLIDUS SMITH, 1841	2	1	0	1.5
	BBRI	BARBUS BREVIPINNIS JUBB, 1966	2	1	0	1.5
	BPAU	BARBUS PALUDINOSUS PETERS, 1852	3	2	1	2.5
	CGAR*	CLARIAS GARIEPINUS (BURCHELL, 1822)	2	2	1	2
	PPHI*	PSEUDOCRENILABRUS PHILANDER (WEBER, 1897)	5	4	3	4
	TSPA*	TILAPIA SPARRMANII SMITH, 1840	5	4	3	4
ALIEN	MSAL*	MICROPTERUS SALMOIDES (LACEPÈDE, 1802)				

* Sampled at site during EFR survey (April 2010)

10.7 MACROINVERTEBRATES

10.7.1 SASS Data

Available SASS5 data collected at or near Site EFR M8 are summarised as follows:

Site	Date	SASS5 Score	ASPT	No. of Taxa	Reference
D4MOLO-BUHRM	18-Apr-2005	83	4.0	21	Hermine Roux (River Health Database)
EWR M8	20-Apr-2010	90	4.5	20	This study

10.7.2 Indicator Taxa

The following macroinvertebrate taxa, arranged in order of decreasing sensitivity to water quality deterioration, were selected as monitoring indicators for EFR M8.

	Flow				Substrate					Wat Qual		
	Standing (<0.1 m/s)	Slow (0.1-0.3 m/s)	Mod (0.3-0.6 m/s)	Fast (>0.6 m/s)	Hard	Boulders/Bedrock	Loose Cobble	Veg	Sand, Gravel, Mud	High (SASS>11)	Mod (SASS 7-10)	Low (SASS 4-6)
Baetidae (>2 spp)	•	•	●	●	•	•	●	•	•		**10**	
Aeshnidae	●	•						●			**8**	
Hydracarinidae	●	●			•	•	•	●			**8**	
Caenidae (Squaregills)	•	●				•	●	•	•			**6**
Ancylidae	•	•	•	•	•	•	•	•				**6**
Simuliidae (Blackflies)		•	●	●	●	●	●	●				**5**

• = Partial Preference ● = Strong Preference

10.7.3 EcoSpecs and TPCs

EcoSpecs and TPCs for the PES at EFR M8 are provided below.

ECOSPECS	TPCs
SASS5 Score between 98 and 111.	SASS5 Score < 103.
ASPT between 5.0 and 5.3.	ASPT < 5.1.
MIRAI Score between 60% and 79%.	MIRAI Score < 63%.
At least 50% indicator taxa present.	Three or more Indicator Taxa absent.
Indicator Taxa	
Baetidae >2 spp.	Baetidae < 2 spp on any one survey.
Aeshnidae present.	Aeshnidae absent on two or more consecutive surveys.
Hydracarinidae present.	Hydracarinidae absent on two or more consecutive surveys.
Caenidae present.	Caenidae absent on two or more consecutive surveys.
Ancylidae present.	Ancylidae absent on two or more consecutive surveys.
Simuliidae present.	Simuliidae absent on two or more consecutive surveys.

11 RECOMMENDATIONS

The effective management of the Orange-Senqu River Basin is particularly complex, but is also vital to the economy of the region. As a result, the riparian states has prioritised this basin for the establishment of a Shared Watercourse Institution under the revised Southern African Development Community (SADC) Protocol for Shared Watercourses. The Orange-Senqu River Commission (ORASECOM) was one of the first of the joint basin commissions to be established under the revised SADC Shared Watercourses Protocol.

During 2009 the ORASECOM Aquatic Ecosystem Health Monitoring Programme (OSAEH Programme) was proposed (ORASECOM, 2009) and provided the details that were required to implement the monitoring of aquatic ecosystem health in the basin, and to report on this on a regular basis

Based on this information, ORASECOM undertook a joint basin wide water quality and aquatic ecosystem health baseline survey in September/October 2010 – *viz*. the Orange-Senqu Joint Baseline Survey with the aim of providing the first comprehensive assessment of the chemical, physical, and ecological condition of the Orange-Senqu Basin, based on the sites included in the OSAEH monitoring programme.

Parallel to these studies, the first comprehensive EFR study on the Orange Basin (this study) was undertaken and the EFR sites and data collected during THIS study is included in the OSAEH programme.

It is essential that a monitoring programme is not established which follows on from the baseline surveys as soon as possible. No Ecological Water Resources Monitoring (EWRM) DSS framework exists which is essential for the monitoring programme. This EWRM programme will be built on the EcoSpecs and TPCs developed during the EFR study and the baseline information collated during the OSAEH programme. The methods applied during monitoring and the identification of EcoSpecs and TPCs require testing and refinement within an adaptive management process. With increased development and pressure on the water resources in SADC countries an integrated EWRM programme is essential in order to monitor the further deterioration of our rivers.

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