WP 10543

REPORT NO. RDM/WMA16/00/CON/1313

RESERVE DETERMINATION STUDIES FOR THE SELECTED SURFACE WATER, GROUNDWATER, ESTUARIES AND WETLANDS IN THE GOURITZ WATER MANAGEMENT AREA

PROJECT TECHNICAL REPORT 12

MONITORING REPORT

November 2015

Department of Water and Sanitation
Chief Directorate: Water Ecosystems

Published by

Department of Water and Sanitation
Private Bag X313
PRETORIA, 0001
Republic of South Africa

Tel: +27 (12) 336 7500
Fax: +27 (12) 323 0321

Copyright reserved

This report should be cited as:

Department of Water and Sanitation (DWS), 2015. *Reserve Determination Studies for the Selected Surface Water, Groundwater, Estuaries and Wetlands in the Gouritz Water Management Area*: Monitoring Report. Prepared by Koekemoer Aquatic Services and Scherman Colloty & Associates cc.. Report no. RDM/WMA16/00/CON/1213.

Compiled by:
Scherman Colloty & Associates cc.
22 Somerset Street
Grahamstown
6139

In association with:
AECOM SA (Pty) Ltd
Waterside Place
South Gate
Tyger Waterfront
Carl Cronje Drive
Bellville
7530

DOCUMENT INDEX

Reports as part of this project:

INDEX NUMBER	REPORT NUMBER	REPORT TITLE
Report Number 01	RDM/WMA16/00/CON/0113	Inception Report
Report Number 02	RDM/WMA16/00/CON/0213	Desktop EcoClassification Report
Report Number 03, Volume 1	RDM/WMA16/00/CON/0313, Volume 1	Delineation Report, Volume 1 (Groundwater, Estuaries and Wetlands)
Report Number 03, Volume 2	RDM/WMA16/00/CON/0313, Volume 2	Delineation Report, Volume 2 (Rivers)
Report Number 04	RDM/WMA16/02/CON/0413	Groundwater Report
Report Number 05	RDM/WMA16/03/CON/0513	Wetland Report
Report Number 06, Volume 1	RDM/WMA16/04/CON/0613, Volume 1	Estuaries RDM Report – Desktop Assessment
Report Number 06, Volume 2	RDM/WMA16/04/CON/0613, Volume 2	Estuaries RDM Report – Desktop Re-evaluation of the 2008 EWR Study on the Keurbooms Estuary
Report Number 07, Volume 1	RDM/WMA16/04/CON/0713, Volume 1	Estuaries RDM Report – Rapid Assessment, Volume 1 (Klein Brak Estuary)
Report Number 07, Volume 2	RDM/WMA16/04/CON/0713, Volume 2	Estuaries RDM Report – Rapid Assessment, Volume 2 (Wilderness System)
Report Number 08, Volume 1	RDM/WMA16/04/CON/0813, Volume 1	Estuaries RDM Report – Intermediate Assessment, Volume 1 (Duiwenhoks Estuary)
Report Number 08, Volume 2	RDM/WMA16/04/CON/0813, Volume 2	Estuaries RDM Report – Intermediate Assessment, Volume 2 (Gouritz Estuary)
Report Number 08, Volume 3	RDM/WMA16/04/CON/0813, Volume 3	Estuaries RDM Report – Intermediate Assessment, Volume 3 (Goukou Estuary)
Report Number 09	RDM/WMA16/00/CON/0913	Scenario Report
Report Number 10	RDM/WMA16/01/CON/1013	Rivers RDM Report – Intermediate Assessment
Report Number 11	RDM/WMA16/01/CON/1113	Rivers RDM Report – Rapid Assessment
Report Number 12	**RDM/WMA16/00/CON/1213**	**Monitoring Report**
Report Number 13	RDM/WMA16/00/CON/1313	Main Report
Report Number 14	RDM/WMA16/00/CON/1413	Study Closure Report

Bold indicates this report.

APPROVAL

TITLE:	Reserve Determination Studies for the Selected Surface Water, Groundwater, Estuaries and Wetlands in the Gouritz Water Management Area: Main Report.
DATE:	November 2015
AUTHORS:	Technical team
EDITOR:	Koekemoer Aquatic Services: Shael Koekemoer; Scherman Colloty & Associates cc.
REVIEWERS:	Project Management Team
LEAD CONSULTANT:	Scherman Colloty & Associates cc.
REPORT NO:	RDM/WMA16/00/CON/1213
FORMAT:	MSWord and PDF
WEB ADDRESS:	http://www.dws.gov.za

Approved for Scherman Colloty & Associates cc:

Dr Patsy Scherman
Technical Team Leader

Approved for AECOM SA (Pty) Ltd:

Dr Aldu le Grange
Study Leader

Approved for the Department of Water and Sanitation by:

Ms Nancy Motebe
Deputy-Director: Groundwater
Reserve Requirements

Ms Barbara Weston
Deputy-Director: Surface Water
Reserve Requirements

Mr Yakeen Atwaru
Director: Reserve Requirements

Ms Ndileka Mohapi
Chief Director: Water Ecosystems

ACKNOWLEDGEMENTS

The following individuals are thanked for their contributions to this project:

Project Co-ordinators

Yakeen Atwaru	Department of Water and Sanitation	Project Director
Barbara Weston	Department of Water and Sanitation	Project Manager: Surface Water
Nancy Motebe	Department of Water and Sanitation	Project Manager: Groundwater
Thapelo Machaba	Department of Water and Sanitation	Project Co-ordinator

Project Team

Aldu le Grange	AECOM SA (Pty) Ltd	Professional Service Provider Study Leader
Patsy Scherman	Scherman Colloty and Associates	Technical Study Team Leader
Simon von Witt	AECOM SA (Pty) Ltd	Professional Service Provider Study Co-ordinator

Members of Project Steering Committee

Names	Affiliation
Ndileka Mohapi	CD: Water Ecosystems (WE)
Yakeen Atwaru	D: Reserve Requirements (RR)
Barbara Weston	D: Surface Water Reserve Requirements (SWRR)
Nancy Motebe	D: Ground Water Reserve Requirements (GWRR)
Thapelo Machaba	D: SWRR
Vuledzani Muthelo	D: RR-SWRR
Gladys Makhado	D: RR
Happy Maleme	D: RR
Wietsche Roets	D: Water Abstraction and Instream Use
Shane Naidoo	D: Water Resources Classification
Vusi Mema	D: Resource Directed Measures Compliance (RDMC)
Boitumelo Sejamoholo	D: RDMC
Manelisi Ndima	D: GWRR
Isa Thompson	DWS: National Planning
Pieter Viljoen	DWS: Water Quality Planning
Mennard Mugumo	DWS: Options Analysis
Fanus Fourie	DWS: Planning Groundwater
Nadene Slabbert	DWS: Resource Quality Services (RQS)
Neels Kleynhans	DWS: RQS
Gerhard Cilliers/Nolu Jafta	DWS: RQS
Rashid Khan	DWS Western Cape (WC): Regional Director
Wilna Kloppers	DWS WC: Resource Protection
Andrew Gordon	DWS WC: Resource Protection
Bertrand van Zyl	DWS WC: Operations
John Roberts/Hester Lyons	DWS WC: Gouritz Catchment Manager
Frans Mouski	DWS WC: Hydrology
Mike Smart	DWS WC: Geo-Hydrology
André Roux	Department of Agriculture Western Cape (DAWC)
Danie Swanepoel/ Francois Naude	Department of Environmental Affairs and Development Planning (DEADP)

Names	Affiliation
Ian Russell/ Dirk Roux	South African National Parks Board (SANParks)
Greg Palmer/ Andrew Turner/ Pierre de Villiers	CapeNature
Heidi Nieuwoudt	South African National Biodiversity Institute (SANBI)
Jannie van Staden	Breede Gouritz Catchment Management Agency (BGCMA)
Vernon Gibbs-Halls	Eden District Municipality
Harold Basson	George Municipality
Alie Killian	Oudtshoorn Municipality
Roy Parry	Knysna Municipality
Johan du Preez	Mossel Bay Municipality
Pikkie Lombard	Bitou Municipality
Reggie Wesso	Hessequa Municipality
Louw Smit/Christopher Wright	Beaufort West Municipality
Richard Fransen/ Heinrich Mettler	Prince Albert Municipality
Jannie Venter	Laingsburg Municipality
Aldu le Grange	AECOM
Simon von Witt	AECOM
Patsy Scherman	SC&A
Cecilia Bester	Agricultural Research Council
Carl Opperman	Agri-Western Cape
Barry Levinrad	Department of Land Affairs
Alwyn Lubbe	Endangered Wildlife Trust
Connie Jonker	Jonkersberg Plantation
Ayanda Matoti	Marine and Coastal Management
Alan Boyd	Marine Protected Area and Estuary Management

AUTHORS

The following persons contributed to this report:

RIVERS TEAM

Authors	Company
Bok, Anton	Anton Bok Aquatic Consultants cc
Koekemoer, Shael	Koekemoer Aquatic Services
Kotzé, Pieter	Clean Stream Biological Services
Louw, Delana	Rivers for Africa eFlows Consulting (Pty) Ltd
Mackenzie, James	Mackenzie Ecological & Developmental Solutions
Scherman, Patsy	Scherman Colloty & Associates cc
Uys, Mandy	Laughing Waters

ESTUARY TEAM

Authors	Company
Adams, Janine	Nelson Mandela Metropolitan University (NMMU)
Lamberth, Stephen	Department of Agriculture, Fisheries and Forestry (DAFF)
Snow, Gavin	NMMU
Taljaard, Susan	Council for Scientific and Industrial Research (CSIR)
Theron, André	CSIR
Turpie, Jane	Anchor Environmental Consulting
Van Niekerk, Lara	CSIR
Wooldridge, Tris	NMMU

WETLANDS AND GROUNDWATER

Authors	Company
WETLANDS	
Rountree, Mark	Fluvius Environmental Consultants
GROUNDWATER	
Grobler, Reuben	Exigo^3 (previously with AGES)
Vivier, Koos	Exigo^3 (previously with AGES)

REPORT SCHEDULE

Version	Date
First and final drafts	November 2015

EXECUTIVE SUMMARY

INTRODUCTION

The purpose of the report is to provide general guidelines for designing monitoring programmes for rivers, estuaries, wetlands and groundwater. Note that the approach and level of monitoring is not consistent between Rivers and Estuaries, as compared to Wetlands and Groundwater. Therefore the following information is provided:

- *Rivers: Ecological Specifications (EcoSpecs) and Thresholds of Potential Concern (TPCs) for habitat and biota, and Level 1 and 2 monitoring. Level 1 monitoring includes desktop approaches at a high frequency (e.g. annually), whereas Level 2 include surveys and specialist analysis at low frequency (e.g. every three years).*
- *Estuaries: EcoSpecs and TPCs for habitat and biota, and additional baseline studies needed to improve the confidence of the Ecological Water Requirement (EWR) results for the various estuaries. Recommended long-term monitoring programmes per estuary are also provided, with the purpose of testing for compliance with EcoSpecs and TPC, and continuously improving understanding of ecosystem function.*
- *Wetlands: EcoSpecs are provided for identified priority wetlands and wetlands in key catchments of the study area.*
- *Groundwater: Evaluation of the current monitoring network, identification of gaps if any, and suggested improvements and/or developing new monitoring borehole sites where deemed necessary.*

EcoSpecs define the Ecological Category (EC). TPCs are upper and lower levels along a continuum of change in selected environmental indicators and are used and interpreted, according to the guidelines set out in Rogers and Bestbier (1997). A monitoring programme must be designed according to the principles of adaptive management to provide guidance on how to address issues if the EcoSpecs and TPCs (Rogers and Bestbier, 1997) are exceeded. The broad objectives of monitoring are to:

- Set EcoSpecs and TPCs for rivers and estuaries.
- Set EcoSpecs for wetlands.
- Provide a monitoring programme to measure the responses and effectiveness in terms of trend and change in EC.

Rivers

Ten EWR sites were selected in the study area. These EWR sites are described in DWA (2014a) and listed in ***Table 1.1*** *of this report.*

The Level 1 monitoring programme proposed for rivers is summarised below:

Indicator	Monitoring action	Temporal scale (frequency and timing)	Spatial scale
All variables measured as standard by DWS as a minimum requirement. Note that temperature and dissolved oxygen should be monitored at all EWR sites as no baseline currently exists for these parameters and they are strongly linked to biotic responses.	*Include additional variables in the formal DWS monitoring programme as indicated by EcoSpecs, specifically periphyton, chlorophyll-a and diatoms. Include toxics monitoring if indicated by biotic response (conducted as part of Level 2 monitoring). See additional information in **Section 6.1.1**. Institute water quality monitoring at J1DORI-EWR7, Doring River, if required. Note that this site was not identified as an ecological hotspot and the need for inclusion in the EWR monitoring programme would have to be ascertained.*	*1. Monthly, or as determined by current monitoring programme per monitoring point. 2. Institute twice per month monitoring at EWR sites with no water quality gauging weir in place. 3. Use Google Earth and available information where data are not available and cannot be collected to identify driving land-uses, associated driving water quality variables and preliminary current state for water quality.*	*1. Relevant water quality monitoring point at gauging weir. 2. Institute a monitoring point downstream of the EWR site if no water quality gauging weir is in place for use.*
Diatoms	*Baseline data is depauperate especially at all the Rapid EWR sites as well as at J2GAMK-EWR4, J1BUFF-EWR5 and J3OLIF-EWR9. Collect baseline data to develop EcoSpecs and TPCs. Field work.*	*Six monthly at all sites preferable during summer and winter or high and low flow conditions.*	*All EWR sites and sites were WQ hotspots have been identified.*
Woody vegetation cover within the riparian zone	*Assessment of satellite imagery: Each time new Google Earth © coverage becomes available (check coverage dates monthly)*	*1. Monthly checks for new satellite data. 2. Vegetation assessment whenever new data become available.*	*EWR reach.*

The Level 2 monitoring programme is summarised below:

Indicator	Monitoring action	Temporal scale (frequency and timing)	Spatial scale
Riparian vegetation			
Woody vegetation within the riparian zone, both terrestrial and indigenous riparian	*Field assessments using VEGRAI level 4. Fixed point photography.*	*Every three years, same month for subsequent surveys.*	*All EWR sites.*
Reeds			
Alien vegetation			
Non-woody vegetation including sedges,			

Indicator	Monitoring action	Temporal scale (frequency and timing)	Spatial scale
grasses, and dicotyledonous forbs, but excluding reeds or palmiet			
Overall PES for riparian vegetation			
Fish			
Species richness and specific indicator fish species with a preference for specific habitat features (such as substrate) or being intolerant to specific impacts (such as water quality deterioration, flow reduction)	*Field assessment (electrofishing and where appropriate using a minnow seine).*	*Every two years (dry season, same as baseline).*	*All EWR sites as above and other sites in Resource Unit (RU) as specified.*
Macroinvertebrates			
Composition and abundance	*Field assessment (SASS5) (high priority).*	*Every two years.*	*All EWR sites as above.*

Estuaries

The Gouritz WMA includes 21 estuaries stretching from the Duiwenhoks Estuary in the west to the Bloukrans Estuary in the east. Within this WMA, 11 estuaries have been assessed as part of previous EWR studies. The Gouritz Reserve Determination Study (GRDS) therefore focused on the remaining 10 estuaries (refer to ***Table 1.2****). Of the 11 estuaries that was assessed previously, EWR assessments on eight of those did not define EcoSpecs and TPCs, nor were monitoring programmes provided. Therefore, the GRDS also defined such parameters and programmes for those eight estuaries (refer to* ***Table 1.2****).*

For estuaries, monitoring requirements are divided into additional baseline surveys and long-term monitoring. The purpose of additional baseline surveys is to collect data and information to improve understanding of the ecosystem functioning of a specific system in order to improve the confidence in EWR results. Long-term monitoring programmes are usually less intensive programmes that are implemented to test compliance with EcoSpecs and TPCs. Long-term monitoring programmes are also used to improve and refine EcoSpecs and TPCs through an iterative management process. Limited financial and human resources are often a reality in the deployment of baseline and long-term monitoring programmes, a list of priority monitoring actions needs to be identified by specialists when defining such surveys and programmes.

For the GRDS, detailed baseline and long-term monitoring programmes were developed for the estuaries that were assessed at the intermediate (i.e. Duiwenhoks, Goukou and Gouritz estuaries) and rapid (i.e. Klein Brak and Wilderness system) levels. For the estuaries that were assessed at a desktop levels (i.e. Blinde, Hartenbos, Piesang, Groot (Wes) and Bloukrans estuaries), as well as the estuaries for which previous EWR studies did not provide baseline or long-term monitoring programmes, a generic monitoring programme was developed. The monitoring programme previously provided for the Keurbooms Estuary as part of the 2008 EWR study was also re-assessed.

It is recommended that the implementation of the additional baseline surveys and long-term monitoring programmes should be undertaken in collaboration with various responsible departments

in DWS, as well as other national and provincial departments and institutions responsible for estuarine resource management such as Department of Agriculture Fisheries and Forestry (DAFF), Department of Environmental Affairs (DEA: Oceans and Coasts), South African National Biodiversity Institute (SANBI), CapeNature, as well as relevant municipal authorities. It is recommended that the estuarine management planning process and the associated institutional structures (as required under the Integrated Coastal Management Act 2008) be used as a mechanism through which to facilitate the implementation of these interventions.

Wetlands

Of the thirty-three potential priority wetlands identified in the Grouritz Water Management Area (WMA), two of the highest priority wetlands, i.e. the Duiwenhoks valley bottom wetland and Bitou floodplain, were selected for field assessments. The purpose of the field assessments was to verify the desktop data and information, to determine the EcoStatus of the priority wetlands, and to identify the threats and achievable management actions which could be implemented to halt or reverse degradation (DWS, 2015f).

In wetlands, the monitoring programmes that are suggested are relatively cheap desktop approaches, with limited field verification if budget and expertise permits. The design of a cost-effective monitoring programme is based on different levels of monitoring as follows:

- *EcoSpecs for priority wetlands; and*
- *EcoSpecs for key catchments.*

<u>Priority wetland 1: Duiwenhoks wetland - EcoSpecs</u>

Monitoring should ensure that:

- *There is no additional erosion in intact wetland sections.*
- *There is no encroachment of agricultural areas into wetlands.*
- *There is removal and control of invasive alien vegetation within and along margins of the wetland. The draining of the wetland areas and/or diverting of flows have already initiated widespread erosion in former pristine wetland areas and further degradation of this type must be prevented; and*
- *The EC must achieve or exceed the 2015 baseline.*

<u>Priority wetland 2: Bitou floodplain - EcoSpecs</u>

Monitoring should focus on the key impacts which affect the wetlands and place at risk the achievement of the REC:

- *No encroachment of agricultural or residential areas in to wetlands.*
- *Removal and control of invasive alien vegetation within and along margins of the wetland. The draining of the wetland areas and/or diverting of flows have already initiated widespread degradation and further degradation of this type must be prevented.*
- *The EC must achieve or exceed the 2015 baseline.*

An additional recommendation would be to promote the vegetation of buffer areas along streams and canals. This would assist to reduce turbidity and sediment losses from the floodplain through stabilised stream and canal banks. The vegetation may also assist with some nutrient trapping and thus a potential reduction in nutrient-rich runoff from the agricultural areas.

Wetlands in key catchments of the Gouritz WMA - EcoSpecs

The monitoring of important quaternary catchments should ensure that:

- *Invasive alien vegetation, especially woody vegetation, within and alongside wetlands does not expand from the baseline (2015) conditions.*
    - *For quaternary catchments K30B, K50B and K80A where the Recommended Ecological Category (REC) is higher than the baseline condition, the extent of invasive alien vegetation should decline relative to the baseline condition.*
- *Erosion dongas, which desiccate wetlands and cause the degradation of wetland habitats, should be stabilised through rehabilitation structures. The unchecked expansion of erosion dongas will cause wetlands to be degraded and lost. Rehabilitation interventions can be implemented in conjunction with the DAFF, DEA and Working for Wetlands (WfWetlands).*
- *Residential, industrial and agricultural landuse encroachment in to wetlands should not take place.*
- *The EC must achieve or exceed the 2015 baseline, and meet the REC.*

Groundwater

Locations of active monitoring boreholes are shown in ***Figure 9.2****. Although a good coverage of the most important Groundwater Resource Units (GRUs) and selected intermediate Reserve quaternaries is achieved with the existing active monitoring boreholes, there are still some areas in the WMA where an additional groundwater monitoring borehole would be prudent. One observation to the active monitoring borehole network is that there are often concentrations of monitoring boreholes at specific towns while other towns have none. It is, however, also true that one has to consider for each town if groundwater level data is really necessary given the town's type of water use (surface- or groundwater-source).*

Based on these considerations, the following areas have been identified:

- *The primary area for inclusion of hydraulic head monitoring data in DWS active monitoring boreholes database is the coastal region between George and Plettenberg Bay.*
- *A second area for consideration is the H90E Stilbaai, Jongensfontein/Gouritzmond coastal dune aquifers area. The reason being that some of the potable water for Stilbaai is supplied from groundwater from springs and boreholes. There is already a number of monitoring boreholes being actively monitored at Albertina close by.*

Although there are no DWS active monitoring boreholes at Laingsburg, Stilbaai or the J31A quaternary catchment, there is active monitoring taking place at these towns of major abstraction boreholes. This groundwater monitoring is handled by the respective local municipalities and in almost all cases contracted out to professional geohydrological service proders. In the case of the former mentioned municipalities, the data was readily made available for this study by the geohydrological service providers (GEOSS, 2012a;b; GEOSS, 2013a).

Every attempt should be made by these municipalities to make the groundwater data accessible to specialists for evaluation, either directly on the website, a contact link to obtain via e-mail or as favoured method provide the data to DWS in the correct format for inclusion in their active

monitoring borehole database. In some rare cases data accessibility is problematic due to the involvement of consultants instead of the data being directly managed by DWS.

Data from the specific wellfield developments and strategic GRU areas such as the Klein Karoo Rural Water Supply Scheme (KKRWSS) and the Deep Artesian Groundwater Exploration for Oudtshoorn Supply (DAGEOS) RUs is available and can be supplied upon request from the consultants involved via DWS. Evaluations of the hydraulic head and water quality data can be found in the respective wellfield groundwater specialist reports (GEOSS, 2014; Hartnady et al., 2014).

Sedgefield and Ladismith have both had further groundwater development in the last three years and monitoring by the respective municipalities should be strongly considered in order to sustainably manage the groundwater resources.

There should be an attempt to include current active monitoring conducted by service providers into the DWS active monitoring boreholes database so that the data is readily available from DWS for any groundwater assessments that need to be performed in specific areas. At the simplest level, Geosite identifiers or borehole numbers with coordinates of active monitoring boreholes should be included in the DWS list/table of active monitoring boreholes. A column (field) can be added to include which organisation is performing the monitoring so that the groundwater investigator can at least know whom to contact for this data. The complete list of active monitoring boreholes will also then provide a complete picture of all active groundwater monitoring taking place. It is recommended that data supply from consultants be realised through an easy to use web-upload interface with registration of the consultants assisting the DWS with monitoring or a specific project that requires access to the data. Those only accessing the data can have read-only rights to the database. Given the simplest level of monitoring, service provider participation in the DWS active monitoring borehole database, as mentioned above is essential, and would require minimal database maintenance effort from both DWS and the consultant.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ACRONYMS

Alt	Altitude
ARC	Agricultural Research Council
ASPT	Average Score Per Taxon
BH	Borehole
BOD	Biological Oxygen Demand
CD: WE	Chief Directorate: Water Ecosystems
CMA	Catchment Management Area/Agency
CPUE	Catch Per Unit Effort
CSIR	Council for Scientific and Industrial Research
CTD	Conductivity-Temperature-Depth
DAFF	Department of Agriculture Fisheries and Forestry
DAGEOS	Deep Artesian Groundwater Exploration for Oudtshoorn Supply
DEA	Department of Environmental Affairs
DIN	Dissolved Inorganic Nitrogen
DIP	Dissolved Inorganic Phosphate
DO	Dissolved Oxygen
D: RQIS	Directorate: Resource Quality Information Services
DSS	Decision Support System
DWA	Department Water Affairs (Name change from DWAF applicable after April 2009)
DWAF	Department Water Affairs and Forestry
DWS	Department Water and Sanitation (Name change from DWA applicable after May 2014)
EC	Ecological Category
EcoSpecs	Ecological specifications
EFZ	Estuary Functional Zone
EI	Ecological Importance
EIS	Ecological Importance and Sensitivity
ES	Ecological Sensitivity
EWR	Ecological Water Requirements
EWRM	Ecological Water Resources Monitoring
FDI	Flow Dependent Macroinvertebrate
FRAI	Fish Response Assessment Index
FROC	Frequency of Occurrence
Geo	Geomorphic
GPS	Global Positioning System
GRDS	Gouritz Reserve Determination Study
GRU	Groundwater Resource Unit
GW	Groundwater
Hor	Horizontal
HPLC	High Performance Liquid Chromatography
ind/min	Individuals per minute
KKRWSS	Klein Karoo Rural Water Supply Scheme
LB	Left bank
MAP	Mean Annual Precipitation
MAR	Mean Annual Runoff

mbgl	Metres below ground level
MCB	Macro-channel Bank
MCM	Million Cubic Metres
MIRAI	Macroinvertebrate Response Assessment Index
MRU	Management Resource Unit
Na	Sodium
NFEPA	National Freshwater Ecosystem Priority Area
NGA	National Groundwater Archive
nMAR	Natural Mean Annual Runoff
NTU	Nephelometric Turbidity Units
NWA	National Water Act
NWRCS	National Water Resource Classification System
ORDS	Outeniqua Reserve Determination Study
PES	Present Ecological State
pMAR	Present Day Mean Annual Runoff
PTV	Pollution Tolerant Valve
Quat	Quaternary catchment
RB	Right bank
RC	Reference Condition
RDRM	Revised Desktop Reserve Model
REC	Recommended Ecological Category
REI	River-Estuary Interface
RHAM	Rapid Habitat Assessment Method
RQIS-RDM	Resource Quality Information Services – Resource Directed Measures
RQO	Resource Quality Objective
RU	Resource Unit
SANBI	South African National Biodiversity Institute
SANParks	South African National Parks Board
SASS5	South African Scoring System version 5
SAWS	South African Weather Services
SPI	Specific Pollution sensitivity Index
SQ	Sub Quaternary
SRP	Soluble Reactive Phosphorous
TDI	Trophic Diatom Index
TIN	Total Inorganic Nitrogen
TPC	Thresholds of Potential Concern
TWQR	Target Water Quality Range
UNEP	United Nations Environment Programme
VEGRAI	Riparian Vegetation Response Assessment Index
WfWetlands	Working for Wetlands
WIO	Western Indian Ocean
WMA	Water Management Area
WMS	Water Management System
WQ	Water Quality
WRC	Water Research Commission
WRYM	Water Resource Yield Model
WWTW	Waste Water Treatment Works
WULA	Water Use Licence Application

Velocity Depth Classes: Fish and Macroinvertebrates

FCS	Fast flow over Coarse Substrate invertebrate habitat
FD	Fast Deep fish habitat
FDI	Flow Dependent Invertebrate
FS	Fast Shallow fish habitat; Fine Substrate invertebrate habitat
GSM	Gravel-Sand-Mud invertebrate habitat
MV	Marginal Vegetation
SD	Slow Deep fish habitat
SIC	Stones-in-Current
SOC	Stones-out-of-Current
SS	Slow Shallow fish habitat
VFCS	Very Fast flow over Coarse Substrate invertebrate habitat

Fish species: Abbreviations

AMAR	*Anguilla marmorata*
AMOS	*Anguilla mossambica*
BAEN	*Labeobarbus aeneus*
BANO	*Barbus anoplus*
CCAR	*Cyprinus carpio*
GZEB	*Galaxias zebratus*
LMAC	*Lepomis macrochirus*
LUMB	*Labeo umbratus*
MCAP	*Myxus capensis*
MCEP	*Mugil cephalus*
MDOL	*Micropterus dolomieu*
MFAL	*Monodactylus falciformis*
MSAL	*Micropterus salmoides*
PAFE	*Pseudobarbus afer*
PASP	*Pseudobarbus asper*
PBUR	*Pseudobarbus burchelli*
PTEN	*Pseudobarbus cf. tenuis*
RDEW	*Redigobius dewaali*
SCAP	*Sandelia capensis*
TSPA	*Tilapia sparrmanii*

Macroinvertebrate taxa: Abbreviations

AES	Aeshnidae (8)
ANC	Ancylidae
ATH	Athericidae
ATY	Atyidae
BAE	Baetidae 2 spp.
BAE-	Baetidae 1 spp.
BAE+	Baetidae > 2 spp.
CAE	Caenidae
CAL	Calopterygidae
COE	Coenagrionidae
ELM	Elmidae
GOM	Gomphidae
HEP	Heptageniidae
HME	Hydrometridae

HYD	Hydropsychidae 2 spp.
HYD-	Hydropsychidae 1 spp.
HYD+	Hydropsychidae > 2 spp.
LEP	Leptophlebiidae
LPC	Leptoceridae
NAU	Naucoridae
PER	Perlidae
PHI	Philopotamidae
SIM	Simuliidae
TAB	Tabanidae
TEL	Telagonodidae
TRI	Trichorythidae

1 INTRODUCTION

1.1 BACKGROUND

The National Water Act (Act No. 36 of 1998) (NWA), Section 3 requires that the Reserve be determined for water resources, i.e. the quantity, quality and reliability of water needed to sustain both human use and aquatic ecosystems, so as to meet the requirements for economic development without seriously impacting on the long-term integrity of ecosystems. The Reserve is one of a range of measures aimed at the ecological protection of water resources and the provision of basic human needs (i.e. in areas where people are not supplied directly from a formal water service delivery system and thus directly dependent on the resource according to Schedule 1 of the NWA). Chief Directorate: Water Ecosystems (CD: WE) within Department Water and Sanitation (DWS) is tasked with the responsibility of ensuring that the Reserve is considered before water allocation and licensing can proceed.

The requirement for detailed Reserve studies in the Gouritz Water Management Area (WMA) became apparent for the following reasons:

- Various licence applications in the area.
- Gaps that have been identified as part of the Outeniqua Reserve Determination Study (ORDS) completed in 2010.
- The conservation status of various priority water resources in the catchment and existing and proposed impacts on them.
- Increasing development pressures and secondary impacts related from the aforementioned and the subsequent impact on the availability of water.

For management and improved governance reasons, South Africa's 19 WMAs have been consolidated into nine (9) WMAs. The Gouritz WMA (previously WMA 16) now forms part of the previous Breede WMA (WMA 8) which now is known as the Breede-Gouritz WMA. It will be governed by the Breede-Gouritz Catchment Management Agency (CMA).

1.2 STUDY AREA OVERVIEW

Although it is acknowledged that the Breede and Gouritz WMA have been consolidated, the focus of this study is the Gouritz River and its associated catchments. Therefore the study area has been described in terms of the original WMA; the Gouritz WMA – WMA 16.

The Breede-Gouritz WMA is situated on the south coast of the Western Cape, largely falling within the Western Cape Province, and with a surface area of approximately 53 000 km^2. It consists of primary drainage region J (approximately 90 quaternary catchments), and part of primary drainage regions K (K1 to K7) and H (H8 to H9). The WMA therefore consists of approximately 100 - 105 quaternary catchments. It consists of the large dry inland area that is comprised of the Karoo and Little Karoo, and the smaller humid strip of land along the coastal belt. The main rivers are the Gouritz and its major tributaries, the Buffels, Touws, Groot, Gamka, Olifants and Kammanassie

rivers, with smaller coastal rivers draining the coastal belt. All the inland rivers drain via the Gouritz River into the Indian Ocean. The Mean Annual Precipitation (MAP) varies from as high as 865 mm in the coastal areas, which experience all year round rainfall, to as little as 160 mm in the drier areas inland to the north, which experience late summer rainfall. A map of the study area is provided below (**Figure 1.1**).

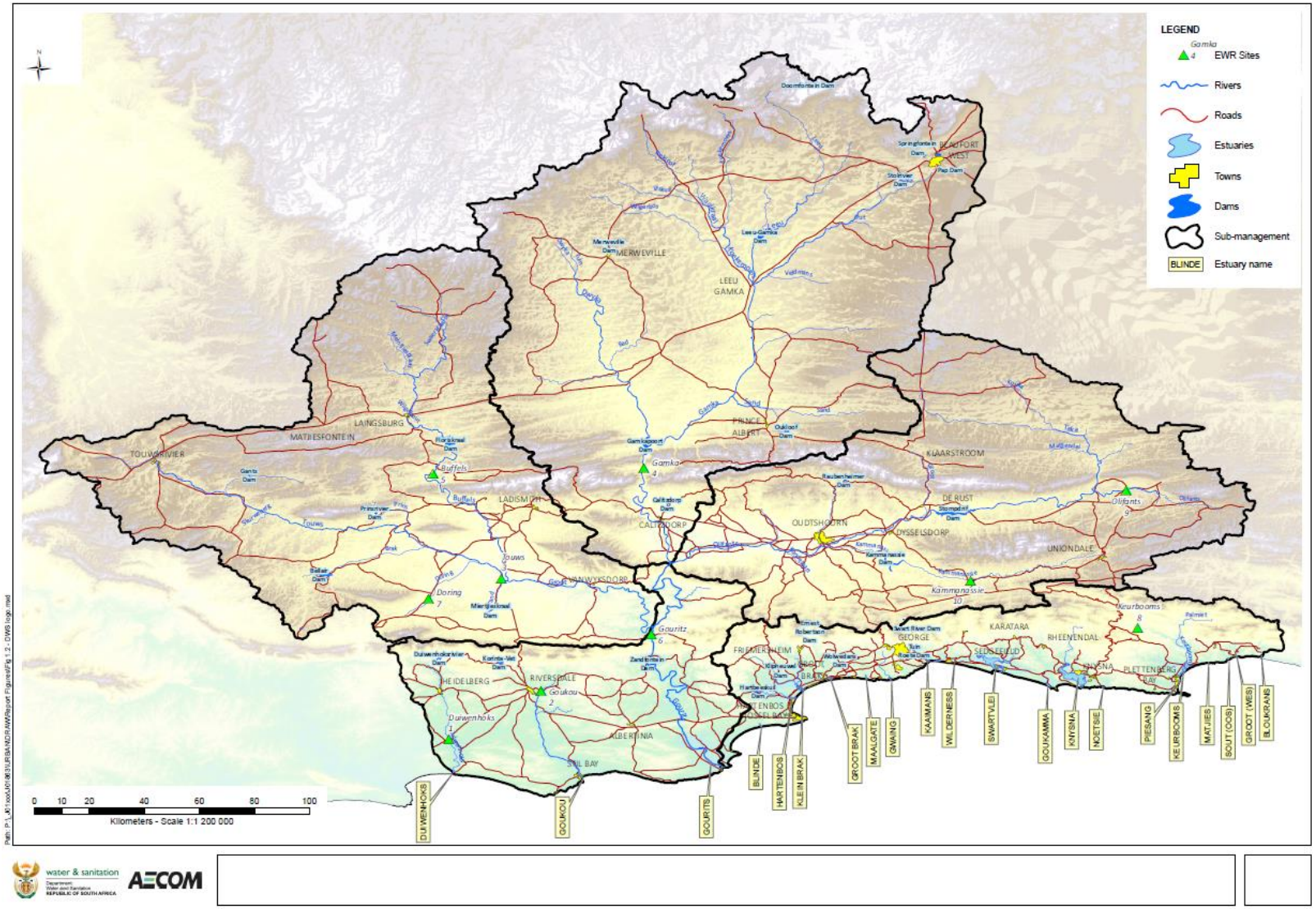

Figure 1.1 Study area

With regard to the sites or areas where ecological monitoring is applicable in the study area, general background is provided in **Section 2.2.1** to **2.2.4**.

1.2.1 Rivers

Ten Ecological Water Requirements (EWR) sites were selected in the study area. These EWR sites are described in DWA (2014a) and listed in **Table 1.1**.

Table 1.1 EWR sites located in various river systems within the study area

EWR site name	SQ[1] reach	River	MRU[2]	Latitude	Longitude	Eco-Region (Level II)	Geo[3] Zone	Alt[4] (m)	Quat[5]
H8DUIW-EWR1	H80E-09314	Duiwen-hoks	MRU Duiwenhoks C	S34.25167	E20.99194	22.02	E Lower Foothills	15	H80E
H9GOUK-EWR2	H90C-09229	Goukou	MRU Goukou A	S34.09324	E21.29300	22.02	E Lower Foothills	87	H90C
J1TOUW-EWR3	J12M-08904	Touws	MRU Touws B	S33.72707	E21.16507	19.07	E Lower Foothills	271	J12M
J2GAMK-EWR4	J25A-08567	Gamka	MRU Gamka B	S33.36472	E21.63051	19.09	E Lower Foothills	375	J25A
J1BUFF-EWR5	J11H-08557	Buffels	MRU Buffels B	S33.38452	E20.94169	19.09	E Lower Foothills	499	J11H
J4GOUR-EWR6	J40B-09106	Gouritz	MRU Gouritz A	S33.90982	E21.65233	19.08	E Lower Foothills	121	J40B
J1DORI-EWR7	J12L-09895	Doring		S33.79137	E20.92699	19.07	E Lower Foothills	370	J12L
K6KEUR-EWR8	K60C-09882	Keur-booms	MRU Keurbooms B	S33.88955	E23.24392	20.02	D Upper Foothills	161	K60C
J3OLIF-EWR9	J31D-08592	Olifants	MRU Olifants A	S33.43813	E23.20587	19.01	E Lower Foothills	621	J31D
J3KAMM-EWR10	J34C-8869	Kamma-nassie	MRU Kammanassie A	S33.73286	E22.69740	19.01	E Lower Foothills	445	J34C

1 Sub Quaternary 2 Management Resource Unit 3 Geomorphic
4 Altitude 5 Quaternary catchment

1.2.2 Estuaries

The Gouritz WMA includes 21 estuaries stretching from the Duiwenhoks Estuary in the west to the Bloukrans Estuary in the east. Within this WMA, 11 estuaries have been assessed a part of previous EWR studies and the Gouritz Reserve Determination Study (GRDS) therefore focused on the remaining 10 estuaries (refer to **Table 1.2**). Of the 11 estuaries that were assessed previously, EWR assessments on eight of those did not define Ecological specifications (referred to in this document as EcoSpecs) and Thresholds of Potential Concern (TPCs), nor were monitoring programmes provided. Therefore, the GRDS also defined such parameters and programmes for those eight estuaries (refer to **Table 1.2**).

Table 1.2 Estuaries from which EcoSpecs, TPCs and monitoring programmes were provided as part of the GRDS

Estuary	EWR level	EcoSpecs/TPCs	Monitoring programme
Duiwenhoks	Intermediate (GRDS study)	✓	✓
Goukou	Intermediate (GRDS study)	✓	✓
Gourits	Intermediate (GRDS study)	✓	✓
Blinde	Desktop (GRDS study)	✓	✓
Hartenbos	Desktop (GRDS study)	✓	✓
Klein Brak	Rapid (GRDS study)	✓	✓
Maalgate	Desktop (previous EWR) (DWA, 2009a)	✓	✓
Gwaing	Desktop (previous EWR) (DWA, 2009a)	✓	✓
Kaaimans	Desktop (previous EWR) (DWA, 2009a)	✓	✓
Wilderness	Rapid (GRDS study)	✓	✓
Goukamma	Rapid (previous EWR) (DWA, 2009b)	✓	✓
Noetsie	Desktop (previous EWR) (DWA, 2009a)	✓	✓
Piesang	Desktop (GRDS study)	✓	✓
Keurbooms	Rapid (previous EWR) (CSIR, 2008)	✓	✓
Matjies	Intermediate (previous EWR) (Bornman, 2007a)	✓	✓
Sout (Oos)	Intermediate (previous EWR) (Bornman, 2007b)	✓	✓
Groot (Wes)	Desktop (GRDS study)	✓	✓
Bloukrans	Desktop (GRDS study)	✓	✓

1.2.3 Wetlands

The majority of the wetlands in the study area are concentrated in the wetter coastal zone. These catchments are often highly transformed by agricultural activities (pastures and cropping), forestry (afforestation) and urban areas as the majority of the population is in this zone. In addition to the direct impacts of these land use practices on wetlands, additional factors, such as dams, abstraction, nutrient enrichment and the spread of invasive vegetation into wetlands, have all impacted upon the Present Ecological State (PES) of the wetlands in the coastal catchments. Consequently, wetlands are on average in a poorer condition along the coast than in the interior.

Wetlands in the drier interior are few – most catchments have less than 0.5% wetlands by area compared with typically at least ten times that proportion in the coastal catchments. Although there are few wetlands, many wetlands and streams in the Karoo are degraded by erosive gullies (dongas) caused by overgrazing, large camp systems, tree removal and burning. Degradation is likely to have started with the intensive livestock operations of early European farmers (Smuts, 2012) which caused erosion and declines in forage productivity (Milton and Dean, 1995). Additional degradation of watercourses may also have been initiated by old access routes – wetlands in the area functioned as the roads for ox-wagon carts that transported people and goods through the Karoo prior to the arrival of cars (Dean and Milton, 1999). Further impacts are caused by the

presence of "thirsty" alien trees that reduce flow or even totally dry up springs and lower water tables.

The extent and density of wetlands across the study area, as indicated by the South African National Biodiversity Institute (SANBI) National Freshwater Ecosystem Priority Area (NFEPA) wetland layer (Driver *et al*., 2012) is provided in **Figure 1.2.** Level 1 NFEPAs are regarded as conservation priorities whereas level 0 wetlands are regarded as non-priority wetlands.

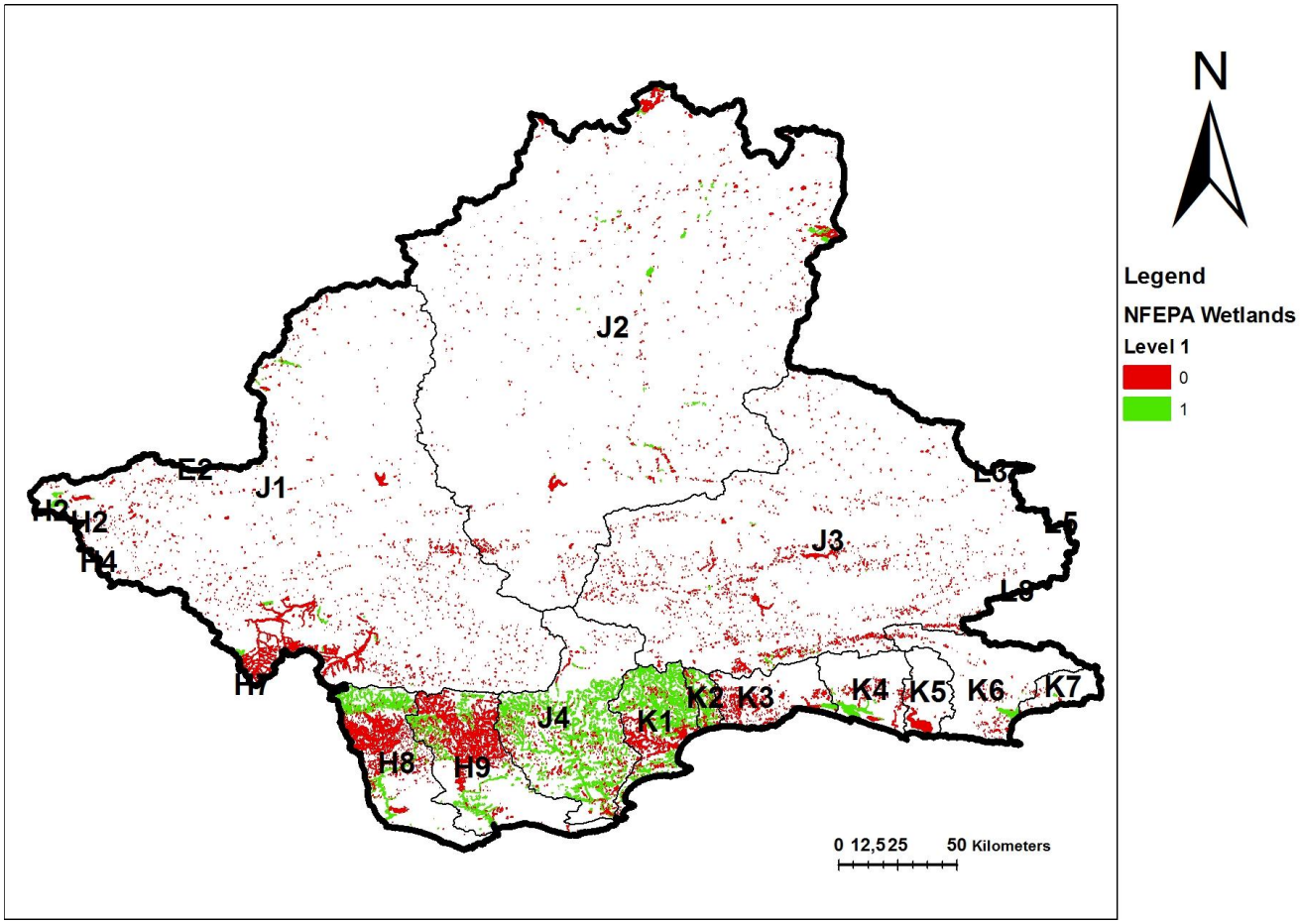

Figure 1.2 The extent and density of wetlands across the study area (Driver *et al*., 2012)

1.2.4 Groundwater

Based on an assessment of the existing active DWS monitoring borehole network, the active network maintained and managed by DWS is well developed compared to networks in some of the other water management areas in South Africa. The spatial distribution of the actively monitored boreholes within the Gouritz WMA is also generally good. According to an extensive recent review (DWS, 2015a) and mapping of all historic and active DWS monitoring boreholes in South Africa (DWS, 2015b) by AECOM (**Table 9.2, Figure 9.1**), there are 81 active DWS groundwater level monitoring boreholes in the Gouritz WMA and 17 active groundwater quality monitoring boreholes (DWS, 2015b). The purpose of this component of the groundwater Reserve determination is to evaluate the current monitoring network, identify gaps, if any, and to suggest improvements and/or new monitoring borehole sites where deemed necessary.

1.3 PURPOSE OF REPORT

The purpose of the report is to provide general guidelines for the development of monitoring programmes for rivers, estuaries, wetlands and groundwater. The level of monitoring is different for rivers and estuaries as compared to wetlands and groundwater. Therefore the following information is provided:

- Rivers: EcoSpecs and TPCs for habitat and biota, and Level 1 and 2 monitoring programme.
- Estuaries: EcoSpecs and TPCs for habitat and biota, and additional baseline studies needed to improve the confidence of the EWR results for the various estuaries. Recommended long-term monitoring programmes per estuary are also provided, which the purpose is to test for compliance with EcoSpecs and TPC and to continuously improve understanding of ecosystem function.
- Wetlands: EcoSpecs are provided for identified priority wetlands and wetlands in key catchments of the study area.
- Groundwater: Evaluation of the current monitoring network, identification of gaps if any, and suggested improvements and/or new monitoring borehole sites where deemed necessary.

1.4 OUTLINE OF THIS REPORT

The report outline is as follows:

- **Section 1** provides general background to the study area and this report.
- **Section 2** provides general information concerning ecological monitoring with reference to rivers and estuaries; and how EcoSpecs and TPCs are used to aid in the interpretation of the attainment of objectives set for the condition and integrity of the resource.
- **Section 3** outlines the methods followed during the determination of EcoSpecs and TPCs for rivers and estuaries.
- **Section 4** provides detailed EcoSpecs and TPCs for the river EWR sites.
- **Section 5** provides detailed EcoSpecs and TPCs for the estuaries in the study area.
- **Section 6** outlines the proposed Level 1 and 2 monitoring programme for rivers in the study area. Level 1 monitoring focusses only on water quality, diatom and woody vegetation monitoring. Level 2 monitoring entails detailed monitoring activities required at a frequency longer than the Level 1 monitoring. The monitoring programme is summarised and additional supporting information on methods for data collection and data analysis is also supplied.
- **Section 7** provides information on additional baseline studies needed to improve the confidence of the EWR results for the various estuaries that were assessed as well as recommended long-term monitoring programmes per estuary.
- **Section 8** provides information on wetland monitoring in the study area. The focus of monitoring is on priority wetlands and wetlands in key catchments of the study area.
- **Section 9** provides information on available groundwater monitoring networks that are active in the study area.
- References are listed in **Section 10**.
- **Appendix A** provides the comments received from various reviewers.

2 RIVERS AND ESTUARIES: MONITORING, ECOSPECS AND TPCs

2.1 ECOSPECS AND TPCs

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 groundwater are included. Groundwater level requirements to maintain spring and base flow in rivers and other ecological features are also considered.
- Biological criteria 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 a specific Ecological Category (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 Decision Support System (DSS) by considering different levels of monitoring surveys.

2.2 RELATIONSHIP BETWEEN ECOSPECS AND HABITAT AND BIOTA RESOURCE QUALITY OBJECTIVES

Resource Quality Objectives (RQOs) are specified Water Resource Classes, with EcoSpecs defined during Reserve studies forming the ecological input to the RQOs. For the purpose of RQO determination and monitoring, the following differentiation is made between biota and habitat EcoSpecs and RQOs.

EcoSpecs are associated with the Ecological Reserve process and are provided at EWR sites. EWR sites are situated in High priority Resource Units (RUs) or Management Resource Units (MRUs, a term used in the Reserve process) and therefore detailed EcoSpecs must be provided as the output of the Reserve study. Detailed RQOs (which include EcoSpecs) must be provided after the Water Resource Classes have been determined. EcoSpecs are the detailed or numerical

ecological input to RQOs as they are quantifiable, measurable, verifiable and enforceable and therefore ensure protection of all components of the resource, which together define ecological integrity. As EcoSpecs are presented in a numerical quantitative format, they can be used for monitoring and compliance purposes. When setting EcoSpecs, the work is usually based on field surveys that have been undertaken. A monitoring baseline is therefore available and monitoring is to either ensure that the present state is maintained, or that the Recommended Ecological Category (REC) is reached. These objectives would be encapsulated in the RQOs (and called the Target EC).

A monitoring programme must be designed according to the principles of adaptive management to provide guidance on how to address issues if the EcoSpecs and TPCs (Rogers and Bestbier, 1997) are exceeded. The broad objectives of monitoring in general are to:

- Set EcoSpecs and TPCs for rivers and estuaries.
- Provide a monitoring programme to measure the responses and effectiveness in terms of trend and change in EC.

The following report sections are modified from DWA (2009c), DWA (2010) and ORASECOM (2013).

2.3 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 Ecological Water Resources Monitoring (EWRM), it is the measurement of EcoSpecs to determine if the 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 *et al*., 1997; Elzinga *et al*., 1998). This would, inter alia, refer to whether flows are released as was specified for the attainment of a particular EC.
- **Effectiveness monitoring measures whether the EC (in terms of EcoSpecs) are attained by following the particular management scenario (Kershner *et al*., 1997).**

If the 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).

EWRM should be undertaken within a structured 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 TPCs (Rogers and Bestbier, 1997) formulated to assess attainment of an EC. Conclusions emanating from the DSS will provide guidance on the management of the resource (Cormier and Suter, 2008).

Note that the River Health Programme (RHP) in South Africa is currently evolving into the River Ecostatus Monitoring Programme (REMP). This initiative is being spearheaded by Dr Neels Kleynhans of DWS's Directorate on Resource Quality Information Services (D: RQIS), and operates at the riverine sub-quaternary (SQ) level. It is specifically designed to align with the requirements of the NWA, i.e. EWRs, WRC and RQOs, and is being applied in the North West Province (Marico and Crocodile West river catchments) and the Berg River catchment in the Western Cape. Dr Kleynhans has also run numerous training courses around the country (information as at July 2015).

2.4 DIFFERENT LEVELS OF MONITORING

Monitoring programmes have generally in South Africa failed due to amongst others the following reasons:

- The lack of a monitoring DSS and an Adaptive Management Framework.
- The perceived high cost associated with the application of an EWR monitoring programme.

In rivers the design of a cost-effective monitoring programme is based on different levels of monitoring as follows:

- Level 1: Desktop approaches at a high frequency (e.g. annually).
- Level 2: Surveys and specialist analysis at low frequency (e.g. every three years).

If Level 1 monitoring indicates that TPCs are exceeded, Level 2 monitoring surveys may need to be initiated to determine the management actions required to address potential problems. Level 1 and Level 2 monitoring is included in the design of this monitoring programme.

For estuaries monitoring requirements are divided into additional baseline surveys and long-term monitoring. The purpose of additional baseline surveys is to collect data and information to improve understanding of the ecosystem functioning of a specific system in order to improving the confidence in EWR results. Long-term monitoring programmes are usually less intensive programmes that are implemented to test compliance with EcoSpecs and TPCs. Long-term monitoring programmes are also used to improve and refine EcoSpecs and TPCs through an iterative management process. Limited financial and human resources are often a reality in the deployment of baseline and long-term monitoring programmes, therefore a list of priority monitoring actions needs to be identified by specialists when defining such surveys and programmes.

2.5 PRINCIPLES OF EWRM, ECOSPECS AND TPCs

Monitoring in this report focusses on measuring the ecological state, i.e. the EC. EcoSpecs and

TPCs therefore describe the PES and/or the Recommended Ecological Category (REC) for each of the biota and habitat indicators. The key principles and concepts are the following:

- The data collated during field surveys form the baseline.
- Future monitoring must compare conditions to the baseline.
- For rivers the EcoSpecs and TPCs therefore describe the baseline, so monitoring can determine whether one is maintaining the PES, further degrading the system, or achieving the REC if different from the PES. For estuaries, EcoSpecs and TPCs describe the recommended state (or REC).
- Monitoring should be initiated soon after the baseline data has been collated to ensure that this data represents the recent baseline.
- Monitoring must be applied within an Adaptive Management Framework.
- The concept of the TPCs provides the basis of a DSS. When TPCs are exceeded, management actions will be necessary.

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. One must therefore clearly distinguish between setting management objectives in terms of habitat to achieve/maintain certain ECs, and defining EcoSpecs for the biophysical responses that describe the ECs.

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

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

3 RIVERS AND ESTUARIES: APPROACH

3.1 RIVERS

When setting EcoSpecs, the work is usually based on field surveys that have been undertaken. A monitoring baseline is therefore available and monitoring is undertaken to either ensure that the present state is maintained, or that the REC is reached. The state of the river is expressed in terms of biophysical components during the EcoClassification process:

- Drivers (physico-chemical and hydrology), which provide a particular habitat template; and
- Biological responses (fish, riparian vegetation and macroinvertebrates).

These biophysical components therefore describe the state of the EWR sites and form the basis for indicator groups to be assessed during ecological monitoring.

3.1.1 Hydrology

Hydrology EcoSpecs are described as for the EWRs (DWS, 2014a; DWS, 2015c) and are summarised in **Section 4** per EWR site for rivers.

3.1.2 Water quality

Detailed EcoSpecs and TPCs are provided for the EWR sites. 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. Note the following points:

- EcoSpecs, i.e. water quality specifications or objectives for the PES and REC, are set for physico-chemical parameters only, i.e. quantifiable measurable parameters. EcoSpecs are presented as percentiles, i.e. values not to be exceeded more than 5% of the time for inorganic salts, physical variables and toxics; and 50th percentiles for nutrients, i.e. Total Inorganic Nitrogen (TIN), Soluble Reactive Phosphorous (SRP) or ortho-phosphate and chlorophyll-a (chl-a).
- TPCs are also set for physico-chemical parameters for the site, i.e. to monitor deterioration from present state. TPCs ranges are defined by the upper boundary of the PES category (see DWAF, 2008a) 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.

> **<u>Note:</u> Percentiles should be calculated within the framework of the current assessment method (DWAF, 2008a), i.e. using the PES monitoring point as indicated for the relevant EWR site, and the most recent three to five years of data, equivalent to a minimum of 60 data points.** Data used from the DWS gauging weir must be requested from the DWS Water Management System (WMS) database.

- Reporting regarding EcoSpecs, TPCs and monitoring for the water quality part of the Ecological Reserve always specifies that someone trained in water quality will be conducting this component.
- As no standard tool is currently available to generate aggregated salts, salt ionic data were used for determining present state for salts where available. This therefore provides some indication of salt levels in river systems. Note that Reference Condition (RC) data were generally not available. Based on biotic responses, it is assumed that most systems were salinized under natural conditions as high salt levels do not always equate to poor ecological state.
- As the water quality Reserve methods for rivers (DWAF, 2008a) allocate A - F Category (or PES rating) benchmark values only for aggregated salts (**Table 3.1**) and salt ions were used here as an indication of salt levels, EcoSpecs and TPCs are set in terms of present state levels of ions and not as values defining upper limits of selected categories.

Table 3.1 Benchmark values for aggregated salts (DWAF, 2008a)

PES rating	Deviation from RC	Water quality category	$MgSO_4$ (mg/L)	Na_2SO_4 (mg/L)	$MgCl_2$ (mg/L)	$CaCl_2$ (mg/L)	NaCl (mg/L)	$CaSO_4$ (mg/L)
0	No change	A	16	20	15	21	45	351
1	Small change	B	23	33	30	57	191	-
2	Moderate change	C	28	38	36	69	243	773
3	Large change	D	37	51	51	105	389	1105
4	Serious change	E	45	64	66	141	535	-
5	Extreme change	F	>45	>64	>66	>141	>535	-

Example: H8DUIW-EWR1:
The 95th percentile for sodium (Na) is 382.2 mg/L (2007 - 2013), with that for Electrical Conductivity being 272 mS/m, i.e. an E/F Category based on DWAF (2008a) (RC = 80 mS/m, indicating natural salinization). As the upper limit of the relevant category for the salt ion sodium cannot be provided, and the REC is to maintain present state, the EcoSpec for sodium ions is related to current levels. This approach was followed for all salt ionic data.

3.1.3 Diatoms

Algal-based bio-assessments in streams have been extensively researched worldwide and applied in regular riverine- and lake-monitoring programmes with great success. Diatoms are commonly employed in monitoring efforts as sensitive biological indicators to determine the anthropogenic impact on aquatic ecosystems, and have for a long time been used in bio-assessments (Kasperovičienė and Vaikutienė, 2007). As benthic diatom assemblages are sessile they are exposed to water quality at a site over a period antecedent to sampling. They therefore indicate recent as well as current water quality (Philibert *et al*., 2006).

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 Diatom Assessment Protocol, a Water Research Commission (WRC) initiative in South Africa, and should be used by a diatomologist with experience in detailed diatom analysis as outlined in Taylor *et al*. (2007a;b).

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). This software 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 the GRDS.

Approach

Within the context of the GRDS, 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.
- 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; Coste in CEMAGREF, 1982).

The confidence in the diatom results generated during the EWR study (DWS, 2014a; DWS, 2015c), was mostly low and moderate to low due to a limited number of samples that were taken at the different EWR sites as well as very limited available data for the study area. The results also exhibited great variation which could not be quantifiably explained. Diatom data on the Breede-Gouritz WMA within the South African National Diatom Collection is also depauperate. At present the data is too limited to set EcoSpecs and TPCs based on diatom results alone.

Therefore general diatom monitoring guidelines were developed for the different EWR sites based on the diatom community composition and the associated temporal and spatial changes exhibited by the community under different flow conditions. Key indicator species/genera that most frequently indicate problems relating to physico-chemical metrics under South African conditions and applicable to the specific EWR sites was identified with the focus being on the general measure of system recovery of the river reach as well as indicating notable changes in selected metrics. These species can then be considered when developing EcoSpecs and TPCs at a later stage when sufficient baseline data becomes available.

The physico-chemical metrics and variables of importance for diatoms included in the approach are listed below and considered the most important and frequent pollution related impacts encountered in South African rivers which is discussed in detail in Dallas and Day (2004):

- pH.
- Salinity.
- Nutrients.
- Oxygen.
- Organics.

Most of the indices included in OMNIDIA were designed to evaluate at least one of these metrics. Note that there is adequate 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 provide the necessary information for additional input to the physico-chemical driver component within the monitoring programme (Dr Scherman, *Pers. Comm*., January 2015).

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 altered SPI scores, the species included in the guidelines are species that occurred frequently in the samples during 2014, and are specifically good indicators of deteriorated water quality conditions or changes in community composition due to water quality changes at the specific EWR site.

Metal toxicity

The presence of valve[1] deformities is an indication of possible metal toxicity that may be present within the aquatic system. According to Luís *et al*. (2008) several studies on metal polluted rivers have shown that diatoms respond to perturbations not only at the community but also at the individual level with alteration in cell wall morphology. In particular, size reduction and frustule deformations have been sometimes associated with high metal concentrations. The general threshold for valve deformities is usually considered potentially hazardous if the valve deformities make up between 1 - 2% of the total count.

3.1.4 Fish

EcoSpecs were described for different metrics, i.e. Ecological Status (PES), species richness, migratory requirements, alien species and for specific habitat features (e.g. fast shallow habitats, rocky substrates). Indicator species were identified for all these various metrics and primary indicator species (that would best provide indication of potential concern, especially in terms of flow and flow related water quality) was then highlighted.

The following terms are used in the fish EcoSpec tables and are applicable for all tables:

- Frequency of Occurrence (FROC) (Kleynhans and Louw, 2007):
  - 0=absent
  - 1=present at very few sites (<10%)
  - 2=present at few sites (>10 - 25%)
  - 3=present at about >25 - 50% of sites

1 Siliceous part of the diatom cell wall, containing most of the morphological features used to describe diatoms.

    - 4=present at most sites (>50 - 75%)
    - 5=present at almost all sites (>75%)
- Indicator - Primary species or variable used as indicator for relevant metric.
- Diadromous - Refers to all fishes that migrate between the sea and fresh water. Diadromous fishes are further separated into catadromous and potadromous.
- Catadromous – Fishes which spend most of their lives in freshwater and migrate as adults to the sea (or saline reaches of estuaries) to breed (e.g. eels). The young fry and juveniles then migrate upstream through the estuaries into the freshwater zones of rivers. These migrations may be many tens of kilometres and in the case of eels are catchment scale migrations.
- Potadromous - Truly migratory species whose entire life cycle is completed within freshwater and that undertake migrations within freshwater zones (between SQ reaches) of rivers for a variety of reasons, such as for spawning, feeding, dispersion after spawning, colonisation after droughts, for over-wintering, etc.

3.1.5 Macroinvertebrates

The following data were used for determining EcoSpecs and TPCs:

- Data collected during the EWR site visits.
- Relevant historic data and observations from previous surveys in the catchment.

For each site, suitable indicator taxa were selected, using the invertebrate preference data in the Macro Invertebrate Response Assessment Index (MIRAI) spreadsheets of Thirion (2007), and on the basis of specialist experience. The MIRAI data indicate, per taxon, the preference for different variables (flow velocity, habitat types, and water quality), increasing from 0 to 5. Preference is defined by the following ratings:

- 0 - No preference (does not occur).
- 1 - Very low preference (coincidental).
- 2 - Low preference.
- 3 - Moderate preference.
- 4 - High preference.
- 5 - Very high preference.

EcoSpecs are provided for a number of parameters, with the intention of enabling the monitoring process:

- South African Scoring System version 5 (SASS5) and Average Score Per Taxon (ASPT).
- MIRAI score.
- Habitat diversity and quality.
- Response to water quality.
- Response to hydraulic habitats: Very Fast Flow over Coarse Substrates (VFCS), Fast Flow over Coarse Substrates (FCS), Fine Substrates (FS) - any flow class, Marginal Vegetation (MV) - any flow class , Gravel /Sand/ Mud (GSM) - any flow class).

The process of setting EcoSpecs and TPCs is guided by an understanding of the site and its hydrology and habitat, the SASS5 and MIRAI scores, and the invertebrate preferences. Wherever possible, the ‘presence/absence’ and ‘abundance’ of indicator taxa are used to set the EcoSpec and

TPC. It should be noted that in a situation where the natural variability of the system is unknown, as in this study, the EcoSpecs and TPCs should be subject to an Adaptive Management approach, and to regular revision, where required.

In the case of temporary systems (intermittent or ephemeral), it is noted that EcoSpecs are set for sampling during flow periods, without antecedent periods of low- or no flow or drought, as the invertebrate community during or following a no-flow period cannot necessarily be predicted.

3.1.6 Riparian vegetation

The following vegetation components, when assessed together, satisfactorily describe the overall state of the riparian zone:

- Invasion by perennial (and in some cases annual) alien species.
- Terrestrialisation (the disproportionate abundance of terrestrial species within the riparian zone).
- General vegetation structure and composition as shown by proportions of riparian woody species, reeds and non-woody obligate riparian species (grasses, sedges and dicotyledonous forbs).

It should be noted that the hypotheses that underpin the RQOs need to be refined by the DSS (ideally each hypothesis should be tested in a research environment).

Invasion of the riparian zone by perennial alien species

The hypothesis relating aerial cover of alien species to the EC of the riparian zone is shown in **Table 3.2**. Data from the Crocodile and Sabie rivers were used to establish the hypothesis (DWA, 2010). Data from the Gouritz WMA were also analysed but no correlation between perennial alien cover (%) and PES score was found (**Figure 3.1**). The relation of the EC (as determined by an overall approach using the Vegetation Response Assessment Index (VEGRAI – Kleynhans, *et al*., 2007) of a site/reach to the permissible aerial cover of perennial alien species is a general rule of acceptance rather than a deterministic relationship, since the overall EC is a function of multiple deviations from the reference condition, and not merely the abundance of alien species.

Table 3.2 Hypothesis for the acceptance levels (% aerial cover) of perennial alien species within the riparian zone, given the overall EC of the zone

EC	% Cover (perennial aliens)
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

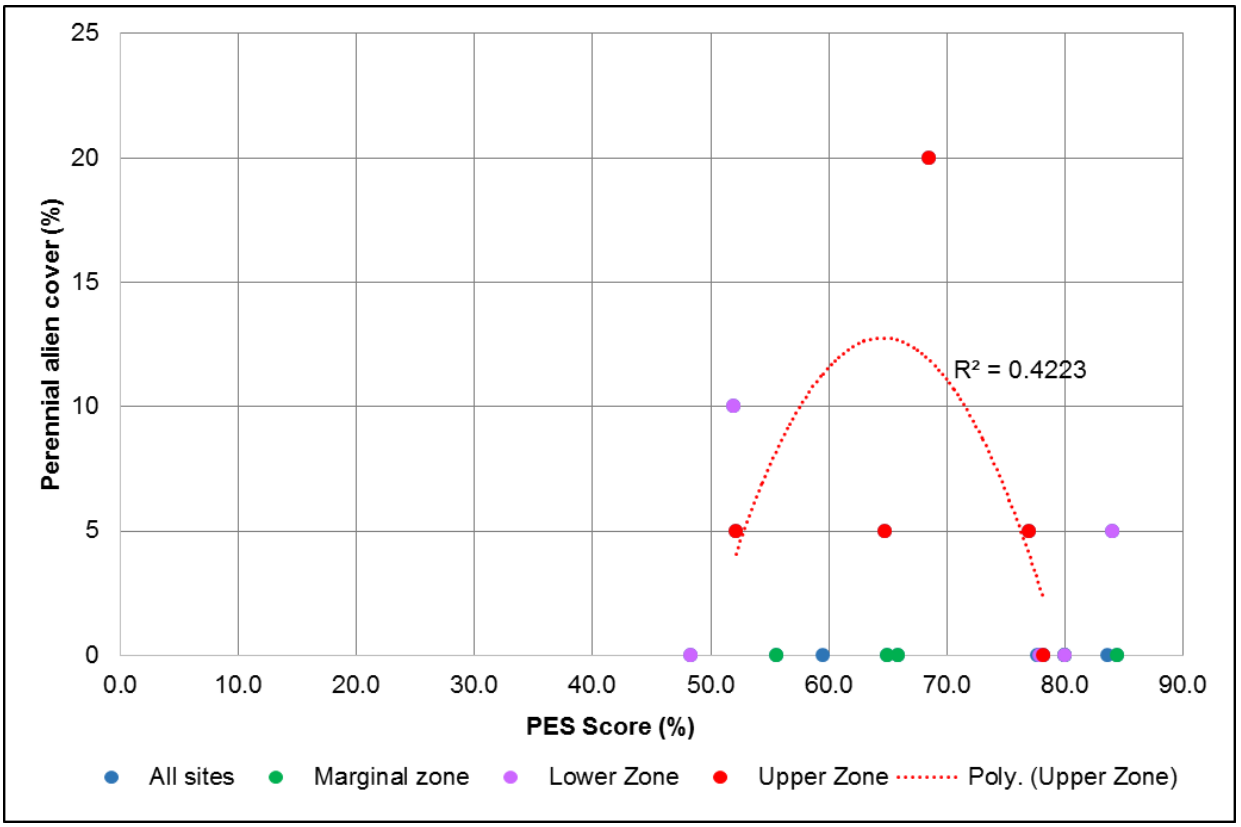

Figure 3.1 Scatter plot of perennial alien species cover (%) and PES score (% from VEGRAI for sub-zone)

Terrestrialisation

Terrestrialisation is the disproportionate abundance, density or occurrence of terrestrial species within the riparian zone. Under RC woody terrestrial species are not expected in the marginal zone, are expected to be transient (if any) in the lower zone due to frequent flooding disturbance, and are expected to occur in the upper zone in numbers concurrent with natural flooding frequency, magnitude and duration for the reach (i.e. hydrologically controlled abundance). In cases where TPCs were set for the riparian obligate/terrestrial species mix, it was always for the upper zone since this is the area where terrestrialization first manifests. **Table 3.3** outlines the hypothesis used to relate the degree of terrestrialisation to the EC. Data for generation of the hypothesis were from the Sabie River initially but refined using correlations from EWR sites in the Gouritz WMA (**Figure 3.2**).

Table 3.3 Hypothesised relationship between degree of terrestrialisation and EC for different sub-zones within the riparian zone

EC	Marginal Zone	Lower Zone	Upper Zone	Note
A	0	0	0	This hypothesis is based on the phenomenon that terrestrial species occur naturally in the riparian zone, but are reduced in cover and abundance by increased flooding disturbance. Data of terrestrial/riparian plant ratios (on the Sabie River) showed a distinct reduction in terrestrial individuals with increasing exposure to flooding disturbance. Similarly terrestrial species cover was weakly inversely correlated to PES score for the Gouritz EWR sites (**Figure 3.2**).
A/B	0	0	0	
B	0	0	1 - 5	
B/C	0	1 - 5	5 - 10	
C	0	5 - 10	10 - 15	
C/D	0	10 - 15	15 - 20	
D	1 - 5	15 - 20	20 - 30	
D/E	5 - 10	20 - 30	30 - 40	
E	10 - 15	30 - 40	40 - 50	
E/F	15 - 20	40 - 50	60 - 70	
F	> 20	> 50	> 70	

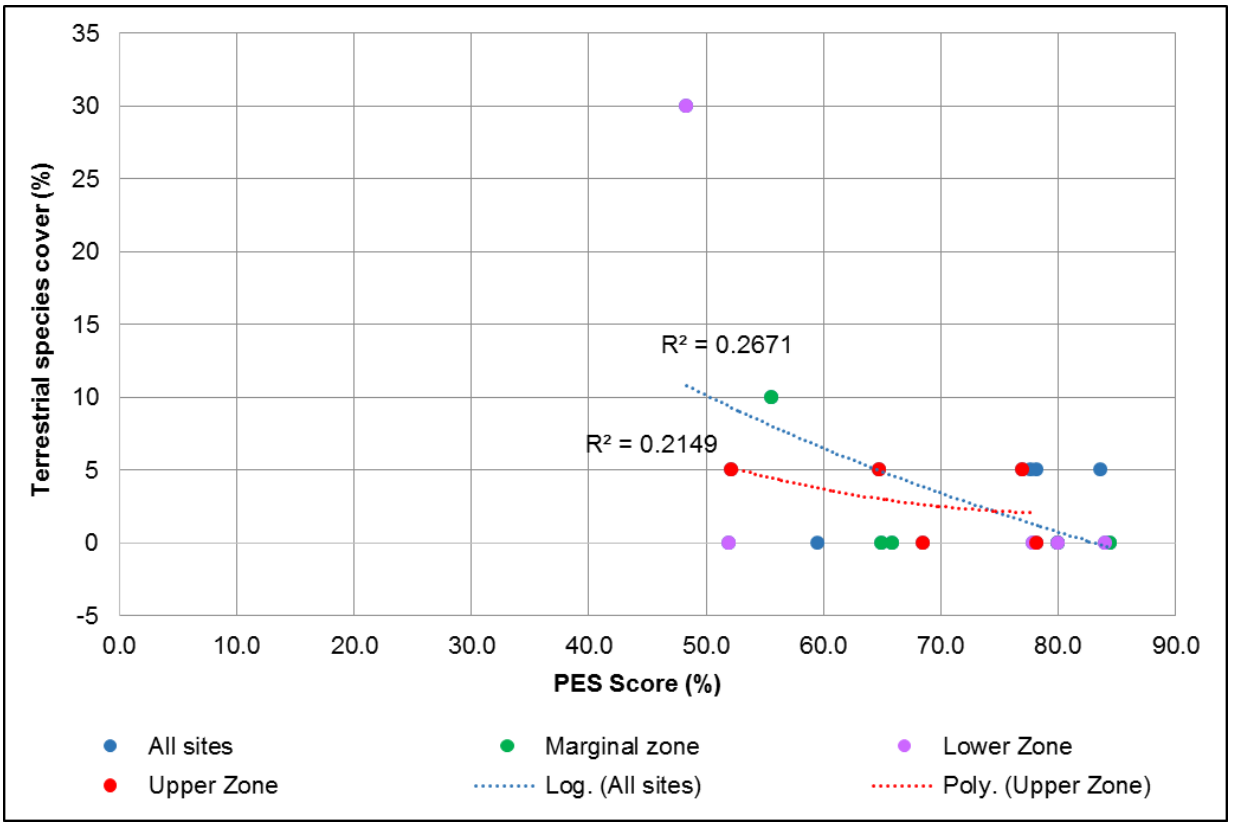

Figure 3.2 Scatterplot of terrestrial species cover with PES score for all Gouritz EWR sites showing weak inverse relationship

Indigenous riparian woody species cover

The hypothesis of expected aerial cover of indigenous riparian woody vegetation is applicable to sites/reaches where the climax community of the Macro-Channel Bank (MCB) and alluvial bars is dominated by woody riparian obligates (**Table 3.4** and **Figure 3.3**). In the absence of natural disturbance the proportion (% cover) will tend to increase with a resultant deterioration of the PES.

The hypothesis is based on the correlation of PES score (%) and woody riparian cover (%) for intermediate EWR sites within the Gouritz WMA.

Table 3.4 Hypothesis relating EC to expected aerial cover of indigenous riparian woody vegetation in different sub-zones of the riparian zone

EC	Marginal Zone	Lower Zone	Upper Zone
A			
A/B		0 - 5	0 - 5
B	0 - 5	5 - 10	5 - 10
B/C			10 - 15
C		10 - 15	20 - 60
C/D	5 - 10	15 - 20	60 - 75
D		20 - 25	>75
D/E	10 - 15	25 -30	
E		30 - 35	
E/F	15 - 20	35 - 40	
F	>20	> 40	

This hypothesis is based on the phenomenon that terrestrial species occur naturally in the riparian zone, but are reduced in cover and abundance by increased flooding disturbance. Terrestrial/riparian plant ratio data (on the Sabie River) showed a distinct reduction in terrestrial individuals with increasing exposure to flooding disturbance. Similarly terrestrial species cover was weakly inversely correlated to PES score for the Gouritz EWR sites (**Figure 3.3**).

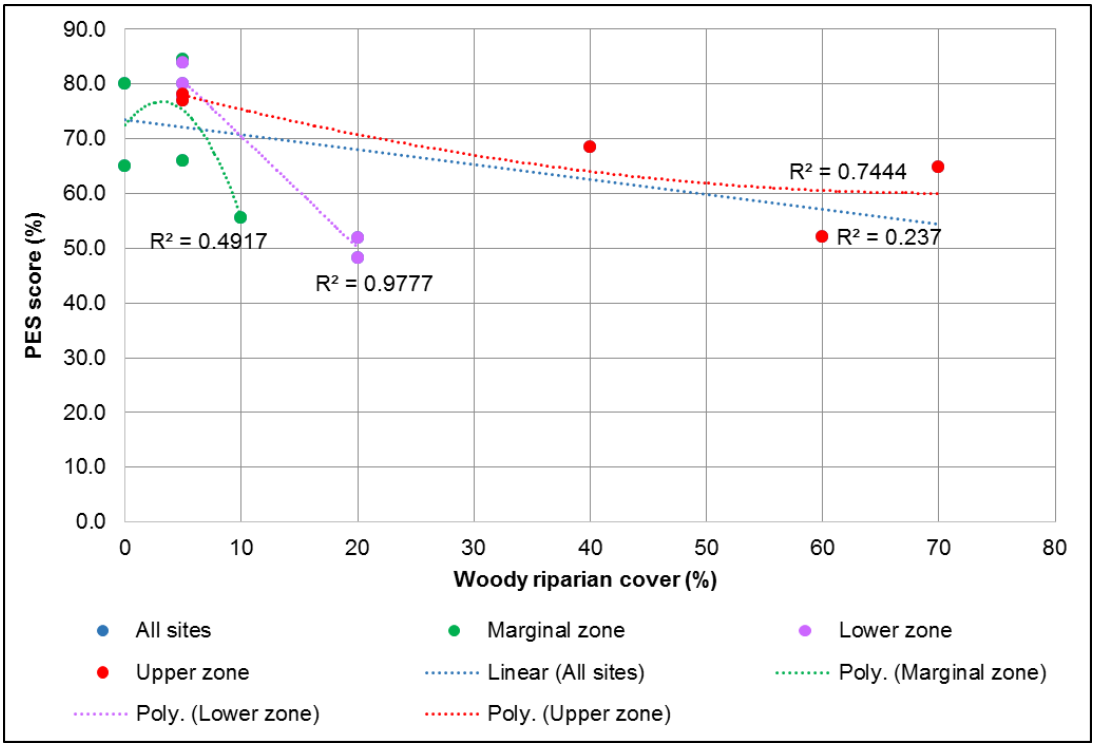

Figure 3.3 Scatterplot showing correlation (best fit) between PES score (%) and woody riparian cover (% aerial) for different sub-zones within the riparian zone

Non-woody indigenous cover (grasses, sedges and dicotyledonous forbs)

The hypothesis of expected aerial cover of indigenous non-woody vegetation is shown in **Table 3.5**. There was no discernible correlation between PES score and non-woody indigenous cover except that it was never absent i.e. 0% (**Figure 3.4**).

Table 3.5 Hypotheses for expected indigenous non-woody cover in relation to EC

EC	Non - woody indigenous cover (grasses, sedges and dicotyledonous forbs)
A	
A/B	40
B	30 - 50
B/C	
C	10 - 90
C/D	
D	<10
D/E	
E	
E/F	
F	

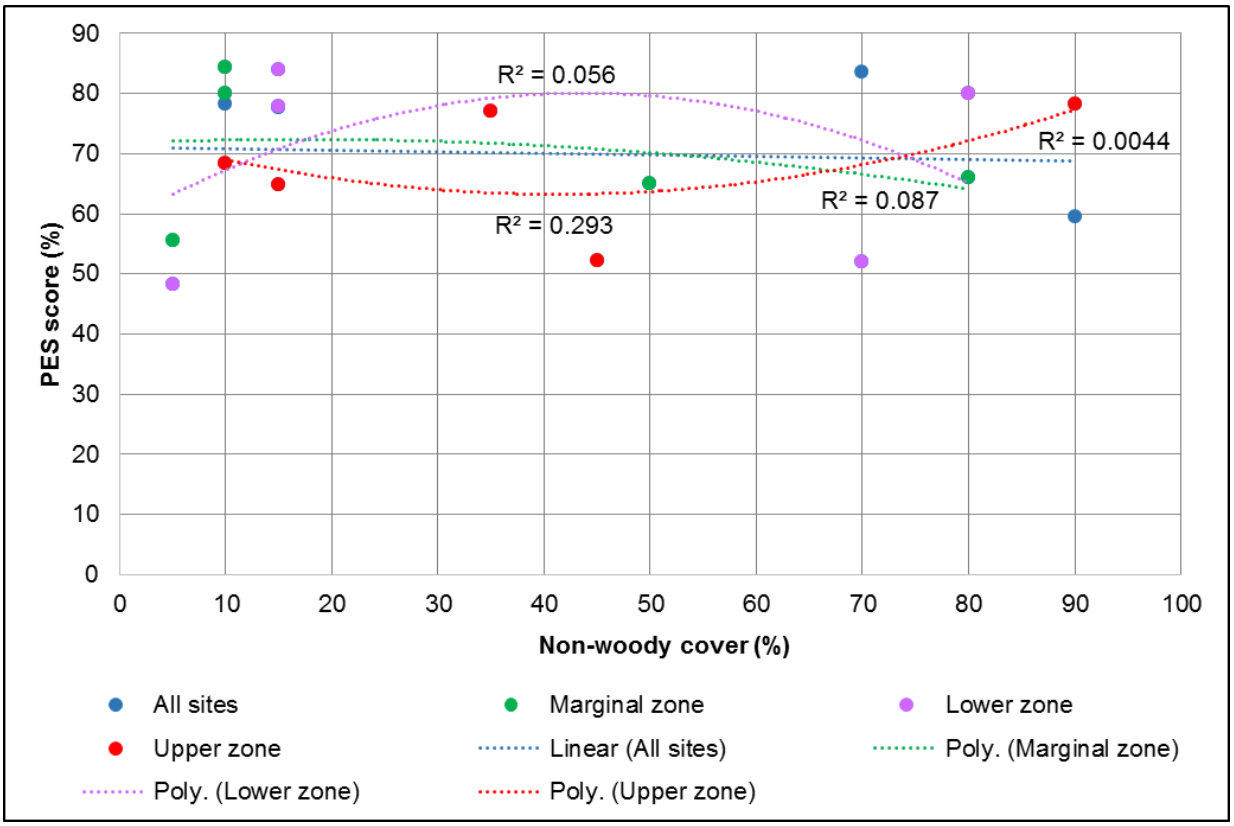

Figure 3.4 Scatterplot showing correlation (best fit) between PES score (%) and non-woody indigenous cover (% aerial) for different sub-zones within the riparian zone

Phragmites (reeds) cover

In both VEGRAI and the Rapid Habitat Assessment Method (RHAM) (DWA, 2009d), reeds are classified as non-woody, and although they are a grass, their importance in riparian structure and function warrants their separate assessment in terms of RQOs, EcoSpecs and TPCs. The expectations for aerial cover of reeds in relation to EC are shown in **Table 3.6**. Reeds were not found to be dominant at any of the sites and were absent at several sites. Their absence is relevant however and has been used as an EcoSpec where applicable.

Table 3.6 Hypotheses for expected *Phragmites* (reed) cover in relation to sub-zones within the riparian zone and EC

EC	Marginal Zone	Lower Zone	Upper Zone
A			
A/B			
B	0 - 10	0 - 15	0 - 5
B/C			
C	10 - 15	15 - 20	
C/D			
D	15 - 20	20 - 25	5 - 10
D/E			
E	20 - 25	25 - 30	>10
E/F			
F	>25	>30	

3.2 ESTUARIES

As per the EWR methods for estuaries (DWAF, 2008b), EcoSpecs and TPCs are provided for the REC as part of the preliminary determination of the EWR. EcoSpecs and TPCs are set for the following components:

- Hydrology (river inflow).
- Hydrodynamics (mouth state).
- Sediment dynamics.
- Water quality (both river inflow and in estuary).
- Microalgae.
- Macrophytes.
- Invertebrates.
- Fish.
- Birds.

Hydrological EcoSpecs and associated TPCs are provided as a flow regime (described by means of a time series) associated with the REC (i.e. a recommended scenario). The output is based on a hydrological time series generated. Hydrodynamics EcoSpecs and TPCs primarily relate the desired tidal variation and mouth state to be maintained in a particular system. TPCs are expressed in terms of an acceptable water level variation and/or duration and frequency of mouth closure (in the case of

temporarily open/closed estuaries), using water level recordings near the mouth and visual observation of mouth state. EcoSpecs and TPCs for sediment dynamics relates to the sediment composition and distribution across the sub-tidal, intertidal and supratidal areas of an estuary that are measured in terms of sediment particle distribution, as well as bathemetic and topographic data.

Unlike for rivers, there is no official, numerical water quality guidelines specified for various ECs because of the diverse and site-specific nature of water quality variables in estuaries, except for toxic substances. Water quality EcoSpecs and associated TPCs for variables such as salinity, pH, dissolved oxygen, turbidity/suspended solids and inorganic nutrients, therefore, were based on an understanding of the biogeochemical character of a specific system, as well as the requirements of associated biotic response components. Such understanding was gained from available data and information on a specific system, as well as the experience gained through research on other, related systems. In the case of toxic substances, it is general practice to adopt targets recommended in suitable water and sediment quality guidelines. In the GRDS the South African Water Quality Guidelines for Coastal Marine Waters (DWAF, 1995), and more updated Western Indian Ocean (WIO) Region guidelines (United Nations Environment Programme (UNEP)/Nairobi Convention Secretariat and the Council for Scientific and Industrial Research (CSIR) (UNEP)/Nairobi Convention Secretariat and CSIR, 2009)) were used. Water quality EcoSpecs and TPCs are set both for river inflow (river water quality) and for conditions in the estuary (estuarine water quality).

In the case of biotic components, the EcoSpecs and TPCs for the REC was set based on an understanding of the biotic characteristics of a specific system, as well as the experience gained through research on other, related systems.

4 RIVERS: ECOSPECS AND TPCs

4.1 DUIWENHOKS RIVER: H8DUIW-EWR1

The Duiwenhoks EWR site is situated in the lower reaches of the Duiwenhoks River downstream of Heidelberg and located downstream of H8H001. The main storage dam in the H80 secondary catchment (Duiwenhoks River Dam) supports irrigation activities (Duiwenhoks Government Scheme) and domestic supply to the town Heidelberg and to Duiwenhoks Rural Water Supply Scheme. Many farm dams that support irrigation are also found in this catchment. Current water requirements exceed supply and the catchment can be regarded as stressed. The upper reaches of the Duiwenhoks River are subjected to primarily non-flow related impacts (agriculture), with the Duiwenshoks Dam situated in the lower reaches of H80A-09154. The Duiwenhoks River improves slightly in the lower reaches (H80D-9286 and H80D-9314) but is still impacted notably by flow modification (Duiwenhoks Dam and abstraction for irrigation) as well as non-flow related activities (farming). Direct impacts on the EWR site are abstraction that has resulted in decreased base flows and possibly zero flows at times. Irrigation return flows have resulted in elevated nutrients and salinity and an overall deterioration in water quality. Alien invasive vegetation and agricultural practices in the riparian zones have led to bank modification and instability in the reach while alien fish species also occur in the reach.in the downstream zone are mostly non-flow related. **Figure 4.1** provides a map and photographs of the EWR site.

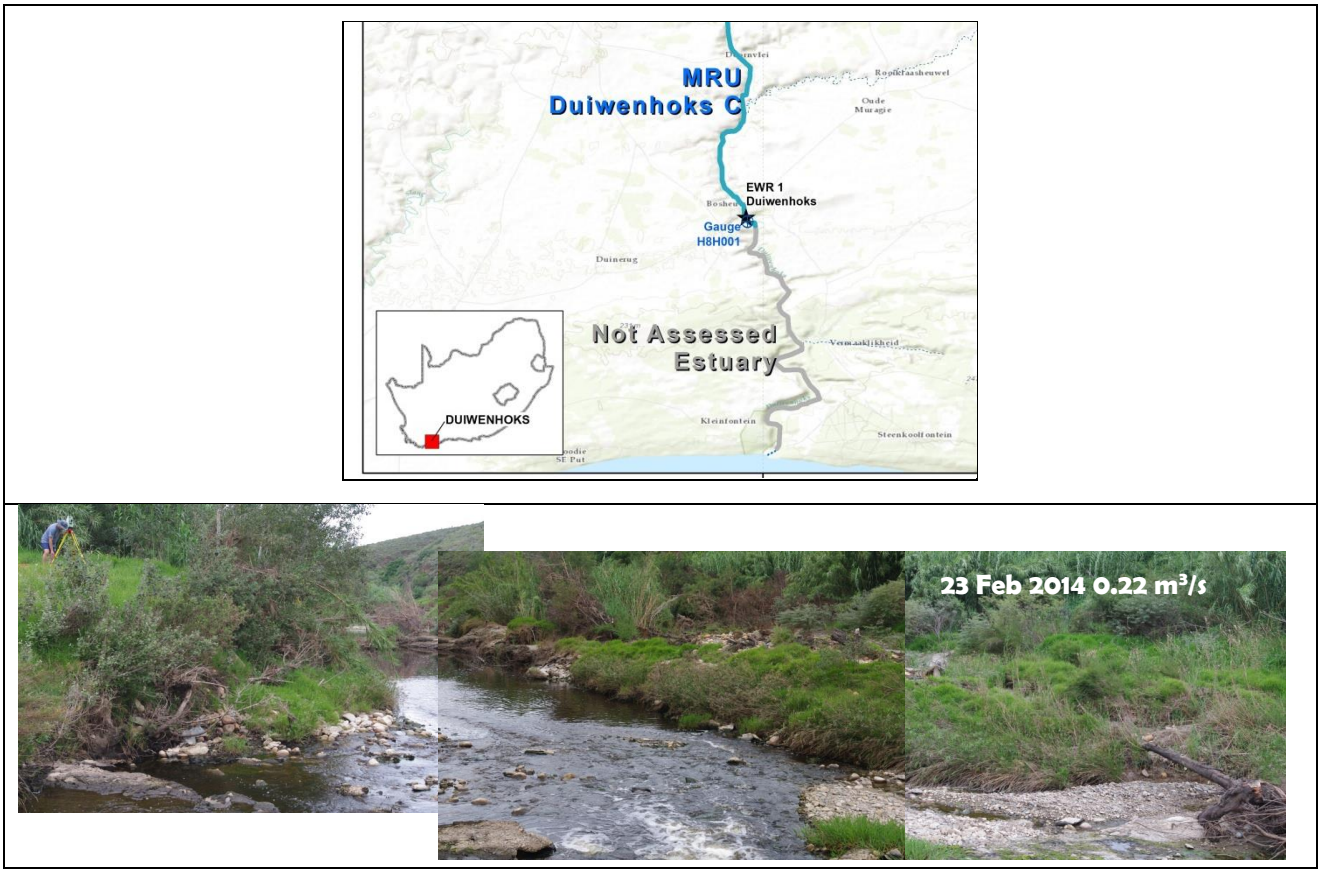

Figure 4.1 A map, and downstream view of H8DUIW-EWR1

4.1.1 Ecological Categories

The ECs, representative of broad qualitative EcoSpecs, and determined for the PES (DWS, 2014a), are provided in **Table 4.1**. The PES is representative of the baseline.

Table 4.1 H8DUIW-EWR1: EcoSpecs as ECs

Component	PES and REC
Water quality	**C**
Fish	**D**
Invertebrates	**D**
Instream	**D**
Riparian vegetation	**C/D**
EcoStatus	**D**

4.1.2 Hydrology: EcoSpecs

Source: DWA (2014b); DWS (2014a).
Model: Revised Desktop Reserve Model (RDRM) (Hughes *et al*., 2011), Water Resource Yield Model (WRYM - DWAF, 2008c).

REC	nMAR[1] (MCM[2])	pMAR[3] (MCM)	Low flows (MCM)	Low flows (%nMAR)	Total flows (MCM)	Total (%nMAR)	October		February	
							90%[4]	60%[4]	90%[4]	60%[4]
D	83.7	79.8	14.2	17	22.7	27.1	0.391	0.573	0.009	0.131

1 Natural Mean Annual Runoff 2 Million Cubic Metres 3 Present Day Mean Annual Runoff
4 Percentiles of the EWR rule (flow duration table) – applicable to all EWR sites.

4.1.3 Water quality (including diatoms): EcoSpecs and TPCs

Water quality
EcoSpecs and TPCs for water quality are shown in **Table 4.2**. Data should be collected from DWS monitoring point H8H001Q01 situated on the Duiwenhoks River.

Table 4.2 H8DUIW-EWR1: Water quality EcoSpecs and TPCs (PES and REC: C)

Metrics	EcoSpecs	TPCs
Inorganic salt ions		
Sulphate as SO_4	-	-
Sodium as Na	The 95th percentile of the data must be ≤ 380 mg/L.	The 95th percentile of the data must be 300 - 380 mg/L.
Magnesium as Mg	The 95th percentile of the data must be ≤ 67 mg/L.	The 95th percentile of the data must be 53.5 - 67 mg/L.
Calcium as Ca	The 95th percentile of the data must be ≤ 55 mg/L.	The 95th percentile of the data must be 44 - 55 mg/L.
Chloride as Cl	The 95th percentile of the data must be ≤ 800 mg/L.	The 95th percentile of the data must be 640 - 800 mg/L.
Potassium as K	The 95th percentile of the data must be ≤ 9 mg/L.	The 95th percentile of the data must be 7 - 9 mg/L.
Physical Variables		
Electrical conductivity (mS/m)	The 95th percentile of the data must be ≤ 270 mS/m.	The 95th percentile of the data must be 210 - 270 mS/m.
pH	The 5th percentile of the data must be 6.5. – 8.0, and the 95th percentile 8.0 - 8.8.	The 5th percentile of the data is ≤ 6.3 and the 95th percentile is ≥ 8.6.
Temperature[(a)]	Natural temperature range.	Initiate baseline monitoring for this variable.
Dissolved oxygen[(a)](DO)	The 5th percentile of the data must be ≥ 7.0 mg/L.	The 5th percentile of the data must be 7.2 - 7.0 mg/L. Initiate baseline monitoring for this variable.
Turbidity[(a)]	Changes in turbidity are related to minor man-made modifications (e.g. gravel mining upstream). Some silting of habitats is expected.	Initiate baseline monitoring for this variable.
Nutrients		
TIN	The 50th percentile of the data must be ≤ 0.25 mg/L.	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 ≤ 0.015 mg/L.	The 50th percentile of the data must be 0.012 - 0.015 mg/L.
Response variables		
Chl-a phytoplankton	The 50th percentile of the data must be < 15 µg/L.	The 50th percentile of the data must be 12 - 15 µg/L.
Chl-a periphyton	The 50th percentile of the data must be ≤ 12 mg/m^2.	The 50th percentile of the data must be 10 - 12 mg/m^2.
Toxics		
Fluoride	The 50th percentile of the data must be ≤ 1.5 mg/L.	The 50th percentile of the data must be 1.2 - 1.5 mg/L.
Ammonia (NH_3-N)	The 50th percentile of the data must be ≤ 0.015 mg/L.	The 50th percentile of the data must be 0.012 - 0.015 mg/L.
Other toxics	The 95th percentile of the data must be within the Target Water Quality Range (TWQR) as stated in DWAF (1996) or the A Category boundary as stated in DWAF (2008a).	An impact is expected if the 95th percentile of the data exceeds the TWQR as stated in DWAF (1996) or the upper limit of the A Category boundary as stated in DWAF (2008a).

- No data

(a) No data were available for this assessment. All EcoSpecs and TPCs need verification as based on expert judgement.

Diatoms

Monitoring guidelines for diatoms are provided in **Table 4.3**. It should be noted that the information provided in **Table 4.3** is based on one sample collected during January 2014 and therefore the confidence is low. The SPI score was 11.1 (C/D EC) with high and problematic nutrient and salinity levels, as well as high organic pollution. Moderate oxygenation rates and heavy pollution levels prevailed (DWS, 2014a). Based on water quality data (DWS, 2014a) the following physico-chemical metrics are of concern:

- Salinity: Salinity levels are naturally high due to geology and river estuary interface at the causeway. This would influence the salinity results for diatoms; however there are indicator species present that are associated with elevated salinity levels due to anthropogenic impact rather than naturally high levels.
- Nutrient and organics: Problematic levels could be originating from the dairy farm in the vicinity of the EWR site and due to irrigation return flows.
- Oxygen: Impacts are expected during low flows.

Table 4.3 H8DUIW-EWR1: Diatoms monitoring guidelines (PES and REC: C/D)

Metric	Indicator species	Indicator/general threshold	Action
Salinity	*Nitzschia frustulum*: Indicator of nutrient and salinity levels.	If present at > 30% these variables will most probably be problematic.	If thresholds are exceeded during consecutive low and high flow assessments water quality analysis should be undertaken.
Oxygen	*Achnanthidium* species: Are associated with elevated flows. The genus generally prefers good water quality with high oxygenation rates (Taylor *et al*., 2007b).	If flows are elevated expect dominance of > 30%.	During high/elevated flow this species must be present and is an important indicator of system recovery. If absent, this variable should be flagged. Species should not be absent in more than one high flow sample. If absent, water quality analysis should be undertaken.
Nutrients	*Nitzschia* species: Associated with water bodies that have readily available nutrients.	If present at > 20% this variable will most probably be problematic.	If thresholds are exceeded during consecutive low and high flow assessments water quality analysis should be undertaken.
Organics	*Planothidium frequentissima, Sellaphora seminulum* and *Eolimna minima.*	Combined abundance of > 10% would indicate potential problems.	If thresholds are exceeded during consecutive low and high flow assessments along with consecutive Pollution Tolerant Valve (PTV) score of > 40% water quality analysis should be undertaken.
	Navicula gregaria, *Navicula erifuga*, small *Navicula* species and *Navicula veneta*: Main indicators of anthropogenic activities relating to increased sewage or other effluent.	Combined abundance of > 5% indicates potential problems.	
Metal toxicity	During 2014 valve deformities were present at an abundance of 0.25%.	A check should be done for valve deformities with every count as this is indicative of metal contamination. Valve deformities abundance should be > 1%.	If thresholds are exceeded during consecutive low and high flow assessments water quality analysis should be undertaken.
SPI score	10 and higher	10 - 12	

4.1.4 Fish: EcoSpecs and TPCs

EcoSpecs and TPCs are provided in **Table 4.4**.

Table 4.4 H8DUIW-EWR1: Fish EcoSpecs and TPCs (PES and REC: D)

Metric	Indicator	EcoSpecs	TPC (Biotic)	TPC (Habitat)
Ecological status	PES	PES: D EC (51.6%).	Decrease of PES into a lower EC than the PES.	Any deterioration in habitat that results in decrease in FROC* of species.
Species richness	All indigenous species	Five of the expected six indigenous fish species are estimated to be present in the reach under PES (three species sampled during EWR study - *Myxus capensis* (MCAP), *Mugil cephalus* (MCEP) and *Redigobius dewaali* (RDEW).	Loss of any indigenous species. Presence of less than three indigenous species at EWR site using similar sampling methods and conducted during similar conditions (season and flow).	Loss in diversity, abundance and condition of velocity-depth categories and cover features that lead to a loss of species. Reduction of freshwater cues in estuary for migration of catadromous species due to reduced river flows.
Requirement for perennial river flows	MCAP	MCAP was present at an abundance of 0.07 individuals per minute (ind/min) during EWR survey and is estimated to occur at a FROC of 2 under PES. This species requires freshwater cues for migration into estuaries from marine spawning areas and then to freshwater zones of rivers and is therefore the most applicable indicator species for flow modification.	MCAP present at abundance < 0.07 ind/min at EWR site (similar methods and conditions) or FROC of < 2 in reach. Absence in any survey of juveniles in Slow Shallow (SS) and Fast Shallow (FS) habitats and adults (>12 cm) in Slow Deep (SD) habitats.	Reduced suitability (abundance and quality) of flowing habitats (i.e. decreased flows, increased zero flows, and altered seasonality).
Water column				Decreased flows and increase in zero flows. Reduction in suitability of water column for adult MCAP (i.e. increased sedimentation of pools, reduced flows).
Fast Deep (FD) habitats	*Anguilla mossambica* (AMOS)	Although not sampled during the EWR survey, AMOS is estimated to still occur at a FROC of 1 under PES. This species (especially juveniles) has a high requirement for fast habitats and is the most applicable indicator species for this velocity-depth category. The juvenile eels furthermore have a high requirement for substrate as cover, while the adults prefer undercut banks, making them an applicable indicator species for these habitat features.	AMOS absent, specifically juveniles in FS habitats or adults in FD habitats during two consecutive surveys OR present at FROC of < 1.	Reduced suitability (abundance and quality) of FD and FS habitats (i.e. decreased flows, increased zero flows).
FS habitats				Increased sedimentation of riffle/rapid substrates, excessive algal growth on substrates. Increased sedimentation of riffle/rapid substrates, excessive algal growth on substrates.
Substrate				

Metric	Indicator	EcoSpecs	TPC (Biotic)	TPC (Habitat)
Undercut banks		This species requires freshwater cues for migration into estuaries from marine spawning areas and then to freshwater zones of rivers.		Significant change in undercut bank and rootwads habitats (e.g. bank erosion, reduced flows).
Water quality intolerance	RDEW	RDEW was sampled at 0.05 individuals per minute (ind/min) during the EWR survey and is estimated to occur at a FROC of 2 in the reach under PES. This species has a high requirement for unmodified water quality, and a preference for vegetation and SD habitat, rendering it the most applicable indicator species for water quality deterioration and these habitat features.	RDEW absent during any survey OR present at abundance of < 0.05 ind/min (same methods and conditions) or FROC of < 2 in reach. **Absence of range of life stages (juveniles to adults) during various surveys.**	Decreased water quality (especially flow related water quality variables e.g. oxygen).
SD habitats				Significant change in SD habitat suitability (i.e. increased or decreased flows, altered seasonality, increased sedimentation of slow habitats).
Instream vegetation	*Sandelia capensis* (SCAP)	Although not sampled during the EWR survey, SCAP is estimated to still occur at a FROC of 1 under PES. This species has a high requirement for instream vegetation and SS habitats and is the most applicable indicator species for this cover feature and velocity-depth category.	SCAP absent during **three** consecutive surveys OR present at FROC of < 1 in reach. Absence of range of life stages (juveniles to adults) during various surveys.	Significant change in instream and marginal vegetation habitats (overgrazing, flow modification, use of herbicides, agriculture).
SS habitats				Significant change in SS habitat suitability (i.e. increased flows, altered seasonality, increased sedimentation of slow habitats).
Alien fish species	Presence of any alien/introduced spp.	One translocated indigenous fish species, *Tilapia sparrmanii* (TSPA) confirmed to be present in the SQ reach. This species was present in abundance of 0.15 ind/min during the EWR survey (June 2014).	Increased abundance of TSPA (> 0.15 ind/min) or presence of any additional alien/introduced species. Absence of small species and juvenile fish vulnerable to predation by alien species.	N/A.
Catadromous species	AMOS, MCAP, MCEP	Presence of MCAP and MCEP (confirmed during EWR survey) and AMOS (estimated to be present).	Loss or decreased FROC or abundance of catadromous species compared to that found during EWR survey.	Reduction of freshwater cues in estuary and sea (loss of longitudinal salinity gradient) for migration of catadromous species due to reduced river flows.
Migratory success	AMOS, MCAP, MCEP	The presence of the catadromous MCAP (0.07 ind/min) and MCEP (0.08 ind/min) was confirmed during the EWR study and it is estimated that AMOS is also still present. These diadromous species require free movement between fresh and saline water.	Loss or decreased FROC or abundance of any of the catadromous species (<0.07 ind/min for MCAP and <0.08 ind/min for MCEP using similar sampling methods during similar conditions (season, flow).	Alteration of longitudinal connectivity through the creation of migration barriers (dams, weirs, zero flows, poor water quality causing chemical barriers). All three species should be able to migrate past existing road bridge located just above tidal limit of estuary at all times of the year.
Primary (flow) indicator species		**MCAP and juvenile eels.**		

* Refer to Section 3.4 for FROC ratings.

4.1.5 Macroinvertebrates: EcoSpecs and TPCs

Indicator taxa are provided in **Table 4.5** and EcoSpecs and TPCs in **Table 4.6**.

Table 4.5 H8DUIW-EWR1: Macroinvertebrate indicator taxa

Indicator acronym	Indicator Family and Score	Velocity preference		Substrate preference				WQ Preference[2]
		0.3 - 0.6 m/s	>0.6 m/s	Cobble	Vegetation	GSM[1]	Water column	
ATY	Atyidae (8)	0	0	1	4	1	0	Moderate
TEL	Telagonodidae (12)	2	4	4	1	0	0	High
HYD+	Hydropsychidae 2 spp. (6)	2	4	3	1	0	0	Low
ELM	Elmidae (8)	4	2	4	1	0	0	Moderate
GOM	Gomphidae (8)	3	0	1	0	5	0	Low
SIM	Simuliidae (5)	2	4	3	2	0	0	Low
ANC	Ancylidae (6)	2	1	2	1	0	0	Low

1 Gravel-Sand-Mud habitat

2 Preferences scored 0 - 4 in ascending order of preference. For water quality (WQ), High = High preference for unimpaired WQ.

Table 4.6 H8DUIW-EWR1: Macroinvertebrate EcoSpecs and TPCs (PES and REC: D)

Parameter	Indicator[1]	EcoSpecs	TPCs
SASS5 and ASPT score		The SASS5 score at sampling was 78 with an ASPT of 5.6. Total scores should remain in the range of 60 - 90, with ASPT values > 5.	SASS5 scores < 60 and ASPT < 5.
MIRAI score		MIRAI score to be within the D (40 - 59%) Category, using the reference data used in this study, or recording alterations to these.	MIRAI < 40%.
Diversity of invertebrate community		More than ten different families (taxa) should be present at an abundance of A to C.	Less than 10 different taxa collected. Any taxon (adult) with an abundance of D.
Physical habitat quality	TEL, ELM, SIM, ANC, ATY	Presence of at least ELM, SIM, and ANC.	Absence or individuals only of any three of the indicators.
Physical habitat diversity	TEL, ELM, SIM, ANC, ATY	Ability to sample four SASS5 biotopes (Stones-in-Current (SIC), Stones-out-of-Current (SOC), MV, and GSM). Presence of at least three indicators.	Stones immobile. No inundated marginal vegetation. More than two indicators absent or in low numbers.
Response to water quality	TEL, ELM, ATY	During flow periods, water should be clear. Algal presence should be low. Cobble surfaces should neither be slippery nor covered with silt drapes. At least ELM and ATY should be present.	Presence or absence of TEL or ELM.
Response to hydraulic habitat availability and persistence			
VFCS	TEL, HYD+, SIM	Hydraulic modelling indicates that VFCS should become available at a discharge of 0.2 m^3/s. If sampling is	Absence or very low numbers of HYD+ or SIM.

Parameter	Indicator[1]	EcoSpecs	TPCs
		conducted at or above this discharge (and not following dry or drought conditions), at least HYD and SIM should be present at A - C abundances.	
FCS	ELM, HYD+, SIM	FCS should be available at a discharge of 0.05 m^3/s. If sampling at or above this discharge, with no antecedent dry or drought conditions, ELM, HYD+ and SIM should be present and abundant.	Absence or very low numbers of indicator families.
MV	ATY	Inundated MV (*Cyperus* sp.) should be present instream and at channel margins. ATY and a number of Hemiptera families (e.g. gerrids, corixids) should be present.	ATY absent or in very low numbers. This could also indicate the presence or increase of predaceous fish *(T. sparrmanii* or other*)*. Encroachment of MV.
FS	GOM	Areas of coarse sandy substrate should be present in fast- and slow-flowing areas. GOM should be present.	Lack of coarse sandy substrate, GOM absent or in very low numbers.

1 The habitat preferences of indicator genera are listed in the Macroinvertebrate Response Assessment Index (MIRAI) worksheets, which are provided electronically.

4.1.6 Riparian vegetation EcoSpecs and TPCs

EcoSpecs and TPCs are provided in **Table 4.7**.

Table 4.7 H8DUIW-EWR1: Riparian vegetation EcoSpecs and TPCs (PES and REC: C/D)

Metric	EcoSpec	TPC
Marginal zone		
Alien invasion (perennial alien species)	Maintain an absence of perennial alien plant species.	Occurrence of perennial alien plant species.
Terrestrial woody species aerial cover	Maintain an absence of terrestrial woody species.	Occurrence of terrestrial woody species in the sub-zone.
Indigenous riparian woody species cover (% aerial)	Maintain cover (% aerial) of indigenous riparian woody species below 10%.	Absence of indigenous riparian woody species OR an increase in cover above 10%.
Non-woody indigenous cover (grasses, sedges and dicotyledonous forbs) (% aerial)	Maintain non-woody cover (% aerial) above 50%.	Decrease in non-woody cover (% aerial) below 50%.
Reed cover (% aerial)	Maintain reed cover below 10%.	Increase in reed cover above 10%.
Lower zone		
Alien invasion (perennial alien species)	Maintain cover (% aerial) of perennial alien plant species at 5% or lower.	Increase in perennial alien plant species cover >15%.
Terrestrial woody species aerial cover	Maintain cover (% aerial) of terrestrial woody species at 5% or lower.	Increases in terrestrial woody species cover above 10%.

Metric	EcoSpec	TPC
Indigenous riparian woody species cover (% aerial)	Maintain cover (% aerial) of indigenous riparian woody species above 5% and below 15%.	Absence of indigenous riparian woody species OR an increase in cover above 15%.
Non-woody indigenous cover (grasses, sedges and dicotyledonous forbs) (% aerial)	Maintain non-woody cover (% aerial) above 50%.	Decrease in non-woody cover (% aerial) below 30%.
Reed cover (% aerial)	Maintain reed cover below 10%.	Increase in perennial alien plant species cover >15%.
Upper zone		
Alien invasion (perennial alien species)	Maintain cover (% aerial) of perennial alien plant species at 10% or lower.	Increase in perennial alien plant species cover >20%.
Terrestrial woody species aerial cover	Maintain cover (% aerial) of terrestrial woody species at 20% or lower.	Increases in terrestrial woody species cover above 30%.
Indigenous riparian woody species cover (% aerial)	Maintain cover (% aerial) of indigenous riparian woody species above 10% and below 80%.	Decreases in indigenous riparian woody species cover below 10% or an increase above 90%.
Non-woody indigenous cover (grasses, sedges and dicotyledonous forbs) (% aerial)	Maintain non-woody cover (% aerial) above 40%.	Decrease in non-woody cover (% aerial) below 30%.
Reed Cover (% aerial)	Maintain reed cover below 5%.	Presence of reeds.
Riparian zone		
PES	Maintain PES score (using VEGRAI level 4 for assessment) of at least 61% for the riparian zone.	Decrease in PES score below 60% for the riparian zone.
Dominant vegetation type	The dominant vegetation type shall remain non-woody in the marginal and lower zones, and woody in the upper zone and largely free of any alien trees	Increased proportion of non-woody cover above 10% in the marginal or 15% in the lower zones.

4.2 GOUKOU RIVER: H9GOUK-EWR2

The Goukou River originates in the Spioenkop Nature Reserve and later flows through the Broomvlei (Kruis River) Nature Reserve. The Korente-Vet Dam in the Korentepoort River (8 million m^3) together with farm dams support irrigation for vineyards, fruit, pastures and vegetables as well as domestic use in Riversdale (H90C/E). Some forestry is found in the upper reaches (H90A). Irrigation farming is therefore the dominant land use. The EWR site is located in a hotspot section in SQ H90C-09229 which lies immediately upstream of Riversdal impacts as well as the impacts of the Vet Tributary of this area downstream of H9H005. Direct impacts on the EWR site are abstraction and upstream farm dams have resulted in decreased base flows and zero flows at times. The cumulative effects of agriculture and return flows e.g. elevated nutrients, salts and some toxicity has resulted in deteriorated water quality. Alien invasive vegetation and agriculture in the riparian zones have led to bank modification and instability in the reach. Alien fish species also occur in the reach. Wood removal in the riparian zones occurs. **Figure 4.2** provides a map and photographs of the EWR site.

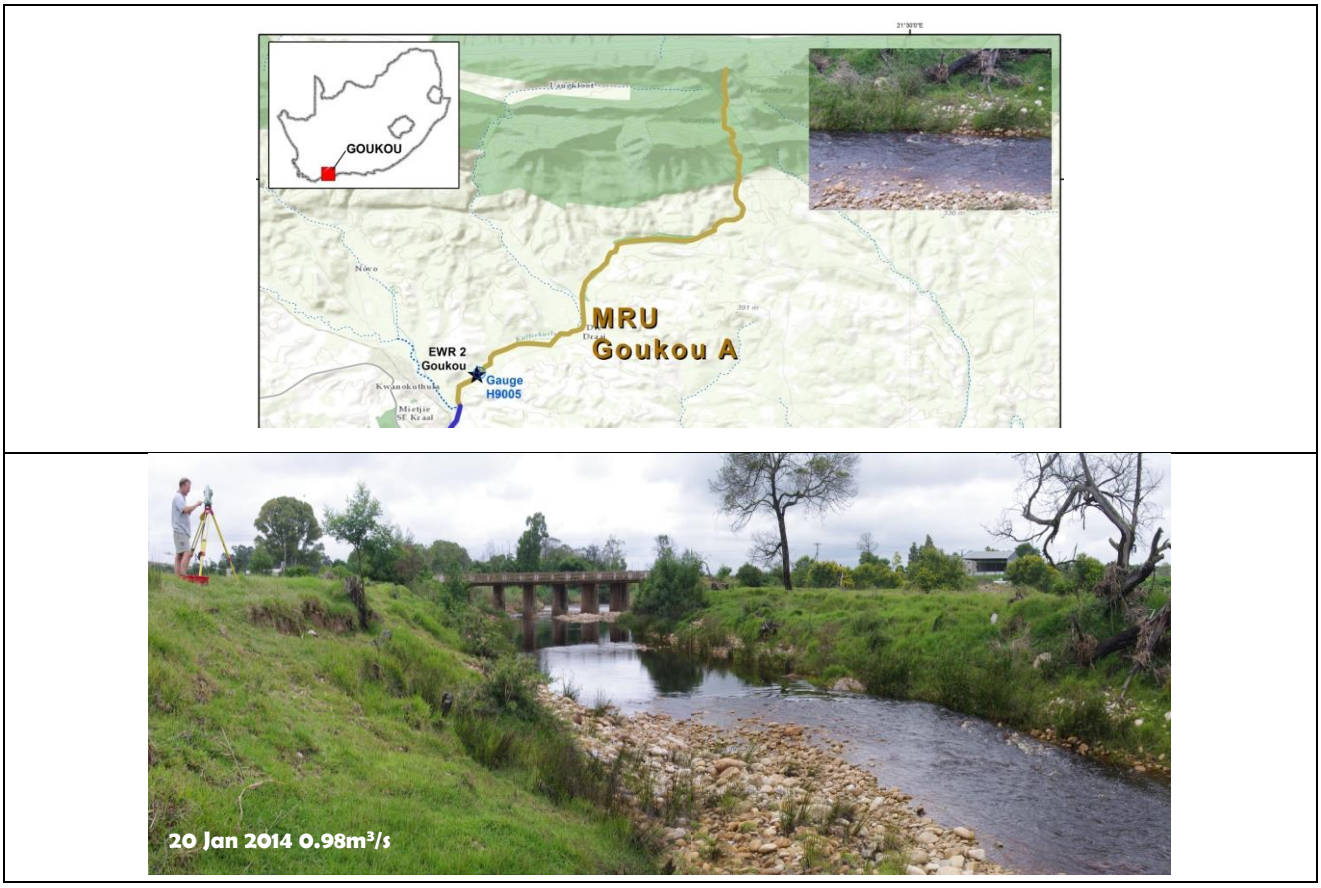

Figure 4.2 A map, and downstream view of H9GOUK-EWR2

4.2.1 Ecological Categories

The ECs, representative of broad qualitative EcoSpecs, and determined for the PES (DWS, 2014a), is provided in **Table 4.8**. The PES is representative of the baseline.

Table 4.8 H9GOUK-EWR2: EcoSpecs as ECs

Component	PES and REC
Water quality	C/D
Fish	D
Invertebrates	D
Instream	D
Riparian vegetation	C
EcoStatus	**C/D**

4.2.2 Hydrology: EcoSpecs

Source: DWA (2014b); DWS (2014a).
Model: RDRM (Hughes *et al*., 2011), WRYM (DWAF, 2008c).

REC	nMAR (MCM)	pMAR (MCM)	Low flows (MCM)	Low flows (%nMAR)	Total flows (MCM)	Total (%nMAR)	October		July	
							90%	60%	90%	60%
C/D	54.1	46	7.1	13.1	11.4	21	0.000	0.252	0.067	0.181

4.2.3 Water quality (including diatoms): EcoSpecs and TPCs

Water quality
EcoSpecs and TPCs for water quality are shown in **Table 4.9**. Data should be collected from DWS monitoring point H9H005Q01 on the Goukou River.

Table 4.9 H9GOUK-EWR2: Water quality EcoSpecs and TPCs (PES and REC: C/D)

Metrics	EcoSpecs	TPCs
Inorganic salt ions		
Sulphate as SO_4	-	-
Sodium as Na	The 95th percentile of the data is between ≤ 650 mg/L.	The 95th percentile of the data is between 520 - 650 mg/L.
Magnesium as Mg	The 95th percentile of the data is between ≤ 80 mg/L.	The 95th percentile of the data is between 64 - 80 mg/L.
Calcium as Ca	The 95th percentile of the data is between ≤ 55 mg/L.	The 95th percentile of the data is between 44 - 55 mg/L.
Chloride as Cl	The 95th percentile of the data is between ≤ 1 000 mg/L.	The 95th percentile of the data is between 800 - 1 000 mg/L.
Potassium as K	The 95th percentile of the data is between ≤ 20 mg/L.	The 95th percentile of the data is between 16 - 20 mg/L.
Physical variables		
Electrical conductivity (mS/m)	The 95th percentile of the data is between ≤ 400 mS/m.	The 95th percentile of the data is between 320 - 400 mS/m.
pH	The 5th percentile of the data must be 6.5. – 8.0, and the 95th percentile 8.0 - 8.8.	The 5th percentile of the data is ≤ 6.3 and the 95th percentile is ≥ 8.6.
Temperature[(a)]	Natural temperature range.	Initiate baseline monitoring for this variable.
Dissolved oxygen[(a)]	The 5th percentile of the data is between ≥ 7.0 mg/L.	The 5th percentile of the data is between 7.2 - 7.0 mg/L. Initiate baseline monitoring for this variable.
Turbidity[(a)]	Changes in turbidity are related to minor man-made modifications. Some silting of habitats is expected.	Initiate baseline monitoring for this variable.
Nutrients		
TIN-N	The 50th percentile of the data is between ≤ 0.25 mg/L.	The 50th percentile of the data is between 0.2 - 0.25 mg/L.

Metrics	EcoSpecs	TPCs
PO_4-P	The 50th percentile of the data is between ≤ 0.125 mg/L.	The 50th percentile of the data is between 0.1 - 0.125 mg/L.
Response variables[(a)]		
Chl-a phytoplankton	The 50th percentile of the data is between < 15 µg/L.	The 50th percentile of the data is between 12 - 15 µg/L.
Chl-a periphyton	The 50th percentile of the data is between ≤ 21 mg/m^2.	The 50th percentile of the data is between 17 - 21 mg/m^2.
Toxics		
Fluoride	The 50th percentile of the data is between ≤ 1.5 mg/L.	The 50th percentile of the data is between 1.2 - 1.5 mg/L.
Ammonia (NH_3-N)	The 50th percentile of the data is between ≤ 0.015 mg/L.	The 50th percentile of the data is between 0.012 - 0.015 mg/L.
Other toxics	The 95th percentile of the data is between within the TWQR as stated in DWAF (1996) or the A Category boundary as stated in DWAF (2008a).	An impact is expected if the 95th percentile of the data exceeds the TWQR as stated in DWAF (1996) or the upper limit of the A Category boundary as stated in DWAF (2008a).

- No data

(a) No data were available for this assessment. All EcoSpecs and TPCs need verification as based on expert judgement.

Diatoms

Monitoring guidelines for diatoms are provided in **Table 4.10**. The SPI score of 12.7 (C EC) was based on the aggregate of the two samples collected on 20 January 2014 (SPI score: 14.4) and 24 June 2014 (SPI score: 11) at the EWR site (DWS, 2014a). However, EcoSpecs and TPCs are provided for a C/D EC due to the presence of valve deformities that were present during both sampling efforts (DWS, 2014a).

No historic or other present data could be sourced for the Goukou River. The confidence in the assessment was higher for the July 2014 sample in terms of species identification. There was a general deterioration in diatom based water quality between January and July 2014 which could mainly be attributed to increased nutrient, organic pollution and salinity levels. From the data it was evident that salinity and organic pollution were the main determining factors of deteriorated water quality. Indicators of industrial and sewage related impacts occurred in low abundance but their presence indicated that anthropogenic activities in the upper reaches of the RU did impact the site. The diatoms indicated that water levels fluctuated as sub-aerial species were present. This would have an impact on the life-cycle of aquatic macro-invertebrates and fish (DWS, 2014a).

Based on water quality data (DWS, 2014a) the following metrics are of concern:

- Salinity: Salinity levels are naturally high due to geology. This would influence the salinity results for diatoms. However there are indicator species present that are associated with elevated salinity levels due to anthropogenic impact rather than naturally high levels.
- Nutrient and organics: There is extensive grazing and agricultural activities in the vicinity of the EWR site.
- Oxygen: Impacts are expected during low flows.
- Toxics: Due to extensive irrigation in the area.

Table 4.10 H9GOUK-EWR2: Diatom monitoring guidelines (PES and REC: C/D)

Metric	Indicator species	Indicator/general threshold	Action
Salinity	*Fragilaria fasciculata*: Indicator of salinity. Has been reported from critically polluted industrial wastewater (Taylor *et al*., 2007b). It has a preference for $S0_4^{-2}$-dominated habitats, especially $MgS0_4$ and is characterized as most indicative of habitats with high specific conductance and euryhaline conditions (Blinn, 1993). This could be an indication of higher herbicide and pesticide use within the reach and the use of Epsom salts ($MgS0_4$) in citrus orchards in the vicinity of the river.	Abundance of > 1.5% would indicate potential problems.	If thresholds are exceeded during consecutive low and high flow assessments water quality analysis should be undertaken.
	N. frustulum: Indicator of nutrient and salinity levels.	If present at >20% these variables will most probably be problematic.	If thresholds are exceeded during consecutive low and high flow assessments water quality analysis should be undertaken.
Oxygen	*Achnanthes oblongella*: Preference for circumneutral oligotrophic electrolyte poor streams (Taylor *et al*., 2007b). High abundance could be associated with elevated flows and high oxygenation rates (Taylor *et al*., 2007b).	If flows are elevated expect dominance of >50%.	During high/elevated flow this species must be present and is an important indicator of system recovery. If absent, this variable should be flagged. Species should not be absent in more than one high flow sample. If absent, water quality analysis should be undertaken.
Nutrients	*Nitzschia* species: Associated with water bodies that have readily available nutrients.	If present at >10% this variable will most probably be problematic.	If thresholds are exceeded during consecutive low and high flow assessments water quality analysis should be undertaken.
Organics	*Navicula gregaria* and *Navicula veneta*: Main indicators of anthropogenic activities relating to increased sewage or other effluent. Common in eutrophic and hyper-eutrophic waters. Moderate to high electrolyte content extending into brackish biotopes. Tolerant of strong pollution and a good indicator of these conditions (Taylor *et al*., 2007b).	Combined abundance of >5% indicates potential problems.	If thresholds are exceeded during consecutive low and high flow assessments along with consecutive PTV score of >25% water quality analysis should be undertaken.
Metal toxicity	General thresholds were exceeded during January 2014 (4%) and June 2014 (2.5%).	A check should be done for valve deformities with every count as this is indicative of metal contamination. Valve deformities should not be present at an abundance of >2%.	If thresholds are exceeded during consecutive low and high flow assessments water quality analysis should be undertaken.
SPI score	10 and higher	10 - 12	

4.2.4 Fish: EcoSpecs and TPCs

EcoSpecs and TPCs are provided in **Table 4.11**.

Table 4.11 H9GOUK-EWR2: Fish EcoSpecs and TPCs (PES and REC: D)

Metric	Indicator	EcoSpecs	TPC (Biotic)	TPC (Habitat)
Ecological status	PES	The PES is in a D (50.8%).	Decrease of PES into a lower EC than the PES (<D).	Any deterioration in habitat that results in decrease in FROC* of any species.
Species richness	All indigenous species	All five of the expected indigenous fish species estimated to still be present in the reach under PES (only *Monodactylus falciformis* (MFAL)) sampled during EWR survey).	Loss of any indigenous species, including those estimated to be present.	Loss in diversity, abundance and condition of velocity-depth categories and cover features that lead to a loss of species. Reduction of freshwater cues in estuary for migration of catadromous species (longitudinal salinity gradient) due to reduced river flows.
FD habitats	AMOS	AMOS was not sampled during the EWR survey but is expected to occur at a FROC* of 1 in this reach under PES. This species has a high requirement for FD, and FS habitats as well as substrate (juveniles) and undercut banks (adults) cover feature. It is therefore the most applicable indicator species for these habitat features.	AMOS absent during two consecutive surveys OR present at FROC of < 1 in reach. Applicable for juveniles in FS and FD habitats and for adults (>12 cm).	Reduced suitability (abundance and quality) of FD habitats (i.e. decreased flows, increased zero flows).
FS habitats				Reduced suitability (abundance and quality) of FS habitats (i.e. decreased flows, increased zero flows).
Substrate	*Pseudobarbus burchelli* (PBUR)	PBUR was not sampled during the EWR survey but is expected at a FROC* of 1 in the reach under PES. It has the highest requirement for flow and unmodified water quality, as well as the highest preference for water column, SD and SS habitats of all indigenous species. It is therefore the most applicable indicator species for these habitat metrics.	PBUR absent during two consecutive surveys OR present at FROC of < 1 in the reach. Absence of range of life stages (juveniles to adults) during various surveys).	Increased sedimentation of riffle/rapid substrates, excessive algal growth on substrates, Increased sedimentation of riffle/rapid substrates, excessive algal growth on substrates.
Undercut banks				Significant change in undercut bank and rootwads habitats (e.g. bank erosion, reduced flows).
Requirement for flowing water				Reduced suitability (abundance and quality) of flowing habitats (i.e. decreased flows, increased zero flows, and altered seasonality).
Water quality intolerance				Decreased water quality (especially flow related water quality variables such as oxygen).
Water column	PBUR MFAL SCAP	PBUR, while not sampled during EWR survey, has the highest preference of species present for SD and SS habitats. Adult MFAL is also found only in SD habitats.	BUR present at FROC of < 1 during two consecutive surveys. Adults of MFAL at FROC of < 2 or a CPUE[1] < 0.02 ind/min using	Reduction in suitability of water column (i.e. increased sedimentation of pools, reduced flows).
SD habitats				Significant change in SD habitat suitability (i.e. increased or decreased flows, altered seasonality, increased

Metric	Indicator	EcoSpecs	TPC (Biotic)	TPC (Habitat)
		SCAP, while not sampled, is expected to be present. This species is largely confined to vegetated SS habitats.	similar methods as during EWR survey. SCAP present at FROC of < 1 or absent during two consecutive surveys.	sedimentation of slow habitats).
SS habitats				Significant change in SS habitat suitability (i.e. increased flows, altered seasonality, increased sedimentation of slow habitats).
Overhanging vegetation	*Galaxias zebratus* (GZEB) SCAP	GZEB was not sampled during EWR survey but is estimated to occur at a FROC* of 1 in the reach under PES. They have a high requirement for overhanging vegetation and are the most applicable indicator species for this habitat feature. SCAP was not sampled during EWR survey but is expected to occur at a FROC* of 1 in the reach under PES. They have a high requirement for instream vegetation and are the most applicable indicator species for this habitat metric.	GZEB absent during two consecutive surveys OR present at FROC of < 1. Absence of range of life stages (juveniles to adults) during various surveys. SCAP absent during two consecutive surveys OR present at FROC of < 1. Absence of range of life stages (juveniles to adults) during various surveys.	Significant change in overhanging and instream vegetation habitats (overgrazing, flow modification, use of herbicides, agriculture).
Instream vegetation				
Alien fish species	Presence of any alien/introduced spp.	*Micropterus salmoides* (MSAL) is known to be present in the SQ reach (sampled at abundance of 0.02 ind/min during EWR survey).	Presence of any additional alien/introduced species or increase in abundance and distribution of MSAL (>0.02 ind/min using similar methods and during similar conditions). Absence of juvenile fish vulnerable to predation by MSAL or other alien species.	N/A
Catadromous species	AMOS MFAL	Presence of MFAL confirmed during EWR survey and AMOS estimated to be present	Loss or decreased FROC or abundance of catadromous species compared to that found during EWR survey.	Reduction or loss of freshwater cues in estuary and sea (loss of longitudinal salinity gradient in estuary) for migration of catadromous species due to reduced river flows
Migratory success	AMOS MFAL	It is estimated that the catadromous AMOS may still be present and the presence of MFAL (facultative) was confirmed during the EWR survey (abundance of 0.02 ind/min).	Loss or decreased FROC[1] or CPUE of catadromous MFAL (<0.02 ind/min) using similar methods during similar conditions (season and flow) as the EWR survey). Absence of AMOS during two consecutive surveys.	Alteration of longitudinal habitat through the creation of migration barriers (dams, weirs, zero flows, poor water quality causing chemical barriers).
Primary (flow) indicator species		**AMOS (juveniles) due to preferred flow dependent habitat being FS. AMOS and MFAL - both are catadromous species requiring minimum flow depths over riffles for migration and need flows into estuary providing freshwater cues for upstream migrations.**		

* Refer to Section 3.4 for FROC ratings.

1 Catch Per Unit Effort

4.2.5 Macroinvertebrates: EcoSpecs and TPCs

Indicator taxa are provided in **Table 4.12** and EcoSpecs and TPCs in **Table 4.13**.

Table 4.12 H9GOUK-EWR2: Macroinvertebrate indicator taxa

Indicator acronym	Indicator Family and Score	Velocity preference		Substrate preference				WQ Preference[1]
		0.3 - 0.6 m/s	>0.6 m/s	Cobble	Vegetation	GSM	Water column	
BAE+	Baetidae >2spp. (12)	2	2	2	2	2	1	High
HEP	Heptageniidae (13)	3	2	4	1	0	0	High
LEP	Leptophlebiidae (9)	2	1	3	2	0	0	Moderate
TRI	Trichorythidae (9)	1	4	4	1	0	0	Moderate
COE	Coenagrionidae (4)	3	1	1	4	1	0	Low
HYD+	Hydropsychidae >2 spp. (12)	2	4	3	1	0	0	High
SIM	Simuliidae (5)	2	4	3	2	0	0	Low

1 Preferences scored 0 - 4 in ascending order of preference. For WQ, High = High preference for unimpaired WQ.

Table 4.13 H9GOUK-EWR2: Macroinvertebrate EcoSpecs and TPCs (PES and REC: D)

Parameter	Indicator	EcoSpecs	TPCs
SASS5 and ASPT score		The SASS5 score at sampling was 113 with an ASPT of 6.6. Total scores should remain in the range of 90 to 130, with ASPT values > 5.8.	SASS5 scores < 90 and ASPT < 5.8.
MIRAI score		MIRAI score to be within the D EC (40 - 59%) Category, using the reference data used in this study, or recording alterations to these.	MIRAI < 40%.
Diversity of invertebrate community		Seventeen families were collected during the field visit. More than 12 different families (taxa), with at least five scoring >8, should be present, at an abundance of A to C.	Less than 12 different taxa collected. Any taxon (adults) with an abundance of D.
Physical habitat quality	HEP, LEP, TRI, HYD+, SIM	Visual: Absence of silt. Cobbles should be mobile and lacking silt drapes or extensive algal cover. Presence of at least four of the indicator taxa.	Siltation, armouring of cobbles, extensive algal cover. Absence or low numbers of HEP, LEP or TRI over two consecutive samples.
Physical habitat diversity	BAE+, HEP, LEP, TRI, HYD+, SIM	Ability to sample four SASS5 biotopes (SIC, SOC, MV, GSM). Inundated MV. Presence of at least four indicators during high flow period, and three during lower flow periods.	Stones immobile. MV exposed or encroaching. More than two indicators absent or in low numbers.
Response to water quality	BAE+, HEP, HYD+	During flow periods, water should be clear, non-odorous, and low in suspended solids. Cobble surfaces should neither be slippery nor covered with silt. Three species of BAE and >2 spp. of HYD+ should be present. HEP should be present in at least one in three samples.	Observed deterioration (turbidity, silt, and odour). Absence of HEP in three consecutive samples. Reduction in number of BAE and HYD+ species in two or more consecutive samples.

Parameter	Indicator	EcoSpecs	TPCs
Response to hydraulic habitat availability and persistence			
VFCS	TRI, HYD+, SIM	There is a small amount of VFCS at a discharge of 0.06 m^3/s. At or above this discharge (where there are no antecedent dry periods); TRI, HYD+ (2 spp.) and SIM should be present, at A - C abundances.	Absence or very low numbers of TRI, HYD+ or SIM.
FCS	ELM, HYD+, SIM	FCS should be available at a discharge of 0.02 m^3/s. If sampling at or above this discharge, with no antecedent dry or drought conditions, ELM, HYD+ and SIM should be present and abundant.	Absence or very low numbers of indicator families, particularly SIM.
MV	COE	MV at channel margins should be inundated to at least 20 cm. COE should be present in at least 1 in 2 samples.	COE absent or in very low numbers in two consecutive samples. Photographic evidence of vegetation encroachment or die-back. Absence of Hemipterans in MV.
FS		Numerous taxa were collected in this biotope but this may be due to flow transfer. At least 1 - 2 families should be present in this biotope (e.g. caenid mayflies, oligochaetes, and gomphids).	Absence of any taxa.

4.2.6 Riparian vegetation EcoSpecs and TPCs

EcoSpecs and TPCs are provided in **Table 4.14**.

Table 4.14 H9GOUK-EWR2: Riparian vegetation EcoSpecs and TPCs (PES and REC: C)

Metric	EcoSpec	TPC
Marginal zone		
Alien invasion (perennial alien species)	Maintain an absence of perennial alien plant species.	Occurrence of perennial alien plant species.
Terrestrial woody species aerial cover	Maintain an absence of terrestrial woody species	Occurrence of terrestrial woody species in the sub-zone.
Indigenous riparian woody species cover (% aerial)	Maintain cover (% aerial) of indigenous riparian woody species below 10%.	Absence of indigenous riparian woody species OR an increase in cover above 10%
Non-woody indigenous cover (grasses, sedges and dicotyledonous forbs) (% aerial)	Maintain non-woody cover (% aerial) above 50%.	Decrease in non-woody cover (% aerial) below 50%.
Reed cover (% aerial)	Maintain reed cover below 5%	Increase in reed cover above 5%
Lower zone		
Alien invasion (perennial alien species)	Maintain cover (% aerial) of perennial alien plant species below 5%.	Increase in perennial alien plant species cover >10%.
Terrestrial woody species aerial cover	Maintain cover (% aerial) of terrestrial woody species at 5% or lower.	Increases in terrestrial woody species cover above 10%.

Metric	EcoSpec	TPC
Indigenous riparian woody species cover (% aerial)	Maintain cover (% aerial) of indigenous riparian woody species above 5% and below 10%.	Absence of indigenous riparian woody species OR an increase in cover above 10%.
Non-woody indigenous cover (grasses, sedges and dicotyledonous forbs) (% aerial)	Maintain non-woody cover (% aerial) above 60%.	Decrease in non-woody cover (% aerial) below 40%.
Reed cover (% aerial)	Maintain reed cover below 5%	Increase in perennial alien plant species cover > 10%.
Upper zone		
Alien invasion (perennial alien species)	Maintain cover (% aerial) of perennial alien plant species at 10% or lower.	Increase in perennial alien plant species cover > 20%.
Terrestrial woody species aerial cover	Maintain cover (% aerial) of terrestrial woody species at 10% or lower.	Increases in terrestrial woody species cover above 20%.
Indigenous riparian woody species cover (% aerial)	Maintain cover (% aerial) of indigenous riparian woody species below 40%.	Decrease in indigenous riparian woody species cover below 20% or an increase above 50%
Non-woody indigenous cover (grasses, sedges and dicotyledonous forbs) (% aerial)	Maintain non-woody cover (% aerial) above 40%.	Decrease in non-woody cover (% aerial) below 30%.
Reed Cover (% aerial)	Maintain reed cover below 5%	Presence of reeds.
Riparian zone		
PES	Maintain PES score (using VEGRAI level 4 for assessment) of at least 71% for the riparian zone.	Decrease in PES score below 70% for the riparian zone.
Dominant vegetation type	The dominant vegetation type shall remain non-woody in the marginal and lower zones, and largely free of any alien trees.	Increased proportion of non-woody cover above 10% in the marginal or 15% in the lower zones.

4.3 TOUWS RIVER: J1TOUW-EWR3

The Touws EWR site is situated just upstream of the confluence with the Buffels River and located downstream of JH018. Three irrigation dams are situated in tertiary catchment J12. The upstream area is in a poor to moderate state due to small farm dams in areas, and irrigation which is extensive in some areas. Non-flow related impacts are mainly agricultural encroachment or clearing of riparian zones and/or floodplains, overgrazing in some areas and physical disturbance (manipulation) of morphological features (localised). The downstream area in which the site is located is mostly in moderate condition which is an improvement due to the decreased irrigation in this area. Direct impacts in the downstream zone are mostly non-flow related. Grazing with some dryland agriculture and minimal irrigation occur. **Figure 4.3** provides a map and photographs of the EWR site.

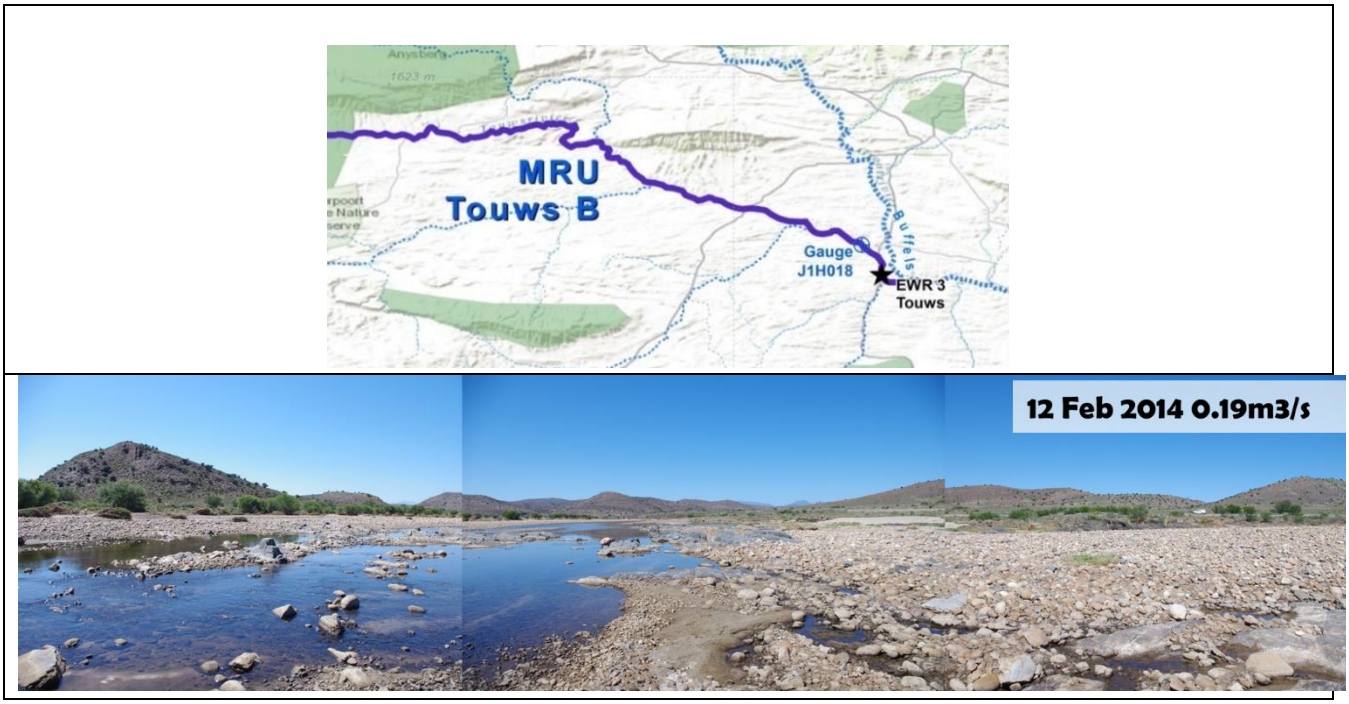

Figure 4.3 A map, Google image and downstream view of J1TOUW-EWR3

4.3.1 Ecological Categories

The ECs representative of broad qualitative EcoSpecs, determined for the PES (DWS, 2015c), is provided in **Table 4.15**. The PES is representative of the baseline.

Table 4.15 J1TOUW-EWR3: EcoSpecs as ECs

Component	PES and REC
Water quality	**B/C**
Geomorphology	**B**
Fish	**C/D**
Invertebrates	**B/C**
Instream	**C**
Riparian vegetation	**B/C**
EcoStatus	**B/C**

4.3.2 Hydrology: EcoSpecs

Source: DWA (2014b); DWS (2015c).
Model: RDRM (Hughes *et al*., 2011); WRYM (DWAF, 2008c).

REC	nMAR (MCM)	pMAR (MCM)	Low flows (MCM)	Low flows (%nMAR)	Total flows (MCM)	Total (%nMAR)	May		February	
							90%	60%	90%	60%
C	45.2	22.26	1.152	2.6	12.69	28.2	0	0.009	0	0

4.3.3 Water quality (including diatoms): EcoSpecs and TPCs

Water quality
EcoSpecs and TPCs for water quality are shown in **Table 4.16**. Data should be collected from the DWS gauging weir upstream of the EWR site, i.e. J1H018Q01 on the Touws River.

Note that all salinity guidelines are exceeded due to high saline geology of the area. It is assumed that some increase in salinity may be expected due to irrigation return flows.

Table 4.16 J1TOUW-EWR3: Water quality EcoSpecs and TPCs (PES and REC: B/C)

Metrics	EcoSpecs	TPCs
Inorganic salt ions		
Sulphate as SO_4	-	-
Sodium as Na	The 95th percentile of the data is between ≤ 2000 mg/L.	The 95th percentile of the data is between 1600 - 2000 mg/L.
Magnesium as Mg	The 95th percentile of the data is between ≤ 370 mg/L.	The 95th percentile of the data is between 300 - 370 mg/L.
Calcium as Ca	The 95th percentile of the data is between ≤ 260 mg/L.	The 95th percentile of the data is between 200 - 260 mg/L.
Chloride as Cl	The 95th percentile of the data is between ≤ 3500 mg/L.	The 95th percentile of the data is between 2800 - 3500 mg/L.
Potassium as K	The 95th percentile of the data is between ≤ 37 mg/L.	The 95th percentile of the data is between 30 - 37 mg/L.
Physical variables		
Electrical conductivity (mS/m)	The 95th percentile of the data is between ≤ 1100 mS/m.	The 95th percentile of the data is between 880 - 1100 mS/m.
pH	The 5th percentile of the data is between 6.5 – 8.0, and the 95th percentile 8.0 - 8.8.	The 5th percentile of the data is ≤ 6.3 and the 95th percentile is ≥ 8.6.
Temperature[(a)]	Natural temperature range.	Initiate baseline monitoring for this variable.
Dissolved oxygen[(a)]	The 5th percentile of the data is between ≥ 7.0 mg/L.	The 5th percentile of the data is between 7.2 - 7.0 mg/L. Initiate baseline monitoring for this variable.
Turbidity[(a)]	Changes in turbidity are related to minor man-made modifications. Some silting of habitats is expected.	Initiate baseline monitoring for this variable.

Metrics	EcoSpecs	TPCs
Nutrients		
TIN-N	The 50th percentile of the data is between ≤ 0.25 mg/L.	The 50th percentile of the data is between 0.2 - 0.25 mg/L.
PO_4-P	The 50th percentile of the data is between ≤ 0.075 mg/L.	The 50th percentile of the data is between 0.06 - 0.075 mg/L.
Response variables[(a)]		
Chl-a phytoplankton	The 50th percentile of the data is between < 15 µg/L.	The 50th percentile of the data is between 12 - 15 µg/L.
Chl-a periphyton	The 50th percentile of the data is between ≤ 21 mg/m^2.	The 50th percentile of the data is between 17 - 21 mg/m^2.
Toxics		
Fluoride	The 50th percentile of the data is between ≤ 1.5 mg/L.	The 50th percentile of the data is between 1.2 - 1.5 mg/L.
Ammonia (NH_3-N)	The 50th percentile of the data is between ≤ 0.015 mg/L.	The 50th percentile of the data is between 0.012 - 0.015 mg/L.
Other toxics	The 95th percentile of the data is between within the TWQR as stated in DWAF (1996) or the A Category boundary as stated in DWAF (2008a).	An impact is expected if the 95th percentile of the data exceeds the TWQR as stated in DWAF (1996) or the upper limit of the A Category boundary as stated in DWAF (2008a).

- No data

(a) No data were available for this assessment. All EcoSpecs and TPCs need verification as based on expert judgement.

Diatoms

Monitoring guidelines for diatoms are provided in **Table 4.17**. The SPI score of 8.6 is based on the aggregate of the four samples collected during January 2014 (SPI score: 5.7), February 2014 (SPI score: 6.3), April 2014 (SPI score: 10.8) and July 2014 (SPI score: 11.5) at the EWR site (DWS, 2015c). No historic or other present data could be sourced for the Touws River. The overall diatom EC was set at a D EC (DWS, 2015a). Nutrient levels, organic pollution and salinity levels were high and problematic most of the time with some improvement evident during April and June 2014. Moderate oxygenation rates and very heavy pollution levels prevailed (DWS, 2015c).

Based on water quality data (DWS, 2015c) the following metrics are of concern:

- Salinity: Levels are naturally high due to geology. This would influence the salinity results for diatoms. However there are indicator species present that are associated with elevated salinity levels due to anthropogenic impact rather than naturally high levels.
- Nutrient and organics: Some nutrient elevations are evident, which is expected from farming activities in the area. Main land uses, however, are grazing with some dryland agriculture and minimal irrigation.
- Oxygen: Impacts are expected during low flows.

Table 4.17 J1TOUW-EWR3: Diatoms monitoring guidelines (PES and REC: D)

Metric	Indicator species	Indicator/general threshold	Action
Salinity	*N. frustulum*: Indicator of nutrient and salinity levels.	If present at > 40% these variables will most probably be problematic.	If thresholds are exceeded during consecutive low and high flow assessments water quality analysis should be undertaken.
	F. fasciculata: Indicator of salinity. Has been reported from critically polluted industrial wastewater (Taylor *et al*., 2007b). It has a preference for $S0_4^{-2}$-dominated habitats.	Abundance of > 1.5% would indicate potential problems.	
	Cyclotella meneghiniana and *Thalassiosira pseudonana:* Indicators of elevated salinity levels and found in electrolyte rich streams (Taylor *et al*., 2007b).	Combined abundance of > 20% would indicate potential problems.	
Oxygen	*Achnanthidium* species: Associated with elevated flows. The genus generally prefers good water quality with high oxygenation rates (Taylor *et al*., 2007b). *A. oblongella*: Preference for circumneutral oligotrophic electrolyte poor streams (Taylor *et al*., 2007b). High abundance could be associated with elevated flows and high oxygenation rates (Taylor *et al*., 2007b).	If flows are elevated expect dominance of either species > 5%.	During high/elevated flow this species must be present and is an important indicator of system recovery. If absent, this variable should be flagged. Species should not be absent in more than one high flow sample. If absent, water quality analysis should be undertaken.
Nutrients	*Nitzschia* species: Associated with water bodies that have readily available nutrients.	If present at > 10% this variable will most probably be problematic.	If thresholds are exceeded during consecutive low and high flow assessments water quality analysis should be undertaken.
Organics	*N. erifuga*, *N. schroeteri* var. *symmetrica*, and *N. veneta*: Main indicators of anthropogenic activities relating to increased sewage or other effluent.	Combined abundance of > 7% indicates potential problems.	If thresholds are exceeded during consecutive low and high flow assessments along with consecutive PTV score of > 50% water quality analysis should be undertaken.
Metal toxicity	During 2014 valve deformities were absent during January and February but during April and July valve deformities were present at an abundance of 1% and 2.5% respectively.	A check should be done for valve deformities with every count as this is indicative of metal contamination. Valve deformities should not be present at an abundance of > 1%.	If thresholds are exceeded during consecutive low and high flow assessments water quality analysis should be undertaken.
SPI score	8 and higher	8 - 10	

4.3.4 Fish: EcoSpecs and TPCs

EcoSpecs and TPCs are provided in **Table 4.18**.

Table 4.18 J1TOUW-EWR3: Fish EcoSpecs and TPCs (PES and REC: D)

Metric	Indicator	EcoSpecs	TPC (Biotic)	TPC (Habitat)
Ecological status	PES	The PES is in a C/D (59%).	Decrease of PES into a lower EC than PES (< C/D).	Any deterioration in habitat that results in decrease in FROC* of species.
Species richness	All indigenous species	All of the expected five indigenous fish species estimated to still be present in the reach under the existing PES, but at low FROCs*.	Loss of any indigenous species. Presence of at least one indigenous species at EWR site using similar sampling methods and conducted during similar conditions (season, flow).	Loss in diversity, abundance and condition of velocity-depth categories and cover features that lead to a loss of species.
Substrate	LUMB (*Labeo umbratus*) PASP (*Pseudobarbus asper*)	Both species estimated to be present at low FROCs and require clean riffle areas for spawning purposes.	LUMB and PASP absent during two consecutive surveys or present a FROC* of < 1. Also absence of juvenile fish in catches.	Increased embeddedness and sedimentation of riffle substrates; increased algal growth on rocky substrates.
Requirement for flowing water.	PASP	PASP was not sampled during EWR survey but is estimated to occur at a FROC* of 1 in the reach under the PES. This species has the highest requirement for flow and unmodified water quality and water column as cover of all species in this reach and is the most applicable indicator species for these habitat features.	PASP absent during two consecutive surveys OR present at FROC* of < 1. Absence of range of life stages (juveniles to adults) during various surveys.	Reduced suitability (abundance and quality) of flowing habitats such as riffle areas (i.e. decreased flows, increased zero flows, and altered seasonality).
Water quality intolerance				Decreased water quality (especially flow related water quality variables such as oxygen).
Water column				Reduction in suitability of water column (i.e. increased sedimentation of pools, reduced flows).
FD habitats	AMOS	AMOS was not sampled during EWR survey but is estimated to occur at a FROC* of 0.5 in the reach under the PES. This species (juveniles) has the highest preference for fast habitats and substrate and undercut banks (adults) of all species in this reach and is the most applicable indicator species for these habitat features.	AMOS absent during three consecutive surveys OR present at FROC* of < 0.5 in the reach.	Reduced suitability (abundance and quality) of FD habitats (i.e. decreased flows, increased zero flows).
FS habitats				Reduced suitability (abundance and quality) of FS habitats (i.e. decreased flows, increased zero flows).
				Loss of FS habitat suitable for juvenile AMOS (sedimentation).

Metric	Indicator	EcoSpecs	TPC (Biotic)	TPC (Habitat)
Undercut banks				Significant change in undercut bank and rootwads habitats (e.g. bank erosion, reduced flows).
Overhanging vegetation	BANO (*Barbus anoplus*)	BANO sampled at abundance of 0.4 ind/min during the EWR survey and estimated to occur at a FROC* of 3 in the reach under the PES. This species has the highest preference for overhanging vegetation and SS habitats of all species in this reach and is the most applicable indicator species for these habitat features.	BANO absent during any survey OR present at FROC* of < 3. Absence of range of life stages (juveniles to adults) during various surveys.	Significant change in overhanging vegetation habitats (overgrazing, flow modification, use of herbicides, agriculture, vegetation removal, alien vegetation encroachment).
SS habitats				Significant change in SS habitat suitability (i.e. increased flows, altered seasonality, increased sedimentation of slow habitats).
Instream vegetation	SCAP	SCAP was not sampled during the EWR survey but is estimated to occur at a FROC* of 1 in the reach under the PES. This species has the highest preference for instream vegetation habitats of all species in this reach and is the most applicable indicator species for this habitat feature.	SCAP absent during two consecutive surveys OR present at FROC* of < 1 in reach. Absence of range of life stages (juveniles to adults) during various surveys.	Significant change in instream vegetation habitats (overgrazing, flow modification, use of herbicides, agriculture, alien macrophytes).
SD habitats	LUMB	LUMB was not sampled during the EWR survey but is estimated to occur at a FROC* of 1 in this reach under the PES. This species has the highest preference for SD habitats of all species in this reach and is the most applicable indicator species for this habitat feature.	LUMB absent during two consecutive surveys OR present at FROC* of < 1 in reach. Absence of range of life stages (juveniles to adults) during various surveys.	Significant change in SD habitat suitability (i.e. increased or decreased flows, altered seasonality, increased sedimentation of slow habitats).
Alien fish species	Presence of any alien/introduced spp.	Presence of indigenous introduced TSPA (1.36 ind/min) and *Labeobarbus aeneus* (BAEN) (0.03 ind/min) confirmed during the EWR survey.	Presence of any additional alien/introduced species or increase in abundance and distribution of existing species.	N/A
Migratory success[2]	AMOS LUMB PASP	It is estimated that the catadromous species AMOS should be present. The potamodromous species PASP, and LUMB should also occur and both species migrate between reaches for spawning in suitable riffles.	Loss or decreased FROC* of catadromous (AMOS) or potamodromous species (LUMB, and BANO).	Alteration of longitudinal habitat through the creation of migration barriers (dams, weirs, zero flows, poor water quality causing chemical barriers).
Primary indicator species		**AMOS, LUMB.**		

* Refer to Section 3.4 for FROC ratings.

4.3.5 Macroinvertebrates: EcoSpecs and TPCs

Indicator taxa are provided in **Table 4.19** and EcoSpecs and TPCs in **Table 4.20**.

Table 4.19 J1TOUW-EWR3: Macroinvertebrate indicator taxa

Indicator acronym	Indicator Family and Score	Velocity preference		Substrate preference				WQ Preference[1]
		0.3 - 0.6 m/s	>0.6 m/s	Cobble	Vegetation	GSM	Water column	
BAE-	Baetidae 1 spp. (6)	2	2	2	2	2	1	Low
CAE	Caenidae (6)	1	1	2	1	3	0	Low
NAU	Naucoridae (7)	3	0	1	1	1	4	Low
COE	Coenagrionidae (4)	3	1	1	4	1	0	Low
GOM	Gomphidae (8)	3	0	1	0	5	0	Low
SIM	Simuliidae (5)	2	4	3	2	0	0	Low

1 Preferences scored 0 - 4 in ascending order of preference. For WQ, High = High preference for unimpaired WQ.

Table 4.20 J1TOUW-EWR3: Macroinvertebrate EcoSpecs and TPCs (PES and REC: B/C)

Parameter	Indicator	EcoSpecs	TPCs
SASS5 and ASPT score		The SASS5 score at sampling was 57 with an ASPT of 4.4. Total scores should remain greater than 45, with an ASPT ≥ 4.	SASS5 scores < 45 and ASPT < 4.
MIRAI score		MIRAI score to be within the B/C (78 - 82%) or B Category, using the reference data used in this study, or recording alterations to these.	MIRAI < 70% using the reference data used in the study.
Diversity of invertebrate community	ALL	Thirteen low-scoring families were collected during the field visit. More than 10 different families (taxa) should be present, unless there have been persistent zero flow conditions prior to sampling, in which case flow-dependent taxa (e.g. SIM) would be absent, but the taxa scoring 5 and less should occur.	Less than 10 different taxa collected (during a flow period).
Physical habitat quality		What constitutes poor habitat in a perennial system (e.g. algal mats) could prove to be critical habitat (e.g. for developing juveniles) in a system which has variable periods of no flow.	Visual record of algae on the majority (70% +) of cobble surfaces. Unnatural growths on invertebrates which would suggest some form of infection or toxicity.
Physical habitat diversity	SIC – SIM MV – COE GSM - GOM	All SASS5 habitats were sampled during the survey in low-flow conditions, and should be present if sampling is conducted during periods of flow. Indicator taxa should be present. Outside of these periods this parameter should be omitted.	Absence of indicator taxa in any one biotope.
Response to water quality	ALL except SIM	All invertebrates collected during sampling were low-scoring and resilient to alterations in water quality,	Less than 10 taxa collected. Absence of > 3 of the indicator taxa.

Parameter	Indicator	EcoSpecs	TPCs
		as is typical of a temporary river invertebrate community. The majority of indicators except SIM should be present in samples year-round, except where there have been antecedent periods of zero flow. SIM should be present if there is flow.	
Response to hydraulic habitat availability and persistence			
VFCS	BAE-SIM	According to the hydraulic modelling, VFCS is present above a discharge of 1 m^3/s. At these flows, and where there are no antecedent dry periods, BAE- and SIM should be present.	Absence of BAE or SIM.
FCS	BAE-SIM	According to the hydraulic modelling, FCS should be available above a discharge of 0.4m^3/s. If sampling at or above this discharge, with no antecedent dry or drought conditions, indicators should be present and BAE- and SIM abundant.	Absence of BAE- or SIM.
MV	COE	Small areas of inundated MV should be present. COE should be present in at least 1 of every 2 samples.	COE absent or in very low numbers. Fixed-point photographic evidence of vegetation encroachment or die-back.
FS	GOM	GOM should be present.	GOM absent.

4.3.6 Riparian vegetation EcoSpecs and TPCs

EcoSpecs and TPCs are provided in **Table 4.21**.

Table 4.21 J3KAMM-EWR10: Riparian vegetation EcoSpecs and TPCs (PES and REC: B/C)

Metric	EcoSpec	TPC
Marginal zone		
Alien invasion (perennial alien species)	Maintain an absence of perennial alien plant species.	Occurrence of perennial alien plant species.
Terrestrial woody species aerial cover	Maintain an absence of terrestrial woody species.	Occurrence of terrestrial woody species in the sub-zone.
Indigenous riparian woody species cover (% aerial)	Maintain cover (% aerial) of indigenous riparian woody species below 5%.	Increase of indigenous riparian woody species cover above 10%.
Non-woody indigenous cover (grasses, sedges and dicotyledonous forbs) (% aerial)	Maintain non-woody cover (% aerial) above 10%.	Decrease in non-woody cover (% aerial) below 10%.
Reed cover (% aerial)	Maintain reed cover below 5%.	Increase in reed cover above 10%.
Lower zone		
Alien invasion (perennial alien species)	Maintain cover (% aerial) of perennial alien plant species at 5% or lower.	Increase in perennial alien plant species cover > 15%.

Metric	EcoSpec	TPC
Terrestrial woody species aerial cover	Maintain cover (% aerial) of terrestrial woody species at 5% or lower.	Increase in terrestrial woody species cover above 15%.
Indigenous riparian woody species cover (% aerial)	Maintain cover (% aerial) of indigenous riparian woody species below 5%.	Increase of indigenous riparian woody species cover above 10%.
Non-woody indigenous cover (grasses, sedges and dicotyledonous forbs) (% aerial)	Maintain non-woody cover (% aerial) above 10%.	Decrease in non-woody cover (% aerial) below 10%.
Reed cover (% aerial)	Maintain reed cover below 5%.	Increase in reed cover above 10%.
Upper zone		
Alien invasion (perennial alien species)	Maintain cover (% aerial) of perennial alien plant species at 5% or lower.	Increase in perennial alien plant species cover > 15%.
Terrestrial woody species aerial cover	Maintain cover (% aerial) of terrestrial woody species at 5% or lower.	Increase in terrestrial woody species cover above 10%.
Indigenous riparian woody species cover (% aerial)	Maintain cover (% aerial) of indigenous riparian woody species below 15%.	Increase in indigenous riparian woody species cover above 20%.
Non-woody indigenous cover (grasses, sedges and dicotyledonous forbs) (% aerial)	Maintain non-woody cover (% aerial) above 30%.	Decrease in non-woody cover (% aerial) below 35%.
Riparian zone		
PES	Maintain PES score (using VEGRAI level 4 for assessment) of at least 78% for the riparian zone.	Decrease in PES score below 77% for the riparian zone.

4.4 GAMKA RIVER: J2GAMK-EWR4

The EWR site is situated in the Gamkaskloof and Die Hel in the Swartberg Nature Reserve, a World Heritage Site. The site is situated in Gamka River poort downstream of the bridge. There are three upstream dams; two of which which supply Beaufort West with domestic water and Gamkapoort Dam upstream of the site which supports domestic water requirements and irrigation downstream. The river is therefore used as a conduit to supply downstream users. The manner of operation is pulsed flow releases with no other releases from the dam apart from a constant leak and spills (**Figure 4.4**).

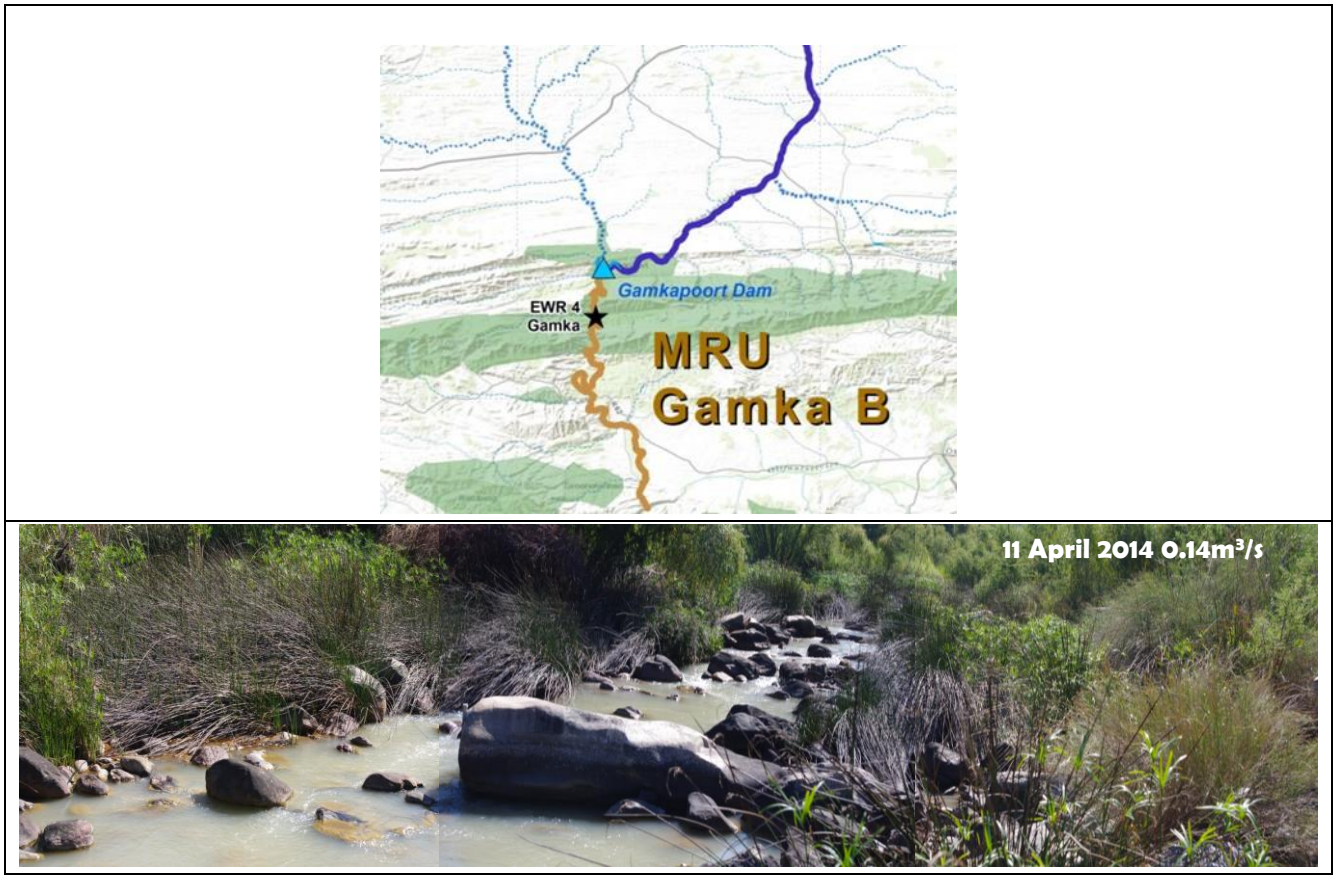

Figure 4.4 A map, Google image and downstream view of J2GAMK-EWR4

4.4.1 Ecological Categories

The ECs are representative of broad qualitative EcoSpecs, as determined for the PES (DWS, 2015c), and are provided in **Table 4.22**. The PES is representative of the baseline.

Table 4.22 J2GAMK-EWR4: EcoSpecs as ECs

Component	PES	REC
Water quality	B/C	B
Geomorphology	D	C
Fish	C/D	C
Invertebrates	C/D	B/C
Instream	C/D	C
Riparian vegetation	D	C
EcoStatus	C/D	C

4.4.2 Hydrology: EcoSpecs

Source: DWA (2014b); DWS (2015c).
Model: RDRM (Hughes *et al*., 2011); WRYM (DWAF, 2008c).

PES	nMAR (MCM)	pMAR (MCM)	Low flows (MCM)	Low flows (%nMAR)	Total flows (MCM)	Total (%nMAR)	March		July	
							90%	60%	90%	60%
C/D	85.54	61.69	3.94	4.6	21.38	25.0	0.024	0.129	0.010	0.046

4.4.3 Water quality (including diatoms): EcoSpecs and TPCs

Water quality

EcoSpecs and TPCs for water quality are shown in **Table 4.23**. Data should be collected from DWS monitoring point J2H016Q01 on the Gamka River. Conditions that would result in an improvement in water quality category from a B/C to a B are indicated in bold red text. Improvements are recommended for variables where data are available. Lowering nutrient levels should result in a concomitant improvement in periphyton levels. Similarly, if electrical conductivity is lowered, some of the salt ions levels will also drop. Improvements in salts and nutrients should result in an improvement of water quality category to at least a B Category.

Table 4.23 J2GAMK-EWR4: Water quality EcoSpecs and TPCs (PES: B/C; REC: B)

Metrics	EcoSpecs: PES EcoSpecs: REC	TPCs: PES TPCs: REC
Inorganic salt ions		
Sulphate as SO_4	-	-
Sodium as Na	The 95th percentile of the data is between ≤ 114 mg/L.	The 95th percentile of the data is between 90 - 114 mg/L.
Magnesium as Mg	The 95th percentile of the data is between ≤ 20 mg/L.	The 95th percentile of the data is between 16 - 20 mg/L.
Calcium as Ca	The 95th percentile of the data is between ≤ 58 mg/L.	The 95th percentile of the data is between 47 - 58 mg/L.
Chloride as Cl	The 95th percentile of the data is between ≤ 155 mg/L.	The 95th percentile of the data is between 124 - 155 mg/L.
Potassium as K	The 95th percentile of the data is between ≤ 8 mg/L.	The 95th percentile of the data is between 6.5 - 8.0 mg/L.
Physical variables		
Electrical conductivity (mS/m)	The 95th percentile of the data is between ≤ 100 mS/m. **The 95th percentile of the data is between ≤ 85 mS/m.**	The 95th percentile of the data is between 80 - 100 mS/m. **The 95th percentile of the data is between 68 - 85 mS/m.**
pH	The 5th percentile of the data is between 5.9 - 6.5, and the 95th percentile 8.0 - 8.8.	The 5th percentile of the data is ≤ 5.7 and the 95th percentile is ≥ 8.6.
Temperature[(a)]	Moderate change to temperature due to upstream Gamkapoort Dam.	Initiate baseline monitoring for this variable.
Dissolved oxygen[(a)]	The 5th percentile of the data is between ≥ 7.0 mg/L. Although some impacts are expected due to the upstream Gamkapoort Dam, the size of the river will mitigate the effects.	The 5th percentile of the data is between 7.2 - 7.0 mg/L. Initiate baseline monitoring for this variable.

Metrics	EcoSpecs: PES EcoSpecs: REC	TPCs: PES TPCs: REC
Turbidity[(a)]	Changes in turbidity are related to minor man-made modifications. Some silting of habitats is expected.	Initiate baseline monitoring for this variable.
Nutrients		
TIN-N	The 50th percentile of the data is between ≤ 0.7 mg/L. **The 50th percentile of the data is between ≤ 0.25 mg/L.**	The 50th percentile of the data is between 0.56 - 0.7 mg/L. **The 50th percentile of the data is between 0.2 - 0.25mg/L.**
PO_4-P	The 50th percentile of the data is between ≤ 0.125 mg/L. **The 50th percentile of the data is between ≤ 0.075 mg/L.**	The 50th percentile of the data is between 0.1 - 0.125 mg/L. **The 50th percentile of the data is between 0.06 - 0.075 mg/L.**
Response variables[(a)]		
Chl-a phytoplankton	The 50th percentile of the data is between < 15 µg/L.	The 50th percentile of the data is between 12 - 15 µg/L.
Chl-a periphyton	The 50th percentile of the data is between ≤ 21 mg/m^2.	The 50th percentile of the data is between 17 - 21 mg/m^2.
Toxics		
Fluoride	The 50th percentile of the data is between ≤ 1.5 mg/L.	The 50th percentile of the data is between 1.2 - 1.5 mg/L.
Ammonia (NH_3-N)	The 50th percentile of the data is between ≤ 0.015 mg/L.	The 50th percentile of the data is between 0.012 - 0.015 mg/L.
Other toxics	The 95th percentile of the data is between within the TWQR as stated in DWAF (1996) or the A Category boundary as stated in DWAF (2008a).	An impact is expected if the 95th percentile of the data exceeds the TWQR as stated in DWAF (1996) or the upper limit of the A Category boundary as stated in DWAF (2008a).

- No data

(a) No data were available for this assessment. All EcoSpecs and TPCs need verification as based on expert judgement.

Diatoms

Monitoring guidelines for diatoms are provided in **Table 4.24**. It should be noted that the information provided in **Table 4.24** is based on one sample collected during July 2014 and therefore the confidence is low. Diatom data indicate that nutrient levels, organic pollution and salinity were high and problematic. Moderate oxygenation rates and very heavy pollution levels prevailed. Based on water quality data (DWS, 2015c) the following metrics are of concern:

- Salinity: Levels are naturally high due to geology. Salt (sodium and chloride) levels are slightly elevated in terms of irrigation guidelines. This would influence the salinity results for diatoms; however there are indicator species present that are associated with elevated salinity levels due to anthropogenic impact rather than naturally high levels.
- Nutrient and organics: Some nutrients and toxics elevations are expected from fertilizer and pesticide use for irrigation purposes, although this is limited. Most impacts are upstream Gamkapoort Dam.
- Oxygen: Impacts are expected downstream of Gamkapoort Dam.

Table 4.24 J2GAMK-EWR4: Diatom monitoring guidelines (PES and REC: D)

Metric	Indicator species	Indicator/general threshold	Action
Salinity	*N. frustulum*: Indicator of nutrient	If present at > 50% these	If thresholds are exceeded

Metric	Indicator species	Indicator/general threshold	Action
	and salinity levels.	variables will most probably be problematic.	during consecutive low and high flow assessments water quality analysis should be undertaken.
	F. fasciculata: Indicator of salinity. Has been reported from critically polluted industrial wastewater (Taylor *et al*., 2007b). It has a preference for $S0_4^{-2}$-dominated habitats.	Abundance of > 1% would indicate potential problems.	
	C. meneghiniana: Indicator of elevated salinity levels. Found in electrolyte rich streams (Taylor *et al*., 2007b).	If present at > 1% would indicate potential problems.	
	E. adnata: Indicator of elevated temperatures, low flows and salinity levels. Tolerant to moderate to high electrolyte content but extends into brackish biotopes (Taylor *et al*., 2007b).	If present at > 10% salinity will most probably be problematic.	
Oxygen	*Fragilaria* species*:* Although not the preferred indicator species no *Achnanthidium* species were present. *Fragilaria* species are associated with elevated flows and should be used as a proxy until sufficient data is collected.	If flows are elevated expect combined dominance of species > 3%.	During high/elevated flow this species must be present. Further data is needed to define threshold.
Organics	*N. veneta*: Main indicator of anthropogenic activities relating to increased sewage or other effluent.	If present at > 7% indicates potential problems.	If thresholds are exceeded during consecutive low and high flow assessments along with consecutive PTV score of > 50% water quality analysis should be undertaken.
Metal toxicity	During July 2014 valve deformities were absent.	A check should be done for valve deformities with every count as this is indicative of metal contamination. Valve deformities should not be present at an abundance of > 1%.	If thresholds are exceeded during consecutive low and high flow assessments water quality analysis should be undertaken.
SPI score	8 and higher	8 - 10	

4.4.4 Fish: EcoSpecs and TPCs

EcoSpecs and TPCs are provided in **Table 4.25**.

Table 4.25 J2GAMK-EWR4: Fish EcoSpecs and TPCs (PES C/D; REC: C)

Metric	Indicator	EcoSpecs for PES	TPC (Biotic) for PES	TPC (Biotic) for REC	TPC (Habitat) for PES and REC
Ecological status	PES/REC	The PES is in a C/D (60.4%) and in a C EC (71.6%) for the REC.	Decrease of PES into a lower EC than PES (< C/D).	Decrease of the REC of C (71.6%) into a lower category.	Any deterioration in habitat that results in decrease in the FROC* of species.
Species richness	All indigenous species	Six indigenous fish species are estimated to still be present in the reach under the current PES.	Loss of any indigenous species. Presence of less than two indigenous species at the EWR site using similar sampling methods and conducted during similar conditions (season, flow).	Loss of any indigenous species. Presence of less than three indigenous species at the EWR site using similar sampling methods and conducted during similar conditions (season, flow).	Loss in diversity, abundance and condition of velocity-depth categories and cover features that lead to a loss of species.
Requirement for flowing water	PASP	PASP was not sampled during EWR survey but is estimated to occur at a FROC* of 0.5 in the reach under the PES. This species has the highest requirement for flow and unmodified water quality and water column as cover of all species in this reach and is the most applicable indicator species for these habitat features.	Absence of PASP during two consecutive surveys OR present at FROC* of < 0.5. Absence of range of life stages (juveniles to adults) during various surveys.	PASP absent during consecutive surveys OR present at FROC of < 1. Absence of range of life stages (juveniles to adults) during various surveys.	Reduced suitability (abundance and quality) of flowing habitats (i.e. decreased flows, increased zero flows, and altered seasonality).
Water quality intolerance					Decreased water quality (especially flow related water quality variables such as oxygen).
Water column					Reduction in suitability of water column (i.e. increased sedimentation of pools, reduced flows).
FD habitats	AMOS *Anguilla marmorata* (AMAR)	AMOS was not sampled during EWR survey but together with AMAR is estimated to occur at a FROC* of 0.5 in the reach under the PES. Both these eel species (juveniles) have the highest preference for fast habitats and substrate and undercut banks (adults) of all species in this reach and are the most applicable indicator species for these habitat features.	AMOS or AMAR absent during two consecutive surveys OR present at FROC* of < 0.5 in the reach.	AMOS or AMAR absent during f one survey OR present at FROC* of < 1 in the reach.	Reduced suitability (abundance and quality) of FD habitats (i.e. decreased flows, increased zero flows).
FS habitats					Reduced suitability (abundance and quality) of FS habitats (i.e. decreased flows, increased zero flows).
Substrate					Increased sedimentation of riffle/rapid substrates, excessive algal growth on substrates.
Undercut banks					Significant change in undercut bank and rootwads habitats (e.g. bank erosion,

Metric	Indicator	EcoSpecs for PES	TPC (Biotic) for PES	TPC (Biotic) for REC	TPC (Habitat) for PES and REC
					reduced flows).
Overhanging vegetation	BANO	BANO was not sampled during EWR survey, but is estimated to occur at a FROC* of 1 in the reach under the PES. This species has the highest preference for overhanging vegetation and SS habitats of all species in this reach and is the most applicable indicator species for these habitat features.	BANO absent during any survey OR present at FROC* of < 1. Absence of range of life stages (juveniles to adults) during various surveys.	BANO absent during any survey OR present at FROC* of < 2. Absence of range of life stages (juveniles to adults) during various surveys.	Significant change in overhanging vegetation habitats (overgrazing, flow modification, use of herbicides, agriculture, vegetation removal, alien vegetation encroachment).
SS habitats					Significant change in SS habitat suitability (i.e. increased flows, altered seasonality, increased sedimentation of slow habitats).
Instream vegetation	SCAP	SCAP was not sampled during the EWR survey but is estimated to occur at a FROC* of 1 in the reach under the PES. This species has the highest preference for instream vegetation habitats of all species in this reach and is the most applicable indicator species for this habitat feature.	SCAP absent during three consecutive surveys OR present at FROC* of < 1 in the reach. Absence of range of life stages (juveniles to adults) during various surveys.	SCAP absent during a surveys OR present at FROC* of < 2 in the reach. Absence of range of life stages (juveniles to adults) during various surveys.	Significant change in instream vegetation habitats (overgrazing, flow modification, use of herbicides, agriculture, alien macrophytes).
SD habitats	LUMB	LUMB was sampled during the EWR survey at a FROC* of 4.5 in the reach under the PES. This species has the highest preference for SD habitats of all species in this reach and is the most applicable indicator species for this habitat feature.	LUMB present at FROC* of < 4.5 in the reach. Absence of range of life stages (juveniles to adults) during various surveys.	LUMB present at FROC* of < 5 in the reach. Absence of range of life stages (juveniles to adults) during various surveys.	Significant change in SD habitat suitability (i.e. increased or decreased flows, altered seasonality, increased sedimentation of slow habitats).
Alien fish species	Presence of any alien/introduced spp.	The presence of five alien species (including indigenous introduced species) confirmed during EWR survey.	Presence of any additional alien/introduced species or increase in abundance and distribution of existing alien species.	Presence of any additional alien/introduced species or increase in abundance and distribution of existing alien species.	N/A
Migratory success	AMAR AMOS LUMB	It is estimated that both catadromous species AMOS and AMAR are present at a FROC* of at least 1. The potamodromous species (LUMB is present at a FROC* of 4.	Loss or decreased FROC* to < 1 for catadromous species (AMOS, AMAR) or decrease FROC of potamodromous species (LUMB) to < 4.	Loss or decreased FROC* to < 2 for catadromous species (AMOS, AMAR) or decrease FROC of potamodromous species (LUMB) to < 5.	Alteration of longitudinal habitat through the creation of migration barriers (dams, weirs, zero flows, drastically reduced summer flows, poor water quality causing chemical barriers).
Primary indicator species		**AMAR, AMOS, LUMB.**			

* Refer to Section 3.4 for FROC ratings.

4.4.5 Macroinvertebrates: EcoSpecs and TPCs

Indicator taxa are provided in **Table 4.26** and EcoSpecs and TPCs in **Table 4.27**.

Table 4.26 J2GAMK-EWR4: Macroinvertebrate indicator taxa

Indicator acronym	Indicator Family and Score	Velocity preference		Substrate preference				WQ Preference[1]
		0.3 - 0.6 m/s	>0.6 m/s	Cobble	Vegetation	GSM	Water column	
BAE+	Baetidae > 2 spp. (12)	2	2	2	2	2	1	High
HYD	Hydropsychidae 2 spp. (6)	2	4	3	1	0	0	Low
COE	Coenagrionidae (4)	3	1	1	4	1	0	Low
HEP	Heptageniidae (13)	3	2	4	1	0	0	High
LPC	Leptoceridae (6)	3	2	2	2	2	0	Low
ELM	Elmidae (8)	4	2	4	1	0	0	Moderate
SIM	Simuliidae (5)	2	4	3	2	0	0	Low
TAB	Tabanidae (5)	1	0	2	0	3	0	Low
TRI	Trichorythidae (9)	1	4	4	1	0	0	Moderate

1 Preferences scored 0 - 4 in ascending order of preference. For WQ, High = High preference for unimpaired WQ.

Table 4.27 J2GAMK-EWR4: Macroinvertebrate EcoSpecs and TPCs (PES: C/D; REC: B/C)

Parameter	Indicator	EcoSpecs	TPCs
SASS5 and ASPT score		PES: The SASS5 score at sampling was 77 with an ASPT of 5.5. Total scores should remain in the range of 60 - 80+, with ASPT values > 4.8. REC: Total scores expected to be > 100, with an ASPT > 5.5.	PES: SASS5 scores < 60 and ASPT < 4. REC: SASS5 scores < 90, ASPT < 5.
MIRAI score		PES: MIRAI score to be within the C/D Category, with the reference data used in this study, or recording alterations to these. REC: MIRAI score expected to be within the B/C range, with the reference data used in this study or recording alterations to these.	PES: MIRAI < 55%. REC: < 75%.
Diversity of invertebrate community	ALL	PES: Fourteen low-scoring families were collected during the field visit. More than 11 different families (taxa) should be present, at an abundance of A to C. All indicators should be present with at least one species of BAE+ and HYD. REC: More than 15 families should occur at an abundance of A to C. At least two taxa (excluding BAE+ and HYD) should score > 10.	PES: Less than 11 taxa collected. Any taxon (adults) with an abundance of D. REC: Less than 15 families collected. Any taxon (adult) with an abundance of D. No single taxa (excluding BAE+ and HYD) scoring > 10.
Physical habitat quality	SIC: BAE+, HYD, ELM	PES: Visual - The small cobble areas downstream of the cross-section	PES: Immobile cobbles, extensive algal cover, lack of inundated

Parameter	Indicator	EcoSpecs	TPCs
	MV: COE, LPC GSM: TAB	should comprise movable cobbles. Indicator taxa for each biotope should be present, with at least one species of BAE+ and HYD. REC: Additional taxa expected, including Perlidae, Leptophlebiidae, Trichorythidae, and Athericidae.	marginal vegetation. Absence of more than one indicator taxa in SIC or MV. Less than one species of BAE+ or HYD. REC: Absence of taxa scoring > 10.
Physical habitat diversity	SIC: BAE+,HYD, ELM MV: COE, LPC GSM: TAB	PES: Availability of all SASS5 biotopes (SIC, MV, GSM). Inundation of MV 10 to 20 cm. The indicator taxa for each biotope should be present. REC: Additional high-scoring taxa expected.	PES: MV exposed (no wetted stems) and/or encroaching. More than one indicator absent per biotope. REC: No high-scoring (> 9) taxa collected.
Response to water quality	BAE+ ELM HYD	PES: During flow periods, water should be clear, non-odorous, and low in suspended solids. Cobble surfaces should neither be slippery nor covered with silt. At least two species of Baetidae and Hydropsychidae should be present. REC: Expect > 2 spp. Baetidae and additional taxa with a preference for high quality water (e.g. Perlidae, Leptophlebiidae, and Trichorythidae).	PES: Observed deterioration (turbidity, silt, and odour). Absence of HEP in three consecutive samples. Reduction in number of baetid and hydropsychid species in two or more consecutive samples. REC: Expect > 2 spp. Baetidae. Additional taxa with a preference for high quality water (e.g. Perlidae, Leptophlebiidae, and Trichorythidae).
Response to hydraulic habitat availability and persistence			
VFCS	TRI HYD SIM	PES: There is a small amount of VFCS at a discharge of 0.06 m^3/s. At or above this discharge (where there are no antecedent dry periods); TRI, HYD and SIM should be present, at A - C abundances. REC: As above, but expect additional Flow Dependent Invertebrates (FDIs) scoring > 9 (e.g. Trichorythidae)	PES: Absence or very low numbers of TRI, HYD or SIM. REC: No FDIs scoring >9.
FCS	ELM HYD SIM	PES: FCS should be available at a discharge of 0.02 m^3/s. If sampling at or above this discharge, with no antecedent dry or drought conditions, ELM, HYD and SIM should be present and abundant. REC: As above, but expect additional Flow Dependent Invertebrates (FDIs) scoring > 9 (e.g. Trichorythidae).	PES: Absence or very low numbers of indicator families, particularly SIM. REC: No FDIs scoring > 9.
MV	COE	PES: MV at channel margins should be inundated to at least 20 cm. COE should be present in at least 1 in 2 samples. At least three types of hemipterans should be present. REC: As above, but expect additional high-scoring invertebrates with preference for vegetation (e.g. Calopterygidae).	PES: COE absent or in very low numbers. Photographic evidence of vegetation encroachment or die-back. Absence of hemipterans in MV. REC: Excluding BAE+ no invertebrates in MV scoring > 10.
FS	TAB	PES and REC: Presence of TAB.	PES and REC: Absence of TAB.

4.4.6 Riparian vegetation EcoSpecs and TPCs

EcoSpecs and TPCs are provided in **Table 4.28**.

Table 4.28 J2GAMK-EWR4: Riparian vegetation EcoSpecs and TPCs (PES: D; REC: C)

Metric	EcoSpec	TPC
Marginal zone		
Alien invasion (perennial alien species)	Maintain an absence of perennial alien plant species.	Occurrence of perennial alien plant species.
Terrestrial woody species aerial cover	Maintain an absence of terrestrial woody species.	Occurrences of terrestrial woody species in the sub-zone above 5% cover.
Indigenous riparian woody species cover (% aerial)	Maintain cover (% aerial) of indigenous riparian woody species below 10%.	Increase of indigenous riparian woody species above 10%.
Non-woody indigenous cover (grasses, sedges and dicotyledonous forbs) (% aerial)	Maintain non-woody cover (% aerial) above 50%.	Decrease in non-woody cover (% aerial) below 10%.
Reed cover (% aerial)	Maintain reed cover below 10%.	Increase in reed cover above 10%.
Lower zone		
Alien invasion (perennial alien species)	Maintain cover (% aerial) of perennial alien plant species at 10% or lower.	Increase in perennial alien plant species cover >20%.
Terrestrial woody species aerial cover	Maintain cover (% aerial) of terrestrial woody species at 5% or lower.	Increases in terrestrial woody species cover above 10%.
Indigenous riparian woody species cover (% aerial)	Maintain cover (% aerial) of indigenous riparian woody species below 20%.	PES: Increase of indigenous riparian woody cover above 25%. Increase of indigenous riparian woody cover above 15%. REC: Reduction in indigenous riparian woody cover due to improved flooding and reduced flow regulation.
Non-woody indigenous cover (grasses, sedges and dicotyledonous forbs) (% aerial)	Maintain non-woody cover (% aerial) above 60%.	Decrease in non-woody cover (% aerial) below 10%.
Reed cover (% aerial)	Maintain reed cover below 10%.	PES: Increase in reed cover above 10%. Increase in reed cover above 5%. REC: A reduction in reed cover due to improved flooding and reduced flow regulation).
Upper zone		
Alien invasion (perennial alien species)	Maintain cover (% aerial) of perennial alien plant species at 10% or lower.	PES: Increase in perennial alien plant species cover >30%. REC: Increase in perennial alien plant species cover >15%.
Terrestrial woody species aerial cover	Maintain cover (% aerial) of terrestrial woody species at 15% or lower.	PES: Increases in terrestrial woody species cover above 20%. Increases in terrestrial woody species cover

Metric	EcoSpec	TPC
		above 10%. REC: Reduction in terrestrial woody cover due to improved flooding.
Indigenous riparian woody species cover (% aerial)	Maintain cover (% aerial) of indigenous riparian woody species below 60%.	PES: Increases in indigenous riparian woody species cover above 75%. Increases in indigenous riparian woody species cover above 60%. REC: Reduction in indigenous riparian woody cover due to improved flooding and reduced flow regulation.
Non-woody indigenous cover (grasses, sedges and dicotyledonous forbs) (% aerial)	Maintain non-woody cover (% aerial) above 10%.	Decrease in non-woody cover (% aerial) below 30%.
Riparian zone		
PES	Maintain PES score (using VEGRAI level 4 for assessment) of at least 42% for the riparian zone.	PES: Decrease in PES score below 40% for the riparian zone. Decrease in PES score below 60% for the riparian zone. REC: Mostly due to a reduction in woody vegetation and reed cover due to improved flooding and reduced flow regulation.

4.5 BUFFELS RIVER: J1BUFF-EWR5

The main dam in the Buffels River is the Floriskraal Dam (50 MCM) in the Buffels River at the outlet of J11G. The catchment area upstream of this dam is typical Karoo with very little development. Some irrigation (9 million m³/a) is practised downstream of this dam. The catchment is stressed as a result of irrigation demands exceeding supply. The J1BUFF-EWR5 is situated about 20 km downstream of Floriskraal Dam on a private reserve at Wagendrift Lodge. There is extensive irrigation downstream of Floriskraal Dam. Flood releases (not pulsed) are made irregularly based on requirements to supply downstream users (**Figure 4.5**). The EWR site is situated within Management Resource Unit (MRU) B (DWA, 2014a) which has irrigation as landuse where the relief allows. The EWR site is nested in a Reserve Assessment Unit which is in better condition (being protected in the poort) than the rest of the MRU.

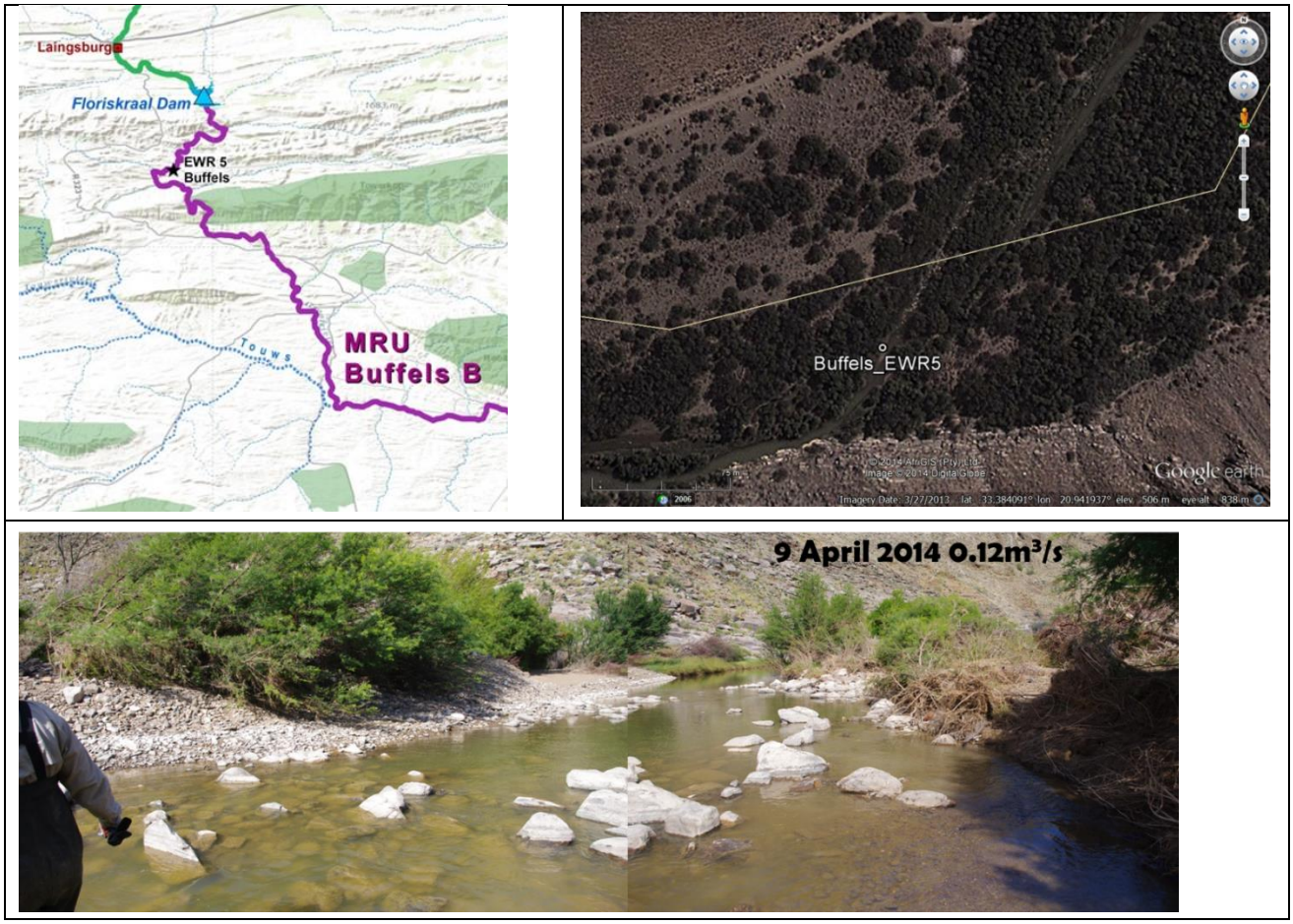

Figure 4.5 A map, and downstream view of J1BUFF-EWR5

4.5.1 Ecological Categories

The ECs representative of broad qualitative EcoSpecs, determined for the PES (DWS, 2015c), is provided in **Table 4.29**. The PES is representative of the baseline.

Table 4.29 J1BUFF-EWR5: EcoSpecs as ECs

Component	PES and REC
Water quality	C
Geomorphology	D
Fish	B/C
Invertebrates	C
Instream	C
Riparian vegetation	D
EcoStatus	C

4.5.2 Hydrology: EcoSpecs

Source: DWA (2014b); DWS (2015c).
Model: RDRM (Hughes *et al*., 2011); WRYM (DWAF, 2008c).

REC	nMAR (MCM)	pMAR (MCM)	Low flows (MCM)	Low flows (%nMAR)	Total flows (MCM)	Total (%nMAR)	April		September	
							90%	50%	90%	50%
C	29.31	18.67	1.37	4.7	8.22	28.0	0.000	0.021	0.001	0.022

4.5.3 Water quality (including diatoms): EcoSpecs and TPCs

Water quality

EcoSpecs and TPCs for water quality are shown in **Table 4.30**. Data should be collected from the DWS monitoring point, i.e.J1H028Q01 on the Buffels River. Note that the data evaluation for the present state assessment shows very stable conditions over time for water quality of this system.

Table 4.30 J1BUFF-EWR5: Water quality: EcoSpecs and TPCs (PES and REC: C)

Metrics	EcoSpecs: PES	TPCs: PES
Inorganic salt ions		
Sulphate as SO_4	The 95th percentile of the data is between ≤ 60 mg/L.	The 95th percentile of the data is between 48 - 60 mg/L.
Sodium as Na	The 95th percentile of the data is between ≤ 80 mg/L.	The 95th percentile of the data is between 64 - 80 mg/L.
Magnesium as Mg	The 95th percentile of the data is between ≤ 25 mg/L.	The 95th percentile of the data is between 20 - 25 mg/L.
Calcium as Ca	The 95th percentile of the data is between ≤ 50 mg/L.	The 95th percentile of the data is between 40 - 50 mg/L.
Chloride as Cl	The 95th percentile of the data is between ≤ 125 mg/L.	The 95th percentile of the data is between 100 – 125 mg/L.
Potassium as K	The 95th percentile of the data is between ≤ 6.0 mg/L.	The 95th percentile of the data is between 4.8 - 6.0 mg/L.
Physical variables		
Electrical conductivity (mS/m)	The 95th percentile of the data is between ≤ 85 mS/m.	The 95th percentile of the data is between 68 - 85 mS/m.
pH	The 5th percentile of the data is between 5.9 - 6.5, and the 95th percentile 8.0 - 8.8.	The 5th percentile of the data is ≤ 5.7 and the 95th percentile is ≥ 8.6.
Temperature[(a)]	Moderate change to temperature expected due to upstream Floriskraal Dam.	Initiate baseline monitoring for this variable.
Dissolved oxygen[(a)]	The 5th percentile of the data is between ≥ 7.0 mg/L. Although some impacts are expected due to the upstream Floriskraal Dam, the size of the river should mitigate the effects.	The 5th percentile of the data is between 7.2 - 7.0 mg/L. Initiate baseline monitoring for this variable.

Metrics	EcoSpecs: PES	TPCs: PES
Turbidity[(a)]	Changes in turbidity are related to minor man-made modifications. Some silting of habitats is expected.	Initiate baseline monitoring for this variable.
Nutrients		
TIN-N	The 50th percentile of the data is between ≤ 0.48 mg/L.	The 50th percentile of the data is between 0.38 - 0.48 mg/L.
PO_4-P	The 50th percentile of the data is between ≤ 0.015 mg/L.	The 50th percentile of the data is between 0.012 - 0.015 mg/L.
Response variables[(a)]		
Chl-a phytoplankton	The 50th percentile of the data is between < 10 µg/L.	The 50th percentile of the data is between 8 - 10 µg/L.
Chl-a periphyton	The 50th percentile of the data is between ≤ 12 mg/m^2.	The 50th percentile of the data is between 10 - 12 mg/m^2.
Toxics		
Fluoride	The 50th percentile of the data is between ≤ 1.5 mg/L.	The 50th percentile of the data is between 1.2 - 1.5 mg/L.
Ammonia (NH_3-N)	The 50th percentile of the data is between ≤ 0.015 mg/L.	The 50th percentile of the data is between 0.012 - 0.015 mg/L.
Other toxics	The 95th percentile of the data is between within the TWQR as stated in DWAF (1996) or the A Category boundary as stated in DWAF (2008a).	An impact is expected if the 95th percentile of the data exceeds the TWQR as stated in DWAF (1996) or the upper limit of the A Category boundary as stated in DWAF (2008a).

- No data
(a) No data were available for this assessment. All EcoSpecs and TPCs need verification as based on expert judgement.

Diatoms

Monitoring guidelines for diatoms are provided in **Table 4.31**. The SPI score of 11.2 is based on the aggregate of the two samples collected April 2014 (SPI score: 5.8) and July 2014 (SPI score: 16.5) at the EWR site. No historic or other present data could be sourced for the Buffels River. The overall diatom EC was set at a C/D (DWS, 2015c). Diatom data indicated that flushing events played a vital role in system recovery in a reach were baseflows have been reduced due to Floriskraal Dam (DWS, 2015c).

Based on water quality data (DWS, 2015c) the following metrics are of concern:

- Salinity Levels are naturally high due to geology. Salt (sodium and chloride) levels are currently slightly elevated in terms of irrigation guidelines. This would influence the salinity results for diatoms. However there are indicator species present that are associated with elevated salinity levels due to anthropogenic impact rather than naturally high levels.
- Nutrient and organics: Although nutrient data shows low levels in the water column, nutrients and toxics are expected from fertilizer and pesticide use for irrigation purposes.
- Oxygen: Impacts are expected as the site is downstream the large Floriskraal Dam.

Table 4.31 J1BUFF-EWR5: Diatoms monitoring guidelines (PES and REC: C/D)

Metric	Indicator species	Indicator/general threshold	Action
Salinity	*N. frustulum*: Indicator of nutrient and salinity levels.	If present at > 50% these variables will most probably be problematic.	If thresholds are exceeded during consecutive low and high flow assessments water quality analysis should be undertaken.
	F. fasciculata: Indicator of salinity. Has been reported from critically polluted industrial wastewater (Taylor *et al*., 2007b). It has a preference for $S0_4^{-2}$-dominated habitats.	Abundance of > 1% would indicate potential problems.	
Oxygen	*A. oblongella*: Preference for circumneutral oligotrophic electrolyte poor streams (Taylor *et al*., 2007b). High abundance could be associated with elevated flows and high oxygenation rates (Taylor *et al*., 2007b).	If flows are elevated expect dominance of > 50%.	During high/elevated flow this species must be present and is an important indicator of system recovery. If absent, this variable should be flagged. Species should not be absent in more than one high flow sample. If absent, water quality analysis should be undertaken.
Nutrients	*Nitzschia* species: Associated with water bodies that have readily available nutrients.	If present at > 5% this variable will most probably be problematic.	If thresholds are exceeded during consecutive low and high flow assessments water quality analysis should be undertaken.
Organics	*Eolimna subminuscula*: Found in a wide range of biotopes including heavily polluted biotopes (Taylor *et al*., 2007b).	If present at > 10% indicates potential problems.	If thresholds are exceeded during consecutive low and high flow assessments along with consecutive PTV score of > 50% water quality analysis should be undertaken.
	C. molestiformis, N. schroeteri var. *symmetrica* and *N. veneta*: Main indicators of anthropogenic activities relating to increased sewage or other effluent.	Combined abundance of > 5% indicates potential problems.	
Metal toxicity	General thresholds were exceeded during July 2014 (1.25%) while present during April 2014 at an abundance of 0.25%.	Valve deformities should not be present at an abundance of > 1%.	If thresholds are exceeded during consecutive low and high flow assessments water quality analysis should be undertaken.
SPI score	10 and higher	10 - 12	

4.5.4 Fish: EcoSpecs and TPCs

EcoSpecs and TPCs are provided in **Table 4.32**.

Table 4.32 J1BUFF-EWR5: Fish EcoSpecs and TPCs (PES and REC: B/C)

Metric	Indicator	EcoSpecs	TPC (Biotic)	TPC (Habitat)
Ecological status	PES	The PES is in a B/C EC (79%).	Decrease of the PES into a lower EC than PES (< B/C).	Any deterioration in habitat that results in decrease in FROC* of species.
Species richness	All indigenous species	All of the expected five indigenous fish species estimated to still be present in the reach under the PES (four species sampled during EWR survey).	Loss of any indigenous species. Presence of less than four indigenous species at EWR site using similar sampling methods and conducted during similar conditions (season, flow) as EWR survey.	Loss in diversity, abundance and condition of velocity-depth categories and cover features that lead to a loss of species.
Requirement for flowing water	PASP and (juvenile eels)	PASP and juvenile eels (AMOS) probably have the highest requirement for flow of all species in this reach and are the most applicable indicator species for flow modification. PASP also have the highest requirement for unmodified water quality and water column as habitat. PASP was sampled at abundance of 2.3 ind/min and estimated to occur at a FROC* of 4.5 in the reach under the PES. AMOS was not sampled but estimated to be present at a FROC* of 1 in reach under PES.	PASP absent during any survey OR present at FROC* of < 4.5 in the reach or significantly lower abundance than during the EWR survey (sampled using similar methods and conditions). Absence of eels (AMOS) during two consecutive surveys. Absence of range of life stages (juveniles to adults) during various surveys.	Reduced suitability (abundance and quality) of flowing habitats (i.e. decreased flows, increased zero flows, and altered seasonality).
Water quality intolerance				Decreased water quality (especially flow related water quality variables such as oxygen).
Water column				Reduction in suitability of water column (i.e. increased sedimentation of pools, reduced flows).
FD habitats	AMOS	AMOS was not sampled during the EWR survey but estimated to occur at a FROC* of 1 in the reach under the PES. This species has the highest preference for fast habitats, substrate and undercut banks of all species in this reach and is the most applicable indicator species for these habitat features.	AMOS absent during two consecutive surveys OR present at FROC* of < 0.5 in the reach.	Reduced suitability (abundance and quality) of FD habitats (i.e. decreased flows, increased zero flows).
FS habitats				Reduced suitability (abundance and quality) of FS habitats (i.e. decreased flows, increased zero flows).
Substrate				Increased sedimentation of riffle/rapid substrates, excessive algal growth on substrates, Increased sedimentation of riffle/rapid substrates, excessive algal growth on substrates.
Undercut banks				Significant change in undercut bank and

Metric	Indicator	EcoSpecs	TPC (Biotic)	TPC (Habitat)
				rootwads habitats (e.g. bank erosion, reduced flows).
Overhanging vegetation	BANO	BANO was sampled at an abundance of 1 ind/min during the EWR survey and estimated to occur at a FROC* of 4 in the reach under the PES. This species have the highest preference for overhanging vegetation habitats of all species in this reach and is the most applicable indicator species for this habitat feature.	BANO absent during any survey OR present in significant lower abundance than during the EWR survey (using similar methods and under similar conditions) OR present at FROC of < 4 in the reach. Absence of range of life stages (juveniles to adults) during various surveys.	Significant change in overhanging vegetation habitats (overgrazing, flow modification, use of herbicides, agriculture, vegetation removal, alien vegetation encroachment).
SS habitats				Significant change in SS habitat suitability (i.e. increased flows, altered seasonality, increased sedimentation of slow habitats).
Instream vegetation	SCAP	SCAP was sampled at an abundance of 0.4 ind/min during the EWR survey and estimated to occur at a FROC* of 4 in the reach under the PES. This species have the highest preference for instream vegetation habitats of all species in this reach and is the most applicable indicator species for this habitat feature.	SCAP absent during any survey OR present at significantly lower abundance than during the EWR survey (0.4 ind/min) under similar conditions OR present at FROC* of < 4. Absence of range of life stages (juveniles to adults) during various surveys.	Significant change in instream vegetation habitats (overgrazing, flow modification, use of herbicides, agriculture, alien macrophytes).
SD habitats	LUMB	LUMB was sampled at an abundance of 0.18 ind/min and estimated to occur at a FROC* of 2.5 in the reach under the PES. This species has the highest preference for SD habitats of all species in this reach and is the most applicable indicator species for this habitat feature.	LUMB absent during any survey OR present at significantly lower abundance than during the EWR survey OR present at FROC* of < 2.5. Absence of range of life stages (juveniles to adults) during various surveys.	Significant change in SD habitat suitability (i.e. increased or decreased flows, altered seasonality, increased sedimentation of slow habitats).
Alien/introduced fish species	Presence of any alien/introduced spp.	Presence of indigenous translocated TSPA (1 ind/min) and BAEN (0.32 ind/min) confirmed during the EWR survey.	Presence of any additional alien/introduced species or increase in abundance and distribution of TSPA (> 1 ind/min) and BAEN (> 0.32 ind/min).	N/A
Migratory success	AMOS PASP LUMB	It is estimated that the catadromous AMOS may still be present, and some potamodromous species (including PASP, and LUMB) also occur.	Loss or decreased FROC* of catadromous (e.g. AMOS) or potamodromous species (e.g. LUMB and PASP).	Alteration of longitudinal habitat through the creation of migration barriers (dams, weirs, zero flows, poor water quality causing chemical barriers).
Primary indicator species		**PASP and juvenile eels (AMOS).**		

* Refer to Section 3.4 for FROC ratings.

4.5.5 Macroinvertebrates: EcoSpecs and TPCs

Indicator taxa are provided in **Table 4.33** and EcoSpecs and TPCs in **Table 4.34**.

Table 4.33 J1BUFF-EWR5: Macroinvertebrate indicator taxa

Indicator acronym	Indicator Family and Score	Velocity preference		Substrate preference				WQ Preference[1]
		0.3 - 0.6 m/s	>0.6 m/s	Cobble	Vegetation	GSM	Water column	
BAE+	Baetidae > 2 spp. (12)	2	2	2	2	2	1	High
CAE	Caenidae (6)	1	1	2	1	3	0	Low
HYD	Hydropsychidae 2 spp. (6)	2	4	3	1	0	0	Low
COE	Coenagrionidae (4)	3	1	1	4	1	0	Low
GOM	Gomphidae (8)	3	0	1	0	5	0	Low
NAU	Naucoridae (7)	3	0	1	1	1	4	Low
ATH	Athericidae (10)	2	2	4	1	1	0	Low
SIM	Simuliidae (5)	2	4	3	2	0	0	Low
TAB	Tabanidae (5)	1	0	2	0	4	0	Low
ANC	Ancylidae (6)	2	1	2	1	0	0	Low

1 Preferences scored 0 - 4 in ascending order of preference. For WQ, High = High preference for unimpaired WQ.

Table 4.34 J1BUFF-EWR5: Macroinvertebrate EcoSpecs and TPCs (PES and REC: C)

Parameter	Indicator	EcoSpecs	TPCs
SASS5 and ASPT score		The SASS5 score at sampling was 103 with an ASPT of 5.4. Total scores should remain > 90, with ASPT values > 5.	SASS5 scores < 85 and ASPT < 5.
MIRAI score		MIRAI score to be within the C (60 - 79%) Category, using the reference data used in this study, or recording alterations to these.	MIRAI < 60%.
Diversity of invertebrate community		Nineteen families were collected during the field visit. At least 15 different families should be present at abundance A to C. At least 7 families should score ≥ 6.	Less than 14 different taxa collected. Less than seven scoring ≥ 6. Any taxon (adults) with an abundance of D.
Physical habitat quality	ALL	Cobbles should be mobile and lacking silt drapes or extensive algal cover. Presence of at least four of the indicator taxa.	Siltation, armouring of cobbles, extensive algal cover. Absence of indicator taxa scoring ≥ 10.
Physical habitat diversity	SIC: HYD, ATH, SIM, ANC MV: COE GSM: GOM,	SASS5 biotopes inundated and available to sample (SIC, MV, GSM). Inundated MV. Presence of at least four indicators during high flow period, and three during lower flow periods.	Stones immobile. MV exposed or encroaching. More than two indicators absent.

Parameter	Indicator	EcoSpecs	TPCs
	TAB		
Response to water quality	BAE+	During flow periods, water should be clear, non-odorous, and low in suspended solids. Algal presence should be low. More than two spp. BAE+ should be present.	Observed deterioration (turbidity, silt, and odour). Loss of one or more species of BAE+.
Response to hydraulic habitat availability and persistence			
VFCS	BAE+ HYD SIM ATH	According to hydraulic modelling, VFCS becomes available above discharge of 0.2 m^3/s. At or above this discharge (where there are no antecedent dry periods); indicators should be present, at A - C abundances.	Absence of HYD, SIM or ATH. Less than 2 species of BAE+.
FCS	BAE+ HYD SIM	According to hydraulic modelling, FCS should be available at a discharge of 0.02 m^3/s. If sampling at or above this discharge, with no antecedent dry or drought conditions, all indicators should be present.	Absence of one or more indicators.
MV	COE	MV at channel margins should be inundated. If sampling with no antecedent dry or drought conditions, all indicators should be present.	Absence of COE.
FS	GOM TAB	Indicators should be present.	Absence of GOM or TAB.

4.5.6 Riparian vegetation EcoSpecs and TPCs

EcoSpecs and TPCs are provided in **Table 4.35**.

Table 4.35 J1BUFF-EWR5: Riparian vegetation EcoSpecs and TPCs (PES and REC: D)

Metric	EcoSpec	TPC
Marginal zone		
Alien invasion (perennial alien species)	Maintain an absence of perennial alien plant species.	Occurrence of perennial alien plant species.
Terrestrial woody species aerial cover	Maintain an absence of terrestrial woody species.	Increases in terrestrial woody species cover more than 5%.
Indigenous riparian woody species cover (% aerial)	Maintain cover (% aerial) of indigenous riparian woody species below 10%.	Increases of indigenous riparian woody species cover above 10%.
Non-woody indigenous cover (grasses, sedges and dicotyledonous forbs) (% aerial)	Maintain non-woody cover (% aerial) above 10%.	Decrease in non-woody cover (% aerial) below 10%.
Reed cover (% aerial)	Maintain reed cover below 10%.	Presence of reeds.
Lower zone		
Alien invasion	Maintain cover (% aerial) of	Increase in perennial alien plant species

Metric	EcoSpec	TPC
(perennial alien species)	perennial alien plant species at 5% or lower.	cover >20%.
Terrestrial woody species aerial cover	Maintain cover (% aerial) of terrestrial woody species at 20% or lower (currently at 30%).	Increases in terrestrial woody species cover above 20%.
Indigenous riparian woody species cover (% aerial)	Maintain cover (% aerial) of indigenous riparian woody species below 25% (currently at 20%).	Increases of indigenous riparian woody species cover above 25%.
Non-woody indigenous cover (grasses, sedges and dicotyledonous forbs) (% aerial)	Maintain non-woody cover (% aerial) above 0% i.e. a presence of non-woody vegetation in the sub-zone (currently at 5%).	Decrease in non-woody cover (% aerial) below 5%.
Reed cover (% aerial)	Maintain an absence of reeds.	Presence of reeds.
Upper zone		
Alien invasion (perennial alien species)	Maintain cover (% aerial) of perennial alien plant species below 10% (currently 5%).	Increase in perennial alien plant species cover >20%.
Terrestrial woody species aerial cover	Maintain cover (% aerial) of terrestrial woody species at 30% or lower (currently at 5%).	Increases in terrestrial woody species cover above 30%.
Indigenous riparian woody species cover (% aerial)	Maintain cover (% aerial) of indigenous riparian woody species below 80% (currently 70%).	Increases in indigenous riparian woody species cover above 80%.
Non-woody indigenous cover (grasses, sedges and dicotyledonous forbs) (% aerial)	Maintain non-woody cover (% aerial) above 10% (currently 15%).	Decrease in non-woody cover (% aerial) below 10%.
Riparian zone		
PES	Maintain PES score (using VEGRAI level 4 for assessment) of at least 43% for the riparian zone (currently 57%).	Decrease in PES score below 42% for the riparian zone.

4.6 GOURITZ RIVER: J4GOUR-EWR6

J4GOUR-EWR6 is downstream of the confluence of the Buffels (Groot) River. It is situated just upstream of a gorge in the Langeberg Mountains. The site is situated quite far upstream from J2H002 which is a rated section. Although extremely inaccruate for low flows, the flow regime (**Figure 4.6**) shows that this area is prone to very low flows in the dry season and very large floods in the wet season. The Gouritz River is short compared to the extensive upstream catchments with the Olifants, Gamka, Buffalo and Touws rivers. J2 and J3 are extenstively impacted by flow related activities. Localised impacts in the Gouritz River consist of irrigation of mainly lucerne and pastures on the banks of the Gouritz River. Various farm dams are found in the Lower Gouritz River.

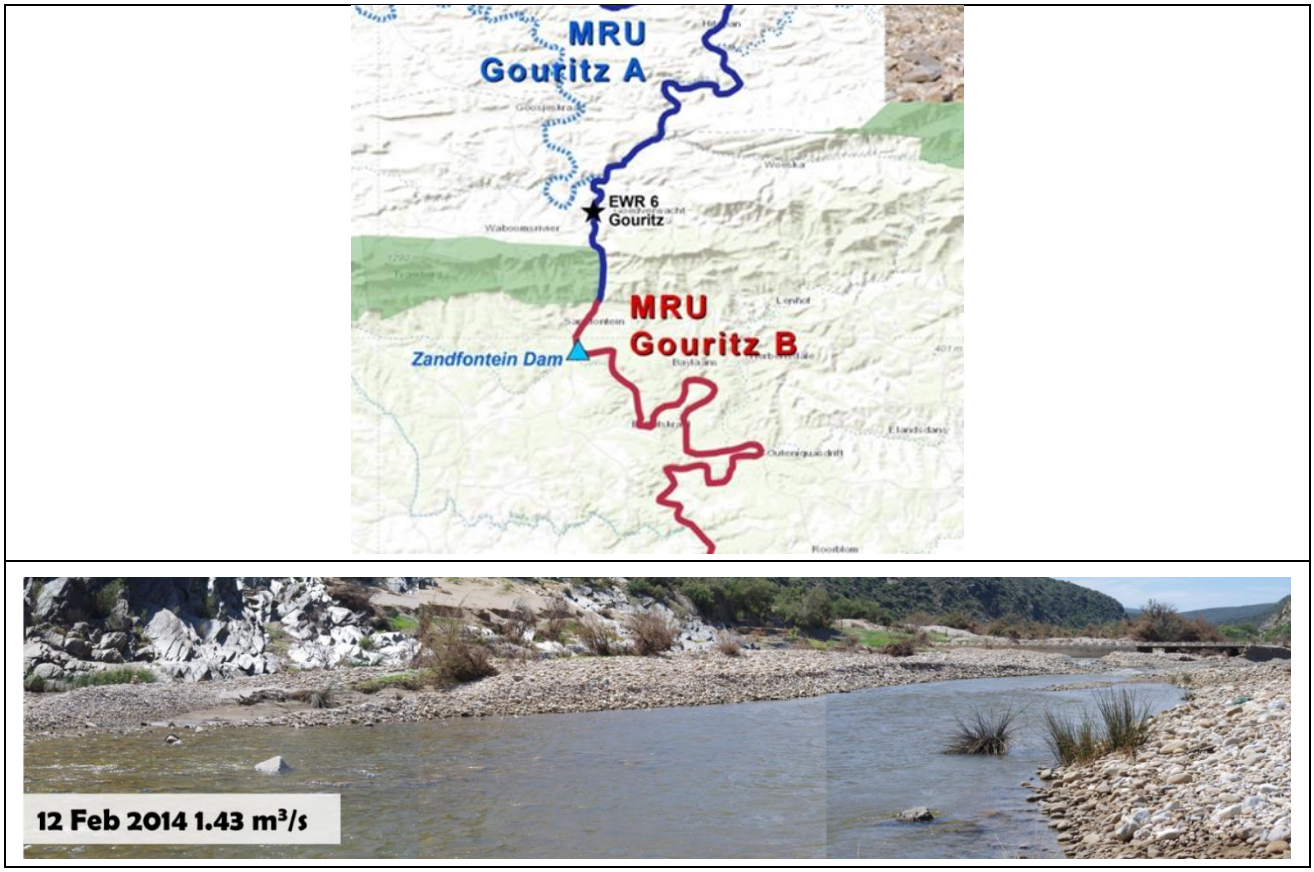

Figure 4.6 A map, Google image and downstream view of J4GOUR-EWR6

4.6.1 Ecological Categories

The ECs representative of broad qualitative EcoSpecs determined, for the PES (DWS, 2015c), is provided in **Table 4.36**. The PES is representative of the baseline.

Table 4.36 J4GOUR-EWR6: EcoSpecs as ECs

Component	PES and REC
Water quality	B/C
Geomorphology	B
Fish	D
Invertebrates	C
Instream	C
Riparian vegetation	B/C
EcoStatus	C

4.6.2 Hydrology: EcoSpecs

Source: DWA (2014b); DWS (2015c).
Model: RDRM (Hughes *et al*., 2011); WRYM (DWAF, 2008c).

REC	nMAR (MCM)	pMAR (MCM)	Low flows (MCM)	Low flows (%nMAR)	Total flows (MCM)	Total (%nMAR)	November		January	
							90%	60%	90%	60%
C	543.52	310.35	27.12	5.0	129.59	23.8	0.326	0.787	0.292	0.594

4.6.3 Water quality (including diatoms): EcoSpecs and TPCs

Water quality
EcoSpecs and TPCs for water quality are shown in **Table 4.37**. Data should be collected from the DWS monitoring point J4H002Q01 on the Gouritz River.

Table 4.37 J4GOUR-EWR6: Water quality EcoSpecs and TPCs (PES and REC: B/C)

Metrics	EcoSpecs	TPCs
Inorganic salt ions		
Sulphate as SO_4	The 95th percentile of the data is between ≤ 690 mg/L.	The 95th percentile of the data is between 550 - 690 mg/L.
Sodium as Na	The 95th percentile of the data is between ≤ 960 mg/L.	The 95th percentile of the data is between 770 - 960 mg/L.
Magnesium as Mg	The 95th percentile of the data is between ≤ 130 mg/L.	The 95th percentile of the data is between 105 - 130 mg/L.
Calcium as Ca	The 95th percentile of the data is between ≤ 120 mg/L.	The 95th percentile of the data is between 95 - 120 mg/L.
Chloride as Cl	The 95th percentile of the data is between ≤ 1300 mg/L.	The 95th percentile of the data is between 1050 - 1300 mg/L.
Potassium as K	The 95th percentile of the data is between ≤ 10 mg/L.	The 95th percentile of the data is between 8 - 10 mg/L.
Physical variables		
Electrical conductivity (mS/m)	The 95th percentile of the data is between ≤ 550 mS/m.	The 95th percentile of the data is between 450 - 550 mS/m.
pH	The 5th percentile of the data is between 5.9 - 6.5, and the 95th percentile 8.0 - 8.8.	The 5th percentile of the data is ≤ 5.7 and the 95th percentile is ≥ 8.6.
Temperature[(a)]	Natural temperature range.	Initiate baseline monitoring for this variable.
Dissolved oxygen[(a)]	The 5th percentile of the data is between ≥ 7.0 mg/L.	The 5th percentile of the data is between 7.2 - 7.0 mg/L. Initiate baseline monitoring for this variable.
Turbidity[(a)]	Changes in turbidity are related to minor man-made modifications. Some silting of habitats is expected.	Initiate baseline monitoring for this variable.
Nutrients		
TIN-N	The 50th percentile of the data is between ≤ 0.25 mg/L.	The 50th percentile of the data is between 0.2 - 0.25 mg/L.

Metrics	EcoSpecs	TPCs
PO_4-P	The 50th percentile of the data is between ≤ 0.015 mg/L.	The 50th percentile of the data is between 0.012 - 0.015 mg/L.
Response variables[(a)]		
Chl-a phytoplankton	The 50th percentile of the data is between < 10 µg/L.	The 50th percentile of the data is between 8 - 10 µg/L.
Chl-a periphyton	The 50th percentile of the data is between ≤ 12 mg/m^2.	The 50th percentile of the data is between 10 - 12 mg/m^2.
Toxics		
Fluoride	The 50th percentile of the data is between ≤ 1.5 mg/L.	The 50th percentile of the data is between 1.2 - 1.5 mg/L.
Ammonia (NH_3-N)	The 50th percentile of the data is between ≤ 0.015 mg/L.	The 50th percentile of the data is between 0.012 - 0.015 mg/L.
Other toxics	The 95th percentile of the data is between within the TWQR as stated in DWAF (1996) or the A Category boundary as stated in DWAF (2008a).	An impact is expected if the 95th percentile of the data exceeds the TWQR as stated in DWAF (1996) or the upper limit of the A Category boundary as stated in DWAF (2008a).

- No data

(a) No data were available for this assessment. All EcoSpecs and TPCs need verification as based on expert judgement.

Diatoms

Monitoring guidelines for diatoms are provided in **Table 4.38**. The SPI score of 10.2 is based on the aggregate of the four samples collected during January 2014 (SPI score: 5.9), February 2014 (SPI score: 9.3), April 2014 (SPI score: 9.6) and July 2014 (SPI score: 16.1) at the EWR site (DWS, 2015c). No historic or other present data could be sourced for the Gouritz River. The overall diatom EC was set at a C/D (DWS, 2015c). Diatom data indicate that nutrient levels are generally high and problematic during January – April and seem to decrease during July. Organic pollution levels generally fluctuate and can reach levels that are unacceptable. Impacts are mainly associated with agricultural activities which include dryland agriculture and cattle. Elevated water temperatures occur at times when water levels are low and water levels generally fluctuate (DWS, 2015c).

Based on water quality data (DWS, 2015c) the following metrics are of concern:

- Salinity: High salt levels are linked to the natural geology, although some irrigation return flows are probably present from upstream system (particularly the Olifants tributary) This would influence the salinity results for diatoms. However there are indicator species present that are associated with elevated salinity levels due to anthropogenic impact rather than naturally high levels.
- Nutrient and organics: Some nutrient elevations are evident due to irrigation return flows.
- Oxygen: Impacts are expected during low flows.

Table 4.38 J4GOUR-EWR6: Diatoms monitoring guidelines (PES and REC: C/D)

Metric	Indicator species	Indicator/general threshold	Action
Salinity	*N. frustulum*: Indicator of nutrient and salinity levels.	If present at > 50% these variables will most probably be problematic.	If thresholds are exceeded during consecutive low and high flow assessments water quality analysis should be undertaken.
	C. meneghiniana and *T. pseudonana:* Indicators of salinity levels. Found in electrolyte rich streams (Taylor *et al*., 2007b).	Combined abundance of > 15% would indicate potential problems.	
	E. adnata: Indicator of elevated temperatures, low flows and salinity levels. Tolerant to moderate to high electrolyte content but extends into brackish biotopes (Taylor *et al*., 2007b).	If present at > 15% salinity will most probably be problematic.	
Oxygen	*A. oblongella* and *Achnanthidium* species: Associated with elevated flows. The genus generally prefers good water quality with high oxygenation rates (Taylor *et al*., 2007b). High abundance could be associated with elevated flows and high oxygenation rates (Taylor *et al*., 2007b).	If flows are elevated expect dominance of > 50%.	During high/elevated flow this species must be present and is an important indicator of system recovery. If absent, this variable should be flagged. Species should not be absent in more than one high flow sample. If absent, water quality analysis should be undertaken.
Nutrients	*Nitzschia* species: Associated with water bodies that have readily available nutrients.	If present at > 5% this variable will most probably be problematic.	If thresholds are exceeded during consecutive low and high flow assessments water quality analysis should be undertaken.
Organics	*P. frequentissima*: Capable of tolerating critically polluted conditions (Taylor *et al*., 2007b).	If present at > 3% indicates potential problems.	If thresholds are exceeded during consecutive low and high flow assessments along with consecutive PTV score of > 40% water quality analysis should be undertaken.
	C. molestiformis, N. schroeteri var. *symmetrica* and *N. veneta*: Main indicators of anthropogenic activities relating to increased sewage or other effluent.	Combined abundance of > 3% indicates potential problems.	
Metal toxicity	No valve deformities were noted during April and July 2014.	Valve deformities should not be present at an abundance of > 1%.	If thresholds are exceeded during consecutive low and high flow assessments water quality analysis should be undertaken.
SPI score	10 and higher	10 - 12	

4.6.4 Fish: EcoSpecs and TPCs

EcoSpecs and TPCs are provided in **Table 4.39**.

Table 4.39 J4GOUR-EWR6: Fish EcoSpecs and TPCs (PES and REC: D)

Metric	Indicator	EcoSpecs	TPC (Biotic)	TPC (Habitat)
Ecological status	PES	The PES is in a D EC (50.1%).	Decrease of PES into a lower EC than PES (< D).	Any deterioration in habitat that results in decrease in FROC* of species.
Species richness	All indigenous species	All five the expected indigenous fish species are estimated to still be present in the reach under the PES.	Loss of any indigenous species.	Loss in diversity, abundance and condition of velocity-depth categories and cover features that lead to a loss of species.
Requirement for flowing water	PASP	PASP was not sampled during the EWR survey but is estimated to occur at a FROC* of 0.5 in the reach under the PES. This species has the highest requirement for flow and unmodified water quality and preference for instream vegetation and water column as habitat of all species in this reach and is the most applicable indicator species for these habitat features.	PASP absent during three consecutive surveys OR present at FROC* of < 0.5 in the reach. Absence of range of life stages (juveniles to adults) during various surveys.	Reduced suitability (abundance and quality) of flowing habitats (i.e. decreased flows, increased zero flows, and altered seasonality).
Water quality intolerance				Decreased water quality (especially flow related water quality variables such as oxygen).
Instream vegetation				Significant change in instream vegetation habitats (overgrazing, flow modification, use of herbicides, agriculture, alien macrophytes).
Water column				Reduction in suitability of water column (i.e. increased sedimentation of pools, reduced flows).
FD habitats	AMOS	AMOS was not sampled during the EWR survey but is estimated to occur at a FROC* of 1 in the reach under the PES. This species (juveniles) has the highest preference for fast habitats; substrate and undercut banks (adults) of all species in this reach and is the most applicable indicator species for these habitat features.	AMOS absent during three consecutive surveys OR present at FROC* of < 1 in reach. Absence of range of life stages (juveniles to adults) during various surveys.	Reduced suitability (abundance and quality) of FD habitats (i.e. decreased flows, increased zero flows).
FS habitats				Reduced suitability (abundance and quality) of FS habitats (i.e. decreased flows, increased zero flows).
Substrate				Increased sedimentation of riffle/rapid substrates, excessive algal growth on substrates, Increased sedimentation of riffle/rapid substrates, excessive algal growth on substrates.

Metric	Indicator	EcoSpecs	TPC (Biotic)	TPC (Habitat)
Undercut banks				Significant change in undercut bank and rootwads habitats (e.g. bank erosion, reduced flows).
Overhanging vegetation	BANO	BANO was not sampled during the EWR survey but is estimated to occur at a FROC* of 1 in the reach under the PES. This species has the highest preference for overhanging vegetation and SS habitats of all species in this reach and is the most applicable indicator species for these habitat features.	BANO absent during three consecutive surveys OR present at FROC* of < 1. Absence of range of life stages (juveniles to adults) during various surveys.	Significant change in overhanging vegetation habitats (overgrazing, flow modification, use of herbicides, agriculture, vegetation removal, alien vegetation encroachment).
SS habitats				Significant change in SS habitat suitability (i.e. increased flows, altered seasonality, increased sedimentation of slow habitats).
SD habitats	LUMB	LUMB was not sampled during the EWR survey but is estimated to occur at a FROC* of 2 the reach under the PES. This species has the highest preference SD habitats of all species in this reach and is the most applicable indicator species for this habitat feature.	LUMB absent during three consecutive surveys OR present at FROC* of < 2 in reach. Absence of range of life stages (juveniles to adults) during various surveys.	Significant change in SD habitat suitability (i.e. increased or decreased flows, altered seasonality, increased sedimentation of slow habitats).
Alien fish species	Presence of any alien/introduced spp.	The presence of alien LMAC (*Lepomis macrochirus*) (0.04 ind/min), MDOL (*Micropterus dolomieu*) (0.02 ind/min), MSAL (0.02 ind/min) and CCAR (*Cyprinus carpio*) (0.02 ind/min) as well as indigenous introduced BAEN (0.7 ind/min) and TSPA (0.4 ind/min) confirmed during the EWR study.	Presence of any additional alien/introduced species or increase in abundance and distribution of existing species.	N/A
Migratory success	AMOS AMAR PASP	It is estimated that the catadromous AMOS and AMAR may still be present, while some potamodromous species (including, LUMB and PASP) also occur.	Loss or decreased FROC* of catadromous (AMOS, and AMAR) or potamodromous species (PASP, LUMB).	Alteration of longitudinal continuity through the creation of migration barriers (dams, weirs, zero flows, poor water quality causing chemical barriers).
Primary indicator species		**PASP/LUMB.**		

* Refer to Section 3.4 for FROC ratings.

4.6.5 Macroinvertebrates: EcoSpecs and TPCs

Indicator taxa are provided in **Table 4.40** and EcoSpecs and TPCs in **Table 4.41**.

Table 4.40 J4GOUR-EWR6: Macroinvertebrate indicator taxa

Indicator acronym	Indicator Family and Score	Velocity preference		Substrate preference				WQ Preference[1]
		0.3 - 0.6 m/s	>0.6 m/s	Cobble	Vegetation	GSM	Water column	
BAE+	Baetidae > 2 spp. (12)	2	2	2	2	2	1	High
CAE	Caenidae (6)	1	1	2	1	3	0	Low
HYD	Hydropsychidae 2 spp. (6)	2	4	3	1	0	0	Low
AES	Aeshnidae (8)	2	2	3	2	0	0	Moderate
COE	Coenagrionidae (4)	3	1	1	4	1	0	Low
GOM	Gomphidae (6)	3	0	1	0	5	0	Low
NAU	Naucoridae (7)		3	0	1	1	1	Moderate
ATH	Athericidae (10)	2	2	4	1	1	0	Low
SIM	Simuliidae (5)	2	4	3	2	0	0	Low
TAB	Tabanidae (5)	1	0	2	0	4	0	Low
ANC	Ancylidae (6)	2	1	2	1	0	0	Low

1 Preferences scored 0 - 4 in ascending order of preference. For WQ, High = High preference for unimpaired WQ.

Table 4.41 J4GOUR-EWR6: Macroinvertebrate EcoSpecs and TPCs (PES and REC: C)

Parameter	Indicator	EcoSpecs	TPCs
SASS5 and ASPT score		The SASS5 score at sampling was 117 with an ASPT of 5.6. Total scores should remain > 100, with ASPT values > 5.2.	SASS5 scores < 100 and ASPT < 5.2.
MIRAI score		MIRAI score to be maintained as a mid-C in the range 60 - 79% using the reference data used in this study, or recording alterations to these.	MIRAI < 60%.
Diversity of invertebrate community	ALL	Twenty-one families were collected during the field visit, with nine scoring ≥ 6. Nine of the 11 indicator taxa should be present, with at least another eight other taxa, all at an abundance of A to C. At least seven of the taxa should score ≥ 6.	More than 2 indicator taxa absent. Less than 17 taxa collected. Any taxon (adults) with an abundance of D.
Physical habitat quality	ALL	Visual: Cobbles should be mobile and lacking silt drapes or extensive algal cover. MV should be inundated to a depth of 10 - 20 cm. Presence of at least nine of the 11 indicator taxa.	Siltation, armouring of cobbles, extensive algal cover. Absence of BAE+, HYD or SIM. Less than nine indicator taxa present.
Physical habitat diversity	SIC: BAE+, HYD, AES, SIM. MV: COE,	All SASS5 biotopes should be present and sampled. MV should be inundated to a depth of 10 – 20 cm (in and out of flow areas). All indicators should be present. At least 2 spp. of BAE+	Cobble areas embedded or armoured. Fixed point photographic evidence of MV exposed (unwetted), or encroaching. More than one indicator taxa absent from any one

Parameter	Indicator	EcoSpecs	TPCs
	NAU GSM: GOM, TAB.	should be present.	biotope.
Response to water quality	BAE+ AES NAU	No observable deterioration in water quality (odour, litter, excessive algae). At least 2 species of BAE+, and AES should be present.	Observed deterioration in water quality. Less than 2 spp. BAE+ or absence of AES or NAU.
Response to hydraulic habitat availability and persistence			
VFCS	HYD SIM	According to hydraulic modelling, some VFCS is present at a discharge of 0.5 m^3/s. At or above this discharge (where there are no antecedent dry periods), HYD (2 spp.) and SIM should be present, at A - C abundances.	Absence or very low numbers of HYD (2 spp.) or SIM.
FCS	BAE+ HYD AES SIM	According to hydraulic modelling, some FCS is available at a discharge of 0.1 m^3/s. If sampling at or above this discharge, with no antecedent dry or drought conditions, BAE+ (at least 2 spp.), HYD, AES and SIM should be present and abundant.	Absence of more than one indicator family.
MV	COE	MV at channel and island margins should be inundated to a depth of 10 – 20 cm. COE should be present. At least three hemipterans expected to be present.	COE absent. Photographic evidence of vegetation encroachment or die-back. Less than three hemipterans present.
FS	GOM TAB	Indicators should be present.	Absence of either indicator.

4.6.6 Riparian vegetation EcoSpecs and TPCs

EcoSpecs and TPCs are provided in **Table 4.42**.

Table 4.42 J4GOUR-EWR6: Riparian vegetation EcoSpecs and TPCs (PES and REC: B/C)

Metric	EcoSpec	TPC
Marginal zone		
Alien invasion (perennial alien species)	Maintain an absence of perennial alien plant species.	Occurrence of perennial alien plant species.
Terrestrial woody species aerial cover	Maintain an absence of terrestrial woody species.	Occurrence of terrestrial woody species in the sub-zone.
Indigenous riparian woody species cover (% aerial)	Maintain cover (% aerial) of indigenous riparian woody species below 10%.	Increases of indigenous riparian woody species cover above 5%.
Non-woody indigenous cover (grasses, sedges and dicotyledonous forbs) (% aerial)	Maintain non-woody cover (% aerial) above 10%.	Decrease in non-woody cover (% aerial) below 20%.

Metric	EcoSpec	TPC
Reed cover (% aerial)	Maintain an absence of reeds.	Presence of reeds.
Lower zone		
Alien invasion (perennial alien species)	Maintain an absence of perennial alien plant species.	Occurrence of perennial alien plant species.
Terrestrial woody species aerial cover	Maintain an absence of terrestrial woody species.	Increases of terrestrial woody species cover above 5%.
Indigenous riparian woody species cover (% aerial)	Maintain cover (% aerial) of indigenous riparian woody species below 10%.	Increases of indigenous riparian woody species cover above 15%.
Non-woody indigenous cover (grasses, sedges and dicotyledonous forbs) (% aerial)	Maintain non-woody cover (% aerial) above 10% (currently 15%).	Decrease in non-woody cover (% aerial) below 20%.
Reed cover (% aerial)	Maintain an absence of reeds.	Presence of reeds.
Upper zone		
Alien invasion (perennial alien species)	Maintain cover (% aerial) of perennial alien plant species at 15% or lower (currently 20%).	An increase in perennial alien plant species cover >15%.
Terrestrial woody species aerial cover	Maintain cover (% aerial) of terrestrial woody species at 10% or lower (currently absent).	Increases in terrestrial woody species cover above 10%.
Indigenous riparian woody species cover (% aerial)	Maintain cover (% aerial) of indigenous riparian woody species below 40%.	Increases in indigenous riparian woody species cover above 20%.
Non-woody indigenous cover (grasses, sedges and dicotyledonous forbs) (% aerial)	Maintain non-woody cover (% aerial) above 10%.	Decrease in non-woody cover (% aerial) below 10%.
Riparian zone		
PES	Maintain PES score (using VEGRAI level 4 for assessment) of at least 78% for the riparian zone.	Decrease in PES score below 77% for the riparian zone.

4.7 DORING RIVER: J1DORI-EWR7

An EWR site in this river was only included in direct reaction to a current/future development in the Lemoenshoek Stream, a tributary of the Doring River. The EWR site was therefore selected in the Doring River as close as possible to and downstream of the confluence of the Lemoenshoek confluence with the Doring River. The major issues that have caused the change from reference condition were mainly flow and some non-flow related issues. Abstraction and upstream dams as well as flow diversions have resulted in decreased base flows and zero flows at times. Deterioration in water quality is mainly due to agricultural return flows. Alien invasive vegetation occurs in the lower and upper zones. Alien fish species also occur in the reach. Clearing and overgrazing as well as catchment erosion have also contributed to bank and bed modification.

4.7.1 Ecological Categories

The ECs, representative of broad qualitative EcoSpecs, and determined for the PES (DWS, 2014a), is provided in **Table 4.43**. The PES is representative of the baseline.

Table 4.43 J1DORI-EWR7: EcoSpecs as EC

Component	PES and REC
Water quality	**C**
Fish	**C/D**
Invertebrates	**D**
Instream	**C/D**
Riparian vegetation	**C/D**
EcoStatus	**C/D**

4.7.2 Hydrology: EcoSpecs

Source: DWA (2014b); DWS (2014a).
Model: RDRM (Hughes *et al*., 2011), WRYM (DWAF, 2008c).

REC	nMAR (MCM)	pMAR (MCM)	Low flows (MCM)	Low flows (%nMAR)	Total flows (MCM)	Total (%nMAR)	April		July	
							90%	60%	90%	60%
C/D	4.52	2.01	0.386	8.5	1.03	22.8	0	0.007	0	0.004

4.7.3 Water quality (including diatoms): EcoSpecs and TPCs

Water quality

As no water quality data exists for the Doring River system and the water quality assessment was based on available information and best judgement, no definitive EcoSpecs and TPCs can be provided. Water quality monitoring would have to be initiated at the site. Once sufficient data has been collected to develop a baseline, EcoSpecs and TPCs can be set for the site. Based on other rivers in the WMA, it is recommended that the following variables be monitored in the first instance.

- Salts.
- Nutrients, i.e. SRP (PO_4-P) and TIN-N (that is NO_3+NO_2-N and NH_4-N).
- Periphyton (chlorophyll-a).
- Temperature.
- Dissolved oxygen.
- Diatoms.
- Monitor biotic response and add toxics to the monitoring programme as and when required.

It is expected that driving issues will be nutrients and salts, with elevated turbidities and impacts on temperature and oxygen expected due to land-use in the upper catchments.

Diatoms

Monitoring guidelines for diatoms are provided in **Table 4.44**. The SPI score of 9.3 (D EC) is based on the aggregate of the two samples collected on 20 January 2014 (SPI score: 11.2) and 9 April 2014 (SPI score: 7.5) at the EWR site. No historic or other present data could be sourced for the Doring River (DWS, 2014a). The overall diatom EC was set at a D EC due to the presence of valve deformities during both sampling efforts (DWS, 2014a). Nutrient levels, organic pollution and salinity were high and problematic for both sampling efforts. The diatoms indicated that salinity levels decreased during April. Nutrient levels increased between January and April while organic pollution levels were stable. Moderate oxygenation rates and high pollution levels prevailed during January and April 2014 (DWS, 2014a).

Based on limited water quality data (DWS, 2014a) the following metrics are of concern:

- Salinity: Salinity levels are naturally high due to geology. This would influence the salinity results for diatoms. However there are indicator species present that are associated with elevated salinity levels due to anthropogenic impact rather than naturally high levels.
- Nutrient and organics: There are grazing and cultivation activities in the vicinity of the EWR site.
- Oxygen, Temperature and Turbidity: Impacts are expected during low flows.

Table 4.44 J1DORI-EWR7: Diatoms monitoring guidelines (PES and REC: D)

Metric	Indicator species	Indicator/general threshold	Action
Salinity	*N. frustulum*: Indicator of nutrient and salinity levels.	If present at > 30% these variables will most probably be problematic.	If thresholds are exceeded during consecutive low and high flow assessments water quality analysis should be undertaken.
	Planothidium engelbrechtii: Indicator of salinity levels. Found in saline inland waters with very high electrolyte content tolerating critical to very heavy pollution (Taylor *et al*., 2007b).	If present at > 5% this variable will most probably be problematic.	
	F. fasciculata: Indicator of salinity. This could be an indication of higher herbicide and pesticide use within the reach and the use of Epsom salts ($MgS0_4$) in citrus orchards in the vicinity of the river.	Abundance of > 2% would indicate potential problems.	
	E. adnata: Indicator of elevated temperatures, low flows and salinity levels. Tolerant to moderate to high electrolyte content but extends into brackish biotopes (Taylor *et al*., 2007b).	If present at > 3% these variables will most probably be problematic.	
Nutrients	*Nitzschia* species: Associated with water bodies that have readily available nutrients.	If present at > 5% these variables will most probably be problematic.	If thresholds are exceeded during consecutive low and high flow assessments water quality analysis should be undertaken.
Organics	*N. gregaria,* small *Navicula* species and *N. veneta*: Main indicators of anthropogenic activities relating to increased sewage or other effluent.	Combined abundance of > 3% indicates potential problems.	If thresholds are exceeded during consecutive low and high flow assessments along with consecutive PTV score of > 45% water quality analysis should be

Metric	Indicator species	Indicator/general threshold	Action
			undertaken.
Metal toxicity	General thresholds were exceeded during June 2014 (1.5%) while present during January 2014 (0.5%).	Valve deformities should not be present at an abundance of > 1%.	If thresholds are exceeded during consecutive low and high flow assessments water quality analysis should be undertaken.
SPI score	8 and higher	8 - 10	

4.7.4 Fish: EcoSpecs and TPCs

EcoSpecs and TPCs are provided in **Table 4.45**.

Table 4.45 J1DORI-EWR7: Fish EcoSpecs and TPCs (PES and REC: C/D)

Metric	Indicator	EcoSpecs	TPC (Biotic)	TPC (Habitat)
Ecological status	PES	The PES is a C/D (58.3%).	Decrease of PES into a lower EC than PES (< C/D).	Any deterioration in habitat that results in decrease in FROC* of species.
Species richness	All indigenous species	All four expected indigenous fish species estimated to be present in the reach under PES.	Loss of any indigenous species. Presence of < 1 indigenous species at EWR site using similar sampling methods and conducted during similar conditions (season, flow).	Loss in diversity, abundance and condition of velocity-depth categories and cover features that lead to a loss of species.
Requirement for flowing water.	PASP LUMB	Both PASP and LUMB were not sampled during EWR survey but are expected to occur at a FROC* of 0.5 in the reach under PES. These two species have the highest requirement for flow for spawning in riffle habitats (FS and some FD). LUMB requires FD over riffles to undertake upstream migrations. Although only partially dependent of flowing water habitats, these are the most applicable indicator species for these metrics.	PASP and/or LUMB absent during **two** consecutive surveys OR present at FROC of < 0.5. Absence of range of life stages (juveniles to adults) during various surveys.	Reduced suitability (abundance and quality) of flowing habitats (i.e. decreased flows, increased zero flows, and altered seasonality).
FS habitats				Reduced suitability (abundance and quality) of FS and FD habitats (i.e. decreased flows, increased zero flows, sedimentation of riffles).
FD habitats				
Water quality intolerance	PASP	PASP was not sampled during EWR survey but is estimated to occur at a FROC* of 0.5 in the reach under PES. This species has the highest requirement for unmodified water quality and highest preference for undercut banks as habitat of all species in this reach and is the most applicable indicator species for these metrics.	PASP absent during **two** consecutive surveys OR present at FROC of < 0.5. Absence of range of life stages (juveniles to adults) during various surveys.	Decreased water quality (especially flow related water quality variables such as oxygen).
Undercut banks				Significant change in undercut bank and rootwads habitats (e.g. bank erosion, reduced flows).
SS habitats	BANO SCAP	BANO was not sampled during the EWR survey but is expected to occur at a FROC* of 0.5 in reach under PES. BANO and SCAP have the highest preference for overhanging vegetation and SS habitats of all species in this reach and is the most applicable indicator species for this habitat feature. SCAP was sampled at abundance of 2.1 ind/min (electrofishing) and estimated to occur at a FROC* of 5 in	BANO absent during two consecutive surveys OR present at FROC of < 0.5 in reach. Absence of range of life stages (juveniles to adults) during various surveys. SCAP absent during any survey OR present in significantly lower abundance as during EWR survey (similar methods	Significant change in overhanging vegetation habitats (overgrazing, flow modification, use of herbicides, agriculture, vegetation removal, alien vegetation encroachment).
Overhanging vegetation				Significant change in SS habitat suitability (i.e. increased flows, altered seasonality, increased sedimentation of slow habitats).

Metric	Indicator	EcoSpecs	TPC (Biotic)	TPC (Habitat)
		the reach under PES. These species have the highest preference for instream vegetation habitats of all species in this reach and are the most applicable indicator species for this habitat feature.	and conditions) OR present at FROC of < 5 in reach. Absence of range of life stages (juveniles to adults) during various surveys.	Significant change in instream vegetation habitats (overgrazing, flow modification, use of herbicides, agriculture, alien macrophytes)
SD habitats	LUMB	LUMB was not sampled during the EWR survey but is estimated to occur at a FROC* of 0.5 in the reach under PES. This species has the highest preference for substrate, water column and SD habitat of all species in this reach and is the most applicable indicator species for this habitat feature.	LUMB absent during two consecutive surveys OR present at FROC of < 0.5 in reach. Absence of range of life stages (juveniles to adults) during various surveys.	Increased sedimentation of riffle/rapid substrates, excessive algal growth on substrates, increased sedimentation of riffle/rapid substrates, excessive algal growth on substrates.
Water Column				Significant change in SD habitat suitability (i.e. increased or decreased flows, altered seasonality, increased sedimentation of slow habitats).
Substrate				Reduction in suitability of water column (i.e. increased sedimentation of pools, reduced flows).
Alien fish species	Presence of any alien/introduced spp	Presence of the indigenous introduced TSPA confirmed during EWR survey (0.6 ind/min).	Presence of any additional alien/introduced species or increase in abundance and distribution of MSAL (>0.02 ind/min using similar methods and during similar conditions). Absence of juvenile fish vulnerable to predation by MSAL or other alien species.	N/A
Migratory success	BANO LUMB	It is estimated that no catadromous species are present but two potamodromous species (BANO and LUMB) that requires migration between and within reaches are present	Loss or decreased FROC* of the potamodromous species (BANO and LUMB).	Alteration of longitudinal habitat through the creation of migration barriers (dams, weirs, zero flows, poor water quality causing chemical barriers).
Primary indicator species		**PASP.**		

* Refer to Section 3.4 for FROC ratings.

4.7.5 Macroinvertebrates: EcoSpecs and TPCs

Indicator taxa are provided in **Table 4.46** and EcoSpecs and TPCs in **Table 4.47**.

Table 4.46 J1DORI-EWR7: Macroinvertebrate indicator taxa

Indicator acronym	Indicator Family and Score	Velocity preference		Substrate preference				WQ Preference[1]
		0.3 - 0.6 m/s	>0.6 m/s	Cobble	Vegetation	GSM	Water column	
BAE	Baetidae 2 spp. (6)	2	2	2	2	2	1	Low
CAE	Caenidae (6)	1	1	2	1	3	0	Low
HYD-	Hydropsychidae 1spp. (4)	2	4	3	1	0	0	Low
COE	Coenagrionidae (4)	3	1	1	4	1	0	Low
GOM	Gomphidae (6)	3	0	1	0	5	0	Low
SIM	Simuliidae (5)	2	4	3	2	0	0	Low

1 Preferences scored 0 - 4 in ascending order of preference. For WQ, High = High preference for unimpaired WQ.

Table 4.47 J1DORI-EWR7: Macroinvertebrate EcoSpecs and TPCs (PES and REC: D)

Parameter	Indicator	EcoSpecs	TPCs
SASS5 and ASPT score	BAE, CAE, HYD-, COE, GOM, SIM	The SASS5 score at sampling was 113 with an ASPT of 4.7. Total scores should remain above 90, with ASPT values > 4.5.	SASS5 scores < 90 and ASPT < 4.5.
MIRAI score		PES was 56.6% (D EC). MIRAI score to be a mid-D EC (40 - 59%), using the reference data used in this study, or recording alterations to these.	MIRAI < 40%.
Diversity of invertebrate community		Twenty families were collected during the field visit. Fifteen or more different families should be present, at an abundance of A to C. No high-scoring (>9) taxa are expected. The community should be balanced in terms of abundances, i.e. the majority of families at A abundance, certain taxa can be at B abundance (e.g. Simuliidae, and Baetidae). No group should consistently dominate the fauna i.e. be present in D abundance (> 1000).	Less than 15 different taxa collected. Any taxon (adults) with an abundance of D.
Physical habitat quality	SIC: BAE, SIM, HYD-, MV: COE GSM: CAE, GOM	Cobbles should be mobile and lacking silt drapes or extensive algal cover. At least four of the indicator taxa should be present.	Siltation, embedded cobbles, extensive algal cover over cobbles or as algal mats. Absence or very low numbers of BAE or SIM.
Physical habitat diversity	BAE, CAE, HYD-, COE, GOM, SIM	All SASS5 Biotopes (SIC, SOC, MV, and GSM) should be available to sample. MV should be inundated. At least four indicator taxa should be present.	Stones immobile. Fixed point photographic records of MV exposure, die-back or encroachment. More than two indicators absent or in low numbers.

Parameter	Indicator	EcoSpecs	TPCs
Response to water quality		During flow periods, water should be clear, non-odorous, and low in suspended solids. Cobble surfaces should neither be covered with algae or silt. HYD- and BAE and two other indicators should be present.	Observed deterioration (turbidity, silt, and odour). Absence of HEP, BAE or HYD-.
Response to hydraulic habitat availability and persistence			
VFCS	HYD-, SIM	According to hydraulic modelling, VFCS becomes available at a discharge of 0.04 m^3/s. At or above this discharge (where there are no antecedent dry periods), HYD- and SIM should be present, at A - C abundances.	Absence or very low numbers of HYD- or SIM.
FCS	BAE, HYD-, SIM	According to hydraulic modelling, FCS becomes available at a discharge of 0.01 m^3/s. If sampling at or above this discharge, with no antecedent dry or drought conditions, these indicator taxa should be present and abundant.	Absence or very low numbers of indicator families.
MV	COE	MV at channel margins should be inundated to at least 10 – 20 cm. COE should be present in at least one of two samples. Three or more aquatic hemipteran families should occur in the vegetation.	COE absent. Photographic evidence of vegetation encroachment or die-back. Absence of Hemipterans in MV.
FS	GOM	GOM should be present.	Absence or individuals only of GOM.

4.7.6 Riparian vegetation EcoSpecs and TPCs

EcoSpecs and TPCs are provided in **Table 4.48**.

Table 4.48 J1DORI-EWR7: Riparian vegetation EcoSpecs and TPCs (PES and REC: C/D)

Metric	EcoSpec	TPC
Marginal zone		
Alien invasion (perennial alien species)	Maintain an absence of perennial alien plant species.	Occurrence of perennial alien plant species.
Terrestrial woody species aerial cover	Maintain an absence of terrestrial woody species	Occurrence of terrestrial woody species in the sub-zone.
Indigenous riparian woody species cover (% aerial)	Maintain cover (% aerial) of indigenous riparian woody species below 10%.	Increases of indigenous riparian woody species cover above 10%.
Non-woody indigenous cover (grasses, sedges and dicotyledonous forbs) (% aerial)	Maintain non-woody cover (% aerial) between 30 and 50%.	Decrease in non-woody cover (% aerial) below 10%.
Reed cover (% aerial)	Maintain reed cover below 30%.	Increase in reed cover above 40%.
Lower zone		
Alien invasion	Maintain cover (% aerial) of	Increase in perennial alien plant species

Metric	EcoSpec	TPC
(perennial alien species)	perennial alien plant species at 5% or lower.	cover > 15%.
Terrestrial woody species aerial cover	Maintain cover (% aerial) of terrestrial woody species at 10% or lower.	Increases in terrestrial woody species cover above 15%.
Indigenous riparian woody species cover (% aerial)	Maintain cover (% aerial) of indigenous riparian woody species below 20%.	Increases of indigenous riparian woody species cover above 20%.
Non-woody indigenous cover (grasses, sedges and dicotyledonous forbs) (% aerial)	Maintain non-woody cover (% aerial) between 30 and 50%.	Decrease in non-woody cover (% aerial) below 10%.
Reed cover (% aerial)	Maintain reed cover below 30%.	Increase in reed cover above 40%.
Upper zone		
Alien invasion (perennial alien species)	Maintain cover (% aerial) of perennial alien plant species at 10% or lower.	Increase in perennial alien plant species cover > 20%.
Terrestrial woody species aerial cover	Maintain cover (% aerial) of terrestrial woody species at 15% or lower.	Increases in terrestrial woody species cover above 20%.
Indigenous riparian woody species cover (% aerial)	Maintain cover (% aerial) of indigenous riparian woody species below 70%.	Increase of indigenous riparian woody species cover above 75%
Non-woody indigenous cover (grasses, sedges and dicotyledonous forbs) (% aerial)	Maintain non-woody cover (% aerial) between 30 and 50%.	Decrease in non-woody cover (% aerial) below 10%.
Reed cover (% aerial)	Maintain reed cover below 5%.	Presence of reeds.
Riparian zone		
PES	Maintain PES score (using VEGRAI level 4 for assessment) of at least 58% for the riparian zone.	Decrease in PES score below 57% for the riparian zone.

4.8 KEURBOOMS RIVER: K6KEUR-EWR8

The area at K6KEUR-EWR8 (**Figure 4.7**) is dominated by forestry. Upstream there is some forestry, agriculture and irrigation. There are no gauging weirs near the EWR site. The river is perennial with low flows being impacted on due to forestry and upstream abstraction.

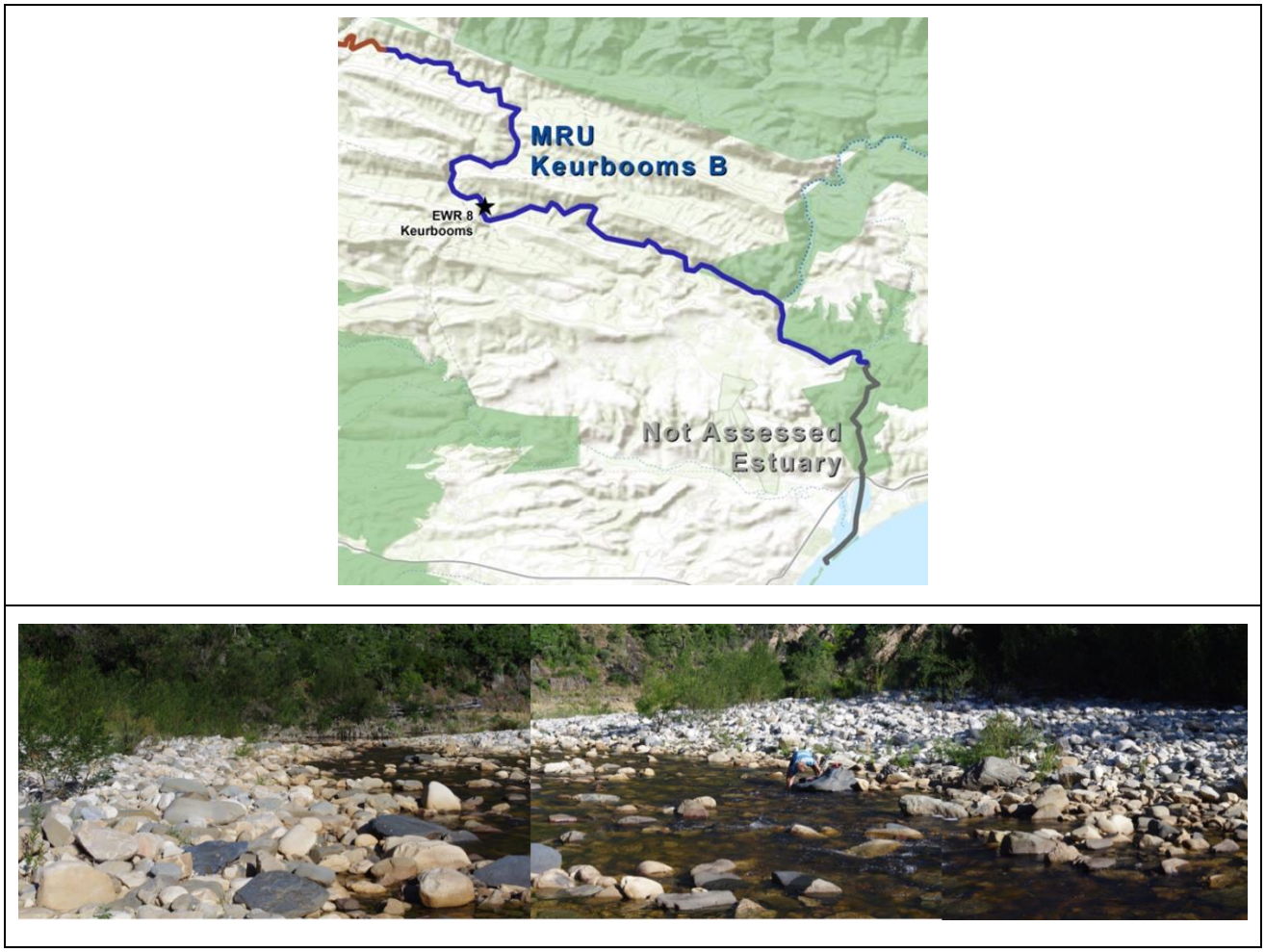

Figure 4.7 A map, Google image and downstream view of K6KEUR-EWR8

4.8.1 Ecological Categories

The ECs representative of broad qualitative EcoSpecs, determined for the PES (DWS, 2015c), is provided in **Table 4.49**. The PES is representative of the baseline.

Table 4.49 K6KEUR-EWR8: EcoSpecs as ECs

Component	PES	REC
IHI Hydrology	B	
Water quality	B	B
Geomorphology	B/C	B
Fish	C	B
Invertebrates	C	B
Instream	C	B
Riparian vegetation	C/D	B/C
EcoStatus	C	B/C

4.8.2 Hydrology: EcoSpecs

Source: DWA (2014b); DWS (2015c).
Model: RDRM (Hughes *et al*., 2011); WRYM (DWAF, 2008c)

REC	nMAR (MCM)	pMAR (MCM)	Low flows (MCM)	Low flows (%nMAR)	Total flows (MCM)	Total (%nMAR)	September		February	
							90%	60%	90%	60%
B	49.81	30.45	13.93	28.0	23.24	46.7	0.218	0.476	0.083	0.170

4.8.3 Water quality (including diatoms): EcoSpecs and TPCs

Water quality

EcoSpecs and TPCs for water quality are shown in **Table 4.50**. Data should be collected from the DWS monitoring point K6H001Q01 on the Keurbooms River. EcoSpecs and TPCs are valid for both the PES and REC.

Table 4.50 K6KEUR-EWR8: Water quality EcoSpecs and TPCs (PES and REC: B EC)

Metrics	EcoSpecs	TPCs
Inorganic salt ions		
Sulphate as SO_4	The 95th percentile of the data is between ≤ 28 mg/L.	The 95th percentile of the data is between 22 - 28 mg/L.
Sodium as Na	The 95th percentile of the data is between ≤ 70 mg/L.	The 95th percentile of the data is between 56 - 70 mg/L.
Magnesium as Mg	The 95th percentile of the data is between ≤ 12 mg/L.	The 95th percentile of the data is between 10 - 12 mg/L.
Calcium as Ca	The 95th percentile of the data is between ≤ 12 mg/L.	The 95th percentile of the data is between 10 - 12 mg/L.
Chloride as Cl	The 95th percentile of the data is between ≤ 130 mg/L.	The 95th percentile of the data is between 104 - 130 mg/L.
Potassium as K	The 95th percentile of the data is	The 95th percentile of the data is between 2.4 -

Metrics	EcoSpecs	TPCs
	between ≤ 3 mg/L.	3.0 mg/L.
Physical variables		
Electrical conductivity (mS/m)	The 95th percentile of the data is between ≤ 55 mS/m.	The 95th percentile of the data is between 45 - 55 mS/m.
pH	The 5th and 95th percentile of the data is between 6.5 - 8.0.	The 5th and 95th percentile of the data is ≥ 6.3 and ≤ 8.2.
Temperature[(a)]	Natural temperature range.	Initiate baseline monitoring for this variable.
Dissolved oxygen[(a)]	The 5th percentile of the data is between ≥ 7.0 mg/L.	The 5th percentile of the data is between 7.2 - 7.0 mg/L. Initiate baseline monitoring for this variable.
Turbidity[(a)]	Changes in turbidity are related to minor man-made modifications. Some silting of habitats is expected.	Initiate baseline monitoring for this variable.
Nutrients		
TIN-N	The 50th percentile of the data is between ≤ 0.25 mg/L.	The 50th percentile of the data is between 0.2 - 0.25 mg/L.
PO_4-P	The 50th percentile of the data is between ≤ 0.015 mg/L.	The 50th percentile of the data is between 0.012 - 0.0715 mg/L.
Response variables[(a)]		
Chl-a phytoplankton	The 50th percentile of the data is between < 10 µg/L.	The 50th percentile of the data is between 8 - 10 µg/L.
Chl-a periphyton	The 50th percentile of the data is between ≤ 12 mg/m^2.	The 50th percentile of the data is between 9.6 - 12.0 mg/m^2.
Toxics		
Fluoride	The 50th percentile of the data is between ≤ 1.5 mg/L.	The 50th percentile of the data is between 1.2 - 1.5 mg/L.
Ammonia (NH_3-N)	The 50th percentile of the data is between ≤ 0.015 mg/L.	The 50th percentile of the data is between 0.012 - 0.015 mg/L.
Other toxics	The 95th percentile of the data is between within the TWQR as stated in DWAF (1996) or the A Category boundary as stated in DWAF (2008a).	An impact is expected if the 95th percentile of the data exceeds the TWQR as stated in DWAF (1996a) or the upper limit of the A Category boundary as stated in DWAF (2008a).

- No data

(a) No data were available for this assessment. All EcoSpecs and TPCs need verification as based on expert judgement.

Diatoms

Monitoring guidelines for diatoms are provided in **Table 4.51**. The SPI score of 9.9 is based on the aggregate of the three samples collected during February 2014 (SPI score: 5.9), June 2014 (SPI score: 16.9) and July 2014 (SPI score: 6.8) at the EWR site (DWS, 2015c). No historic or other present data could be sourced for the Keurbooms River. The overall diatom EC was set at a D (DWS, 2015c). Diatom data suggested high salinity, nutrient and organic pollution levels. During June 2014 flows were higher and an improvement in water quality was noted with nutrient, salinity and organic pollution levels improving to levels associated with good water quality. July 2014 data also indicated that metal toxicity could potentially be hazardous (DWS, 2015c).

Based on water quality data (DWS, 2015c) the following metrics are of concern:

- Salinity: Salt (sodium and chloride) levels are slightly elevated in terms of the TWQR for irrigation. This would influence the salinity results for diatoms. However there are indicator species present that are associated with elevated salinity levels due to anthropogenic impact rather than naturally high levels.
- Nutrient and organics: Some nutrients and toxics elevations are expected from fertilizer and pesticide use for irrigation purposes, but water quality is generally in a Good state.
- Oxygen and Temperature: Some impacts expected at low flows, although on-site data still shows high levels.

Table 4.51 K6KEUR-EWR8: Diatoms and monitoring guidelines (PES and REC: D)

Metric	Indicator species	Indicator/general threshold	Action
Salinity	*N. frustulum*: Indicator of nutrient and salinity levels.	If present at > 50% these variables will most probably be problematic.	If thresholds are exceeded during consecutive low and high flow assessments water quality analysis should be undertaken.
	E. adnata: Indicator of elevated temperatures, low flows and salinity levels. Tolerant to moderate to high electrolyte content but extends into brackish biotopes (Taylor *et al*., 2007b).	If present at > 15% salinity will most probably be problematic.	
	F. fasciculata: Indicator of salinity. Has been reported from critically polluted industrial wastewater (Taylor *et al*., 2007b). It has a preference for $S0_4^{-2}$-dominated habitats.	Abundance of >5% would indicate potential problems.	
Oxygen	*A. oblongella* and *Achnanthidium* species: Are associated with elevated flows. The genus generally prefers good water quality with high oxygenation rates (Taylor *et al*., 2007b). High abundance could be associated with elevated flows and high oxygenation rates (Taylor *et al*., 2007b).	If flows are elevated expect dominance of > 50%.	During high/elevated flow this species must be present and is an important indicator of system recovery. If absent, this variable should be flagged. Species should not be absent in more than one high flow sample. If absent, water quality analysis should be undertaken.
Nutrients	*Nitzschia* species: Associated with water bodies that have readily available nutrients.	If present at > 5% this variable will most probably be problematic.	If thresholds are exceeded during consecutive low and high flow assessments water quality analysis should be undertaken.
Organics	*P. frequentissima*: Capable of tolerating critically polluted conditions (Taylor *et al*., 2007b).	If present at > 3% indicates potential problems.	If thresholds are exceeded during consecutive low and high flow assessments along with consecutive PTV score of > 40% water quality analysis should be undertaken.
	C. molestiformis, N. schroeteri var. *symmetrica* and *N. veneta*: Main indicator of anthropogenic activities relating to increased sewage or other effluent.	Combined abundance of > 3% indicates potential problems.	
Metal toxicity	No valve deformities were noted during February and June 2014. However thresholds were exceeded during Jul	Valve deformities should not be present at an abundance of >	If thresholds are exceeded during consecutive low and high flow assessments water

Metric	Indicator species	Indicator/general threshold	Action
	2014 (1.75%).	1%.	quality analysis should be undertaken.
SPI score	8 and higher	8 - 10	

4.8.4 Fish: EcoSpecs and TPCs

EcoSpecs and TPCs are provided in **Table 4.52**.

Table 4.52 K6KEUR-EWR8: Fish EcoSpecs and TPCs (PES: C; REC: B)

Metric	Indicator	EcoSpecs for PES	TPC (Biotic) for PES	TPC (Biotic) for REC	TPC (Habitat) for PES and REC
Ecological status	PES	The PES is in a C (76.4%).	Decrease of PES into a lower EC than PES (<C).	Decrease of REC to lower EC than the REC of a B EC (82.3%).	Any deterioration in habitat that results in decrease in recommended FROC* of species.
Species richness	All indigenous species	All five of the expected indigenous fish species are estimated to still be present in the reach under the PES and REC. The confidence of the presence of *Pseudobarbus* cf. *tenuis* (PTEN) in the main channel of river system is low.	Loss of any indigenous species.	Loss of any indigenous species.	Loss in diversity, abundance and condition of velocity-depth categories and cover features that lead to a loss of species.
Requirement for flowing water	*Pseudobarbus afer* (PAFE)	PAFE was sampled at a FROC* of 3. This species has the highest requirement for flow and unmodified water quality and preference for overhanging vegetation and undercut banks as habitat of all species in this reach and is the most applicable indicator species for these habitat features.	PAFE absent during any surveys OR present at FROC* of < 3 in the reach. Absence of range of life stages (juveniles to adults) during various surveys.	PAFE absent during any surveys OR present at FROC* of < 4 in the reach. Absence of range of life stages (juveniles to adults) during various surveys.	Reduced suitability (abundance and quality) of flowing habitats (i.e. decreased flows, increased zero flows, and altered seasonality).
Water quality intolerance					Decreased water quality (especially flow related water quality variables such as oxygen).
overhanging vegetation					Significant change in overhanging vegetation and undercut bank habitats (overgrazing, flow modification, use of herbicides, agriculture, alien macrophytes, bank erosion, reduced flows).
Undercut banks					
FD habitats	AMOS	AMOS was present during the EWR survey at a FROC* of 2 in the reach under the PES. This species (juveniles) has the highest preference for fast habitats; substrate and undercut banks (adults) of all species in this reach and is the most applicable indicator species for these habitat features.	AMOS absent during two consecutive surveys OR present at FROC* of < 2 in the reach.	AMOS absent during any survey OR present at FROC* of < 2 in the reach.	Reduced suitability (abundance and quality) of FD habitats (i.e. decreased flows, increased zero flows).
FS habitats					Reduced suitability (abundance and quality) of FS habitats (i.e. decreased flows, increased zero flows).
Substrate					Increased sedimentation of riffle/rapid substrates, excessive algal growth on

Metric	Indicator	EcoSpecs for PES	TPC (Biotic) for PES	TPC (Biotic) for REC	TPC (Habitat) for PES and REC
					substrates. Increased sedimentation of riffle/rapid substrates, excessive algal growth on substrates.
SS habitats	SCAP	SCAP was not sampled during the EWR survey but is estimated to occur at a FROC* of 1 in the reach under the PES and 2 under the REC. This species has the highest preference for instream vegetation and SS habitats of all species in this reach and is the most applicable indicator species for these habitat features.	SCAP absent during two consecutive surveys OR present at FROC* of < 1.	SCAP absent during any surveys OR present at FROC* of < 2. Absence of range of life stages (juveniles to adults) during various surveys.	Significant change in stream vegetation habitats (flow modification, use of herbicides, vegetation removal, alien vegetation encroachment).
Instream vegetation					Significant change in SS habitat suitability (i.e. increased flows, altered seasonality, increased sedimentation of slow habitats).
SD habitats	AMOS (adults); PAFE	AMOS and PAFE was sampled during the EWR survey at a FROC* of 2 and 3 respectively in the reach under the PES. These species have the highest preference for SD habitats of all species in this reach and is the most applicable indicator species for this habitat feature.	AMOS or PAFE absent during any consecutive surveys OR present at FROC* of < 2 and< 3 respectively, in the reach.	AMOS or PAFE absent during any consecutive surveys OR present at FROC* of < 2 and < 4 respectively, in the reach. Absence of range of life stages of PAFE (juveniles to adults) during various surveys.	Significant change in SD habitat suitability (i.e. increased or decreased flows, altered seasonality, increased sedimentation of slow habitats).
Alien fish species	Presence of any alien/introduced spp.	The presence of alien TSPA at an abundance of 0.5 ind/min was confirmed during EWR study.	Presence of any additional alien or introduced species or increase in distribution or abundance of TSPA to > 0.5 ind/min	Presence of any additional alien or introduced species or increase in distribution or abundance of TSPA to > 0.2 ind/min	N/A
Migratory success	AMOS	Catadromous AMOS is present at a FROC* of 2	Loss or decreased FROC* to < 2 of catadromous AMOS.	Loss or decreased FROC* to < 2 of catadromous AMOS.	Alteration of longitudinal continuity through the creation of migration barriers (dams, weirs, zero flows, poor water quality causing chemical barriers).
Primary indicator species		**PAFE**			

* Refer to Section 3.4 for FROC ratings.

4.8.5 Macroinvertebrates: EcoSpecs and TPCs

Indicator taxa are provided in **Table 4.53** and EcoSpecs and TPCs in **Table 4.54**.

Table 4.53 K6KEUR-EWR8: Macroinvertebrate indicator taxa

Indicator acronym	Indicator Family and Score	Velocity preference		Substrate preference				WQ Preference[1]
		0.3 - 0.6 m/s	>0.6 m/s	Cobble	Vegetation	GSM	Water column	
PER	Perlidae (12)	1	5	4	1	0	0	Low
BAE+	Baetidae >2 spp. (12)	2	2	2	2	2	1	High
HEP	Heptageniidae (13)	3	2	4	1	0	0	High
LEP	Leptophlebiidae (9)	2	1	3	2	0	0	Moderate
TRI	Trichorythidae (9)	1	4	4	1	0	0	Moderate
TEL	Telagonodidae (12)	2	4	4	1	0	0	High
COE	Coenagrionidae (4)	3	1	1	4	1	0	Low
CAL	Calopterygidae	1	0	1	3	1	0	Moderate
PHI	Philopotamidae (10)	2	3	4	1	1	0	High
HYD-	Hydropsychidae 1 spp. (4)	2	4	3	1	0	0	Low
SIM	Simuliidae (5)	2	4	3	2	0	0	Low
TAB	Tabanidae (5)	1	0	2	0	3	0	Low

1 Preferences scored 0 - 4 in ascending order of preference. For WQ, High = High preference for unimpaired WQ.

Table 4.54 K6KEUR-EWR8: Macroinvertebrate EcoSpecs and TPCs (PES: C; REC: B)

Parameter	Indicator	EcoSpecs	TPCs
SASS5 and ASPT score		PES: The SASS5 score at sampling was 150 with an ASPT of 7.5. Total scores should be > 130, with ASPT values > 7. REC: Total scores expected to be > 180, with an ASPT > 6.5 (over time).	PES: SASS5 scores < 120 and ASPT < 6.5. REC: SASS5 scores < 150, ASPT < 6.5.
MIRAI score		PES: MIRAI score to be within the mid C Category (i.e. > 65%) with the reference data used in this study, or recording alterations to these. REC: MIRAI score expected to be within the B Category (80 - 89%), with the reference data used in this study or recording alterations to these.	PES: MIRAI < 60%. REC: MIRAI < 75%.
Diversity of invertebrate community	ALL	PES: Twenty families were collected during the field visit. Of these, seven scored ≥ 10. More than 15 different families (taxa) should be present, with at least five of these scoring ≥ 9, and at an abundance of A to C. All indicators should be present. REC: More than 15 families should occur at an abundance of A to C. At	PES: Less than 15 taxa collected. Less than five taxa scoring ≥ 9. Any taxon (adults) with an abundance of D. REC: Less than 15 families, with less than two taxa scoring ≥ 12 (excluding BAE+ and HYD-). Any taxon (adult) with an abundance of D.

Parameter	Indicator	EcoSpecs	TPCs
		least two taxa (excluding BAE+ and HYD-) should score ≥ 12.	
Physical habitat quality	SIC: HEP, TRI, TEL, PHI, HYD- MV: CAL, LEP GSM: TAB	PES: Visual - Cobbles should be mobile, with no silt matting or algae on their surfaces. Indicator taxa for each biotope should be present, with at least one species of BAE+ and HYD-. REC: Additional taxa expected, including Perlidae, Trichorythidae, and Athericidae.	PES: Immobile cobbles, extensive algal cover, lack of inundated MV. Absence of more than one indicator taxon in SIC or MV. Less than one species of BAE+ or HYD-. REC: Absence of taxa scoring > 10.
Physical habitat diversity	SIC: BAE+, HYD, ELM MV: COE, LEP GSM: TAB	PES: Availability of all SASS5 biotopes (SIC, MV, GSM). Inundation of MV (when flow is high). The indicator taxa for each biotope should be present. REC: Additional high-scoring taxa expected.	PES: MV exposed (no wetted stems) and/or encroaching. More than one indicator absent per biotope. REC: No high-scoring (> 9) taxa collected.
Response to water quality	BAE+ HEP TEL PHI	PES: During flow periods, water should be clear, non-odorous, and low in suspended solids. Cobble surfaces should neither be slippery nor covered with silt. Three of the four indicators and least two species of BAE+ should be present. REC: Expect >2 spp. BAE+ and additional taxa with a preference for high quality water (e.g. Perlidae, Leptophlebiidae, and Trichorythidae).	PES: Observed deterioration (turbidity, silt, and odour). Absence of more than one indicator. Less than two BAE+ species. REC: Expect > 2 spp. BAE+. Additional taxa with a preference for high quality water (e.g. Perlidae, Leptophlebiidae, and Trichorythidae).
Response to hydraulic habitat availability and persistence			
VFCS	PER TRI TEL HYD- SIM	PES: According to the hydraulic modelling, there is a small amount of VFCS at a discharge above 0.1 m^3/s. At or above this discharge (where there are no antecedent dry periods); the indicator taxa should be present, at A - C abundances. REC: As above, but expect at least one additional FDIs scoring > 10 (e.g. Notonemouridae, and Petrothrincidae).	PES: Absence of more than two indicators. REC: Absence of any indicators, no additional FDIs scoring > 10.
FCS	BAE+ HEP TEL SIM	PES: FCS should be available at a discharge of 0.02 m^3/s. If sampling at or above this discharge, with no antecedent dry or drought conditions, indicator taxa should be present. REC: As above, but expect additional FDIs scoring > 10 (e.g. Petrothrincidae).	PES: Absence of one or more indicator families. REC: No FDIs scoring > 10.
MV	CAL COE	PES: MV at channel margins and on the edge of the instream islands should be inundated. Indicator taxa should be present. At least three types of hemipterans should be present. REC: As above, but expect additional hemipterans or coleopterans with a preference for vegetation (e.g.	PES: CAL or COE absent. Photographic evidence of alien vegetation encroachment or indigenous vegetation die-back. Less than three types of hemipterans in MV. REC: No 'new' taxa in MV sample.

Parameter	Indicator	EcoSpecs	TPCs
		Naucoridae, Haliplidae, Dytiscidae, and Hydraenidae)	
FS	TAB	PES: Presence of TAB. REC: As above. Expect Gomphidae.	PES: Absence of TAB. REC: As above. If Gomphidae have been recorded in previous monitoring session, they should be present.

4.8.6 Riparian vegetation EcoSpecs and TPCs

EcoSpecs and TPCs are provided in **Table 4.55**.

Table 4.55 K6KEUR-EWR8: Riparian vegetation EcoSpecs and TPCs (PES: C/D; REC: B/C)

Metric	EcoSpec	TPC
Marginal zone		
Alien invasion (perennial alien species)	Maintain an absence of perennial alien plant species.	Occurrence of perennial alien plant species.
Terrestrial woody species aerial cover	Maintain an absence of terrestrial woody species.	Occurrence of terrestrial woody species in the sub-zone.
Indigenous riparian woody species cover (% aerial)	Maintain cover (% aerial) of indigenous riparian woody species below 10%.	Increases of indigenous riparian woody species cover above 10%.
Non-woody indigenous cover (grasses, sedges and dicotyledonous forbs) (% aerial)	Maintain non-woody cover (% aerial) above 10%.	Decrease in non-woody cover (% aerial) below 10%.
Reed cover (% aerial)	Maintain an absence of reeds.	Presence of reeds.
Lower zone		
Alien invasion (perennial alien species)	Maintain an absence of perennial alien plant species.	Occurrence of perennial alien plant species.
Terrestrial woody species aerial cover	Maintain cover (% aerial) of terrestrial woody species at 15% or lower.	Increases in terrestrial woody species cover above 10%.
Indigenous riparian woody species cover (% aerial)	Maintain cover (% aerial) of indigenous riparian woody species below 20%.	Increases of indigenous riparian woody species cover above 20%.
Non-woody indigenous cover (grasses, sedges and dicotyledonous forbs) (% aerial)	Maintain non-woody cover (% aerial) above 10%.	Decrease in non-woody cover (% aerial) below 10%.
Reed cover (% aerial)	Maintain an absence of reeds.	Presence of reeds.
Upper zone		
Alien invasion (perennial alien species)	Maintain cover (% aerial) of perennial alien plant species below 30%.	PES: Increase in perennial alien plant species cover >30%. Increase in perennial alien plant species cover >15%. REC: Achieving the REC is based on alien

Metric	EcoSpec	TPC
		removal which occurs predominantly in the upper zone.
Terrestrial woody species aerial cover	Maintain cover (% aerial) of terrestrial woody species at 20% or lower.	Increases in terrestrial woody species cover above 15%.
Indigenous riparian woody species cover (% aerial)	Maintain cover (% aerial) of indigenous riparian woody species below 70%.	Increases in indigenous riparian woody species cover above 75%.
Non-woody indigenous cover (grasses, sedges and dicotyledonous forbs) (% aerial)	Maintain non-woody cover (% aerial) above 10%.	Decrease in non-woody cover (% aerial) below 10%.
Riparian zone		
PES	Maintain PES score (using VEGRAI level 4 for assessment) of at least 58% for the riparian zone.	PES: Decrease in PES score below 57% for the riparian zone. REC: Decrease in PES score below 77% for the riparian zone.

4.9 OLIFANTS RIVER: J3OLIF-EWR9

The Goukou River originates in the Spioenkop Nature Reserve and later flows through the Broomvlei (Kruis River) Nature Reserve. The Korente-Vet Dam in the Korentepoort River (8 million m^3) together with farm dams support irrigation for vineyards, fruit, pastures and vegetables as well as domestic use in Riversdale (H90C/E). Some forestry is found in the upper reaches (H90A). Irrigation farming is therefore the dominant land use. The EWR site is located in a hotspot section in SQ H90C-09229 which lies immediately upstream of Riversdal impacts as well as the impacts of the Vet Tributary of this area downstream of H9H005. Direct impacts on the EWR site are abstraction and upstream farm dams have resulted in decreased base flows and zero flows at times. The cumulative effects of agriculture and return flows e.g. elevated nutrients, salts and some toxicity has resulted in deteriorated water quality. Alien invasive vegetation and agriculture in the riparian zones have led to bank modification and instability in the reach. Alien fish species also occur in the reach. Wood removal in the riparian zones occurs. **Figure 4.8** provides a map and photographs of the EWR site.

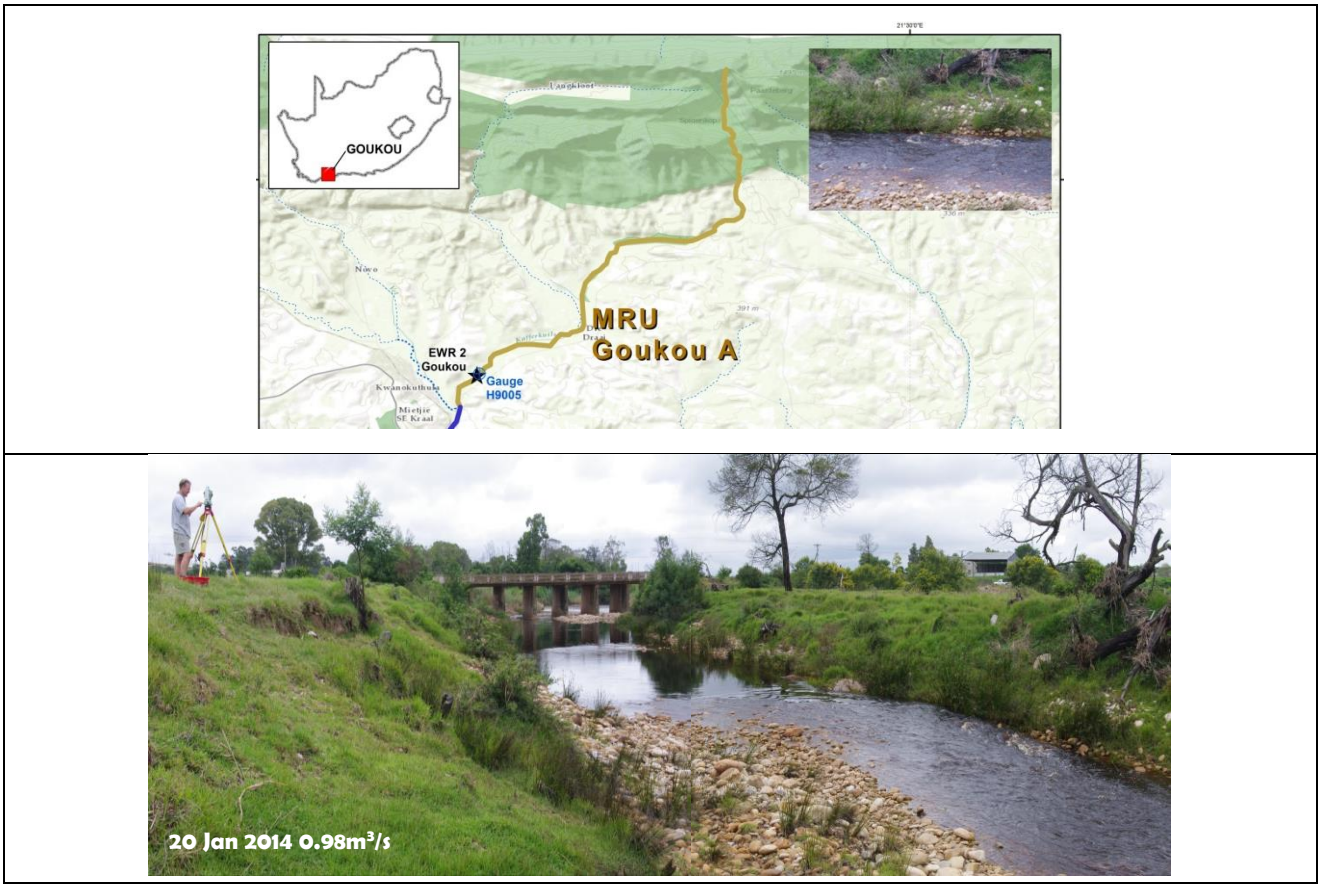

Figure 4.8 A map, and downstream view of H9GOUK-EWR2

4.9.1 Ecological Categories

The ECs representative of broad qualitative EcoSpecs, determined for the PES (DWS, 2014a), is provided in **Table 4.56**. The PES is representative of the baseline.

Table 4.56 EcoSpecs as ECs at J3OLIF-EWR9

Component	PES and REC
Water quality	**C**
Invertebrates	**C**
Instream	**C**
Riparian vegetation	**C**
EcoStatus	**C**

4.9.2 Water quality (including diatoms): EcoSpecs and TPCs

Water quality

Although a number of water quality monitoring points are located on the Olifants River, only one was suitable for this assessment, i.e. J3H021Q01, downstream of the site and upstream of Stompdrift Dam. Note that data were only collected until 1993, so if this site were to be used for monitoring, water quality data collection at this weir would need to be reinstituted.

Note that salt levels are highly elevated, which is also linked to the high natural levels expected due to the geology of the region. Of concern is the high sulphate levels recorded, which needs to be monitored at the site.

Table 4.57 J3OLIF-EWR9: Water quality EcoSpecs and TPCs (PES and REC: C EC)

Metrics	EcoSpecs	TPCs
Inorganic salt ions		
Sulphate as SO_4	The 95th percentile of the data is between ≤ 1350 mg/L.	The 95th percentile of the data is between 1080 - 1350 mg/L.
Sodium as Na	The 95th percentile of the data is between ≤ 1775 mg/L.	The 95th percentile of the data is between 1420 - 1775 mg/L.
Magnesium as Mg	The 95th percentile of the data is between ≤ 335 mg/L.	The 95th percentile of the data is between 270 - 335 mg/L.
Calcium as Ca	The 95th percentile of the data is between ≤ 285 mg/L.	The 95th percentile of the data is between 230 - 285 mg/L.
Chloride as Cl	The 95th percentile of the data is between ≤ 3000 mg/L.	The 95th percentile of the data is between 2400 - 3000 mg/L.
Potassium as K	The 95th percentile of the data is between ≤ 30 mg/L.	The 95th percentile of the data is between 24 - 30 mg/L.
Physical variables		
Electrical conductivity (mS/m)	The 95th percentile of the data is between ≤ 1100 mS/m.	The 95th percentile of the data is between 880 - 1100 mS/m.
pH	The 5th percentile of the data is between 5.9 - 6.5, and the 95th percentile 8.8 - 9.2.	The 5th percentile of the data is ≤ 5.7 and the 95th percentile is ≥ 9.0.
Temperature[(a)]	The upper Olifants mostly runs underground, with water appearing in places. This is not groundwater from a deep aquifer, but water from the vadose zone. Elevated temperatures and low DO levels would be expected under these conditions. EcoSpecs and TPCs are therefore difficult to set for these variables, and should rather be linked to meeting biotic requirements and monitoring biotic responses.	Initiate baseline monitoring for this variable.
Dissolved oxygen[(a)]		Initiate baseline monitoring for this variable where and if possible.
Turbidity[(a)]	Changes in turbidity are related to minor man-made modifications. Some silting of habitats and temporary high turbidity levels are expected.	Initiate baseline monitoring for this variable.
Nutrients		

Metrics	EcoSpecs	TPCs
TIN-N	The 50th percentile of the data is between ≤ 0.25 mg/L.	The 50th percentile of the data is between 0.2 - 0.25 mg/L.
PO_4-P	The 50th percentile of the data is between ≤ 0.025 mg/L.	The 50th percentile of the data is between 0.02 - 0.025 mg/L.
Response variables[(a)]		
Chl-a phytoplankton	The 50th percentile of the data is between < 15 µg/L.	The 50th percentile of the data is between 12 - 15 µg/L.
Chl-a periphyton	The 50th percentile of the data is between ≤ 21 mg/m^2.	The 50th percentile of the data is between 17 - 21 mg/m^2.
Toxics		
Fluoride	The 50th percentile of the data is between ≤ 1.5 mg/L.	The 50th percentile of the data is between 1.2 - 1.5 mg/L.
Ammonia (NH_3-N)	The 50th percentile of the data is between ≤ 0.044 mg/L.	The 50th percentile of the data is between 0.035 - 0.044 mg/L.
Other toxics	The 95th percentile of the data is between within the TWQR as stated in DWAF (1996) or the A Category boundary as stated in DWAF (2008a).	An impact is expected if the 95th percentile of the data exceeds the TWQR as stated in DWAF (1996) or the upper limit of the A Category boundary as stated in DWAF (2008a).

- No data

(a) No data were available for this assessment. All EcoSpecs and TPCs need verification as based on expert judgement.

Diatoms

Monitoring guidelines for diatoms are provided in **Table 4.58**. The SPI score of 6 is based on the aggregate of the two samples collected February 2014 (SPI score: 4.9) and June 2014 (SPI score: 7) at the EWR site. No historic or other present data could be sourced for the Olifants River. The overall diatom EC was set at a D/E (DWS, 2014a). Diatom data indicate Poor biological water quality with elevated nutrient levels, organic pollution and high salinities. The diatom community is representative of a stressed environment where low flows dominate. During these conditions nutrient and organic pollution increases are expected. Although valve deformities occurred at low abundance their presence was continual and would have long term effects on aquatic biota. It is assumed that the low category assigned to diatoms may be linked to stress due to low flows, rather than poor water quality (DWS, 2014a).

Based on water quality data (DWS, 2014a) the following metrics are of concern:

- Salinity: Salt levels are elevated, which is also linked to the high natural levels expected due to the geology of the region. Of concern is the high sulphate levels recorded.
- Nutrient and organics: Some nutrients and toxics elevations are expected from fertilizer and pesticide use for irrigation purposes. Irrigation activities are limited in this area, with livestock farming being the predominant land-use activity.
- Oxygen: Impacts are expected when little flow is present.

Table 4.58 J3OLIF-EWR9: Diatoms monitoring guidelines (PES and REC: D)

Metric	Indicator species	Indicator/general threshold	Action
Salinity	*N. frustulum*: Indicator of nutrient and salinity levels.	If present at > 50% these variables will most probably be problematic.	If thresholds are exceeded during consecutive low and high flow assessments water quality analysis should be undertaken.
	F. fasciculata: Indicator of salinity. Has been reported from critically polluted industrial wastewater (Taylor *et al*., 2007b). It has a preference for SO_4^{-2}-dominated habitats.	Abundance of > 2.5% would indicate potential problems.	
Oxygen	*A. oblongella* and *Achnanthidium* species: Are associated with elevated flows. The genus generally prefers good water quality with high oxygenation rates (Taylor *et al*., 2007b). High abundance could be associated with elevated flows and high oxygenation rates (Taylor *et al*., 2007b).	If flows are elevated expect dominance of > 30%.	During high/elevated flow this species must be present and is an important indicator of system recovery. If absent, this variable should be flagged. Species should not be absent in more than one high flow sample. If absent, water quality analysis should be undertaken.
Nutrients	*Nitzschia* species: Associated with water bodies that have readily available nutrients.	If present at > 15% this variable will most probably be problematic.	If thresholds are exceeded during consecutive low and high flow assessments water quality analysis should be undertaken.
Organics	*C. molestiformis, N. recens, N. erifuga, N. gregaria* and *N. veneta*: Main indicators of anthropogenic activities relating to increased sewage or other effluent.	Combined abundance of > 5% indicates potential problems.	If thresholds are exceeded during consecutive low and high flow assessments along with consecutive PTV score of > 60% water quality analysis should be undertaken.
Metal toxicity	During 2014 valve deformities were present at an abundance of 0.25%.	A check should be done for valve deformities with every count as this is indicative of metal contamination. Valve deformities should not be present at an abundance of > 1%.	If thresholds are exceeded during consecutive low and high flow assessments water quality analysis should be undertaken.
SPI score	6 and higher	6 - 8	

4.9.3 Riparian vegetation EcoSpecs and TPCs

EcoSpecs and TPCs are provided in **Table 4.59**.

Table 4.59 J3OLIF-EWR9: Riparian vegetation EcoSpecs and TPCs (PES and REC: C)

Metric	EcoSpec	TPC
Marginal zone		
Alien invasion (perennial alien species)	Maintain an absence of perennial alien plant species.	Occurrence of perennial alien plant species.
Terrestrial woody species aerial cover	Maintain an absence of terrestrial woody species.	Occurrence of terrestrial woody species in the sub-zone.
Indigenous riparian woody species cover (% aerial)	Maintain cover (% aerial) of indigenous riparian woody species below 5%.	Increases of indigenous riparian woody species cover above 10%.
Non-woody indigenous cover (grasses, sedges and dicotyledonous forbs) (% aerial)	Maintain non-woody cover (% aerial) above 15%.	Decrease in non-woody cover (% aerial) below 10%.
Reed cover (% aerial)	Maintain an absence of reeds.	Presence of reeds.
Lower zone		
Alien invasion (perennial alien species)	Maintain an absence of perennial alien plant species.	Occurrence of perennial alien plant species.
Terrestrial woody species aerial cover	Maintain an absence of terrestrial woody species.	Increases in terrestrial woody species cover above 10%.
Indigenous riparian woody species cover (% aerial)	Maintain cover (% aerial) of indigenous riparian woody species below 15%.	Increases of indigenous riparian woody species cover above 20%.
Non-woody indigenous cover (grasses, sedges and dicotyledonous forbs) (% aerial)	Maintain non-woody cover (% aerial) above 40%.	Decrease in non-woody cover (% aerial) below 30%.
Reed cover (% aerial)	Maintain an absence of reeds	A presence of reeds
Upper zone		
Alien invasion (perennial alien species)	Maintain an absence of perennial alien plant species.	An occurrence of perennial alien plant species.
Terrestrial woody species aerial cover	Maintain an absence of terrestrial woody species.	Increases in terrestrial woody species cover above 15%.
Indigenous riparian woody species cover (% aerial)	Maintain cover (% aerial) of indigenous riparian woody species below 60%.	Increases in indigenous riparian woody species cover above 70%.
Non-woody indigenous cover (grasses, sedges and dicotyledonous forbs) (% aerial)	Maintain non-woody cover (% aerial) above 50%.	Decrease in non-woody cover (% aerial) below 40%.
Floodplain		
Alien invasion (perennial alien species)	Alien invasion (perennial alien species).	Alien invasion (perennial alien species).
Terrestrial woody species aerial cover	Maintain an absence of terrestrial woody species.	Increases in terrestrial woody species cover above 15%.

Metric	EcoSpec	TPC
Indigenous riparian woody species cover (% aerial)	Maintain cover (% aerial) of indigenous riparian woody species below 80%.	Increases in indigenous riparian woody species cover above 85%.
Non-woody indigenous cover (grasses, sedges and dicotyledonous forbs) (% aerial)	Maintain non-woody cover (% aerial) above 15%.	Decrease in non-woody cover (% aerial) below 10%.
Riparian zone		
PES	Maintain PES score (using VEGRAI level 4 for assessment) of at least 70% for the riparian zone.	Decrease in PES score below 62% for the riparian zone.

4.10 KAMMANASSIE RIVER: J3KAMM-EWR10

The Kammanassie Dam is the only large dam that can be used to operate the system. The dam is located in the lower reaches of the river. Upstream of the dam, flow operation can only be managed through restrictions and removal of alien vegetation. The Kammanassie River downstream of the Kammanassie Dam has degraded to an E and D/E PES due to the significant flow modification in the sub quaternary reaches, agricultural fields, return flows as well as extensive reed growth. The land use is dominated by irrigation which is extensive downstream of the Kammanassie Dam. Upstream of the dam irrigation occurs wherever the relief allows even in the source zone. Extensive alien vegetation occurs. The major issues that have caused the change from reference condition were mainly flow and some non-flow related issues. Irrigation return flows, abstraction and farm dams have resulted in decreased base flows with zero flows at times. Intensive farming result in impacts on water quality due to irrigation return flows. Elevated sediment input reduces pool depth and degrades the substrate for biota. Alien vegetation occurs in the upper riparian zone whereas the indigenous *C. textillis* (Flat Sedge) has encroached significantly in area. This is possibly due to nutrient enrichment and more consistent flows or seepage from return flows during dry times. Alien fish species also occur in the reach. **Figure 4.9** provides a map and photographs of the EWR site.

Figure 4.9 A map, Google image and downstream view of J3KAMM-EWR10

4.10.1 Ecological Categories

The ECs, representative of broad qualitative EcoSpecs, and determined for the PES (DWS, 2014a), is provided in **Table 4.60**. The PES is representative of the baseline.

Table 4.60 J3KAMM-EWR10: EcoSpecs as ECs

Component	PES and REC
Water quality	C
Fish	D
Invertebrates	C/D
Instream	D
Riparian vegetation	C/D
EcoStatus	C/D

4.10.2 Hydrology: EcoSpecs

Source: DWA (2014b); DWS (2014a).
Model: RDRM (Hughes *et al*., 2011), WRYM (DWAF, 2008c).

REC	nMAR (MCM)	pMAR (MCM)	Low flows (MCM)	Low flows (%nMAR)	Total flows (MCM)	Total (%nMAR)	September		February	
							90%	60%	90%	60%
C/D	20.6	19.6	1.8	8.9	4.6	21	0.015	0.054	0	0.020

4.10.3 Water quality (including diatoms): EcoSpecs and TPCs

Water quality

As no water quality data exists for the Kammanassie River system and the water quality assessment was based on available information and best judgement, no definitive EcoSpecs and TPCs can be provided. Water quality monitoring would have to be initiated at the site. Once sufficient data has been collected to develop a baseline, EcoSpecs and TPCs can be set for the site. Based on other rivers in the WMA, it is recommended that the following variables be monitored in the first instance.

- Salts.
- Nutrients, i.e. SRP (PO_4-P) and TIN-N (that is NO_3+NO_2-N and NH_4-N).
- Periphyton (chlorophyll-a).
- Temperature.
- Dissolved oxygen.
- Diatoms.
- Monitor biotic response and add toxics to the monitoring programme as and when required, Diatoms samples (n = 2, so more data is required to confirm preliminary findings) suggest organic pollution in the area.

It is expected that driving issues will be nutrients and salts, with impacts on temperature and oxygen at low flows. Note the potential impact of the Uniondale Waste Water Treatment Works (WWTW) on the Holdrif River just upstream of its confluence with the Kammanassie River, which has a Critical

risk rating (e.g. no monitoring is in place) according to DWA (2012), i.e. the Green Drop Report for the Western Cape.

Diatoms

Monitoring guidelines for diatoms are provided in **Table 4.61**. The SPI score of 11.7 (C/D EC) is based on the aggregate of the two samples collected on 12 February 2014 (SPI score: 10.1) and 24 June 2014 (SPI score: 13.3) at the EWR site (DWS, 2014a). No historic or other present data could be sourced for the Kammanassie River. Nutrient levels, organic pollution and salinity were elevated with salinity and organic pollution levels becoming problematic. These variables improved during June 2014. Moderate oxygenation rates and moderate pollution levels prevailed (DWS, 2014a).

Based on the limited water quality data (DWS, 2014a) the following metrics are of concern:

- Nutrient and organics: Irrigated farming along river margins and livestock farming are the dominant land-uses in the area.
- Oxygen and Temperature: Impacts are expected during low flows.

Table 4.61 J3KAMM-EWR10: Diatoms monitoring guidelines (PES and REC: C/D)

Metric	Indicator species	Indicator/general threshold	Action
Salinity	*N. frustulum*: Indicator of nutrient and salinity levels.	If present at >5% these variables will most probably be problematic.	If thresholds are exceeded during consecutive low and high flow assessments water quality analysis should be undertaken.
Oxygen	*Achnanthidium* species: Are associated with elevated flows. The genus generally prefers good water quality with high oxygenation rates (Taylor *et al*., 2007b).	If flows are elevated expect dominance of >20%.	
Nutrients	*Nitzschia* species: Associated with water bodies that have readily available nutrients.	If present at >10% this variable will most probably be problematic.	
Organics	*Gomphonema parvulum*: Indicator of organic pollution. Tolerant to extreme pollution (Taylor *et al*., 2007b).	If present at >5% these variables will most probably be problematic.	
	N. gregaria, *N. schroeteri* var. *symmetrica*, *Craticula halophila* and *N. veneta*: Main indicators of anthropogenic activities relating to increased sewage or other effluent. Although it is acknowledged that cattle is contributing to higher organic and nutrient loads in the system, *N. gregaria* and *N. schroeteri* var. *symmetrica* are indicator species of sewage related activities and their the presence could be due to septic tanks and soak aways located in the vicinity. If cattle were the main contributing factor to increased organic pollution loads it would be expected that there would be a greater abundance or dominance of *Planothidium* species. Higher organic loads could also be due	Combined abundance of >25% indicates potential problems.	If thresholds are exceeded during consecutive low and high flow assessments along with consecutive PTV score of >30% water quality analysis should be undertaken.

Metric	Indicator species	Indicator/general threshold	Action
	to the use of pesticides and herbicides in the area.		
Metal toxicity	General thresholds were not exceeded during February (0.5%) and June 2014 (0%).	Valve deformities should not be present at an abundance of >1%.	If thresholds are exceeded during consecutive low and high flow assessments water quality analysis should be undertaken.
SPI score	10 and higher	10 - 12	

4.10.4 Fish: EcoSpecs and TPCs

EcoSpecs and TPCs are provided in **Table 4.62**.

Table 4.62 J3KAMM-EWR10: Fish EcoSpecs and TPCs (PES and REC: D)

Metric	Indicator	EcoSpecs	TPC (Biotic)	TPC (Habitat)
Ecological status	PES	The PES is in a D (46.9%).	Decrease of PES into a lower EC than PES (<D).	Any deterioration in habitat that results in decrease in FROC* of species.
Species richness	All indigenous species	Both of the expected two indigenous fish species, namely PASP and SCAP estimated to be present in the reach under PES.	Loss of any indigenous species. Absence of either indigenous species at EWR site during two consecutive surveys).	Loss in diversity, abundance and condition of velocity-depth categories and cover features that lead to a loss of species.
Requirement for flowing water	PASP	PASP was not sampled during EWR survey but is expected to occur at a FROC* of 0.5 in the reach under PES. This species has the highest requirement for flow of two indigenous species in this reach and is thus the most applicable indicator species for this metric.	PASP absent during two consecutive surveys OR present at FROC of < 0.5. Absence of range of life stages (juveniles to adults) during various surveys.	Reduced suitability (abundance and quality) of flowing habitats (i.e. decreased flows, increased zero flows, and altered seasonality).
FS habitats	PASP	This species has the highest requirement and preference for fast habitats as breeds in riffles with FS (and limited FD habitats). It has the highest requirement in terms of water quality and has the strongest preference for undercut banks of all species in this reach. It is thus the most applicable indicator species for these metrics.	PASP absent during two consecutive surveys OR present at FROC of < 0.5. Absence of range of life stages (juveniles to adults) during various surveys.	Reduced suitability (abundance and quality) of FS habitats (i.e. decreased flows, increased zero flows).
Water quality intolerance				Decreased water quality (especially flow related water quality variables such as oxygen).
Undercut banks				Significant change in undercut bank and rootwads habitats (e.g. bank erosion, reduced flows).
Overhanging vegetation and instream vegetation	SCAP	SCAP was not sampled during the EWR survey but is estimated to occur at a FROC* of at least 0.5 in the reach under PES. This species has a high preference for overhanging vegetation and instream vegetation and SS habitats as well as vegetation of all species in this reach and is the most applicable indicator species for this habitat feature.	SCAP absent during two consecutive surveys OR present at FROC of < 0.5 in reach. Absence of range of life stages (juveniles to adults) during various surveys.	Significant change in overhanging vegetation and instream vegetation habitats (overgrazing, flow modification, use of herbicides, agriculture, vegetation removal, alien vegetation encroachment).
SS habitats				Significant change in SS habitat suitability (i.e. increased flows, altered seasonality, increased sedimentation of slow habitats).

Metric	Indicator	EcoSpecs	TPC (Biotic)	TPC (Habitat)
Substrate	PASP	PASP was not sampled during the EWR survey but is estimated to occur at a FROC* of 0.5 in the reach under PES. This species has the highest preference for substrate of two species in this reach (for spawning) and is the most applicable indicator species for this habitat feature.	PASP absent during three consecutive surveys OR present at FROC of < 0.5 in reach. Absence of range of life stages (juveniles to adults) during various surveys.	Increased sedimentation of riffle/rapid substrates, excessive algal growth on substrates. Increased sedimentation of riffle/rapid substrates, excessive algal growth on substrates.
Alien fish species	Presence of any alien/introduced spp.	Presence of the alien predator MSAL confirmed during EWR survey (0.5 ind/min).	Presence of any additional alien/introduced species or increase in abundance and distribution of existing species.	N/A
Migratory success[2]	PASP	It is estimated that catadromous species are absent but only the potamodromous PASP that requires migration between and within reaches to spawning riffles are present.	Loss or decreased FROC* of the potamodromous species PASP.	Alteration of longitudinal habitat through the creation of migration barriers (dams, weirs, zero flows, poor water quality causing chemical barriers).
Primary indicator species		**PASP.**		

* Refer to Section 3.4 for FROC ratings.

4.10.5 Macroinvertebrates: EcoSpecs and TPCs

Indicator taxa are provided in **Table 4.63** and EcoSpecs and TPCs in **Table 4.64**.

Table 4.63 J3KAMM-EWR10: Macroinvertebrate indicator taxa

Indicator acronym	Indicator Family and Score	Velocity preference		Substrate preference				WQ Preference[1]
		0.3 - 0.6 m/s	>0.6 m/s	Cobble	Vegetation	GSM	Water column	
HYD	Hydracarina (8)	2	0	1	2	3	1	Moderate
BAE+	Baetidae >2 spp. (12)	2	2	2	2	2	1	High
BAE	Baetidae 2 spp. (6)	2	2	2	2	2	1	Low
CAE	Caenidae (6)	1	1	2	1	3	0	Low
AES	Aeshnidae (8)	2	2	3	2	0	0	Moderate
GOM	Gomphidae (8)	3	0	1	0	5	0	Low
COE	Coenagrionidae (4)	3	1	1	4	1	0	Low
HYD-	Hydropsychidae 1spp. (4)	2	4	3	1	0	0	High
HME	Hydrometrid (6)	0	0	0	2	0	4	Moderate
ELM	Elmidae (8)	4	2	4	1	0	0	Moderate
TAB	Tabanidae (5)	1	0	2	0	4	0	Low
SIM	Simuliidae (5)	2	4	3	2	0	0	Low

1 Preferences scored 0 - 4 in ascending order of preference. For WQ, High = High preference for unimpaired WQ.

Table 4.64 J3KAMM-EWR10: Macroinvertebrate EcoSpecs and TPCs (PES and REC: C/D)

Parameter	Indicator	EcoSpecs	TPCs
SASS5 and ASPT score		The SASS5 score at sampling was 113 with an ASPT of 4.7. Total scores should remain above 90, with ASPT values > 4.5.	SASS5 scores < 90 and ASPT < 4.5.
MIRAI score		The PES was 61.7 (C/D) (MIRAI score to be a C/D (58 - 62%) Category, using the reference data used in this study, or recording alterations to these.	MIRAI < 40% (<D EC) with the reference data used in this study.
Diversity of invertebrate community	ALL	Twenty three families were collected during the field visit. All were relatively low-scoring. Seventeen or more different families should be present, at an abundance of A to C. Two or more species of baetids should be present. The community should be balanced in terms of abundances, i.e. the majority of families at A abundance, certain taxa can be at B abundance (e.g. SIM). No group should consistently dominate the fauna i.e. be present in D abundance (> 1000).	Less than 17 different taxa, with hand-picking of cobbles. Any taxon (adults) with an abundance of D. Less than two species of Baetidae.
Physical habitat quality	SIC: BAE+, AES, SIM,	Cobbles should be mobile and lacking silt drapes or extensive algal cover.	Siltation, embedded cobbles, extensive algal cover over cobbles or

Parameter	Indicator	EcoSpecs	TPCs
	HYD- MV: COE GSM: CAE, GOM, TAB	With appropriate sampling effort and hand-picking, all indicator taxa should be present at abundances A - C. Hand-picking is necessary.	as algal mats. SIC: Absence or low numbers of Baetidae or SIM. Less than 2 species of Baetidae. MV: Absence of COE. GSM: Absence of any one indicator taxon.
Physical habitat diversity	ALL	All SASS5 biotopes (Stones, MV, and GSM) should be available to sample. MV should be inundated at least 10 - 20 cm. At least nine of the eleven indicator taxa should be present.	Stones immobile. Fixed point photographic records of MV exposure (lack of inundation), die-back or further encroachment. More than two indicators absent or in low numbers.
Response to water quality	BAE+ ELM HYD- HME	During flow periods, water should be clear, non-odorous, and low in suspended solids. Cobble surfaces should neither be covered with algae or silt. Two or more species of BAE+, and two other indicators should be present.	Observed deterioration (turbidity, silt, and odour). Less than 2 spp. Baetidae. Absence of more than one indicator.
Response to hydraulic habitat availability and persistence			
VFCS	HYD-, SIM	According to hydraulic modelling, VFCS becomes available at a discharge of 0.1 m^3/s. At or above this discharge (where there are no antecedent drought periods), HYD- and SIM should be present, at A - C abundances.	Absence of HYD- or very low numbers of SIM.
FCS	ELM, HYD-	According to hydraulic modelling, FCS becomes available at a discharge of 0.03 m^3/s. If sampling at or above this discharge, with no antecedent dry or drought conditions, these indicator taxa should be present and abundant.	Absence of indicator families (after intensified sampling).
MV	COE	MV at channel margins should be inundated to at least 10 - 20 cm. COE should be present at A abundances. Three or more aquatic hemipteran families should occur in the vegetation.	COE absent. Photographic evidence of further vegetation encroachment or die-back. Absence of Hemipterans in MV.
FS	GOM	GOM should be present.	Absence or individuals only of GOM.

4.10.6 Riparian vegetation EcoSpecs and TPCs

EcoSpecs and TPCs are provided in **Table 4.65**.

Table 4.65 J3KAMM-EWR10: Riparian vegetation EcoSpecs and TPCs (PES and REC: C/D)

Metric	EcoSpec	TPC
Marginal zone		
Alien invasion (perennial alien species)	Maintain an absence of perennial alien plant species.	Occurrence of perennial alien plant species.
Terrestrial woody species aerial cover	Maintain an absence of terrestrial woody species.	Occurrence of terrestrial woody species in the sub-zone.
Indigenous riparian woody species cover (% aerial)	Maintain cover (% aerial) of indigenous riparian woody species below 10%.	Absence of indigenous riparian woody species OR an increase in cover above 10%.
Non-woody indigenous cover (grasses, sedges and dicotyledonous forbs) (% aerial)	Maintain non-woody cover (% aerial) above 50%.	Decrease in non-woody cover (% aerial) below 50%.
Reed cover (% aerial)	Maintain reed cover below 10%	Increase in reed cover above 10%
Lower zone		
Alien invasion (perennial alien species)	Maintain cover (% aerial) of perennial alien plant species at 5% or lower.	Increase in perennial alien plant species cover >15%.
Terrestrial woody species aerial cover	Maintain cover (% aerial) of terrestrial woody species at 5% or lower.	Increases in terrestrial woody species cover above 10%.
Indigenous riparian woody species cover (% aerial)	Maintain cover (% aerial) of indigenous riparian woody species above 5% and below 15%.	Absence of indigenous riparian woody species OR an increase in cover above 15%.
Non-woody indigenous cover (grasses, sedges and dicotyledonous forbs) (% aerial)	Maintain non-woody cover (% aerial) above 50%.	Decrease in non-woody cover (% aerial) below 30%.
Reed cover (% aerial)	Maintain reed cover below 10%.	Increase in perennial alien plant species cover > 15%.
Upper zone		
Alien invasion (perennial alien species)	Maintain cover (% aerial) of perennial alien plant species at 10% or lower.	Increase in perennial alien plant species cover > 20%.
Terrestrial woody species aerial cover	Maintain cover (% aerial) of terrestrial woody species at 20% or lower.	Increases in terrestrial woody species cover above 30%.
Indigenous riparian woody species cover (% aerial)	Maintain cover (% aerial) of indigenous riparian woody species above 10% and below 80%.	Decreases in indigenous riparian woody species cover below 10% or an increase above 90%.
Non-woody indigenous cover (grasses, sedges and dicotyledonous forbs) (% aerial)	Maintain non-woody cover (% aerial) above 40%.	Decrease in non-woody cover (% aerial) below 30%.
Reed Cover (%aerial)	Maintain reed cover below 5%.	Presence of reeds.
Riparian zone		
PES	Maintain PES score (using VEGRAI	Decrease in PES score below 65% for the

Metric	EcoSpec	TPC
	level 4 for assessment) of at least 68% for the riparian zone.	riparian zone.
Dominant vegetation type	The dominant vegetation type shall remain non-woody in the marginal and lower zones, and woody in the upper zone and largely free of any alien trees.	Increased proportion of non-woody cover above 10% in the marginal or 15% in the lower zones.

5 ESTUARIES: ECOSPECS AND TPCs

For the GRDS, EcoSpecs and TPCs were developed for the estuaries assessed at the intermediate (i.e. Duiwenhoks, Goukou and Gouritz estuaries), rapid (i.e. Klein Brak and Wilderness system) and desktop level (i.e. Blinde, Hartenbos, Piesang, Groot (Wes) and Bloukrans estuaries) as part of this study, as well as for estuaries for which previous EWR studies did not provide EcoSpecs and TPCs (i.e. Maalgate, Gwaing, Kaaimans, Goukamma, Noetsie, Keurbooms, Matjies estuaries).

5.1 DUIWENHOKS ESTUARY

The EcoSpecs, as well as the TPCs, representative of the REC (Category B) for the Duiwenhoks Estuary are presented in **Table 5.1**.

Table 5.1 EcoSpecs and TPCs for the Duiwenhoks Estuary (REC: B)

EcoSpecs	TPC
Hydrology	
Maintain flow regime as per recommended ecological flow.	River inflow: ▪ < 0.1 m^3/s for more than one month a year. ▪ < 1.0 m^3/s for more than three months a year.
Hydrodynamics	
Maintain connectivity with marine environment.	Average tidal amplitude < 10% of present observed data from the water level recorder in the estuary near the mouth during low flows (summer).
Sediments	
▪ Flood regime to maintain the sediment distribution patterns and aquatic habitat (instream physical habitat) for biota. ▪ No significant changes in sediment grain size and organic matter distribution patterns for biota. ▪ No significant change in average sediment composition and characteristics. ▪ No significant change in average bathymetry.	▪ Average sediment composition in any survey (% fractions) along estuary change from that of the Present State (2014/2015 baseline, to be measured) by 30%. ▪ Average organic fraction in sediment along length of estuary >5%. ▪ Average bathymetry along main channel in the middle and lower reaches (8 km upstream) change by 30% in any survey from that of the Present State (2015 baseline, to be measured) (system expected to significantly fluctuate in terms of bathymetry between floods). ▪ Average bathymetry along main channel in the upper reaches (above 8 km from the mouth – above Zone C) change by 10% in any survey from that of the Present State (2014/2015 baseline, to be measured).
Water quality	
Salinity distribution not to cause exceedance of TPCs for biota (see below).	▪ Salinity > 0 at head of estuary. ▪ Average salinity in Zone D > 5. ▪ Average salinity in Zone C > 20. ▪ Average salinity 5 km upstream from mouth > 20 more than three months of the year.
System variables (pH, dissolved oxygen and turbidity) not to cause exceedance of TPCs for biota (see below).	River inflow: ▪ 6.0 < pH > 7.5. ▪ DO < 5 mg/L. ▪ Suspended solids >5 mg/L (low flow).

EcoSpecs	TPC
	Estuary: ▪ Average turbidity >10 Nephelometric Turbidity Units (NTU) (low flow). ▪ Average 6.0 < pH > 8.5 (increasing with increase in salinity). ▪ Average DO < 5 mg/L.
Inorganic nutrient concentrations (NO_3-N, NH_3-N and PO_4-P) not to cause in exceedance of TPCs for macrophytes and microalgae (see below).	River inflow: ▪ NO_x-N >150 µg/L over two consecutive months. ▪ NH_3-N > 20 µg/L over two consecutive months. ▪ PO_4-PP > 20 µg/L over two consecutive months. Estuary (except during upwelling or floods): ▪ Average NO_x-N 150 µg/L single concentration > 200 µg/L. ▪ Average NH_3-N > 20 µg/L during survey, single concentration > 100 µg/L. ▪ Average PO_4-P > 20 µg/L during survey, single concentration > 50 µg/L.
Presence of toxic substances (e.g. trace metals and pesticides/herbicides) not to cause exceedance of TPCs for biota (see below).	River inflow: ▪ Trace metals (to be refined and confirmed through future monitoring). ▪ Pesticides/herbicides (to be refined and confirmed through future monitoring). Estuary: ▪ Concentrations in water column exceed target values as per SA Water Quality Guidelines for Coastal Marine Waters (DWAF, 1995). ▪ Concentrations in sediment exceed target values as per WIO Region guidelines (UNEP/Nairobi Convention Secretariat and CSIR, 2009)
Microalgae	
▪ Maintain a low median phytoplankton biomass. ▪ Maintain a high median intertidal benthic microalgal biomass. ▪ Prevent formation of localised phytoplankton blooms.	▪ Median phytoplankton chlorophyll-a (minimum five sites) exceeds 3.5 µg/L. ▪ Median intertidal benthic chlorophyll-a (minimum five sites) exceeds 42 mg/m^2. ▪ Site specific chlorophyll-a concentration exceeds 20 µg/L and cell density exceeds 10 000 cells/ml.
Macrophytes	
▪ Maintain the distribution of macrophyte habitats, particularly the salt marsh, reeds and sedges. ▪ Maintain the integrity of the salt marsh. ▪ Maintain the reed and sedge stands in the middle and upper reaches of the estuary. ▪ Rehabilitate 10% of the floodplain habitat by removing any agricultural berms and invasive plants. ▪ Maintain the integrity of the riparian zone.	▪ Greater than 20% change in the area covered by salt marsh and reeds and sedges (2013 survey). ▪ Increase in bare areas in the salt marsh because of a decrease in moisture and increase in salinity. Hypersaline sediment caused by evaporation, infrequent flooding or rainfall on this area. ▪ Loss and die-back of reeds fringing the estuary 5 - 10 km upstream from the mouth; salinity should not be greater than 20 for three months. ▪ Drying of floodplain habitat. Invasive plants (e.g. black wattle, prickly pear, *Tamarix*) cover > 5% of total floodplain area. ▪ Unvegetated, cleared areas along the banks caused by human disturbance.

EcoSpecs	TPC
Invertebrates	
▪ Maintain presence of sand prawn *Callichirus kraussi* on sand banks in lower estuary. ▪ Maintain the presence of River-Estuary Interface (REI) species in the upper estuary for specific invertebrate communities associated with REI (zooplankton and benthos).	▪ Sand prawn density should not deviate from average baseline levels (as determined in the eight visits undertaken in the first two years) by more than 40% in each season. ▪ Dominant species in the REI zone (zooplankton and benthos) should not deviate from average baseline levels (as determined in the eight visits undertaken in the first two years) by more than 40% in each season.
Fish	
Fish assemblage should comprise the five estuarine association categories in similar proportions (diversity and abundance) to that under the reference. Numerically assemblage should comprise: ▪ Ia estuarine residents (50 - 80%). ▪ Ib marine and estuarine breeders (10 - 20%). ▪ IIa obligate estuarine-dependent (10 - 20%). ▪ IIb estuarine associated species (5 - 10%). ▪ IIc marine opportunists (20 - 80%). ▪ IV indigenous fish (1 - 5%). ▪ V catadromous species (1 - 5%). Category Ia species should contain viable populations of at least 4 species (including *Gilchristella aestuaria, Hyporamphus capensis,* and *Omobranchus woodii*). Category IIa obligate dependents should be well represented by large exploited species especially *Argyrosomus japonicus, Lithognathus lithognathus*, *Pomadasys commersonii,* and *Lichia amia*). REI species dominated by both *Myxus capensis* and *G. aestuaria*.	▪ Ia estuarine residents < 50%. ▪ Ib marine and estuarine breeders < 10%. ▪ IIa obligate estuarine-dependent < 10%. ▪ IIb estuarine associated species < 5%. ▪ IIc marine opportunists < 50%. ▪ IV indigenous fish < 1%. ▪ V catadromous species < 1%. ▪ Ia represented only by *G. aestuaria.* ▪ IIa exploited species in very low numbers or absent. ▪ REI species represented only by *G. aestuaria*, *M. capensis* absent.
Birds	
The estuary should contain a diverse avifaunal community that includes representatives of all the original groups. Tern roosts should be seen at the estuary on a regular basis. Apart from gulls, terns and regionally increasing species such as Egyptian Goose, the estuary should generally support more than 50 birds.	▪ Numbers of birds other than gulls, terns and regionally increasing species fall below 50 for three consecutive counts. ▪ Numbers of waterbird species drop below 10 for three consecutive counts.

5.2 GOUKOU ESTUARY

The EcoSpecs, as well as the TPCs, representative of the REC (Category B) for the Goukou Estuary are presented in **Table 5.2**.

Table 5.2 EcoSpecs and TPCs for the Goukou Estuary (REC: B)

EcoSpecs	TPCs
Hydrology	
▪ Maintain flow regime as per recommended ecological flow. ▪ Ensure the persistence of freshwater seepage sites in the lower and middle reaches of the estuary.	River inflow: ▪ < 0.3 m^3/s for more than one month a year. ▪ < 1.0 m^3/s for more than three months a year. ▪ Maintain water levels in fountains (determine trough baseline study).
Hydrodynamics	
▪ Maintain connectivity with marine environment. ▪ Maintain connectivity with terrestrial environment through the presence of fountains and seeps.	▪ Average tidal amplitude < 20% of present observed data from the water level recorder in the estuary near the mouth during low flows (summer). ▪ Loss of wet riparian zones.
Sediment	
▪ Flood regime to maintain the sediment distribution patterns and aquatic habitat (instream physical habitat) for biota. ▪ No significant changes in sediment grain size and organic matter distribution patterns for biota. ▪ No significant change in average sediment composition and characteristics. ▪ No significant change in average bathymetry.	▪ Average sediment composition in any survey (% fractions) along estuary change from that of the Present State (2014/2015 baseline, to be measured) by 30%. ▪ Average organic fraction in sediment along length of estuary > 5%. ▪ Average bathymetry along main channel in the middle and lower reaches (10 km upstream) change by 30% in any survey from that of the Present State (2015 baseline, to be measured) (system expected to significantly fluctuate in terms of bathymetry between flood). ▪ Average bathymetry along main channel in the upper reaches (above 10 km from the mouth – above Zone C) change by 10% in any survey from that of the Present State (2014/2015 baseline, to be measured).
Water quality	
Salinity distribution not to cause exceedance of TPCs for biota (see below).	▪ Salinity > 0 at head of estuary. ▪ Average salinity in Zone D > 5. ▪ Average salinity in Zone C > 20. ▪ Average salinity 9.5 km upstream from mouth > 20 more than three months of the year. ▪ Salinity in interstitial water at seep sites > 20 ▪ Salinity > 40 in saltmarsh sediments (linked to decrease in moisture and drying of floodplain habitat).
System variables (pH, dissolved oxygen and turbidity) not to cause exceedance of TPCs for biota (see below).	River inflow: ▪ 6.0 < pH > 8.0 (black water system). ▪ DO < 5 mg/L. ▪ Suspended solids > 5 mg/L (low flow). Estuary: ▪ Average turbidity > 10 NTU (low flow). ▪ Average 6.0 < pH > 8.5 (increasing with increase in salinity). ▪ Average DO < 5 mg/L.
Inorganic nutrient concentrations (NO_3-N, NH_3-N and PO_4-P) not to cause in exceedance of TPCs for macrophytes and microalgae (see below).	River inflow: ▪ NO_x-N >150 µg/L over two consecutive months. ▪ NH_3-N > 20 µg/L over two consecutive months. ▪ PO_4-P > 20 µg/L over two consecutive months. Estuary (except during upwelling or floods): ▪ Average NO_x-N > 150 µg/L single concentration > 200

EcoSpecs	TPCs
	µg/L. ▪ Average NH_3-N > 20 µg/L during survey, single concentration > 100 µg/L. ▪ Average PO_4-P > 20 µg/L during survey, single concentration > 50 µg/L.
Presence of toxic substances (e.g. trace metals and pesticides/herbicides) not to cause exceedance of TPCs for biota (see below)	River inflow: ▪ Trace metals (to be refined and confirmed through future monitoring). ▪ Pesticides/herbicides (to be refined and confirmed through future monitoring). Estuary: ▪ Concentrations in water column exceed target values as per SA Water Quality Guidelines for Coastal Marine Waters (DWAF, 1995). ▪ Concentrations in sediment exceed target values as per WIO Region guidelines (UNEP/Nairobi Convention Secretariat and CSIR, 2009).
Microalgae	
▪ Maintain a low median phytoplankton biomass. ▪ Maintain a high median intertidal benthic microalgal biomass. ▪ Prevent formation of localised phytoplankton blooms.	▪ Median phytoplankton chlorophyll-a (minimum five sites) exceeds 3.5 µg/L. ▪ Median intertidal benthic chlorophyll-a (minimum five sites) exceeds 42 mg/m^2. ▪ Site specific chlorophyll-a concentration exceeds 20 µg/L and cell density exceeds 10 000 cells/L.
Macrophytes	
▪ Maintain the distribution of macrophyte habitats, particularly the submerged macrophytes, salt marsh, reeds and sedges. ▪ Maintain pockets of reeds in lower and middle reaches (linked to freshwater seepage sites). ▪ Maintain the reed and sedge stands in the upper reaches of the estuary. ▪ Rehabilitate 20% of the floodplain habitat by removing agriculture and invasive plants. ▪ Maintain the integrity of the riparian zone.	▪ Greater than 20% change in the area covered by salt marsh, reeds and sedges (2014 survey). Loss of submerged macrophytes (e.g. *Stukenia pectinata, Zostera capensis*) over a three year period. ▪ Decrease in cover of reeds at the freshwater seepage sites in the lower and middle reaches of the estuary (linked to salinity in interstitial water > 20 for three months). ▪ Increase in bare areas in the salt marsh (linked to a decrease in moisture and increase in salinity in sediment – i.e. drying of floodplain habitat). ▪ Loss and die-back of reeds fringing the estuary in the upper reaches (linked to salinity being > 20 for three months). ▪ Invasive plants (e.g. *Acacia cyclops*, prickly pear) cover > 5% of total floodplain area. ▪ Unvegetated, cleared areas along the banks caused by human disturbance.
Invertebrates	
▪ Maintain rich populations of the mudprawn *Upogebia africana* on mudbanks in the middle estuary (Zones A and B). ▪ Maintain rich invertebrate communities associated with the REI zone in the upper estuary (zooplankton and benthos).	▪ Mudprawn density should not deviate from average baseline levels (as determined in the eight visits undertaken quarterly in the first two years) by more than 25% in each season. ▪ The dominant species in the zone (zooplankton and benthos) should not deviate from average baseline levels (as determined in the eight visits undertaken quarterly in the first two years) by more than 40% in each season.

EcoSpecs	TPCs
Fish	
Fish assemblage should comprise the five estuarine association categories in similar proportions (diversity and abundance) to that under the reference (DWS, 2015d). Numerically assemblage should comprise: ▪ Ia estuarine residents (50 - 80% of total abundance). ▪ Ib marine and estuarine breeders (10 - 20%). ▪ IIa obligate estuarine-dependent (10 - 20%). ▪ IIb estuarine associated species (5-15%). ▪ IIc marine opportunists (20 - 80%) ▪ III marine vagrants (not more than 5%). ▪ IV indigenous fish (1 - 5%). ▪ V catadromous species (1 - 5%). Category Ia species should contain viable populations of at least four species (including *G. aestuaria, H. capensis,* and *O. woodii*). Category IIa obligate dependents should be well represented by large exploited species especially *A. japonicus, L. lithognathus, P. commersonii,* and *L. amia.* REI species dominated by both *M. capensis* and *G. aestuaria*.	▪ Ia estuarine residents < 50%. ▪ Ib marine and estuarine breeders < 10%. ▪ IIa obligate estuarine-dependent < 10%. ▪ IIb estuarine associated species < 5%. ▪ IIc marine opportunists < 20%. ▪ III marine vagrants > 5%. ▪ IV indigenous fish < 1%. ▪ V catadromous species < 1% (also linked to presence of freshwater seepage areas). ▪ Ia represented only by *G. aestuaria*. ▪ IIa exploited species in very low numbers or absent. ▪ REI species represented only by *G. aestuaria*, *M. capensis* absent.
Birds	
The estuary should contain a diverse avifaunal community that includes representatives of all the original taxonomic groups (DWS, 2015d). Tern roosts should be seen at the estuary on a regular basis. Apart from gulls, terns and regionally increasing species such as Egyptian Goose, the estuary should generally support more than 200 birds.	▪ Numbers of birds other than gulls, terns and regionally increasing species fall below 120 for three consecutive counts. ▪ Numbers of waterbird species drop below 15 for three consecutive counts.

5.3 GOURITZ ESTUARY

The EcoSpecs, as well as the TPCs, representative of a REC (Category B) for the Gouritz Estuary are presented in **Table 5.3**.

Table 5.3 EcoSpecs and TPCs for the Gouritz Estuary (REC: B)

EcoSpecs	TPCs
Hydrology	
Maintain flow regime as per recommended ecological flow.	River inflow: < 0.5 m^3/s for more than one month a year. < 5.0 m^3/s for more than six months a year.
Hydrodynamics	
Maintain connectivity with marine environment.	Average tidal amplitude < 30% of present observed data from the water level recorder in the estuary near the mouth during low flows (summer).
Sediment dynamics	
▪ Flood regime to maintain the sediment distribution patterns and aquatic habitat (instream physical habitat) for biota. ▪ No significant changes in sediment grain size and organic matter distribution patterns for biota. ▪ No significant change in average sediment composition and characteristics. ▪ No significant change in average bathymetry.	▪ Average sediment composition in any survey (% fractions) along estuary change from that of the Present State (2014/2015 baseline, to be measured) by 30%. ▪ Average organic fraction in sediment along length of estuary > 5%. ▪ Average bathymetry along main channel in the estuary change by 30% in any survey from that of the Present State (2014/2015 baseline, to be measured) (system expected to significantly fluctuate in terms of bathymetry between flood).
Water quality	
Salinity distribution not to cause exceedence of TPCs for biota (see below).	▪ Salinity > 0 at head of estuary. ▪ Average salinity in Site 11 1 km upstream of bridge > 5. ▪ Average salinity in Zone C > 20. ▪ Average salinity 11 km upstream from mouth > 20 more than three months of the year. ▪ Salinity > 40 in saltmarsh sediments (linked to decrease in moisture and drying of floodplain habitat).
System variables (pH, dissolved oxygen and turbidity) not to cause exceedence of TPCs for biota (see below).	River inflow: 7.0 < pH > 8.3. ▪ DO < 5 mg/L. ▪ Suspended solids >5 mg/L (low flow). Estuary: ▪ Average turbidity >10 NTU (low flow). ▪ Average 6.0 < pH > 8.5 (increasing with increase in salinity). ▪ Average DO < 5 mg/L.
Inorganic nutrient concentrations (NO_3-N, NH_3-N and PO_4-P) not to cause in exceedance of TPCs for macrophytes and microalgae (see below)	River inflow: ▪ NO_x-N >100 µg/L over two consecutive months. ▪ NH_3-N > 20 µg/L over two consecutive months. ▪ PO_4-P > 20 µg/L over two consecutive months. Estuary (except during upwelling or floods): ▪ Average NO_x-N > 100 µg/L single concentration > 150 µg/L. ▪ Average NH_3-N > 20 µg/l during survey, single concentration > 100 µg/L. ▪ Average PO_4-P > 20 µg/L during survey, single concentration > 50 µg/L.
Presence of toxic substances (e.g. trace metals and pesticides/herbicides) not to cause exceedence of TPCs for biota (see below).	River inflow: ▪ Trace metals (to be refined and confirmed through future monitoring). ▪ Pesticides/herbicides (to be refined and confirmed through future monitoring).

EcoSpecs	TPCs
	Estuary: ▪ Concentrations in water column exceed target values as per SA Water Quality Guidelines for Coastal Marine Waters (DWAF, 1995). ▪ Concentrations in sediment exceed target values as per WIO Region guidelines (UNEP/Nairobi Convention Secretariat and CSIR, 2009).
Microalgae	
▪ Maintain a low median phytoplankton biomass. ▪ Maintain a high median intertidal benthic microalgal biomass. ▪ Prevent formation of localised phytoplankton blooms.	▪ Median phytoplankton chlorophyll-a (minimum five sites) exceeds 3.5 µg/L. ▪ Median intertidal benthic chlorophyll-a (minimum five sites) exceeds 42 mg/m^2. ▪ Site specific chlorophyll-a concentration exceeds 20 µg/L and cell density exceeds 10 000 cells/L.
Macrophytes	
▪ Maintain the distribution of macrophyte habitats, particularly the salt marsh, reeds and sedges. ▪ Maintain the integrity of the remaining supratidal salt marsh. ▪ Maintain the reed and sedge stands in the upper reaches of the estuary. ▪ Rehabilitate 20% of the floodplain habitat by removing any agricultural berms and invasive plants. ▪ Maintain the integrity of the riparian zone.	▪ Greater than 20% change in the area covered by salt marsh, reeds and sedges. ▪ Increase in bare areas in the salt marsh (linked to decrease in moisture and increase in salinity drying of floodplain habitat). ▪ Loss and die-back of reeds fringing the estuary in the upper reaches (Zone D) (linked to salinity > 20 for three months). ▪ Invasive plants (e.g. *Eucalyptus*, prickly pear, *Tamarix*) cover > 5% of total floodplain area. ▪ Unvegetated, cleared areas along the banks caused by human disturbance.
Invertebrates	
▪ Maintain populations of the mudprawn *U. africana* on mudbanks in the middle estuary (Zone B). ▪ Maintain invertebrate communities associated with the REI zone in the upper estuary (zooplankton and benthos).	▪ Mudprawn density should not deviate from average baseline levels (as determined in the eight visits undertaken quarterly in the first two years) by more than 25% in each season. ▪ The dominant species in the zone (zooplankton and benthos) should not deviate from average baseline levels (as determined in the eight visits undertaken quarterly in the first two years) by more than 40% in each season.
Fish	
Fish assemblage should comprise the five estuarine association categories in similar proportions (diversity and abundance) to that under the reference (as defined in this this report). Numerically assemblage should comprise: ▪ Ia estuarine residents (50 - 80% of total abundance). ▪ Ib marine and estuarine breeders (10 - 20%). ▪ IIa obligate estuarine-dependent (10 - 20%). ▪ IIb estuarine associated species (5 - 15%). ▪ IIc marine opportunists (20 - 80%) ▪ III marine vagrants (not more than 5%). ▪ IV indigenous fish (1-5%). ▪ V catadromous species (1 - 5%).	▪ Ia estuarine residents < 50% or > 80%. ▪ Ib marine and estuarine breeders < 10%. ▪ IIa obligate estuarine-dependent < 10%. ▪ IIb estuarine associated species < 5%. ▪ IIc marine opportunists < 20%. ▪ III marine vagrants > 5%. ▪ IV indigenous fish < 1%. ▪ V catadromous species < 1%. ▪ Ia represented only by *G. aestuaria*. ▪ IIa exploited species in very low numbers or absent. ▪ REI species represented only by *G. aestuaria*, *M. capensis* absent.

EcoSpecs	TPCs
Category Ia species should contain viable populations of at least four species (including *G. aestuaria, H. capensis,* and *O. woodii*). Category IIa obligate dependents should be well represented by large exploited species especially *A. japonicus, L. lithognathus, P. commersonii,* and *L. amia*. REI species dominated by both *M. capensis* and *G. aestuaria*.	
Birds	
The estuary should contain a diverse avifaunal community that includes representatives of all the original groups. Tern roosts should be seen at the estuary on a regular basis. Apart from gulls, terns and regionally increasing species such as Egyptian Goose, the estuary should generally support more than 250 birds.	▪ Numbers of birds other than gulls, terns and regionally increasing species fall below 120 for three consecutive summer counts. ▪ Numbers of waterbird species drop below 20 for three consecutive summer counts.

5.4 BLINDE ESTUARY

The EcoSpecs and TPCs representative of a REC (Category C) for the Blinde Estuary are presented in **Table 5.4**.

Table 5.4 EcoSpecs and TPCs for the Blinde Estuary (REC: C)

EcoSpecs	TPCs
Hydrology	
Maintain flow regime (small system needs most flows).	▪ Mean Annual Runoff (MAR) do not vary by more than 10% from Present. ▪ Floods (indicated by 1:10 year event) do not reduce by more than 5% from present. ▪ Base flows do not differ by more than 5% from present.
Hydrodynamics	
Maintain mouth state to create the required habitat for birds, fish, macrophytes, microalgae and water quality.	▪ Closed mouth state increase/decrease by 10% from present. ▪ Presence of semi-closed mouth state with continuous out flow to sea. ▪ Average Water depth < 0.5 m (to be confirmed by monitoring). ▪ Rate of change in water level > 30% from present.
Water quality	
▪ Salinity distribution not to cause exceedance of TPCs for fish, invertebrates, macrophytes and microalgae. ▪ Turbidity and DO not to cause exceedance of TPCs for biota. ▪ Dissolved Inorganic Nitrogen/ Dissolved Inorganic Phosphate (DIN/DIP)	▪ Salinity > 20 (expected range 5 - 15). ▪ DO < 5 mg/L in estuary ▪ Turbidity > 10 NTU in low flow. ▪ Secchi depth: To bottom. ▪ DIN >100 µg/L (average). ▪ DIP > 20 µg/L (average). ▪ Concentrations in water column exceed target values as

EcoSpecs	TPCs
concentrations not to cause in exceedance of TPCs for macrophytes and microalgae. ▪ Toxic substances not to cause exceedance of TPCs for biota.	per SA Water Quality Guidelines for Coastal Marine Waters (DWAF, 1995). ▪ Concentrations in sediment exceed target values as per WIO Region guidelines (UNEP/Nairobi Convention Secretariat and CSIR, 2009).
Sediment dynamics	
▪ Flood regime to maintain the sediment distribution patterns and aquatic habitat (instream physical habitat) so as not to exceed TPCs for biota. ▪ Changes in sediment grain size distribution patterns not to cause exceedance of TPCs in benthic invertebrates. ▪ Change in average sediment composition and characteristics. ▪ Change in average bathymetry.	▪ Average sediment composition (% fractions) along estuary change from baseline (to be measured) by 30% (per survey). ▪ Average depth along main channel change from 30% of baseline (to be determined) (system expected to significant fluctuation in bathymetry between flood and extended closed periods).
Microalgae	
▪ Maintain low/median phytoplankton/benthic microalgae biomass. ▪ Prevent formation of phytoplankton blooms.	▪ Phytoplankton> 3.5 µg/L (median). ▪ Benthic microalgae > 23 mg/m^2 (median). ▪ Phytoplankton > 20 µg/L and/or cell density >10 000 cells/ml (once-off).
Macrophytes	
▪ Maintain distribution of macrophyte habitats. ▪ Prevent the spread of reeds into open water. ▪ Prevent an increase in nutrients and macroalgal blooms. ▪ Prevent the spread of invasive trees (e.g. *Acacia* spp.) in the riparian zone.	▪ 20% change in the macrophyte area. (Reeds currently cover 0.04 ha.). ▪ Reeds occupy > 0.5 ha. ▪ Macroalgal blooms cover > 50% of the open water area. ▪ Presence of invasive aquatic macrophytes e.g. *Azolla*, water hyacinth. ▪ Invasive trees cover > 50% of riparian zone.
Invertebrates	
▪ Establish presence absence of sand prawn *C. kraussi* on sand banks in lower estuary. ▪ Establish presence absence of the copepod *Pseudodiaptomus hessei* or estuarine congeneric in the zooplankton of the estuary.	If present populations deviate from average baselines (as determined in first three visits) by more 30%.
Fish	
Fish assemblage should comprise the five estuarine association categories in similar proportions (diversity and abundance) to that under the reference. Numerically assemblage should comprise: ▪ Ia estuarine residents (50 - 80% of total abundance). ▪ Ib marine and estuarine breeders (5 - 20%). ▪ IIa obligate estuarine-dependent (10 - 20%). ▪ IIb estuarine associated species (5 - 15%). ▪ IIc marine opportunists (20 - 80%). ▪ III marine vagrants (not more than 5%). ▪ IV indigenous fish (1 - 5%). ▪ V catadromous species (1 - 5%).	▪ Ia estuarine residents < 50%. ▪ Ib marine and estuarine breeders < 10%. ▪ IIa obligate estuarine-dependent <10%. ▪ IIb estuarine associated species < 5%. ▪ IIc marine opportunists < 20%. ▪ III marine vagrants > 5%. ▪ IV indigenous fish < 1%. ▪ V catadromous species < 1%.

EcoSpecs	TPCs
Category Ia species should contain viable populations of at least two species (e.g. *G. aestuaria,* and *Hyporamphus capensis.* Category IIa obligate dependents should be well represented by at least 2 large exploited species (i.e. *L. lithognathus,* and *L. amia*). REI species dominated by both *M. capensis* and *G. aestuaria*.	
Birds	
Maintain population of original groups of birds present on the estuary.	Number of birds in any group, other than species that are increasing regionally such as Egyptian geese, drops below the baseline median (determined by past data and or initial surveys) number of species and/or birds counted for three consecutive summer or winter counts.

5.5 HARTENBOS ESTUARY

The EcoSpecs and TPCs representative of a REC (Category C) for the Hartenbos Estuary are presented in **Table 5.5**.

Table 5.5 EcoSpecs and TPCs for the Hartenbos Estuary (REC: C)

EcoSpecs	TPCs
Hydrology	
Maintain present day base flows	▪ MAR does not vary by more than 10%. ▪ Floods (indicated by 1:10 year event) do not reduce by more than 5% from present. ▪ Base flows do not increase by more than 50% from present.
Hydrodynamics	
Maintain mouth state to create the required habitat for birds, fish, macrophytes, microalgae and water quality.	▪ Closed mouth state does not decrease by 10% from present. ▪ Average water level in system > 10% from present. ▪ Tidal amplitude (when open) < 20%.
Water quality	
▪ Salinity distribution not to cause exceedance of TPCs for fish, invertebrates, macrophytes and microalgae. ▪ Turbidity and DO not to cause exceedance of TPCs for biota. ▪ DIN/DIP concentrations not to cause in exceedance of TPCs for macrophytes and microalgae. ▪ Toxic substances not to cause exceedance of TPCs for biota.	▪ Average salinity along estuary decrease by five below baseline average (to be determined). ▪ DO < 5 mg/L in estuary. ▪ Turbidity > 20 NTU in low flow ▪ Secchi in fresher part: <0.5 m ▪ DIN > 200 µg/L average (to be refined and confirmed through future monitoring). ▪ DIP > 50 µg/L average (to be refined and confirmed through future monitoring). ▪ Concentrations in water column exceed target values as per SA Water Quality Guidelines for Coastal Marine Waters (DWAF, 1995). ▪ Concentrations in sediment exceed target values as per WIO Region guidelines (UNEP/Nairobi Convention Secretariat and CSIR, 2009).

EcoSpecs	TPCs
Sediment dynamics	
▪ Flood regime to maintain the sediment distribution patterns and aquatic habitat (instream physical habitat) so as not to exceed TPCs for biota. ▪ Changes in sediment grain size distribution patterns not to cause exceedance of TPCs in benthic invertebrates. ▪ Change in average sediment composition and characteristics. ▪ Change in average bathymetry.	▪ Average sediment composition (% fractions) along estuary change from baseline (to be measured) by 30% (per survey). ▪ Average depth along main channel change from 30% of baseline (to be determine) (system expected to significant fluctuation in bathymetry between flood and extended closed periods).
Microalgae	
▪ Maintain median phytoplankton/benthic microalgae biomass. ▪ Prevent formation of phytoplankton blooms.	▪ Phytoplankton > 8 µg/L (median). ▪ Benthic microalgae > 42 mg/m^2 (median). ▪ Phytoplankton > 20 µg/L and/or cell density > 10 000 cells/ml (once-off). ▪ Dinoflagellates, chlorophytes and/or cyanobacteria > 10% of relative abundance.
Macrophytes	
▪ Maintain distribution of macrophyte habitats. ▪ Prevent the spread of reeds into open water. ▪ Prevent an increase in nutrients and macroalgal blooms. ▪ Prevent the spread of invasive trees (e.g. *Acacia* spp.) in the riparian zone. ▪ Maintain integrity of salt marsh.	▪ 20% change in macrophyte area (Reeds currently cover 9 ha, saltmarsh 47 ha.) ▪ Macroalgal blooms cover > 50% of the open water area. ▪ Presence of invasive aquatic macrophytes e.g. *Azolla*, water hyacinth. ▪ Invasive plants cover > 10% of flood plain. ▪ Increase in bare areas in salt marsh because of decrease in moisture and increase in salinity >30% of salt marsh.
Invertebrates	
▪ Establish presence absence of sand prawn *C. kraus*si on sand banks in lower estuary. ▪ Establish abundance of the copepod *P. hessei* or estuarine congeneric in the zooplankton of the estuary.	▪ If present populations deviate from average baselines (as determined in first three visits) by more 30%.
Fish	
Fish assemblage should comprise the five estuarine association categories in similar proportions (diversity and abundance) to that under the reference. Numerically assemblage should comprise: ▪ Ia estuarine residents (20 - 60%). ▪ b marine and estuarine breeders (10 - 30%). ▪ IIa obligate estuarine-dependent (20 - 40%). ▪ IIb estuarine associated species (5 - 20%). ▪ IIc marine opportunists (20 - 80%). ▪ IV indigenous fish (1 - 5%). ▪ V catadromous species (1 - 5%). Category Ia species should contain viable populations of at least two species (e.g. *G. aestuaria, H. capensis,* and *O. woodii*).	▪ Ia estuarine residents < 20%. ▪ Ib marine and estuarine breeders < 10%. ▪ IIa obligate estuarine-dependent < 20% ▪ IIb estuarine associated species < 5%. ▪ IIc marine opportunists < 20%. ▪ IV indigenous fish < 1%. ▪ V catadromous species < 1%. ▪ Ia represented only by *G. aestuaria*. ▪ IIa exploited species in very low numbers or absent. ▪ REI species represented only by *G. aestuaria*, *M.s capensis* absent.

EcoSpecs	TPCs
Category IIa obligate dependents should be well represented by large exploited species (i.e. *A. japonicus, L. lithognathus, P. commersonnii,* and *L. amia*). REI species dominated by both *M. capensis* and *G. aestuaria*.	
Birds	
Maintain population of original groups of birds present on the estuary.	Number of birds in any group, other than species that are increasing regionally such as Egyptian geese, drops below the baseline median (determined by past data and or initial surveys) number of species and/or birds counted for three consecutive summer or winter counts.

5.6 KLEIN BRAK ESTUARY

The EcoSpecs and TPCs representative of a REC (Category C) for the Klein Brak Estuary are presented in **Table 5.6**.

Table 5.6 EcoSpecs and TPCs for the Klein Brak Estuary (REC: C)

EcoSpecs	TPCs
Hydrology	
Maintain a flow regime to create the required habitat for birds, fish, macrophytes, microalgae and water quality.	▪ River inflow: ▪ Monthly river inflow < 0.4 m^3/s persists for more than 30% of the time. ▪ Monthly river inflow < 0.15 m^3/s persists for more than 15% of the time. ▪ Monthly river inflow drops to 0 m^3/s.
Hydrodynamics	
Maintain connectivity with marine environment.	▪ Mouth closure occurs. ▪ Upper reaches above the weirs do not contribute to tidal flow to maintain open mouth conditions. ▪ Average tidal amplitude < 20% of present observed data from the water level recorder in the estuary near the mouth.
Sediment dynamics	
▪ Flood regime to maintain the sediment distribution patterns and aquatic habitat (instream physical habitat) for biota. ▪ No significant changes in sediment grain size distribution patterns for biota. ▪ No significant change in average sediment composition and characteristics. ▪ No significant change in average bathymetry.	▪ Average sediment composition in any survey (% fractions) along estuary change from that of the Present State (2014/2015 baseline, to be measured) by 30%. ▪ Average bathymetry along main channel change by 30% in any survey along estuary from that of the Present State (2014/2015 baseline, to be measured) (system expected to significantly fluctuate in terms of bathymetry between flood and extended closed periods).
Water quality	
Salinity distribution not to cause exceedence of TPCs for biota (see below).	▪ No salinity gradient in the upper reaches of the estuary (Zone D and F). ▪ No REI in the upper reaches of the estuary (Zone D and F).

EcoSpecs	TPCs
	▪ Salinity> 35.
System variables (pH, DO and turbidity) not to cause exceedence of TPCs for biota (see below).	River inflow: ▪ 7.0 < pH > 8.5. ▪ DO < 5 mg/L. ▪ Suspended solids > 5 mg/L (low flow). Estuary: ▪ Average turbidity > 10 NTU (low flow). ▪ Average 7.0 < pH > 8.5 (increasing with increase in salinity). ▪ Average DO < 5 mg/L.
Inorganic nutrient concentrations (NO_3-N, NH_3-N and PO_4-P) not to cause in exceedance of TPCs for macrophytes and microalgae (see below)	River inflow: ▪ NO_x-N >150 µg/L over two consecutive months. ▪ NH_3-N > 20 µg/L over two consecutive months. ▪ PO_4-P > 20 µg/L over two consecutive months. Estuary (except during upwelling or floods): ▪ Average NO_x-N > 150 µg/L during survey, single concentration > 200 µg/L. ▪ Average NH_3-N > 20 µg/L during survey, single concentration > 100 µg/L. ▪ Average PO_4-P > 20 µg/L during survey, single concentration > 50 µg//L.
Presence of toxic substances (e.g. trace metals and pesticides/herbicides) not to cause exceedence of TPCs for biota (see below).	River inflow: ▪ Trace metals (to be refined and confirmed through future monitoring). ▪ Pesticides/herbicides (to be refined and confirmed through future monitoring). Estuary: ▪ Concentrations in water column exceed target values as per SA Water Quality Guidelines for Coastal Marine Waters (DWAF, 1995). ▪ Concentrations in sediment exceed target values as per WIO Region guidelines (UNEP/Nairobi Convention Secretariat and CSIR, 2009).
Microalgae	
▪ Maintain a medium median phytoplankton biomass. ▪ Prevent median intertidal benthic microalgal biomass from exceeding 60 mg m^{-2}. ▪ Prevent formation of localised phytoplankton blooms.	▪ Median phytoplankton chlorophyll-a (minimum five sites) exceeds 3.5 µg/L. ▪ Median intertidal benthic chlorophyll-a (minimum five sites) exceeds 60 mg/m^2. ▪ Site specific chlorophyll-a concentration exceeds 20 µg//L and cell density exceeds 10 000 cells/ml.
Macrophytes	
▪ Maintain the distribution of sensitive macrophyte habitats (e.g. salt marsh, submerged macrophytes). ▪ Maintain the integrity of the salt marsh. ▪ Rehabilitate the floodplain habitat by removing weirs, berms and invasive plants. ▪ Prevent an increase in nutrient input leading to macroalgal blooms.	▪ Greater than 20% change in the area covered by submerged macrophytes and salt marsh. ▪ Increase in bare areas in the salt marsh because of a decrease in moisture and increase in salinity. ▪ Hypersaline sediment caused by evaporation, infrequent flooding or rainfall on this area. ▪ Drying of floodplain habitat. ▪ Invasive plants cover > 10% of total floodplain area. ▪ Macroalgal blooms cover > 50% of the open water area during closed mouth conditions.
Invertebrates	
▪ Maintain rich populations of mudprawn *U. africana* on intertidal banks in middle estuary.	▪ Mudprawn populations should not deviate from average baseline values (as determined in first three visits) by more 25%.

EcoSpecs	TPCs
▪ Maintain *P. hessei* as the numerically dominant copepod in the zooplankton of the estuary.	▪ *P. hessei* populations should not deviate from average baseline values (as determined in first three visits) by more 30%.
Fish	
Fish assemblage should comprise the five estuarine association categories in similar proportions (diversity and abundance) to that under the reference. Numerically assemblage should comprise: ▪ Ia estuarine residents (20 - 60%). ▪ Ib marine and estuarine breeders (10 - 30%). ▪ IIa obligate estuarine-dependent (20 - 40%). ▪ IIb estuarine associated species (5 - 20%). ▪ IIc marine opportunists (20 - 80%). ▪ IV indigenous fish (1 - 5%). ▪ V catadromous species (1 - 5%). Category Ia species should contain viable populations of at least four species (including *G. aestuaria, H. capensis,* and *O. woodii*). Category IIa obligate dependents should be well represented by large exploited species especially *A. japonicus, L. lithognathus, P. commersonnii,* and *L. amia* REI species dominated by both *M. capensis* and *G. aestuaria*.	▪ Ia estuarine residents < 20%. ▪ Ib marine and estuarine breeders < 10%. ▪ IIa obligate estuarine-dependent < 20%. ▪ IIb estuarine associated species < 5%. ▪ IIc marine opportunists < 20%. ▪ IV indigenous fish < 1%. ▪ V catadromous species < 1%. ▪ Ia represented only by *G. aestuaria*. ▪ IIa exploited species in very low numbers or absent. ▪ REI species represented only by *G. aestuaria*, *M. capensis* absent.
Birds	
Estuary should contain a diverse avifaunal community that includes representatives of all the original groups. Saltmarsh/wetlands in the floodplain should be rich in birdlife. Intertidal areas should have a good density and diversity of both larger and smaller waders.	Numbers of waterbirds on the entire system drops below 30 species or below 250 birds for three consecutive counts. Numbers of waterbirds in the lower estuary drops below 10 species or 50 birds (excluding terns and gulls) for three consecutive counts.

5.7 MAALGATE ESTUARY

The EcoSpecs and TPCs representative of the REC (Category B) for the Maalgate Estuary are presented in **Table 5.7**.

Table 5.7 EcoSpecs and TPCs for the Maalgate Estuary (REC: B)

EcoSpecs	TPCs
Hydrology	
Maintain flow regime (small system needs most flows).	Varies more than 10% of MAR.
Hydrodynamics	
Maintain mouth state to create the required habitat for birds, fish, macrophytes, microalgae and water quality.	▪ Closed mouth state varies by > 20% from present. ▪ Average water depth < 1.0 m (to be confirmed by monitoring). ▪ Average water level change by more than 20% from present.
Water quality	
▪ Salinity distribution not to cause exceedance of TPCs for fish, invertebrates, macrophytes and microalgae. ▪ Turbidity and DO not to cause exceedance of TPCs for biota. ▪ DIN/DIP concentrations not to cause in exceedance of TPCs for macrophytes and microalgae. ▪ Toxic substances not to cause exceedance of TPCs for biota.	▪ Average salinity < 10 (expected average range 10 - 30). ▪ DO < 5 mg/L in estuary. ▪ Turbidity > 10 NTU in low flow. ▪ Secchi: To bottom. ▪ DIN > 100 µg/L once-off. ▪ DIP > 20 µg/L once-off. ▪ Concentrations in water column exceed target values as per SA Water Quality Guidelines for Coastal Marine Waters (DWAF, 1995). ▪ Concentrations in sediment exceed target values as per WIO Region guidelines (UNEP/Nairobi Convention Secretariat and CSIR, 2009).
Sediment dynamics	
▪ Flood regime to maintain the sediment distribution patterns and aquatic habitat (instream physical habitat) so as not to exceed TPCs for biota. ▪ Changes in sediment grain size distribution patterns not to cause exceedance of TPCs in benthic invertebrates. ▪ Change in average sediment composition and characteristics. ▪ Change in average bathymetry.	▪ Average sediment composition (% fractions) along estuary change from baseline (to be measured) by 30% (per survey). ▪ Average depth along main channel change from 30% of baseline (to be determined) (system expected to significant fluctuation in bathymetry between flood and extended closed periods).
Microalgae	
▪ Maintain median phytoplankton/benthic microalgae biomass. ▪ Prevent formation of phytoplankton blooms.	▪ Phytoplankton > 3.5 µg/L (median). ▪ Benthic microalgae >23 mg/m^2 (median). ▪ Phytoplankton > 20 µg/L and/or cell density >10 000 cells/ml (once-off). ▪ Dinoflagellates, chlorophytes and/or cyanobacteria > 10% of relative abundance.
Macrophytes	
▪ Prevent an increase in macroalgal blooms. ▪ Prevent the spread of invasive trees (e.g. *Acacia* spp.) in the riparian zone.	▪ Macroalgal blooms cover > 20% of the open water area. ▪ Invasive trees cover > 20% of riparian zone.
Invertebrates	
▪ Establish presence absence of sand prawn *C. krauss*i on sand banks in lower estuary. ▪ Establish presence absence of the copepod *P. hessei* or estuarine congeneric in the zooplankton of the estuary.	If present populations deviate from average baselines (as determined in first three visits) by more 30%.

EcoSpecs	TPCs
Fish	
Fish assemblage should comprise the five estuarine association categories in similar proportions (diversity and abundance) to that under the present. Numerically assemblage should comprise: ▪ Ia estuarine residents (50 - 80% of total abundance). ▪ Ib marine and estuarine breeders (5 - 20%). ▪ IIa obligate estuarine-dependent (10 - 20%). ▪ IIb estuarine associated species (5 - 15%). ▪ IIc marine opportunists (20 - 80%). ▪ III marine vagrants (not more than 5%). ▪ IV indigenous fish (1 - 5%). ▪ V catadromous species (1 - 5%). Category Ia species should contain viable populations of at least two species (e.g. *G. aestuaria,* and *H. capensis*). Category IIa obligate dependents should be well represented by at least 2 large exploited species (i.e. *L. lithognathus,* and *L. amia*). REI species dominated by both *M. capensis* and *G. aestuaria*.	▪ Ia estuarine residents < 50%. ▪ Ib marine and estuarine breeders < 10%. ▪ IIa obligate estuarine-dependent < 10%. ▪ IIb estuarine associated species < 5%. ▪ IIc marine opportunists < 20%. ▪ III marine vagrants > 5%. ▪ IV indigenous fish < 1%. ▪ V catadromous species < 1%. ▪ Species composition > 50% similar to last three sampling trip (system naturally highly unstable due to resetting events).
Birds	
Maintain population of original groups of birds present on the estuary.	Number of birds in any group, other than species that are increasing regionally such as Egyptian geese, drops below the baseline median (determined by past data and or initial surveys) number of species and/or birds counted for three consecutive summer or winter counts.

5.8 GWAING ESTUARY

The EcoSpecs and TPCs representative of the REC (Category B/C) for the Gwaing Estuary are presented in **Table 5.8**.

Table 5.8 EcoSpecs and TPCs for the Gwaing Estuary (REC: B/C)

EcoSpecs	TPCs
Hydrology	
Maintain flow regime.	Varies more than 10% of MAR.
Hydrodynamics	
Maintain mouth state to create the required habitat for birds, fish, macrophytes, microalgae and water quality.	▪ Closed mouth state varies by > 20% from present. ▪ Average water depth < 1.0 m (to be confirmed by monitoring). ▪ Average water level change by more than 20% from present.

EcoSpecs	TPCs
Water quality	
▪ Salinity distribution not to cause exceedance of TPCs for fish, invertebrates, macrophytes and microalgae. ▪ Turbidity and DO not to cause exceedance of TPCs for biota. ▪ DIN/DIP concentrations not to cause in exceedance of TPCs for macrophytes and microalgae. ▪ Toxic substances not to cause exceedance of TPCs for biota.	▪ Average salinity < 15 (expected average range 10 - 30, but to be verified by baseline studies. ▪ DO < 5 mg/L in estuary (surface water especially). ▪ Turbidity > 10 NTU in low flow. ▪ Secchi: To bottom. ▪ DIN > 150 µg/L once-off. ▪ DIP > 30 µg/L once-off. ▪ Concentrations in water column exceed target values as per SA Water Quality Guidelines for Coastal Marine Waters (DWAF, 1995). ▪ Concentrations in sediment exceed target values as per WIO Region guidelines (UNEP/Nairobi Convention Secretariat and CSIR, 2009).
Sediment dynamics	
▪ Flood regime to maintain the sediment distribution patterns and aquatic habitat (instream physical habitat) so as not to exceed TPCs for biota. ▪ Changes in sediment grain size distribution patterns not to cause exceedance of TPCs in benthic invertebrates. ▪ Change in average sediment composition and characteristics ▪ Change in average bathymetry.	▪ Average sediment composition (% fractions) along estuary change from baseline (to be measured) by 30% (per survey). ▪ Average depth along main channel change from 30% of baseline (to be determine) (system expected to significant fluctuation in bathymetry between flood and extended closed periods).
Microalgae	
▪ Maintain median phytoplankton/benthic microalgae biomass. ▪ Prevent formation of phytoplankton blooms.	▪ Phytoplankton > 8 µg/L (median). ▪ Benthic microalgae > 42 mg/m^2 (median). ▪ Phytoplankton > 20 µg/L and/or cell density > 10 000 cells/ml (once-off). ▪ Dinoflagellates, chlorophytes and/or cyanobacteria >10% of relative abundance.
Macrophytes	
▪ Maintain distribution of macrophyte habitats. ▪ Prevent the spread of reeds into open water. ▪ Prevent an increase in nutrients, macroalgal blooms and aquatic invasive plants. ▪ Prevent the spread of invasive trees (e.g. *Acacia* spp.) in the riparian zone.	▪ 20% change in the macrophyte area. (Reeds currently cover 0.14 ha. and salt marsh 1.58 ha). ▪ Reeds occupy > 0.5 ha. ▪ Macroalgal blooms cover > 50% of the open water area. ▪ Presence of invasive aquatic macrophytes e.g. *Azolla*, water hyacinth. ▪ Invasive trees cover > 20% of riparian zone.
Invertebrates	
Establish presence absence of sand prawn *C. kraussi* on sand banks in lower estuary. Establish presence absence of the copepod *P. hessei* or estuarine congeneric in the zooplankton of the estuary.	If present populations deviate from average baselines (as determined in first three visits) by more 30%.
Fish	
▪ Fish assemblage should comprise the five estuarine association categories in similar proportions (diversity and abundance) to that under the present. Numerically assemblage should comprise:	▪ Ia estuarine residents < 50%. ▪ Ib marine and estuarine breeders < 10%. ▪ IIa obligate estuarine-dependent < 10%. ▪ IIb estuarine associated species < 5%. ▪ IIc marine opportunists < 20%.

EcoSpecs	TPCs
▪ Ia estuarine residents (50 - 80% of total abundance). ▪ Ib marine and estuarine breeders (5 - 20%). ▪ IIa obligate estuarine-dependent (10 - 20%). ▪ IIb estuarine associated species (5 - 15%). ▪ IIc marine opportunists (20 - 80%). ▪ III marine vagrants (not more than 5%). ▪ IV indigenous fish (1 - 5%). ▪ V catadromous species (1 - 5%). Category Ia species should contain viable populations of at least 2 species (e.g. *G. aestuaria,* and *H. capensis*). Category IIa obligate dependents should be well represented by at least two large exploited species (i.e. *L. lithognathus,* and *L. amia*). REI species dominated by both *M. capensis* and *G. aestuaria*.	▪ III marine vagrants > 5%. ▪ IV indigenous fish < 1%. ▪ V catadromous species < 1%. ▪ Species composition > 50% similar to last three sampling trip (system naturally highly unstable due to resetting events).
Birds	
Maintain population of original groups of birds present on the estuary.	Number of birds in any group, other than species that are increasing regionally such as Egyptian geese, drops below the baseline median (determined by past data and or initial surveys) number of species and/or birds counted for three consecutive summer or winter counts.

5.9 KAAIMANS ESTUARY

The EcoSpecs and TPCs representative of the REC (Category A/B) for the Kaaimans Estuary are presented in **Table 5.9**.

Table 5.9 EcoSpecs and TPCs for the Kaaimans Estuary (REC: A/B)

EcoSpecs	TPCs
Hydrology	
Maintain flow regime.	Varies more than 10% of MAR
Hydrodynamics	
Maintain mouth state to create the required habitat for birds, fish, macrophytes, microalgae and water quality.	▪ Closed mouth state varies by > 10% from present. ▪ Average water depth < 0.5 m in the mouth region (to be confirmed by monitoring). ▪ Average water depth < 1.0 m in the middle to upper region, excluding Swart Arm (western arm) which is 5 to 10 m deep (to be confirmed by monitoring). ▪ Average water level change by more than 20% from present.
Water quality	
▪ Salinity distribution not to cause exceedance of TPCs for fish, invertebrates, macrophytes and microalgae.	▪ Average Salinity > 30 (expected average range 10 - 30). ▪ DO < 5 mg/L in estuary.

EcoSpecs	TPCs
▪ Turbidity and DO not to cause exceedance of TPCs for biota. ▪ DIN/DIP concentrations not to cause in exceedance of TPCs for macrophytes and microalgae. ▪ Toxic substances not to cause exceedance of TPCs for biota.	▪ Turbidity > 10 NTU in low flow. ▪ Secchi: To bottom. ▪ DIN > 100 µg/L once-off. ▪ DIP > 20 µg/L once-off. ▪ Concentrations in water column exceed target values as per SA Water Quality Guidelines for Coastal Marine Waters (DWAF, 1995). ▪ Concentrations in sediment exceed target values as per WIO Region guidelines (UNEP/Nairobi Convention Secretariat and CSIR, 2009).
Sediment dynamics	
▪ Flood regime to maintain the sediment distribution patterns and aquatic habitat (instream physical habitat) so as not to exceed TPCs for biota. ▪ Changes in sediment grain size distribution patterns not to cause exceedance of TPCs in benthic invertebrates. ▪ Change in average sediment composition and characteristics. ▪ Change in average bathymetry.	▪ Average sediment composition (% fractions) along estuary change from baseline (to be measured) by 30% (per survey). ▪ Average depth along main channel change from 30% of baseline (to be determine) (system expected to significant fluctuation in bathymetry between flood and extended closed periods).
Microalgae	
▪ Maintain median phytoplankton/benthic microalgae biomass. ▪ Prevent formation of phytoplankton blooms.	▪ Phytoplankton > 3.5 µg/L (median). ▪ Benthic microalgae >11 mg/m^2 (median). ▪ Phytoplankton > 20 µg/L and/or cell density > 10 000 cells/ml (once-off).
Macrophytes	
Maintain distribution of macrophyte habitats.	20% change in the macrophyte area (reeds currently cover 0.6 ha and salt marsh 0.02 ha).
Invertebrates	
▪ Establish presence absence of sand prawn *C. krauss*i on sand banks in lower estuary. ▪ Establish presence absence of the copepod *P. hessei* or estuarine congeneric in the zooplankton of the estuary.	If present populations deviate from average baselines (as determined in first three visits) by more 30%.
Fish	
Fish assemblage should comprise the five estuarine association categories in similar proportions (diversity and abundance) to that under the present. Numerically assemblage should comprise: ▪ Ia estuarine residents (50 - 80% of total abundance). ▪ Ib marine and estuarine breeders (5 - 20%). ▪ IIa obligate estuarine-dependent (10 - 20%). ▪ IIb estuarine associated species (5 - 15%). ▪ IIc marine opportunists (20 - 80%). ▪ III marine vagrants (not more than 5%). ▪ IV indigenous fish (1 - 5%). ▪ V catadromous species (1 - 5%). Category Ia species should contain viable populations of at least two species (e.g. *G.*	▪ Ia estuarine residents < 50%. ▪ Ib marine and estuarine breeders < 10%. ▪ IIa obligate estuarine-dependent < 10%. ▪ IIb estuarine associated species < 5%. ▪ IIc marine opportunists < 20%. ▪ III marine vagrants > 5%. ▪ IV indigenous fish < 1%. ▪ V catadromous species < 1%. ▪ Species composition > 50% similar to last three sampling trip (system naturally highly unstable due to resetting events).

EcoSpecs	TPCs
aestuaria, and *Hyporamphus capensis*). Category IIa obligate dependents should be well represented by at least two large exploited species (i.e. *L. lithognathus,* and *L. amia*). REI species dominated by both *M. capensis* and *G. aestuaria*.	
Birds	
Maintain population of original groups of birds present on the estuary.	Number of birds in any group, other than species that are increasing regionally such as Egyptian geese, drops below the baseline median (determined by past data and or initial surveys) number of species and/or birds counted for three consecutive summer or winter counts.

5.10 WILDERNESS SYSTEM

The EcoSpecs and TPCs representative of a REC (Category B) for the Wilderness System are presented in **Table 5.10**.

Table 5.10 EcoSpecs and TPCs for the Wilderness System (REC: B)

EcoSpecs	TPCs
Hydrology	
Maintain a flow regime to create the required habitat for birds, fish, macrophytes, microalgae and water quality.	▪ River inflow distribution patterns differ by more than 5% from that of Present day. ▪ Monthly river inflow < 0.1 m^3/s persists for longer than 20% of the time.
Hydrodynamics	
Maintain intermittent connectivity with marine environment.	▪ During the open state average tidal amplitude < 30% of present observed data from the water level recorder in the estuary near the mouth. ▪ Mouth closure > 60% of the time over a five year period.
Sediment dynamics	
▪ Flood regime to maintain the sediment distribution patterns and aquatic habitat (instream physical habitat) for biota. ▪ No significant changes in sediment grain size distribution patterns for biota ▪ No significant change in average sediment composition and characteristics ▪ No significant change in average bathymetry. ▪ Connecting channel bathymetry to be such that adequate flow connectivity is maintained.	▪ Average sediment composition in any survey (% fractions) along estuary change from that of the Present State (2014/2015 baseline, to be measured) by 30%. ▪ Average sediment composition in any survey (% fractions) in each of the lakes change from that of the Present State (2014/2015 baseline, to be measured) by 5%. ▪ Average bathymetry along main channel change by 30% in any survey along estuary from that of the Present State (2014/2015 baseline, to be measured) (system expected to significantly fluctuate in terms of bathymetry between flood and extended closed periods). ▪ Average bathymetry change by 2 to 5% in any survey in each of the lakes from that of the Present State (2014/2015 baseline, to be measured). ▪ Average bathymetry along connecting channels to be

EcoSpecs	TPCs
	maintained (average depth threshold to be determined following a baseline monitoring survey).
Water quality	
Salinity	Estuary in the closed state: ▪ Average salinity in Zone A < 12. ▪ Average salinity in Zone B: < 10. ▪ Average salinity in Zone C < 5. Lakes average salinity +2 from baseline (2013) and variability do not increase as below: ▪ Serpentine: 12 ± 10. ▪ Eilandvlei: 8 ± 5. ▪ Langvlei: 10 ±4. ▪ Rondevlei: 10 ±5.
System variables (pH, DO and turbidity) not to cause exceedance of TPCs for biota (see below).	River inflow: ▪ 6.0 < pH > 7.0 (Touws River). ▪ 7.0 < pH > 8.0 (Duiwenhoks River). ▪ DO < 5 mg/L. ▪ Suspended solids > 5 mg/L (low flow). Estuary: ▪ Average turbidity > 5 NTU (low flow). ▪ Average 6.0 < pH > 8.5 (increasing with increase in salinity). ▪ Average DO < 5 mg/L. Lakes: ▪ Average turbidity > 5 NTU. ▪ Average 7.0 < pH > 8.5. ▪ Average DO < 5 mg/L.
Inorganic nutrient concentrations (NO_3-N, NH_3-N and PO_4-P) not to cause in exceedance of TPCs for macrophytes and microalgae (see below).	River inflow: ▪ NO_x-N > 50 µg/L over two consecutive months. ▪ NH_3-N > 10 µg/L over two consecutive months. ▪ PO_4-P > 10 µg/L over two consecutive months. Estuary (except during upwelling or floods): ▪ Average NO_x-N > 50 µg/L single concentration > 100 µg/L. ▪ Average NH_3-N > 10 µg/L during survey, single concentration > 100 µg/L. ▪ Average PO_4-P > 10 µg/L during survey, single concentration > 50 µg/L. Lakes: ▪ Average NO_x-N > 50 µg/L during survey, single concentration > 100 µg/L. ▪ Average NH_3-N > 20 µg/L during survey (to be refined and confirmed through future monitoring). ▪ Average PO_4-P > 20 µg/L during survey (to be confirmed.)
Presence of toxic substances (e.g. trace metals and pesticides/herbicides) not to cause exceedance of TPCs for biota (see below).	River inflow: ▪ Trace metals (to be refined and confirmed through future monitoring). ▪ Pesticides/herbicides (to be refined and confirmed through future monitoring). Estuary: ▪ Concentrations in water column exceed target values as per SA Water Quality Guidelines for Coastal Marine Waters (DWAF, 1995). ▪ Concentrations in sediment exceed target values as per WIO Region guidelines (UNEP and CSIR, 2009).

EcoSpecs	TPCs
Microalgae	
▪ Maintain low median phytoplankton biomass. ▪ Maintain medium median benthic microalgal biomass. ▪ Prevent formation of phytoplankton blooms. ▪ Prevent dramatic shift of phytoplankton community structure.	▪ Median phytoplankton chlorophyll-a (minimum five sites) exceeds 3.5 µg/L during any survey. ▪ Median intertidal benthic chlorophyll-a (minimum five sites) exceeds 23 mg/m^2 during any survey. ▪ Site specific chlorophyll-a concentration exceeds 20 µg/L and/or cell density exceeds 10 000 cells/ml during any survey. ▪ Dinoflagellates, cyanobacteria and/or chlorophytes > 10% of relative abundance during any survey.
Macrophytes	
▪ Maintain the distribution of sensitive macrophyte habitats (e.g. salt marsh, submerged macrophytes). ▪ No invasive plants. ▪ Prevent the spread of reeds into open water.	▪ Greater than 20% change in the area covered by submerged macrophytes and salt marsh due to disturbance, freshening of the system and changes in turbidity. ▪ Presence of invasive floating aquatic macrophytes, ▪ Invasive plants cover > 5% of total floodplain area. ▪ Increase in reeds and sedges and encroachment into main water channel due to infilling and drop in water level.
Invertebrates	
▪ Maintain presence of sand prawn *C. kraussi* on sand banks in lower Touw estuary. ▪ Maintain rich populations of the benthic amphipod *G. lignorum* throughout the lakes and estuary.	Populations should not deviate from average baseline values (as determined in first three visits) by more 30%.
Fish	
Fish assemblage should comprise the five estuarine association categories in similar proportions (diversity and abundance) to that under the reference (DWS, 2014b). Relative proportions should be roughly similar to that currently in the Touw Estuary and Wilderness Lakes. Numerically assemblage should comprise: ▪ Ia estuarine residents (20 - 60% of total abundance). ▪ Ib marine and estuarine breeders (20 - 60%). ▪ IIa obligate estuarine-dependent (5 - 10%). ▪ IIb estuarine associated species (1 - 10%). ▪ IIc marine opportunists (5 - 20%). ▪ III marine vagrants (not more than 5%). ▪ IV indigenous fish (1 - 5%). ▪ V catadromous species (1 - 5%). Category Ia species should contain viable populations of at least four species (including *G. aestuaria, H. capensis,* and *O. woodii*). Category IIa obligate dependents should be well represented by large exploited species especially *A. japonicus, L. lithognathus, P. commersonii,* and *L. amia.*	▪ Ia estuarine residents < 20% ▪ Ib marine and estuarine breeders < 20% ▪ IIa obligate estuarine-dependent < 5% ▪ IIb estuarine associated species < 1% ▪ IIc marine opportunists < 5% ▪ III marine vagrants > 5% ▪ IV indigenous fish < 1% ▪ V catadromous species < 1% ▪ Ia represented only by *G. aestuaria*. ▪ IIa exploited species in very low numbers or absent. ▪ REI species represented only by *G. aestuaria*, *M. capensis* absent.

EcoSpecs	TPCs
REI species dominated by both *M. capensis* and *G. aestuaria*.	
Birds	
The estuarine lake system should contain a diverse avifaunal community that includes representatives of all the original groups, and that sustains the populations for which the system has acquired Ramsar status.	Numbers of waterbirds on the entire system, other than those that have or are increasing regionally such as Egyptian Goose, drops below 40 species or below 1500 birds for three consecutive counts.

5.11 GOUKAMMA ESTUARY

The EcoSpecs and TPCs representative of a REC (Category A) for the Goukamma Estuary are presented in **Table 5.11**.

Table 5.11 EcoSpecs and TPCs for the Goukamma Estuary (REC: A)

EcoSpecs	TPCs
Hydrology	
Maintain flow regime.	Varies more than 10% of MAR.
Hydrodynamics	
Maintain mouth state to create the required habitat for birds, fish, macrophytes, microalgae and water quality.	▪ Closed mouth state varies by > 10% from present. ▪ Average water depth < 0.5 m in lower reaches (to be confirmed by monitoring). ▪ Average water depth < 2.5 m in middle and upper reaches (to be confirmed by monitoring) 9expected range 2.0 to 3.0 m). ▪ Average water level change by more than 20% from present.
Water quality	
▪ Salinity distribution not to cause exceedance of TPCs for fish, invertebrates, macrophytes and microalgae. ▪ Turbidity and DO not to cause exceedance of TPCs for biota. ▪ DIN/DIP concentrations not to cause in exceedance of TPCs for macrophytes and microalgae. ▪ Toxic substances not to cause exceedance of TPCs for biota.	▪ Average salinity not between 15 - 35 in lower reaches. ▪ Salinity > 10 in upper reaches. ▪ DO < 5 mg/L in estuary. ▪ Turbidity > 10 NTU in low flow. ▪ Secchi: To bottom. ▪ DIN > 100 µg/L once-off. ▪ DIP > 20 µg/L once-off. ▪ Concentrations in water column exceed target values as per SA Water Quality Guidelines for Coastal Marine Waters (DWAF, 1995). ▪ Concentrations in sediment exceed target values as per WIO Region guidelines (UNEP/Nairobi Convention Secretariat and CSIR, 2009).
Sediment dynamics	
▪ Flood regime to maintain the sediment distribution patterns and aquatic habitat (instream physical habitat) so as not to exceed TPCs for biota. ▪ Changes in sediment grain size distribution patterns not to cause exceedance of TPCs in benthic invertebrates. ▪ Change in average sediment composition	▪ Average sediment composition (% fractions) along estuary change from baseline (to be measured) by 30% (per survey). ▪ Average depth along main channel change from 30% of baseline (to be determine) (system expected to significant fluctuation in bathymetry between flood and extended closed periods).

EcoSpecs	TPCs
and characteristics. ▪ Change in average bathymetry.	
Microalgae	
Maintain median phytoplankton/benthic microalgae biomass. Prevent formation of phytoplankton blooms.	▪ Phytoplankton > 1.0 µg/L (median). ▪ Benthic microalgae > 11 mg/m^2 (median). ▪ Phytoplankton > 20 µg/L and/or cell density >10 000 cells/ml (once-off).
Macrophytes	
Maintain distribution of macrophyte habitats. Prevent the spread of invasive trees (e.g. *Acacia* spp.) in the riparian zone.	▪ 20% change in the macrophyte area (reeds currently cover 4.1 ha and salt marsh 7.2 ha). ▪ Invasive plants cover > 20% of riparian zone.
Invertebrates	
▪ Establish presence absence of sand prawn *C. krauss*i on sand banks in lower estuary. ▪ Establish presence absence of the copepod *P. hessei* or estuarine congeneric in the zooplankton of the estuary.	If present populations deviate from average baselines (as determined in first three visits) by more 30%.
Fish	
Fish assemblage should comprise the five estuarine association categories in similar proportions (diversity and abundance) to that under the present. Numerically assemblage should comprise: ▪ Ia estuarine residents (50 - 80% of total abundance). ▪ Ib marine and estuarine breeders (5 - 20%). ▪ IIa obligate estuarine-dependent (10 - 20%). ▪ IIb estuarine associated species (5 - 15%). ▪ IIc marine opportunists (20 - 80%). ▪ III marine vagrants (not more than 5%). ▪ IV indigenous fish (1 - 5%). ▪ V catadromous species (1 - 5%). Category Ia species should contain viable populations of at least two species (e.g. *G. aestuaria,* and *H. capensis*). Category IIa obligate dependents should be well represented by at least two large exploited species (*L. lithognathus,* and *L. amia*). REI species dominated by both *M. capensis* and *G. aestuaria*.	▪ Ia estuarine residents < 50%. ▪ Ib marine and estuarine breeders < 10%. ▪ IIa obligate estuarine-dependent < 10%. ▪ IIb estuarine associated species < 5%. ▪ IIc marine opportunists < 20%. ▪ III marine vagrants > 5%. ▪ IV indigenous fish < 1%. ▪ V catadromous species < 1%. ▪ Species composition > 50% similar to last three sampling trip (system naturally highly unstable due to resetting events).
Birds	
Maintain population of original groups of birds present on the estuary.	Number of birds in any group, other than species that are increasing regionally such as Egyptian geese, drops below the baseline median (determined by past data and or initial surveys) number of species and/or birds counted for three consecutive summer or winter counts.

5.12 NOETSIE ESTUARY

The EcoSpecs and TPCs representative of a REC (Category A) for the Noetsie Estuary are presented in **Table 5.12**.

Table 5.12 EcoSpecs and TPCs for the Noetsie Estuary (REC: A)

EcoSpecs	TPCs
Hydrology	
Maintain flow regime.	Varies more than 10% of MAR.
Hydrodynamics	
Maintain mouth state to create the required habitat for birds, fish, macrophytes, microalgae and water quality.	▪ Closed mouth state varies by > 10% from present. ▪ Average water depth < 1.0 m (to be confirmed by monitoring). ▪ Average water level change by more than 20% from present.
Water quality	
▪ Salinity distribution not to cause exceedance of TPCs for fish, invertebrates, macrophytes and microalgae. ▪ Turbidity and DO not to cause exceedance of TPCs for biota. ▪ DIN/DIP concentrations not to cause in exceedance of TPCs for macrophytes and microalgae. ▪ Toxic substances not to cause exceedance of TPCs for biota.	▪ Average Salinity < 10 (expected average range 10 - 20) ▪ DO < 5 mg/L in estuary. ▪ Turbidity > 10 NTU in low flow. ▪ Secchi: To bottom. ▪ DIN >100 µg/L once-off. ▪ DIP > 20 µg/L once-off. ▪ Concentrations in water column exceed target values as per SA Water Quality Guidelines for Coastal Marine Waters (DWAF, 1995). ▪ Concentrations in sediment exceed target values as per WIO Region guidelines (UNEP/Nairobi Convention Secretariat and CSIR, 2009).
Sediment dynamics	
▪ Flood regime to maintain the sediment distribution patterns and aquatic habitat (instream physical habitat) so as not to exceed TPCs for biota. ▪ Changes in sediment grain size distribution patterns not to cause exceedance of TPCs in benthic invertebrates. ▪ Change in average sediment composition and characteristics. ▪ Change in average bathymetry.	▪ Average sediment composition (% fractions) along estuary change from baseline (to be measured) by 30% (per survey). ▪ Average depth along main channel change from 30% of baseline (to be determine) (system expected to significant fluctuation in bathymetry between flood and extended closed periods).
Microalgae	
▪ Maintain median phytoplankton/benthic microalgae biomass. ▪ Prevent formation of phytoplankton blooms.	▪ Phytoplankton > 1.0 µg/L (median). ▪ Benthic microalgae > 11 mg/m^2 (median). ▪ Phytoplankton > 20 µg/L and/or cell density >10 000 cells/ml (once-off).
Macrophytes	
▪ Maintain distribution of macrophyte habitats. ▪ Prevent an increase in nutrient input leading to macroalgal blooms.	▪ Greater than 20% change in the area covered by macrophytes (submerged macrophytes currently cover 0.1 ha and reeds and sedges 2.71 ha). ▪ Macroalgal blooms cover > 50% of the open water area.

EcoSpecs	TPCs
Invertebrates	
▪ Establish presence absence of sand prawn *C. kraussi* on sand banks in lower estuary. ▪ Establish presence absence of the copepod *P. hessei* or estuarine congeneric in the zooplankton of the estuary.	If present populations deviate from average baselines (as determined in first three visits) by more 30%.
Fish	
Fish assemblage should comprise the five estuarine association categories in similar proportions (diversity and abundance) to that under the reference. Numerically assemblage should comprise: ▪ Ia estuarine residents (50 - 80% of total abundance). ▪ Ib marine and estuarine breeders (5 - 20%). ▪ IIa obligate estuarine-dependent (10 - 20%). ▪ IIb estuarine associated species (5 - 15%). ▪ IIc marine opportunists (20 - 80%). ▪ III marine vagrants (not more than 5%). ▪ IV indigenous fish (1 - 5%). ▪ V catadromous species (1 - 5%). Category Ia species should contain viable populations of at least two species (e.g. *G. aestuaria,* and *H. capensis*). Category IIa obligate dependents should be well represented by at least two large exploited species (i.e. *L. lithognathus,* and *Lichia amia*). REI species dominated by both *M. capensis* and *G. aestuaria*.	▪ Ia estuarine residents < 50%. ▪ Ib marine and estuarine breeders < 10%. ▪ IIa obligate estuarine-dependent < 10%. ▪ IIb estuarine associated species < 5%. ▪ IIc marine opportunists < 20%. ▪ III marine vagrants > 5%. ▪ IV indigenous fish <1%. ▪ V catadromous species < 1%.
Birds	
Maintain population of original groups of birds present on the estuary.	Number of birds in any group, other than species that are increasing regionally such as Egyptian geese, drops below the baseline median (determined by past data and or initial surveys) number of species and/or birds counted for three consecutive summer or winter counts.

5.13 PIESANG ESTUARY

The EcoSpecs and TPCs representative of a REC (Category B/C) for the Piesang Estuary are presented in **Table 5.13**.

Table 5.13 EcoSpecs and TPCs for the Piesang Estuary (REC: B/C)

EcoSpecs	TPCs
Hydrology	
Maintain present day base flows.	▪ MAR does not vary by more than 10%. ▪ Floods (indicated by 1:10 year event) do not reduce by more than 5% from present. ▪ Base flows do not increase by more than 50% from present.
Hydrodynamics	
Maintain mouth state to create the required habitat for birds, fish, macrophytes, microalgae and water quality.	▪ Closed mouth state increase by 10% from present. ▪ Average water level in system > 10% from present. ▪ Tidal amplitude (when open) < 20%.
Water quality	
▪ Salinity distribution not to cause exceedance of TPCs for fish, invertebrates, macrophytes and microalgae. ▪ Turbidity and DO not to cause exceedance of TPCs for biota. ▪ DIN/DIP concentrations not to cause in exceedance of TPCs for macrophytes and microalgae. ▪ Toxic substances not to cause exceedance of TPCs for biota.	▪ Salinity > 20 (expected range 10 - 20). ▪ Salinity < 5 (expected range 10 - 20). ▪ DO < 5 mg/L in estuary. ▪ Turbidity > 10 NTU in low flow ▪ Secchi: To bottom. ▪ DIN > 100 µg/L once-off. ▪ DIP > 20 µg/L once-off. ▪ Concentrations in water column exceed target values as per SA Water Quality Guidelines for Coastal Marine Waters (DWAF, 1995). ▪ Concentrations in sediment exceed target values as per WIO Region guidelines (UNEP/Nairobi Convention Secretariat and CSIR, 2009).
Sediment dynamics	
▪ Flood regime to maintain the sediment distribution patterns and aquatic habitat (instream physical habitat) so as not to exceed TPCs for biota. ▪ Changes in sediment grain size distribution patterns not to cause exceedance of TPCs in benthic invertebrates. ▪ Change in average sediment composition and characteristics. ▪ Change in average bathymetry.	▪ Average sediment composition (% fractions) along estuary change from baseline (to be measured) by 30% (per survey). ▪ Average depth along main channel change from 30% of baseline (to be determine) (system expected to significant fluctuation in bathymetry between flood and extended closed periods).
Microalgae	
▪ Maintain median phytoplankton/benthic microalgae biomass. ▪ Prevent formation of phytoplankton blooms.	▪ Phytoplankton > 3.5 µg/L (median). ▪ Benthic microalgae > 11 mg/m^2 (median). ▪ Phytoplankton > 20 µg/L and/or cell density >10 000 cells/ml (once-off).
Macrophytes	
▪ Maintain distribution of macrophyte habitats. ▪ Prevent an increase in nutrient input leading to macroalgal blooms. ▪ Control the spread of invasive plants in the riparian zone.	▪ Greater than 20% change in the area covered by macrophytes (reeds and sedges currently cover 3.14 ha, submerged macrophytes and salt marsh present). ▪ Macroalgal blooms cover > 50% of the open water area during closed mouth conditions. ▪ Invasive plants cover > 5% of total habitat.

EcoSpecs	TPCs
Invertebrates	
▪ Maintain presence of sand prawn *C. kraussi* on sand banks in lower estuary. ▪ Maintain presence of the copepod *P. hessei* or estuarine congeneric in the zooplankton of the estuary.	Populations deviate from average baselines (as determined in first three visits) by more 30%.
Fish	
Fish assemblage should comprise the five estuarine association categories in similar proportions (diversity and abundance) to that under the reference. Numerically assemblage should comprise: ▪ Ia estuarine residents (50 - 80% of total abundance). ▪ Ib marine and estuarine breeders (5 - 20%). ▪ IIa obligate estuarine-dependent (10 - 20%). ▪ IIb estuarine associated species (5 - 15%). ▪ IIc marine opportunists (20 - 80%). ▪ III marine vagrants (not more than 5%). ▪ IV indigenous fish (1 - 5%). ▪ V catadromous species (1 - 5%). Category Ia species should contain viable populations of at least two species (e.g. *G. aestuaria,* and *H. capensis*). Category IIa obligate dependents should be well represented by at least two large exploited species (i.e. *L. lithognathus,* and *Lichia amia*). REI species dominated by both *M. capensis* and *G. aestuaria*.	▪ Ia estuarine residents < 50%. ▪ Ib marine and estuarine breeders < 10%. ▪ IIa obligate estuarine-dependent < 10%. ▪ IIb estuarine associated species < 5%. ▪ IIc marine opportunists < 20%. ▪ III marine vagrants > 5%. ▪ IV indigenous fish <1%. ▪ V catadromous species < 1%.
Birds	
Maintain population of original groups of birds present on the estuary.	Number of birds in any group, other than species that are increasing regionally such as Egyptian geese, drops below the baseline median (determined by past data and or initial surveys) number of species and/or birds counted for three consecutive summer or winter counts.

5.14 KEURBOOMS ESTUARY

The EcoSpecs and TPCs representative of a REC (Category A/B) for the Keurbooms Estuary are presented in **Table 5.14**.

Table 5.14 EcoSpecs and TPCs for the Keurbooms Estuary (REC: A/B)

EcoSpecs	TPCs
Hydrology	
Maintain flow regime.	▪ Varies more than 10% of present MAR. ▪ Inflow < 1.0 m^3/s for more than 10% of the time over a 5 year period.
Hydrodynamics	
Maintain mouth state to create the required habitat for birds, fish, macrophytes, microalgae and water quality.	▪ Mouth closure occurs. ▪ Average water level change by more than 20% from present. ▪ Mouth entrance channel becomes < 1.0 m deep.
Water quality	
▪ Salinity distribution not to cause exceedance of TPCs for fish, invertebrates, macrophytes and microalgae. ▪ Turbidity and DO not to cause exceedance of TPCs for biota. ▪ DIN/DIP concentrations not to cause in exceedance of TPCs for macrophytes and microalgae. ▪ Toxic substances not to cause exceedance of TPCs for biota.	▪ Average salinity > 10 at the top of the estuary in the Keurbooms and/or Bitou Arms. ▪ Average salinity > 20 along the length of the system (to be confirmed by monitoring). ▪ DO < 5 mg/L in estuary. ▪ Turbidity > 10 NTU in low flow. ▪ Secchi: To bottom. ▪ DIN > 100 µg/L once-off. ▪ DIP > 20 µg/L once-off. ▪ Concentrations in water column exceed target values as per SA Water Quality Guidelines for Coastal Marine Waters (DWAF, 1995). ▪ Concentrations in sediment exceed target values as per WIO Region guidelines (UNEP/Nairobi Convention Secretariat and CSIR, 2009).
Sediment dynamics	
▪ Flood regime to maintain the sediment distribution patterns and aquatic habitat (instream physical habitat) so as not to exceed TPCs for biota. ▪ Changes in sediment grain size distribution patterns not to cause exceedance of TPCs in benthic invertebrates. ▪ Change in average sediment composition and characteristics. ▪ Change in average bathymetry.	▪ Average sediment composition (% fractions) along estuary change from baseline (to be measured) by 30% (per survey). ▪ Average depth along main channel change from 30% of baseline (to be determine) (system expected to significant fluctuation in bathymetry between flood and extended closed periods).
Microalgae	
▪ Maintain median phytoplankton/ benthic microalgae biomass. ▪ Prevent formation of phytoplankton blooms.	▪ Phytoplankton > 3.5 µg/L (median). ▪ Benthic microalgae >11 mg/m^2 (median). ▪ Phytoplankton > 20 µg/L and/or cell density >10 000 cells/ml (once-off).
Macrophytes	
▪ Maintain the distribution of sensitive macrophyte habitats (e.g. salt marsh, submerged macrophytes, reeds and sedges) (of special importance are the submerged macrophytes in the Bitou Arms as habitat for the endangered seahorses *H. capensis*). ▪ Rehabilitate the Bitou wetlands by removing weirs, berms, old bridges.	▪ Greater than 20% change in the area covered by salt marsh, submerged macrophytes and reeds and sedges. ▪ No weirs, berms, old bridges in the Bitou wetlands. ▪ Invasive plants cover less than 5% of the total estuarine area. ▪ Unvegetated cleared areas along the banks caused by human disturbance.

EcoSpecs	TPCs
▪ Limit the spread of invasive plants. ▪ Maintain the integrity of the riparian zone.	
Invertebrates	
▪ Maintain high biomass and diversity of benthic invertebrates in the lagoon area in the lower estuary. ▪ Maintain rich invertebrate communities associated with the REI zone in the upper estuary (zooplankton and benthos).	▪ Invertebrate densities of each of the three numerically dominant benthic species should not deviate from average baseline levels (as determined in the eight visits undertaken quarterly in the first two years) by more than 30% in each season. ▪ The dominant species in the zone (zooplankton and benthos) should not deviate from average baseline levels (as determined in the eight visits undertaken quarterly in the first two years) by more than 30% in each season.
Fish	
Fish assemblage should comprise the five estuarine association categories in similar proportions (diversity and abundance) to that under the reference (CSIR, 2008). Numerically assemblage should comprise: ▪ Ia estuarine residents (50 - 80% of total abundance). ▪ Ib marine and estuarine breeders (10 - 20%). ▪ IIa obligate estuarine-dependent (10 - 20%). ▪ IIb estuarine associated species (5 - 15%). ▪ IIc marine opportunists (20 - 80%). ▪ III marine vagrants (not more than 5%). ▪ IV indigenous fish (1 - 5%). V catadromous species (1 - 5%). Category Ia species should contain viable populations of at least 4 species (*G. aestuaria, Hyporamphus capensis,* and *O. woodii*). Category IIa obligate dependents should be well represented by large exploited species (*A. japonicus, L. lithognathus, P. commersonii,* and *L. amia*). REI species dominated by both *M. capensis* and *G. aestuaria*.	▪ Ia estuarine residents < 50%. ▪ Ib marine and estuarine breeders < 10%. ▪ IIa obligate estuarine-dependent < 10%. ▪ IIb estuarine associated species < 5%. ▪ IIc marine opportunists < 20%. ▪ III marine vagrants > 5%. ▪ IV indigenous fish < 1%. ▪ V catadromous species < 1%. ▪ Abundance of *H. capensis* deviates by more than 10% from baseline (Project Seahorse studies, e.g. Lockyear *et al*., 2006; Bell *et al*., 2003).
Birds	
Maintain population of original groups of birds present on the estuary.	Number of birds in any group, other than species that are increasing regionally such as Egyptian geese, drops below the baseline median (determined by past data and or initial surveys) number of species and/or birds counted for three consecutive summer or winter counts.

5.15 MATJIES ESTUARY

The EcoSpecs and TPCs representative of a REC (Category B) for the Matjies Estuary are presented in **Table 5.15**.

Table 5.15 EcoSpecs and TPCs for the Matjies Estuary (REC: B)

EcoSpecs	TPCs
Hydrology	
Maintain flow regime.	▪ Varies more than 10% of MAR. ▪ Inflow < 0.03 m^3/s for more than 27% of the time over a 5 year period. ▪ Inflow < 0.1 m^3/s for more than 55% of the time over a 5 year period.
Hydrodynamics	
Maintain mouth state to create the required habitat for birds, fish, macrophytes, microalgae and water quality.	▪ Closed mouth state varies by > 10% from present. ▪ Average water depth < 1.0 m Average water level change by more than 20% from present.
Water quality	
▪ Salinity distribution not to cause exceedance of TPCs for fish, invertebrates, macrophytes and microalgae. ▪ Turbidity and DO not to cause exceedance of TPCs for biota. ▪ DIN/DIP concentrations not to cause in exceedance of TPCs for macrophytes and microalgae. ▪ Toxic substances not to cause exceedance of TPCs for biota.	▪ Average Salinity > 20 for more than 20% of the time (indicative of flow reduction). ▪ Average Salinity < 5 for more than 20% of the time (indicative of extended closure). ▪ DO < 5 mg/L in estuary. ▪ Turbidity > 10 NTU in low flow. ▪ Secchi: To bottom. ▪ DIN > 100 µg/L once-off. ▪ DIP > 20 µg/L once-off. ▪ Concentrations in water column exceed target values as per SA Water Quality Guidelines for Coastal Marine Waters (DWAF, 1995). ▪ Concentrations in sediment exceed target values as per WIO Region guidelines (UNEP/Nairobi Convention Secretariat and CSIR, 2009).
Sediment dynamics	
▪ Flood regime to maintain the sediment distribution patterns and aquatic habitat (instream physical habitat) so as not to exceed TPCs for biota. ▪ Changes in sediment grain size distribution patterns not to cause exceedance of TPCs in benthic invertebrates. ▪ Change in average sediment composition and characteristics. ▪ Change in average bathymetry.	▪ Average sediment composition (% fractions) along estuary change from baseline (to be measured) by 30% (per survey). ▪ Average depth along main channel change from 30% of baseline (to be determined) (significant fluctuation in bathymetry between flood and extended closed periods is expected within system).
Microalgae	
▪ Maintain median phytoplankton/benthic microalgae biomass. ▪ Prevent formation of phytoplankton blooms.	▪ Phytoplankton > 3.5 µg/L (median). ▪ Benthic microalgae >11 mg/m^2 (median). ▪ Phytoplankton > 20 µg/L and/or cell density >10 000 cells/ml (once-off).
Macrophytes	
▪ Maintain distribution of macrophyte habitats. ▪ Prevent an increase in nutrient input leading to macroalgal blooms. ▪ Control the spread of invasive plants in the riparian zone.	▪ Greater than 20% change in the area covered by macrophytes (reeds and sedges currently cover 0.2 ha). ▪ Macroalgal blooms cover > 50% of the open water area during closed mouth conditions. ▪ Invasive plants cover > 5% of total habitat.

EcoSpecs	TPCs
Invertebrates	
▪ Establish presence absence of sand prawn *C. kraussi* on sand banks in lower estuary. ▪ Establish presence absence of the copepod *P. hessei* or estuarine congeneric in the zooplankton of the estuary.	If present populations deviate from average baselines (as determined in first three visits) by more 30%.
Fish	
Fish assemblage should comprise the five estuarine association categories in similar proportions (diversity and abundance) to that under the reference. Numerically assemblage should comprise: ▪ Ia estuarine residents (50 - 80% of total abundance). ▪ Ib marine and estuarine breeders (5 - 20%). ▪ IIa obligate estuarine-dependent (10 - 20%). ▪ IIb estuarine associated species (5 - 15%). ▪ IIc marine opportunists (20 - 80%). ▪ III marine vagrants (not more than 5%). ▪ IV indigenous fish (1 - 5%). ▪ V catadromous species (1 - 5%). Category Ia species should contain viable populations of at least two species (e.g. *G. aestuaria,* and *H. capensis*). Category IIa obligate dependents should be well represented by at least two large exploited species (i.e. *L. lithognathus,* and *Lichia amia*). REI species dominated by both *M. capensis* and *G. aestuaria*.	▪ Ia estuarine residents < 50%. ▪ Ib marine and estuarine breeders < 10%. ▪ IIa obligate estuarine-dependent < 10%. ▪ IIb estuarine associated species < 5%. ▪ IIc marine opportunists < 20%. ▪ III marine vagrants > 5%. ▪ IV indigenous fish < 1%. ▪ V catadromous species < 1%.
Birds	
Maintain population of original groups of birds present on the estuary.	Number of birds in any group, other than species that are increasing regionally such as Egyptian geese, drops below the baseline median (determined by past data and or initial surveys) number of species and/or birds counted for three consecutive summer or winter counts.

5.16 SOUT (OOS) ESTUARY

The EcoSpecs and TPCs representative of a REC (Category A) for the Sout (Oos) Estuary are presented in **Table 5.16**.

Table 5.16 EcoSpecs and TPCs for the Sout (Oos) Estuary (REC: A)

EcoSpecs	TPCs
Hydrology	
Maintain present day base flows.	▪ MAR does not vary by more than 10%. ▪ Floods (indicated by 1:10 year event) do not reduce by more than 5% from present. ▪ Base flows do not increase by more than 50% from present.
Hydrodynamics	
Maintain mouth state to create the required habitat for birds, fish, macrophytes, microalgae and water quality.	▪ Closed mouth state increase by 10% from present. ▪ Average water level in system > 10% from present. ▪ Tidal amplitude (when open) < 20%.
Water quality	
▪ Salinity distribution not to cause exceedance of TPCs for fish, invertebrates, macrophytes and microalgae. ▪ Turbidity and DO not to cause exceedance of TPCs for biota. ▪ DIN/DIP concentrations not to cause in exceedance of TPCs for macrophytes and microalgae. ▪ Toxic substances not to cause exceedance of TPCs for biota.	▪ Average salinity along estuary decrease by 5 below baseline average (to be determined). ▪ Average salinity < 10 at the head of the estuary (expected average range 5 - 10 for most of the system) ▪ DO < 5 mg/L in estuary. ▪ Turbidity > 10 NTU in low flow. ▪ Secchi: To bottom. ▪ DIN > 100 µg/L once-off. ▪ DIP > 20 µg/L once-off. ▪ Concentrations in water column exceed target values as per SA Water Quality Guidelines for Coastal Marine Waters (DWAF, 1995). ▪ Concentrations in sediment exceed target values as per WIO Region guidelines (UNEP/Nairobi Convention Secretariat and CSIR, 2009).
Sediment dynamics	
▪ Flood regime to maintain the sediment distribution patterns and aquatic habitat (instream physical habitat) so as not to exceed TPCs for biota. ▪ Changes in sediment grain size distribution patterns not to cause exceedance of TPCs in benthic invertebrates. ▪ Change in average sediment composition and characteristics. ▪ Change in average bathymetry.	▪ Average sediment composition (% fractions) along estuary change from baseline (to be measured) by 30% (per survey). ▪ Average depth along main channel change from 30% of baseline (to be determined) (significant fluctuation in bathymetry between flood and extended closed periods is expected within system).
Microalgae	
▪ Maintain median phytoplankton/benthic microalgae biomass. ▪ Prevent formation of phytoplankton blooms.	▪ Phytoplankton > 3.5 µg/L (median). ▪ Benthic microalgae > 11 mg/m^2 (median). ▪ Phytoplankton > 20 µg/L and/or cell density >10 000 cells/ml (once-off).
Macrophytes	
▪ Maintain distribution of macrophyte habitats. ▪ Prevent an increase in nutrient input leading to macroalgal blooms. ▪ Control the spread of invasive plants in the riparian zone.	▪ Greater than 20% change in the area covered by macrophytes (reeds and sedges currently cover 2.54 ha salt marsh 0.76 ha). ▪ Macroalgal blooms cover > 50% of the open water area during closed mouth conditions. ▪ Invasive plants cover > 5% of total habitat.

EcoSpecs	TPCs
Invertebrates	
▪ Establish presence absence of sand prawn *C. kraussi* on sand banks in lower estuary. ▪ Establish presence absence of the copepod *P. hessei* or estuarine congeneric in the zooplankton of the estuary.	If present populations deviate from average baselines (as determined in first three visits) by more 30%.
Fish	
Fish assemblage should comprise the five estuarine association categories in similar proportions (diversity and abundance) to that under the reference. Numerically assemblage should comprise: ▪ Ia estuarine residents (50 - 80% of total abundance). ▪ Ib marine and estuarine breeders (5 - 20%). ▪ IIa obligate estuarine-dependent (10 - 20%). ▪ IIb estuarine associated species (5 - 15%). ▪ IIc marine opportunists (20 - 80%). ▪ III marine vagrants (not more than 5%). ▪ IV indigenous fish (1 - 5%). ▪ V catadromous species (1 - 5%). Category Ia species should contain viable populations of at least two species (e.g. *G. aestuaria,* and *H. capensis*). Category IIa obligate dependents should be well represented by at least two large exploited species (i.e. *L. lithognathus,* and *Lichia amia*). REI species dominated by both *M. capensis* and *G. aestuaria*.	Ia estuarine residents < 50%. Ib marine and estuarine breeders < 10%. IIa obligate estuarine-dependent < 10%. IIb estuarine associated species < 5%. IIc marine opportunists < 20%. III marine vagrants > 5%. IV indigenous fish < 1%. V catadromous species < 1%.
Birds	
Maintain population of original groups of birds present on the estuary.	Number of birds in any group, other than species that are increasing regionally such as Egyptian geese, drops below the baseline median (determined by past data and or initial surveys) number of species and/or birds counted for three consecutive summer or winter counts.

5.17 GROOT (WES) ESTUARY

The EcoSpecs and TPCs representative of a REC (Category A) for the Groot (Wes) Estuary are presented in **Table 5.17**.

Table 5.17 EcoSpecs and TPCs for the Groot (Wes) Estuary (REC: A)

EcoSpecs	TPCs
Hydrology	
Maintain present day base flows.	▪ MAR does not vary by more than 10%. ▪ Floods (indicated by 1:10 year event) do not reduce by more than 5% from present. ▪ Base flows do not increase by more than 50% from present.
Hydrodynamics	
Maintain mouth state to create the required habitat for birds, fish, macrophytes, microalgae and water quality.	▪ Closed mouth state increase by 10% from present. ▪ Average water level in system > 10% from present. ▪ Tidal amplitude (when open) < 20%.
Water quality	
▪ Salinity distribution not to cause exceedance of TPCs for fish, invertebrates, macrophytes and microalgae. ▪ Turbidity and DO not to cause exceedance of TPCs for biota. ▪ DIN/DIP concentrations not to cause in exceedance of TPCs for macrophytes and microalgae. ▪ Toxic substances not to cause exceedance of TPCs for biota.	▪ Average salinity along estuary decrease by five below baseline average (to be determined). ▪ Average salinity < 10 at the head of the estuary (expected average range 5 - 10 for most of the system). ▪ DO < 5 mg/L in estuary. ▪ Turbidity > 10 NTU in low flow. ▪ Secchi: to bottom. ▪ DIN > 100 µg/L once-off. ▪ DIP > 20 µg/L once-off. ▪ Concentrations in water column exceed target values as per SA Water Quality Guidelines for Coastal Marine Waters (DWAF, 1995). ▪ Concentrations in sediment exceed target values as per WIO Region guidelines (UNEP/Nairobi Convention Secretariat and CSIR, 2009).
Sediment dynamics	
▪ Flood regime to maintain the sediment distribution patterns and aquatic habitat (instream physical habitat) so as not to exceed TPCs for biota. ▪ Changes in sediment grain size distribution patterns not to cause exceedance of TPCs in benthic invertebrates. ▪ Change in average sediment composition and characteristics. ▪ Change in average bathymetry.	▪ Average sediment composition (% fractions) along estuary change from baseline (to be measured) by 30% (per survey). ▪ Average depth along main channel change from 30% of baseline (to be determine) (system expected to significant fluctuation in bathymetry between flood and extended closed periods).
Microalgae	
▪ Maintain median phytoplankton/benthic microalgae biomass. ▪ Prevent formation of phytoplankton blooms.	▪ Phytoplankton > 3.5 µg/L (median). ▪ Benthic microalgae >11 mg/m^2 (median). ▪ Phytoplankton > 20 µg/L and/or cell density >10 000 cells/ml (once-off).
Macrophytes	
▪ Maintain distribution of macrophyte habitats. ▪ Prevent an increase in nutrient input leading to macroalgal blooms. ▪ Control the spread of invasive plants in the riparian zone.	▪ Greater than 20% change in the area covered by macrophytes (reeds and sedges currently cover 2.54 ha salt marsh 0.76 ha). ▪ Macroalgal blooms cover > 50% of the open water area during closed mouth conditions. ▪ Invasive plants cover > 5% of total habitat.

EcoSpecs	TPCs
Invertebrates	
Establish presence absence of sand prawn *C. kraus*si on sand banks in lower estuary. Establish presence absence of the copepod *P. hessei* or estuarine congeneric in the zooplankton of the estuary.	If present populations deviate from average baselines (as determined in first three visits) by more 30%.
Fish	
Fish assemblage should comprise the five estuarine association categories in similar proportions (diversity and abundance) to that under the reference. Numerically assemblage should comprise: ▪ Ia estuarine residents (50 - 80% of total abundance). ▪ Ib marine and estuarine breeders (5 - 20%). ▪ IIa obligate estuarine-dependent (10 - 20%). ▪ IIb estuarine associated species (5 - 15%). ▪ IIc marine opportunists (20 - 80%). ▪ III marine vagrants (not more than 5%). ▪ IV indigenous fish (1 - 5%). ▪ V catadromous species (1 - 5%). Category Ia species should contain viable populations of at least two species (e.g. *G. aestuaria,* and *H. capensis*). Category IIa obligate dependents should be well represented by at least two large exploited species (i.e. *L. lithognathus,* and *Lichia amia*). REI species dominated by both *M. capensis* and *G. aestuaria*.	▪ Ia estuarine residents < 50%. ▪ Ib marine and estuarine breeders < 10%. ▪ IIa obligate estuarine-dependent < 10%. ▪ IIb estuarine associated species < 5%. ▪ IIc marine opportunists < 20%. ▪ III marine vagrants > 5%. ▪ IV indigenous fish < 1%. ▪ V catadromous species < 1%.
Birds	
Maintain population of original groups of birds present on the estuary	Number of birds in any group, other than species that are increasing regionally such as Egyptian geese, drops below the baseline median (determined by past data and or initial surveys) number of species and/or birds counted for three consecutive summer or winter counts.

5.18 BLOUKRANS ESTUARY

The EcoSpecs and TPCs representative of a REC (Category A) for the Bloukrans are presented in **Table 5.18**.

Table 5.18 EcoSpecs and TPCs for the Bloukrans Estuary (REC: A)

EcoSpecs	TPCs
Hydrology	
Maintain flow regime.	Varies more than 10% of MAR.
Hydrodynamics	
Maintain mouth state to create the required habitat for birds, fish, macrophytes, microalgae and water quality.	Estuary mouth closes.
Water quality	
▪ Salinity distribution not to cause exceedance of TPCs for fish, invertebrates, macrophytes and microalgae. ▪ Turbidity and DO not to cause exceedance of TPCs for biota. ▪ DIN/DIP concentrations not to cause in exceedance of TPCs for macrophytes and microalgae. ▪ Toxic substances not to cause exceedance of TPCs for biota.	▪ Average salinity < 10 at the head of the estuary (expected average range > 30 for most of the system). ▪ DO < 5 mg/L in estuary. ▪ Turbidity > 10 NTU in low flow. ▪ Secchi: To bottom. ▪ DIN > 100 µg/L once-off. ▪ DIP > 20 µg/L once-off. ▪ Concentrations in water column exceed target values as per SA Water Quality Guidelines for Coastal Marine Waters (DWAF, 1995). ▪ Concentrations in sediment exceed target values as per WIO Region guidelines (UNEP and CSIR, 2009).
Sediment dynamics	
▪ Flood regime to maintain the sediment distribution patterns and aquatic habitat (instream physical habitat) so as not to exceed TPCs for biota. ▪ Changes in sediment grain size distribution patterns not to cause exceedance of TPCs in benthic invertebrates. ▪ Change in average sediment composition and characteristics. ▪ Change in average bathymetry.	▪ Average sediment composition (% fractions) along estuary change from baseline (to be measured) by 30% (per survey). ▪ Average depth along main channel change from 30% of baseline (to be determined) (significant fluctuation in bathymetry between flood and extended closed periods is expected within system).
Microalgae	
▪ Maintain median phytoplankton/benthic microalgae biomass. ▪ Prevent formation of phytoplankton blooms.	▪ Phytoplankton > 1.0 µg/L (median). ▪ Benthic microalgae > 11 mg/m^2 (median). ▪ Phytoplankton > 20 µg/L and/or cell density >10 000 cells/ml (once-off).
Macrophytes	
The estuary habitats only consists of sand/mud banks (0.63 ha) and channel (2.88 ha), no macrophytes.	N/A.
Invertebrates	
▪ Establish presence absence of sand prawn *C. krauss*i on sand banks in lower estuary. ▪ Establish presence absence of the copepod *P. hessei* or estuarine congeneric in the zooplankton of the estuary.	If present populations deviate from average baselines (as determined in first three visits) by more 30%.
Fish	
Fish assemblage should comprise the five estuarine association categories in similar proportions (diversity and abundance) to that	▪ Ia estuarine residents < 50%. ▪ Ib marine and estuarine breeders < 10%. ▪ IIa obligate estuarine-dependent < 10%.

EcoSpecs	TPCs
under the reference. Numerically assemblage should comprise: ▪ Ia estuarine residents (50 - 80% of total abundance). ▪ Ib marine and estuarine breeders (10 - 20%). ▪ IIa obligate estuarine-dependent (10 - 20%). ▪ IIb estuarine associated species (5 - 15%). ▪ IIc marine opportunists (20 - 80%). ▪ III marine vagrants (not more than 5%). ▪ IV indigenous fish (1 - 5%). ▪ V catadromous species (1 - 5%). Category Ia species should contain viable populations of at least four species (*G. aestuaria, H. capensis,* and *O. woodii*). Category IIa obligate dependents should be well represented by large exploited species (*A. japonicus, L. lithognathus, P. commersonii,* and *L. amia*). REI species dominated by both *M. capensis* and *G. aestuaria*.	▪ IIb estuarine associated species < 5%. ▪ IIc marine opportunists < 20%. ▪ III marine vagrants > 5%. ▪ IV indigenous fish < 1%. ▪ V catadromous species < 1%.
Birds	
Maintain population of original groups of birds present on the estuary	Number of birds in any group, other than species that are increasing regionally such as Egyptian geese, drops below the baseline median (determined by past data and or initial surveys) number of species and/or birds counted for three consecutive summer or winter counts.

6 RIVERS: MONITORING PROGRAMME

6.1 LEVEL 1 MONITORING PROGRAMME

Level 1 monitoring refers to monitoring that is undertaken at a higher frequency (yearly or monthly or as specified by the current DWS monitoring programme) than more detailed Level 2 monitoring (three-yearly), which also include response indicators. The Level 1 monitoring focuses only on water quality, diatom and woody vegetation monitoring. The Level 1 monitoring programme is summarised in **Table 6.1**.

Table 6.1 Rivers: Water quality, diatom and woody vegetation Level 1 monitoring programme

Indicator	Monitoring action	Temporal scale (frequency and timing)	Spatial scale
All water quality variables measured as standard by DWS as a minimum requirement. Note that temperature and DO should be monitored at all EWR sites as no baseline currently exists for these parameters and they are strongly linked to biotic responses.	Include additional variables in the formal DWS monitoring programme as indicated by EcoSpecs, specifically periphyton chlorophyll-a and diatoms. Include toxics monitoring if indicated by biotic response (conducted as part of Level 2 monitoring). See additional information in **Section 6.1.1**. Institute water quality monitoring at J1DORI-EWR7, Doring River, if required. Note that this site was not identified as an ecological hotspot and the need for inclusion in the EWR monitoring programme would have to be ascertained.	1. Monthly, or as determined by current monitoring programme per monitoring point. 2. Institute twice per month monitoring at EWR sites with no water quality gauging weir in place. 3. Use Google Earth and available information where data are not available and cannot be collected to identify driving land-uses, associated driving water quality variables and preliminary current state for water quality.	1. Relevant water quality monitoring point at gauging weir. 2. Institute a monitoring point downstream of the EWR site if no water quality gauging weir is in place for use.
Diatoms	Baseline data is depauperate especially at all the Rapid EWR sites as well as at J2GAMK-EWR4, J1BUFF-EWR5 and J3OLIF-EWR9. Collect baseline data to develop EcoSpecs and TPCs. Field work.	Six monthly at all sites preferable during summer and winter or high and low flow conditions.	All EWR sites and sites were WQ hotspots have been identified.
Woody vegetation cover within the riparian zone	Assessment of satellite imagery: Each time new Google Earth © coverage becomes available (check coverage dates monthly)	1. Monthly checks for new satellite data. 2. Vegetation assessment whenever new data become available.	EWR reach.

6.1.1 Water quality

At sites where water quality monitoring is not currently in place, i.e. the Doring and Kammanassie rivers, bi-monthly (i.e. every two weeks) monitoring of specific variables (see the relevant sections of this document) should take place to build up a water quality database and develop a monitoring baseline. EcoSpecs and TPCs can then be developed when sufficient data are available, and compliance to the EcoSpecs measured.

It is recommended that toxics monitoring be best achieved through toxicity testing of water samples to a range of organisms in the first instance. Should toxicity then be detected, identification of toxicants through more detailed sampled and chemical analyses, e.g. a metals scan or identification of biocides used in the area will have to be undertaken.

The range of organisms that are recommended for toxicity testing include the following:

- Crustaceans, e.g. a 24 and 48hr *Daphnia magna* acute toxicity screening test.
- Fish, e.g. a 96h *Poecilia reticulata* acute toxicity screening test.
- Algae, e.g. a 72h *Selenastrum capricornutum* growth inhibition screening test.

Note that these recommended tests are short-term (or acute) screening tests. Should toxicity be determined, additional tests, e.g. chronic or sub-chronic tests or tests using additional organisms can be undertaken to determine causes of effects seen.

6.1.2 Diatoms

Current available data, that is based on a samples collected at the various EWR sites during 2014 as part of the GRDS EWR study, is generally of low and moderate to low confidence. Additional sampling during summer and winter is therefore needed. It is recommended that the diatom sampling and analysis be included as part of a monitoring programme on a six monthly basis. This would serve as part of Level 1 monitoring. Additional baseline data is necessary in order to develop a monitoring baseline and then in future develop EcoSpecs and TPCs.

Collection and analysis of further baseline data should be based on the following methods and approach based on detail information provided in DWS (2014a) and DWS (2015c):

- Sampling methods and species identification as outlined in Taylor *et al*. (2007a; 2007b) should be followed and the European numerical diatom index, SPI (Coste in CEMAGREF, 1982) should be used to interpret results with the database programme OMNIDIA (Lecointe *et al*., 1993). The classification of ecological indicators and class ranking based on van Dam *et al*. (1994) is provided in **Table 6.2** and can be used to define EcoSpecs and TPCs from baseline data for both the wet season (or periods when the flow is elevated) and the dry season (or when the flow is low).
- Diatom data analysis should include the following data output or indicators:
    - Diatom based water quality score: Using the SPI to interpret results which include adjusted class limits.
    - Diatom based Ecological classification according to Van Dam *et al*. (1994).

- The results from the Trophic Diatom Index (TDI) (Kelly and Whitton, 1995) should be included as this index provides the percentage pollution tolerant diatom valves in a sample and was developed for monitoring sewage outfall (orthophosphate-phosphorus concentrations), and not general stream quality. The presence of more than 20% PTVs shows significant organic impact.

Table 6.2 Description of the ecological classification and interpretation of the class rankings according to Van Dam *et al*. (1994)

Metric and rank	Classification of Indicator	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		
1	Fresh	< 3 mS/m
2	Fresh-brackish	< 139 mS/m
3	Brackish-fresh	139 - 277 mS/m
4	Brackish	277 - 1385 mS/m
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	Biological Oxygen Demand (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-α-mesosaprobic).
3	Strongly polluted	BOD < 13, O_2 deficit < 75% (α-mesosaprobic)
4	Very heavily polluted	BOD < 22, O_2 deficit <90% (α-meso-polysaprobic).
5	Extremely polluted	BOD > 22, O_2 deficit >90% (polysaprobic).

6.1.3 Riparian vegetation

Satellite images from Google Earth © should be used to assess the change in woody cover along the riparian zone over time. Google Earth © should be checked on a monthly basis to determine whether new coverage data are available. Subsequent assessments should be conducted each time new data become available and new coverages should be saved as image files for record purposes. Within each EWR reach at least 20 line transects should be assessed for woody vegetation cover, covering at least 5 km of river (see **Figure 6.1** for example), i.e. at least 200 m apart. Each line transect should span the riparian zone and remain consistent in length and placement for subsequent surveys. The percentage of each line transect, that crosses woody vegetation is estimated (see example inset where woody vegetation [green line] is shown alongside the line transect [red line]) and an overall average determined for the reach. This average woody cover is monitored over time as new data become available. The advantage of this method is its speed and low cost and also that an increased sample area, which will better represent the changes within a reach as a whole, is achieved relative to field visits. The disadvantage is that recruiting woody individuals and smaller species are excluded because they are not visible on images.

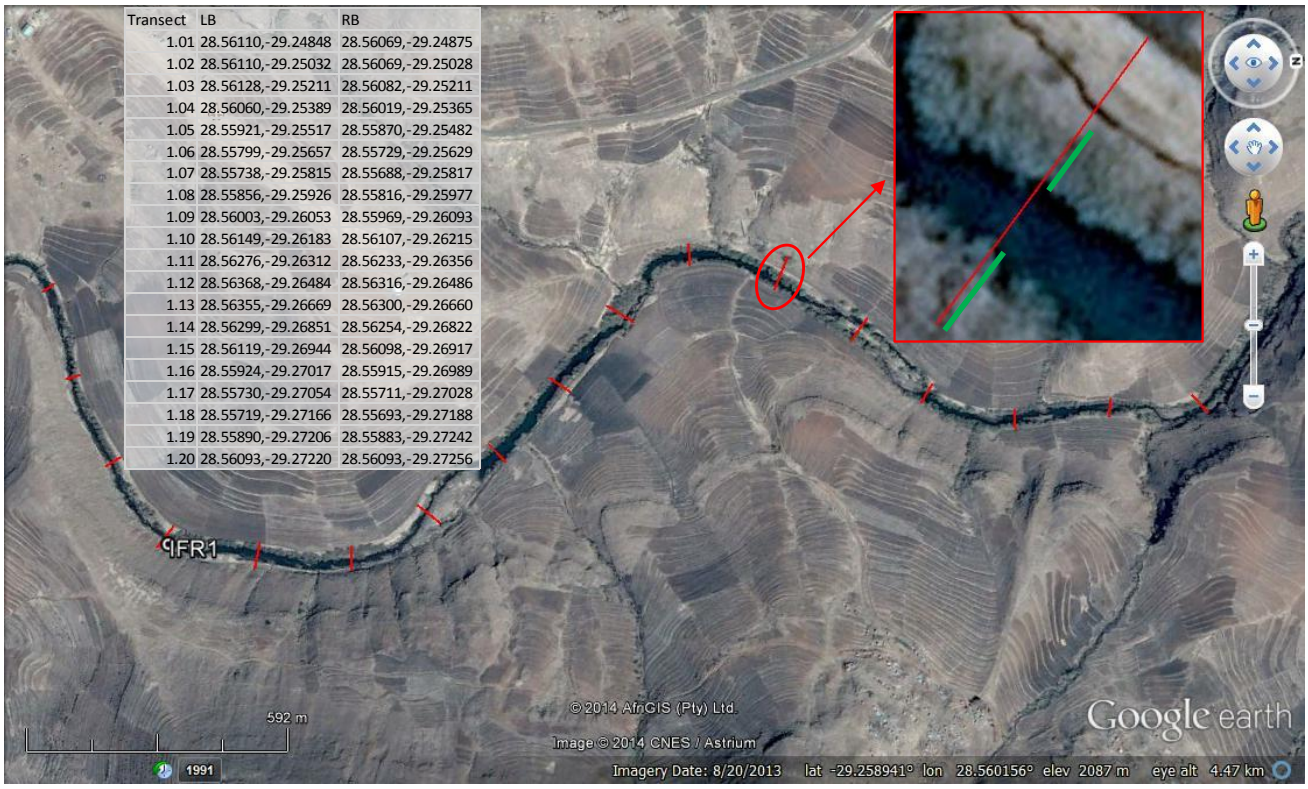

Figure 6.1 Example of aerial image analysis showing 20 line transects along a reach (red lines). The inset shows a single line transect with 50% woody vegetation coverage (green lines)

6.2 LEVEL 2 MONITORING PROGRAMME

Level 2 monitoring should be applied on a regular basis at the EWR sites. Monitoring should include water quality, diatoms and hydrology as outlined in the previous sections as well as other indicators.

More detail is provided for habitat and biota in the next Section. Therefore, whereas Level 1 monitoring focuses on water quality and diatoms as well as the continuous hydrological gauging; Level 2 focuses on the more detailed work at a lower frequency required for biota and habitat. Note that Level 1 monitoring runs parallel with the Level 2 monitoring, and monitoring for water quality should be the same as for Level 1 as it is understood that water quality data may assist in explaining biotic response. As mentioned for Level 1 monitoring, testing for toxics should only be undertaken in response to biotic indicators, where already being assessed as part of the existing DWS programme, or where a specific toxic has been mentioned in the water quality EcoSpecs. Note that monitoring for water quality will therefore be more frequent than the three-yearly monitoring recommended for biotic indicators and will follow Level 1 guidelines.

There are current initiatives in DWS with the revitalising of the RHP and the use of the RHAM (DWA, 2009d) in determining and measuring EcoSpecs at a rapid level. It is recommended that this monitoring dictates the level required and the methods to be followed. As the RHAM is a rapid approach, this may well fit into the Level 1 monitoring programme described in Chapter 14. However, at priority EWR sites, detailed work to determine and update the ECs (i.e. ecological responses) for the fish, macroinvertebrate and riparian vegetation should be undertaken, albeit at a lower frequency. This response monitoring is described in this chapter as the Level 2 monitoring.

Habitat and biota monitoring should be applied as part of Level 2 monitoring. This implies detailed monitoring at a lower frequency than Level 1. It is acknowledged that resources may not be available to undertake this work (even at a lower frequency) at all EWR sites.

In **Table 6.3**, a monitoring programme for Level 2 is provided at for riparian vegetation, fish and macroinvertebrates.

Table 6.3 Rivers: Level 2 monitoring programme at EWR sites

Indicator	Monitoring action	Temporal scale (frequency and timing)	Spatial scale
Riparian vegetation			
Woody vegetation within the riparian zone, both terrestrial and indigenous riparian	Field assessments using VEGRAI level 4. Fixed point photography.	Every three years, same month for subsequent surveys.	All EWR sites.
Reeds			
Alien vegetation			
Non-woody vegetation including sedges, grasses, and dicotyledonous forbs, but excluding reeds or palmiet			
Overall PES for riparian vegetation			
Fish			
Species richness and specific indicator fish species with a preference for specific habitat features (such as substrate) or being intolerant to specific impacts (such as water quality	Field assessment (electrofishing and where appropriate using a minnow seine).	Every two years (dry season, same as baseline).	All EWR sites as above and other sites in RU as specified.

Indicator	Monitoring action	Temporal scale (frequency and timing)	Spatial scale
deterioration, flow reduction)			
Macroinvertebrates			
Composition and abundance	Field assessment (SASS5) (high priority).	Every two years.	All EWR sites as above.

6.2.1 Fish

Fish surveys should be done at representative sites within the EWR SQ reach. At least two different sites or various different sub-sites at the EWR site should ideally be sampled. The minimum sampling effort per site should be electrofishing for a period of at least, but not limited to, 30 minutes. The preferred habitats of the primary indicator species (generally fast flowing habitats, FD and FS/rapids/runs/riffles) should be targeted to determine the presence/absence of the species at the site. Other methods such as the use of a minnow seine net should also be applied where applicable and where suitable conditions prevail at a site. This is especially important when targeting indicator species in a specific habitat, for example using a seine net to capture PASP in deep pools with overhanging vegetation and turbid water.

This can include methods such as 10 sweeps with a 4 m pole seine net in pools (SD or SS), or electrofishing overhanging vegetation in shallow pools when searching for indicator species with a preference for these habitat features. Specific attention in these follow-up studies should be given in habitats difficult to sample effectively, such as SD (deep pools) in order to capture adult eels or adults of larger species such as LUMB and PASP that prefer this habitat type,

The data gathered during these surveys should be used to run the Fish Response Assessment Index (FRAI; Kleynhans, 2007) and the results should then be used to determine whether any of the TPCs has been reached (preferably use the FRAI model populated as part of the reserve study as a starting point). The information used in the compilation of the initial FRAIs should be verified and refined as more information (actual fish data) becomes available. Should TPCs indicate possible deterioration or “red flags”, reference should be made to other available information and more detailed or focussed fish surveys referred to above may be required.

The results gathered through any fish surveys in a SQ reach should be used to run the FRAI (preferably use the FRAI model populated as part of the GRDS as a starting point). The information used in the compilation of the initial FRAIs should be verified and refined as more information (actual fish data) becomes available. The results should be used to verify whether the RQOs for the reach are met and to identify any potential deterioration (any new fish distribution information should also be used to update the Resource Quality Information Services – Resource Directed Measures (RQIS-RDM) PES and Ecological Importance (EI) - Ecological Sensitivity (ES) referred to as the PES/EIS database (DWA, 2013).

6.2.2 Macroinvertebrates

In the current GRDS study area, where the EWR sites are a mix of both perennial and seasonal, either naturally or due to anthropological changes, and where flow seasonality has in some cases been altered, a monitoring programme should ideally be designed on the basis of the present-day and antecedent hydrological conditions of the individual sites. However, over the entire area, it is not necessarily possible to plan the monitoring at a time which is hydrologically suited to the task. For this reason, prior to sampling, recent flow gauge or rainfall data should be used to assess hydrological conditions of the individual sites in the month/s prior to sampling. This information should be recorded together with the monitoring data to ensure best possible interpretation, and application of the EcoSpecs and TPCs.

Sampling should be conducted in early to mid-summer (January to April), following a moderately wet period. Where flooding has occurred, monitoring should be conducted only three weeks to a month later if possible. Ideally sampling should be done once a year for the first three years, or at least once every two years, on similar dates and where possible by the same practitioner.

The method used is the latest SASS sampling methodology (Dickens and Graham, 2002), sampling individual biotopes, and hand-picking of stones. Fixed-point photography (cross-section, upstream, downstream, individual habitat details, water level using a depth stick, water clarity, and water colour) would be an advantage for interpretation and application of EcoSpecs, and photographs should be dated, labelled and kept on file for future management purposes. The site should be assessed visually for habitat diversity and quality, using a suitable method, and a record should be kept. Discharge should be measured and recorded.

The monitoring should only be done by a DWS (RHP) accredited practitioner. The practitioner should be supplied the EcoSpecs and TPCs for each site ahead of sampling, so that they can develop a set of criteria which will inform them on site of any conditions that are not meeting the EcoSpec, or are triggering a TPC. If the sampling is done in this way, the practitioner will be aware immediately if a TPC is triggered, and can intensify sampling efforts in the relevant biotope to double-check. This is critical to the effective use of the TPCs as sampling effort is likely to vary to some extent between practitioners, and because it is not uncommon in these system to have only one individual of a taxon in a SASS5 tray.

The data gathered should be applied to both the SASS5 index as well as the MIRAI (Thirion, 2007) for the determination of the Invertebrate EC. MIRAI integrates the ecological requirements of the invertebrate taxa in a community or assemblage and their response to modified habitat conditions. The reference condition for the site as developed in this study (electronic MIRAI copies per site) should be used for consistency, and the original MIRAI for the EWR site survey should be referred to. If the reference condition is altered in any way, this must be recorded and noted, with motivations, and the amended reference condition should then become the standard one in use.

The SASS5 and MIRAI information should then be used to identify any areas of concern by referring to the EcoSpecs and TPCs for the site.

6.2.3 Riparian vegetation

Although VEGRAI is now consistently used for the assessment of riparian vegetation, it was not developed with the intention of monitoring unless the EcoStatus of riparian vegetation is the indicator of focus. Both level 1 and level 2 monitoring procedures have been suggested (above and below respectively) which, when used in conjunction with VEGRAI, will facilitate effective monitoring of riparian vegetation EcoSpecs and TPCs.

VEGRAI

VEGRAI level 4 should be used by a sufficiently trained vegetation specialist but at the minimum cover (% aerial) for basic vegetation components should be estimated for each sub-zone within the riparian zone, or for each geomorphic feature (see **Table 6.4** for woody vegetation components and **Table 6.5** for non-woody components). The average size of each sub-zone (such as marginal, lower and upper) should also be quantified for use in calculating weighted averages e.g. recording the start and end (m) of each sub-zone for relative size/area.

Table 6.4 Example data showing woody components for which % aerial cover should be estimated

Riparian sub-zone/ Geomorphic Feature	Hor[1] Distance start (m)	Hor Distance end (m)	Woody components (% aerial cover)						
			Woody Riparian	Woody Terrestrial	Non-woody (incl. reeds)	Perennial Alien	Open (Alluvium)	Open (Bedrock)	Other
Fan			5	0	35	10	25	25	
Terrace RB[2]			5	5	60	5	25	0	
Terrace LB[3]			0	5	20	30	45	0	
Boulder Bar			5	5	15	5	10	60	
Terrace Marginal Zone			20	0	60	10	10	0	

1 Horizontal 2 Right bank 3 Left bank

Table 6.5 Example data showing non-woody components for which % aerial cover should be estimated

Riparian sub-zone/ Geomorphic Feature	Hor Distance start (m)	Hor Distance end (m)	Non-woody components (% aerial cover)								
			Reeds	Rushes/ Palmiet	Sedges	Large-leaved macro-phytes	Open areas	Grasses	Low woody (≤ 50 cm)	Alien Veg	Other
Fan			0	0	5	5	50	10	5	25	
Terrace RB			5	0	5	5	25	30	5	25	
Terrace LB			0	0	5	5	45	10	5	30	
Boulder Bar			0	0	5	5	65	10	5	10	
Terrace Marginal Zone			0	0	30	10	10	35	5	10	

Fixed point photographs

Fixed-point photographs should be taken at various locations and recorded with Global Positioning System (GPS) co-ordinates or maps that will facilitate accurate repetition with each field visit. These should be used to assess change in vegetation structure and abundance. Fixed point photographs should be analysed qualitatively and quantitatively. Qualitative statements consist of the viewer's assessment of woody vegetation cover and abundance in terms of whether there is more or less woody vegetation at each site (considering all available photographs at each site), and whether existing vegetation had increased in size (see **Table 6.6**). A simple "Yes" with a note completes the assessment. Subsequent photographs should be repeated as accurately as possible in order to improve relevancy of comparisons.

Table 6.6 Format of qualitative assessment of fixed point photographs

Site	Fixed photo reference	Component to assess	General increase	General decrease	No discernable difference	Mixed Response within the photograph
		Are there more or less? The numbers of woody individuals, irrespective of size or structure or species				
		Are they bigger? The general size of individuals i.e. has existing trees that occur in both photos grown?				

For the quantitative assessment, photographs from different time frames should be aligned as close as possible and overlaid with equally sized grids. Focus should be given to key unmovable components within the river environment (such as bedrock, banks, large boulders, rapids, etc.) to align as close as possible with the same grid. Each grid is then assessed and counted if any part of the grid contains woody vegetation (any component of the plant) (see example in **Figure 6.2**). The number of grids containing woody vegetation is then expressed as a proportion of the total number of grids, and an average for all photographs at a site presented as representative of change within that reach. The example in **Figure 6.2** shows how woody vegetation (Willow and Poplar) at the site increased by 46% from 2005 to 2013. Photographs from 2005 (A and B) were compared to comparable photographs from 2013 (C and D). Each overlaid with the same grid and only grids containing woody vegetation were counted (coloured orange in B and D for illustration).

Such quantitative assessments are not without problems. Obvious problems include error of parallax and scaling differences within different photos of the same area, but the analysis provides useful insight regarding the changes to woody vegetation structure and abundance. In general fixed point photographs cover a much larger area of assessment (with significantly less time requirements) at each site and therefore provide a more representative analysis of changes.

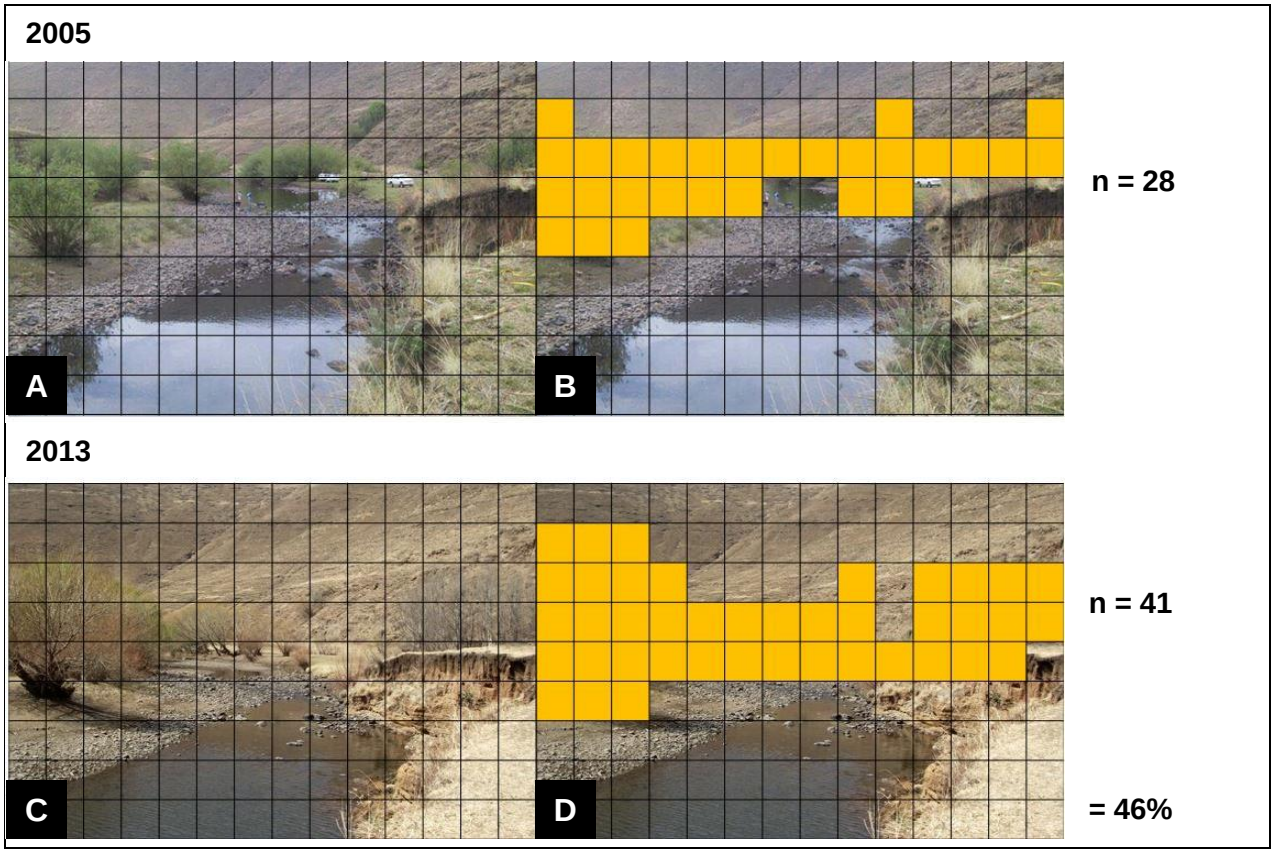

Figure 6.2 Example of qualitative assessments of fixed point photographs

7 ESTUARIES: MONITORING PROGRAMME

For the GRDS, detailed baseline and long-term monitoring programmes were developed for the estuaries that were assessed at the Intermediate (i.e. Duiwenhoks, Goukou and Gouritz estuaries) and Rapid (i.e. Klein Brak estuary and Wilderness system) levels. For the estuaries that were assessed at a Desktop levels (i.e. Blinde, Hartenbos, Piesang, Groot (Wes) and Bloukrans estuaries), as well as the estuaries for which previous EWR studies did not provide baseline or long-term monitoring programmes a generic monitoring programme was developed. The monitoring programme previously provided for the Keurbooms Estuary in 2008 was also re-assessed and is also presented in this section.

It is recommended that the implementation of the additional baseline surveys and long-term monitoring programmes should be undertaken in collaboration with various responsible departments in the DWS, as well as other national and provincial departments and institutions responsible for estuarine resource management such as DAFF, DEA: Oceans and Coasts, SANBI, CapeNature, as well as relevant municipal authorities. It is recommended that the estuarine management planning process and the associated institutional structures (as required under the Integrated Coastal Management Act 2008) be used as a mechanisms through which to facilitate the implementation these interventions.

7.1 DUIWENHOKS ESTUARY

Additional baseline studies to improve the confidence of the EWR results for the Duiwenhoks Estuary are presented in **Table 7.1.** These components are all important to improve the confidence overall, but especially the sediment dynamics and invertebrate components are of a high priority.

The recommended long-term monitoring programme, the purpose of which is to test for compliance with EcoSpecs and TPC and to continuously improve understanding of ecosystem function, is presented in **Table 7.2**. While all components in the long-term monitoring programme remain important, certain primary (abiotic) data, as highlighted in **Table 7.2**, is of highest priority.

Table 7.1 Additional baselines surveys to improve confidence of EWR study on the Duiwenhoks Estuary (priority components are highlighted)

Action	Temporal Scale (frequency and timing)	Spatial Scale (Number of stations)
Sediment dynamics		
Bathymetric surveys: Series of cross-section profiles and a longitudinal profile collected at fixed 500 m intervals, but in more detail in the mouth including the berm (every 100 m). Vertical accuracy at least 5 cm.	Once-off.	Entire estuary.
Collect sediment grab samples (at cross section profiles) for analysis of particle size distribution and organic content (and ideally origin, i.e. microscopic observations).	Once-off.	Entire estuary.
Water quality		
Collect samples for pesticides/herbicide and metal determinations in river inflow.	Once-off.	Near head of estuary (H8H001).
Collect surface and bottom water samples for inorganic nutrients (and organic nutrient) and suspended solid analysis, together the *in situ* salinity, temperature, pH, DO and turbidity profiles.	Quarterly, preferably over two years.	Entire estuary (13 stations, coinciding with microalgae and invert sampling sites).
Measure pesticides/herbicides and metal accumulation in sediments (for metals investigate establishment of distribution models – refer to Newman and Watling, 2007).	Once-off.	Entire estuary, including depositional areas (i.e. muddy areas).
Microalgae		
▪ Record relative abundance of dominant phytoplankton groups, i.e. flagellates, dinoflagellates, diatoms, chlorophytes and blue-green algae. ▪ Chlorophyll-a measurements taken at the surface, 0.5 m and 1 m depths, under typically high and low flow conditions using a recognised technique, e.g. spectrophotometer, High Performance Liquid Chromatography (HPLC) or fluoroprobe. ▪ Intertidal and subtidal benthic chlorophyll-a measurements (four replicates each) using a recognised technique, e.g. sediment corer or fluoroprobe.	Quarterly, preferably over two years.	Along length of estuary minimum five stations.
Invertebrates		
▪ Collect duplicate zooplankton samples at night from mid-water levels using WP2 nets (190 µm mesh). ▪ Collect grab samples (five replicates) (day) from the bottom substrate in mid-channel areas at same sites as zooplankton (each sample to be sieved through 500 µm). ▪ Collect sled samples (day) at same zooplankton sites for hyper benthos (190 µm). ▪ Intertidal invertebrate hole counts using 0.25 m^2 grid (five replicates per site). Establish the species concerned using a prawn pump. ▪ Collect sediment samples using the grab for particle size analysis and organic content (at same sites as zooplankton).	Quarterly, preferably over two years.	Minimum of three sites along length of entire estuary. For hole counts – three sites on sandy substrata near the mouth (western shore).

Table 7.2 Recommended long-term monitoring programme for the Duiwenhoks Estuary (priority components are highlighted)

Monitoring action	Temporal Scale (frequency and timing)	Spatial Scale (Number of stations)
Hydrodynamics		
Record water levels.	Continuous.	Near the mouth of the estuary.
Measure freshwater inflow into the estuary.	Continuous.	Near head of estuary (H8H001).
Aerial photographs of estuary (spring low tide).	Every three years.	Entire estuary.
Sediment dynamics		
Monitoring berm height using appropriate technologies.	Quarterly.	Mouth.
Bathymetric surveys: Series of cross-section profiles and a longitudinal profile collected at fixed 500 m intervals, but in more detail in the mouth including the berm (every 100 m). Vertical accuracy at least 5 cm.	Every three years (and after large resetting event).	Entire estuary.
Collect sediment grab samples (at cross section profiles) for analysis of particle size distribution and organic content (and ideally origin, i.e. microscopic observations).	Every three years.	Entire estuary.
Water quality		
Collect data on conductivity, temperature, suspended solids, pH, inorganic nutrients (N, P and Si) and organic content (Total P and Kjeldahl N) in river inflow.	Monthly, continuous.	Near head of estuary (H8H001).
Collect samples for pesticides/herbicide and metal determinations in river inflow.	Every three - six years if baseline shows contamination.	Near head of estuary (H8H001).
Collect *in situ* continuous salinity data with mini Conductivity-Temperature-Depth (CTD) probe at a depth of about 1 m.	Continuous.	3 sites - 5 km, 10 km from the mouth head and near head of estuary (above 16 km from mouth).
Record longitudinal *in situ* salinity and temperature pH, DO, turbidity profiles.	Seasonally.	Entire estuary (13 stations).
Collect surface and bottom water samples for inorganic nutrients (and organic nutrient) and suspended solid analysis, together the *in situ* salinity, temperature, pH, DO and turbidity profiles.	Every three years (high flow and low flow) or when significant change in WQ expected.	Entire estuary (13 stations, coinciding with microalgae and invert sampling sites).
Measure pesticides/herbicides and metal accumulation in sediments (for metals investigate establishment of distribution models – refer to Newman and Watling, 2007).	Every three - six years, if results show contamination.	Entire estuary, including depositional areas (i.e. muddy areas).

Monitoring action	Temporal Scale (frequency and timing)	Spatial Scale (Number of stations)
Microalgae		
▪ Record relative abundance of dominant phytoplankton groups, i.e. flagellates, dinoflagellates, diatoms, chlorophytes and blue-green algae. ▪ Chlorophyll-a measurements taken at the surface, 0.5 m and 1 m depths, under typically high and low flow conditions using a recognised technique, e.g. spectrophotometer, HPLC or fluoroprobe. ▪ Intertidal and subtidal benthic chlorophyll-a measurements (four replicates each) using a recognised technique, e.g. sediment corer or fluoroprobe.	Low flow surveys. Every three years.	Along length of estuary minimum five stations.
Macrophytes		
▪ Ground-truthed maps to update the map produced for 2013 and to check the areas covered by the different macrophyte habitats. ▪ Record boundaries of macrophyte habitats and total number of macrophyte species in the field. ▪ Assess extent of invasive species within the 5 m contour line. ▪ Check for loss of reed and sedge area in the middle reaches (5 - 10 km). Check for increase in bare areas in salt marsh habitat from mapping. ▪ Measure macrophyte and sediment characteristics along transects in the main salt marsh areas. Percentage plant cover measured in duplicate 1 m^2 quadrats along the transects and an elevation gradient from the water to the terrestrial habitat. ▪ Duplicate sediment samples collected in three zones along each transect to represent the lower intertidal, upper intertidal and supratidal salt marsh. Analysed in the laboratory for sediment moisture, organic content, electrical conductivity, pH and redox potential. In the field measure depth to water table and ground water salinity.	Summer survey. Every three years.	Entire estuary for mapping (transect sites as shown in DWS, 2014c).
Invertebrates		
▪ Collect duplicate zooplankton samples at night from mid-water levels using WP2 nets (190 µm mesh) ▪ Collect grab samples (five replicates) (day) from the bottom substrate in mid-channel areas at same sites as zooplankton (each sample to be sieved through 500 µm). ▪ Collect sled samples (day) at same zooplankton sites for hyper benthos (190 µm) ▪ Intertidal invertebrate hole counts using 0.25 m^2 grid (five replicates per site). Establish the species concerned using a prawn pump. ▪ Collect sediment samples using the grab for particle size analysis and organic content (at same sites as zooplankton)	Every two years mid-summer.	Minimum of three sites along length of entire estuary. For hole counts – three sites on sandy substrata near the mouth (western shore).

Monitoring action	Temporal Scale (frequency and timing)	Spatial Scale (Number of stations)
Fish		
▪ Record species and abundance of fish, based on seine net and gill net sampling. Sampling with a small beam trawl for channel fish should also be considered. ▪ Seine net specifications: 30 m x 2m, 15 mm bar mesh seine with a 5 mm bar mesh with a 5 mm bar mesh 5 m either side and including the cod-end. ▪ Gill nets specifications: Set of gill nets each panel 30 m long by 2 m deep with mesh sizes of 44 mm, 48 mm, 51 mm, 54 mm, 75 mm, 100 mm and 145 mm. ▪ Trawl specification: 2 m wide by 3 m long, 10 mm bar nylon mesh in the main net body and a 5 mm bar in the cod-end.	Twice annually Spring/Summer and autumn/winter	Entire estuary (10 stations). Spacing of station Stations ~ estuary length/10.
Birds		
Undertake counts of all non-passerine water birds, identified to species level (DWS, 2014c).	Annual winter and summer surveys.	Entire estuary (about six sections, must be standardised).

7.2 GOUKOU ESTUARY

Additional baseline studies that are important to the improvement of the confidence of the Goukou Estuary EWR study are provided in **Table 7.3.** These components are all important to improve the confidence overall, but especially the sediment dynamics and invertebrate components are of a high priority.

The recommended long-term monitoring programme, the purpose of which is to test for compliance with EcoSpecs and TPC and to continuously improve understanding of ecosystem function, is presented in **Table 7.4**. While all components in the long-term monitoring programme remain important, certain primary (abiotic) data, as highlighted in **Table 7.4**, is of highest priority.

Table 7.3 Additional baseline surveys to improve confidence of EWR study on the Goukou Estuary (priority components are highlighted)

Action	Temporal Scale (frequency and timing)	Spatial Scale (Number of stations)
Hydrodynamics		
Measure freshwater inflow into the estuary.	Continuous.	Near head of estuary (H9H5 to far upstream, new station is required).
Aerial photographs of estuary (spring low tide).	Baseline.	Entire estuary.
Sediment dynamics		
Monitoring berm height using appropriate technologies.	Quarterly.	Mouth.
Bathymetric surveys: Series of cross section profiles and a longitudinal profile collected at fixed 500 m intervals, but in more detail in mouth including berm (every 100 m). Vertical accuracy at least 5 cm.	Once-off.	Entire estuary.
Collect sediment grab samples (at cross section profiles) for analysis of particle size distribution (and ideally origin, i.e. microscopic observations).	Once-off.	Entire estuary.
Water quality		
River inflow: Conductivity, temperature, suspended solids, pH, inorganic nutrients (N, P and Si) and organic content (Total P and Kjeldahl N) in river inflow.	Monthly continuous.	Near head of estuary (H9H5 to far upstream, new station is required).
River inflow: Pesticides/herbicide and metal accumulation.	Once-off.	Near head of estuary (H9H5 to far upstream, new station is required).
Collect surface and bottom water samples for inorganic nutrients (and organic nutrient) and suspended solid analysis, together the in situ salinity, temperature, pH, DO and turbidity profiles.	Quarterly, preferably over two years.	Entire estuary (10 - 15 stations).
Measure pesticides/herbicides and metal accumulation in sediments (for metals investigate establishment of distribution models – refer to Newman and Watling, 2007).	Once-off.	Entire estuary, including depositional areas (i.e. muddy areas).
Microalgae		
▪ Record relative abundance of dominant phytoplankton groups, i.e. flagellates, dinoflagellates, diatoms, chlorophytes and blue-green algae. ▪ Chlorophyll-a measurements taken at the surface, 0.5 m and 1 m depths, under typically high and low flow conditions using a recognised technique, e.g. spectrophotometer, HPLC, fluoroprobe. ▪ Intertidal and subtidal benthic chlorophyll-a measurements (four replicates each) using a recognised technique, e.g. sediment corer or fluoroprobe.	Quarterly preferably over two years	Along length of estuary minimum five stations

Action	Temporal Scale (frequency and timing)	Spatial Scale (Number of stations)
Invertebrates		
▪ Collect duplicate zooplankton samples at night from mid-water levels using WP2 nets (190 µm mesh) along the estuary at five sites. ▪ Collect grab samples (five replicates) (day) from the bottom substrate in mid-channel areas at same sites as zooplankton (each samples to be sieved through 500 µm). ▪ Collect sled samples (day) at same zooplankton sites for hyper benthos (190 µm) ▪ Intertidal invertebrate hole counts using 0.25 m^2 grid (five replicates per site). ▪ Establish the species concerned using a prawn pump (Zones A and B). ▪ Collect sediment samples using the grab for particle size analysis and organic content (at same sites as zooplankton). ▪ Three replicate hole counts of *U. africana* at three intertidal sites in Zone B.	Quarterly, preferably over two years	Minimum of five sites along length of estuary. For intertidal counts – minimum of five sites.

Table 7.4 Recommended long-term monitoring programme for the Goukou Estuary (priority components are highlighted)

Monitoring action	Temporal Scale (frequency and timing)	Spatial Scale (Number of stations)
Hydrodynamics		
Measure freshwater inflow into the estuary.	Continuous.	Near head of estuary (H9H5 to far upstream, new station is required.)
Aerial photographs of estuary (spring low tide).	Every three years.	Entire estuary.
Sediment dynamics		
Monitoring berm height using appropriate technologies.	Quarterly.	Mouth.
Bathymetric surveys: Series of cross section profiles and a longitudinal profile collected at fixed 500 m intervals, but in more detail in mouth including berm (every 100 m). Vertical accuracy at least 5 cm.	Every three years (and after large resetting event).	Entire estuary.
Collect sediment grab samples (at cross section profiles) for analysis of particle size distribution (and ideally origin, i.e. microscopic observations).	Every three years.	Entire estuary.
Water quality		
River inflow: Conductivity, temperature, suspended solids, pH, inorganic nutrients (N, P and Si) and organic content (Total P and Kjeldahl N) in river inflow.	Monthly, continuous.	Near head of estuary (H9H5 to far upstream, new station is required).

Monitoring action	Temporal Scale (frequency and timing)	Spatial Scale (Number of stations)
River inflow: Pesticides/herbicide and metal contamination.	Seasonally, or when contamination is expected.	Near head of estuary (H9H5 to far upstream, new station is required).
Collect in situ continuous salinity data with mini CTD probe at a depth of about 1 m.	Continuous.	Three sites - 5 km, 10 km from the mouth head and near head of estuary.
Record longitudinal *in sit*u salinity and temperature pH, DO, turbidity profiles.	Seasonally, every year.	Entire estuary (17 stations).
Collect surface and bottom water samples for inorganic nutrients (and organic nutrient) and suspended solid analysis, together the in situ salinity, temperature, pH, DO and turbidity profiles.	Every three years (high flow and low flow) or when significant change in WQ expected.	Entire estuary (10 - 17 stations).
Measure pesticides/herbicides and metal accumulation in sediments (for metals investigate establishment of distribution models – refer to Newman and Watling, 2007).	Every three – six years.	Entire estuary, including depositional areas (i.e. muddy areas).
Microalgae		
▪ Record relative abundance of dominant phytoplankton groups, i.e. flagellates, dinoflagellates, diatoms, chlorophytes and blue-green algae. ▪ Chlorophyll-a measurements taken at the surface, 0.5 m and 1 m depths, under typically high and low flow conditions using a recognised technique, e.g. spectrophotometer, HPLC, or fluoroprobe. ▪ Intertidal and subtidal benthic chlorophyll-a measurements (four replicates each) using a recognised technique, e.g. sediment corer or fluoroprobe.	Low flow surveys. Every three years	Along length of estuary minimum five stations
Macrophytes		
▪ Ground-truthed maps to update the map produced for 2013 and to check the areas covered by the different macrophyte habitats. ▪ Record boundaries of macrophyte habitats and total number of macrophyte species in the field. ▪ Assess extent of invasive species within the 5 m contour line. ▪ Check for loss of reed and sedge area in the middle/upper reaches. Check for increase in bare areas in salt marsh habitat from mapping. ▪ Measure macrophyte and sediment characteristics along transects in the main salt marsh areas. Percentage plant cover measured in duplicate 1 m^2 quadrats along transects and an elevation gradient from the water to the terrestrial habitat. ▪ Duplicate sediment samples collected in three zones along each transect to represent the lower intertidal, upper intertidal and supratidal salt marsh. Analysed in the laboratory for sediment moisture, organic content, electrical conductivity, pH and redox potential. In the field measure depth to water table and ground water salinity.	Summer survey. Every three years.	Entire estuary for mapping (transects located in the middle and lower reaches).

Monitoring action	Temporal Scale (frequency and timing)	Spatial Scale (Number of stations)
Invertebrates		
▪ Collect duplicate zooplankton samples at night from mid-water levels using WP2 nets (190 µm mesh) along the estuary at five sites. ▪ Collect grab samples (five replicates) (day) from the bottom substrate in mid-channel areas at same sites as zooplankton (each samples to be sieved through 500 µ m). ▪ Collect sled samples (day) at same zooplankton sites for hyper benthos (190 µ m) ▪ Intertidal invertebrate hole counts using 0.25 m^2 grid (five replicates per site). ▪ Establish the species concerned using a prawn pump (Zones A and B). ▪ Collect sediment samples using the grab for particle size analysis and organic content (at same sites as zooplankton). ▪ Three replicate hole counts of *U. africana* at three intertidal sites in Zone B.	Every two years in mid-summer	Minimum of five sites along length of estuary. For intertidal counts – minimum of five sites.
Fish		
Record species and abundance of fish, based on seine net and gill net sampling.	Summer and winter survey Every three years.	Entire estuary (17 stations).
Birds		
Undertake counts of all non-passerine waterbirds, identified to species level.	Annual winter and summer surveys.	Entire estuary (seven sections – see DWS, 2015d, Figure F6).

7.3 GOURITZ ESTUARY

Additional baseline studies that are important to the improvement of the confidence of the Gouritz Estuary EWR study are provided in **Table 7.5.** These components are all important to improve the confidence overall, but especially the sediment dynamics and invertebrate components are of a high priority.

The recommended long-term monitoring programme, the purpose of which is to test for compliance with EcoSpecs and TPC and to continuously improve understanding of ecosystem function, is presented in **Table 7.6**. While all components in the long-term monitoring programme remain important, certain primary (abiotic) data, as highlighted in **Table 7.6**, is of highest priority.

Table 7.5 Additional baseline surveys to improve confidence of EWR study on the Gouritz Estuary (highest priorities are highlighted)

Action	Temporal Scale (frequency and timing)	Spatial Scale (Number of stations)
Hydrodynamics		
Record water levels.	Continuous.	Near the mouth (to be installed).
Measure freshwater inflow into the estuary.	Continuous.	Near head of estuary (to be refined and confirmed through future monitoring).
Sediment dynamics		
Bathymetric surveys: Series of cross section profiles and a longitudinal profile collected at fixed 500 m intervals, but in more detail in the mouth including the berm (every 100 m). Vertical accuracy at least 5 cm.	Once-off.	Entire estuary.
Collect sediment grab samples (at cross section profiles) for analysis of particle size distribution and organic content (and ideally origin, i.e. microscopic observations).	Once-off.	Entire estuary.
Water quality		
Collect samples for pesticides/herbicide and metal determinations in river inflow.	Once-off.	Near head of estuary (to be installed).
Collect surface and bottom water samples for inorganic nutrients (and organic nutrient) and suspended solid analysis, together the in situ salinity, temperature, pH, DO and turbidity profiles.	Quarterly, preferably over two years.	Entire estuary (12 stations, coinciding with microalgae and invert sampling sites).
Measure pesticides/herbicides and metal accumulation in sediments (for metals investigate establishment of distribution models – refer to Newman and Watling, 2007).	Once-off.	Entire estuary, including depositional areas (i.e. muddy areas).
Microalgae		
▪ Record relative abundance of dominant phytoplankton groups, i.e. flagellates, dinoflagellates, diatoms, chlorophytes and blue-green algae. ▪ Chlorophyll-a measurements taken at the surface, 0.5 m and 1 m depths, under typically high and low flow conditions using a recognised technique, e.g. spectrophotometer, HPLC or fluoroprobe. ▪ Intertidal and subtidal benthic chlorophyll-a measurements (four replicates each) using a recognised technique, e.g. sediment corer or fluoroprobe.	Quarterly, preferably over two years.	Along length of estuary minimum five stations.

Action	Temporal Scale (frequency and timing)	Spatial Scale (Number of stations)
Invertebrates		
▪ Collect duplicate zooplankton samples at night from mid-water levels using WP2 nets (190 µm mesh). ▪ Collect grab samples (five replicates) (day) from the bottom substrate in mid-channel areas at same sites as zooplankton (each sample to be sieved through 500 µm). ▪ Collect sled samples (day) at same zooplankton sites for hyper benthos (190 µm). ▪ Intertidal invertebrate hole counts using 0.25 m^2 grid (five replicates per site). Establish the species concerned using a prawn pump. ▪ Collect sediment samples using the grab for particle size analysis and organic content (at same sites as zooplankton).	Quarterly, preferably over two years.	Minimum of three sites along length of entire estuary. For hole counts – three sites on sandy substrata near the mouth (western shore).

Table 7.6 Recommended long-term monitoring programme for the Gouritz Estuary (highest priorities are highlighted)

Monitoring action	Temporal Scale (frequency and timing)	Spatial Scale (Number of stations)
Hydrodynamics		
Record water levels.	Continuous.	Near the mouth (to be installed).
Measure freshwater inflow into the estuary.	Continuous.	Near head of estuary (to be refined and confirmed through future monitoring).
Aerial photographs of estuary (spring low tide).	Baseline and then Every three years.	Entire estuary.
Sediment dynamics		
Monitoring Berm height using appropriate technologies.	Quarterly.	Mouth.
Bathymetric surveys: Series of cross section profiles and a longitudinal profile collected at fixed 500 m intervals, but in more detail in the mouth including the berm (every 100 m). Vertical accuracy at least 5 cm.	Every three years (and after large resetting event).	Entire estuary.
Collect sediment grab samples (at cross section profiles) for analysis of particle size distribution and organic content (and ideally origin, i.e. microscopic observations).	Every three years.	Entire estuary.
Water quality		
Collect data on conductivity, temperature, suspended solids, pH, inorganic nutrients (N, P and Si) and organic content (Total P and Kjeldahl N) in river inflow.	Monthly, continuous.	Near head of estuary (current station too far upstream).

Monitoring action	Temporal Scale (frequency and timing)	Spatial Scale (Number of stations)
Collect samples for pesticides/herbicide and metal determinations in river inflow.	Every three – six years if baseline shows contamination.	Near head of estuary.
Record longitudinal in situ salinity and temperature pH, DO, turbidity profiles.	Seasonally, every year.	Entire estuary (12 stations).
Collect surface and bottom water samples for inorganic nutrients (and organic nutrient) and suspended solid analysis, together the *in situ* salinity, temperature, pH, DO and turbidity profiles.	High. Every three years (high flow and low flow) or when significant change in WQ expected.	Entire estuary (12 stations).
Measure pesticides/herbicides and metal accumulation in sediments (for metals investigate establishment of distribution models – refer to Newman and Watling, 2007).	Once-off, then Every three – six years, if results show contamination.	Entire estuary, including depositional areas (i.e. muddy areas).
Microalgae		
▪ Record relative abundance of dominant phytoplankton groups, i.e. flagellates, dinoflagellates, diatoms, chlorophytes and blue-green algae. ▪ Chlorophyll-a measurements taken at the surface, 0.5 m and 1 m depths, under typically high and low flow conditions using a recognised technique, e.g. spectrophotometer, HPLC fluoroprobe. ▪ Intertidal and subtidal benthic chlorophyll-a measurements (four replicates each) using a recognised technique, e.g. sediment corer or fluoroprobe.	Every three years.	Along length of estuary minimum five stations.
Macrophytes		
▪ Ground-truthed maps to update the map produced for 2013 and to check the areas covered by the different macrophyte habitats. ▪ Record boundaries of macrophyte habitats and total number of macrophyte species in the field. ▪ Assess extent of invasive species within the 5 m contour line. ▪ Check for loss of reed and sedge area in the upper reaches. ▪ Check for increase in bare areas in supratidal salt marsh habitat from mapping. ▪ Measure macrophyte and sediment characteristics along transects in the lower salt marsh. Percentage plant cover measured in duplicate 1 m^2 quadrats along the transects and an elevation gradient from the water to the terrestrial habitat. ▪ Duplicate sediment samples collected in three zones along each transect to represent the different supratidal salt marsh zones. Analysed in the laboratory for sediment moisture, organic content, electrical conductivity, pH and redox potential. In the field measure depth to water table and ground water salinity.	Summer survey. Every three years.	Entire estuary for mapping (transect sites in the lower reaches on the west bank).

Monitoring action	Temporal Scale (frequency and timing)	Spatial Scale (Number of stations)
Invertebrates		
▪ Collect duplicate zooplankton samples at night from mid-water levels using WP2 nets (190 µm mesh) along the estuary at five sites. ▪ Collect grab samples (five replicates) (day) from the bottom substrate in mid-channel areas at same sites as zooplankton (each samples to be sieved through 500 µm). ▪ Collect sled samples (day) at same zooplankton sites for hyper benthos (190 µm). ▪ Collect sediment samples using the grab for particle size analysis and organic content (at same sites as zooplankton). ▪ Intertidal invertebrate hole counts using 0.25 m^2 grid (five replicates per site) on eastern shore in Zone B. Establish the species concerned using a prawn pump.	Every two years, mid-summer.	Minimum of five sites along length of entire estuary For prawn hole counts – minimum of five intertidal sites
Fish		
Record species and abundance of fish, based on seine net and gill net sampling.	Summer and winter survey Every three years.	Entire estuary (12 - 15 stations).
Birds		
Undertake counts of all non-passerine waterbirds, identified to species level.	Annual winter and summer surveys.	Entire estuary (seven sections, see DWS, 2015e, Figure F6).

7.4 KLEIN BRAK ESTUARY

Additional baseline studies that are important to the improvement of the confidence of the Klein Brak Estuary EWR study are provided in **Table 7.7.** These components are all important to improve the confidence overall, but priority components are highlighted. The recommended long-term monitoring programme, the purpose of which is to test for compliance with EcoSpecs and TPC and to continuously improve understanding of ecosystem function, is presented in **Table 7.8**. While all components in the long-term monitoring programme remain important, certain primary (abiotic) data, as highlighted in **Table 7.8**, is of highest priority.

Table 7.7 Additional baseline surveys to improve confidence of EWR study on the Klein Brak Estuary (priority components are highlighted)

Action	Temporal Scale (frequency and timing)	Spatial Scale (Number of stations)
Sediment dynamics		
Monitoring berm height using appropriate technologies.	Quarterly.	Mouth.
Bathymetric surveys: Series of cross section profiles and a longitudinal profile collected at fixed 500 m intervals, but in more detail in the mouth including the berm (every 100 m). Vertical accuracy at least 5 cm.	Once-off.	Entire estuary.
Collect sediment grab samples (at cross section profiles) for analysis of particle size distribution and organic content (and ideally origin, i.e. microscopic observations).	Once-off.	Entire estuary.
Water quality		
Collect samples for pesticides/herbicide and metal determinations in river inflow.	Once-off.	Near head of estuary in Moordkuils (K1H5) and Brandwag (K1H4) tributaries.
Collect surface and bottom water samples for inorganic nutrients (and organic nutrient) and suspended solid analysis, together the in situ salinity, temperature, pH, DO and turbidity profiles.	Quarterly, preferably for 2 years	Entire estuary (10 - 13 stations).
Measure pesticides/herbicides and metal accumulation in sediments (for metals investigate establishment of distribution models – refer to Newman and Watling, 2007).	Once-off.	Entire estuary, including depositional areas (i.e. muddy areas).
Microalgae		
▪ Record relative abundance of dominant phytoplankton groups, i.e. flagellates, dinoflagellates, diatoms, chlorophytes and blue-green algae. ▪ Chlorophyll-a measurements taken at the surface, 0.5 m and 1 m depths, under typically high and low flow conditions using a recognised technique, e.g. spectrophotometer, HPLC or fluoroprobe. ▪ Intertidal and subtidal benthic chlorophyll-a measurements (four replicates each) using a recognised technique, e.g. sediment corer or fluoroprobe.	Quarterly, preferably over two years	Along length of estuary minimum five stations (include stations in upper reaches of Brandwag and Moordkuil arms).

Action	Temporal Scale (frequency and timing)	Spatial Scale (Number of stations)
Macrophytes		
▪ In the field map the area covered by the different macrophyte habitats. Record boundaries and the total number of macrophytes species. 2013 was a rapid field survey and did not include detailed vegetation mapping and ground-truthing. ▪ Assess extent of invasive species within the 5 m contour line. ▪ Locate the position of reed and sedge areas as indicators of future salinity changes. ▪ Identify supratidal salt marsh areas and their condition in terms of area of bareground. ▪ Map sensitive submerged macrophyte habitats such as *Ruppia cirrhosa* and *Z. capensis* beds. ▪ Identify macroalgae present, their distribution and potential for future expansion (bloom formation) particularly under low flow conditions. ▪ Measure macrophyte and sediment characteristics along transects in the main salt marsh areas. Percentage plant cover measured in duplicate 1 m^2 quadrats along the transects and an elevation gradient from the water to the terrestrial habitat. ▪ Duplicate sediment samples collected in three zones along each transect to represent the lower intertidal, upper intertidal and supratidal salt marsh. Analysed in the laboratory for sediment moisture, organic content, electrical conductivity, pH and redox potential. In the field measure depth to water table and ground water salinity.	Once-off.	Entire estuary.
Invertebrates		
▪ Collect duplicate zooplankton samples at night from mid-water levels using WP2 nets (190 µm mesh). ▪ Collect grab samples (five replicates) (day) from the bottom substrate in mid-channel areas at same sites as zooplankton (each samples to be sieved through 500 µm). ▪ Collect sled samples (day) at same zooplankton sites for hyper benthos (190 µm). ▪ Intertidal invertebrate hole counts using 0.25 m^2 grid (five replicates per site). Establish the species concerned using a prawn pump. ▪ Collect sediment samples using the grab for particle size analysis and organic content (at same sites as zooplankton).	Quarterly, preferably over two years.	Minimum of three sites along length of entire estuary. For hole counts – three sites in muddy substrata on eastern shore below N2 bridge.

Table 7.8 Recommended long-term monitoring programme for the Klein Brak Estuary (priority components are highlighted)

Monitoring action	Temporal Scale (frequency and timing)	Spatial Scale (Number of stations)
Hydrodynamics		
Record water levels.	Continuous.	At bridge near mouth.
Measure freshwater inflow into the estuary.	Continuous.	Near head of estuary in Moordkuils (K1H5) and Brandwag (K1H4) tributaries.
Aerial photographs of estuary (spring low tide).	Every three years.	Entire estuary.
Sediment dynamics		
Monitoring berm height using appropriate technologies	Quarterly.	Mouth.
Bathymetric surveys: Series of cross section profiles and a longitudinal profile collected at fixed 500 m intervals but in more detail in mouth including berm (every 100 m). Vertical accuracy at least 5 cm.	Every three years (and after large resetting event).	Entire estuary.
Collect sediment grab samples (at cross section profiles) for analysis of particle size distribution and organic content (and ideally origin, i.e. microscopic observations).	Every three years.	Entire estuary.
Water quality		
Collect data on conductivity, temperature, suspended solids, pH, inorganic nutrients (N, P and Si) and organic content (Total P and Kjeldahl N) in river inflow.	Monthly, continuous.	Near head of estuary in Moordkuils (K1H5) and Brandwag (K1H4) tributaries.
Collect samples for pesticides/herbicide and metal determinations in river inflow.	Every three - six years, or when contamination is expected.	Near head of estuary in Moordkuils (K1H5) and Brandwag (K1H4) tributaries.
Collect *in situ* continuous salinity data with mini CTD probe at a depth of about 1 m.	Continuous.	Four - six sites. Head of the estuary in the Brandwag and Moordkuils arms, Brandwag and Moordkuil weirs/causeways, the confluence of the two arms, the lower bridge.
Record longitudinal *in situ* salinity and temperature pH, DO, turbidity profiles.	Seasonally, every year.	Entire estuary (10 - 13 stations).
Collect surface and bottom water samples for inorganic nutrients (and organic nutrient) and suspended solid analysis, together the in situ salinity, temperature, pH, DO and turbidity profiles.	Every three years (high flow and low flow) or when significant change in WQ expected.	Entire estuary (10 - 13 stations).

Monitoring action	Temporal Scale (frequency and timing)	Spatial Scale (Number of stations)
Measure pesticides/herbicides and metal accumulation in sediments.	Every three - six years, or when contamination is expected.	Entire estuary, including depositional areas (i.e. muddy areas).
Microalgae		
▪ Record relative abundance of dominant phytoplankton groups, i.e. flagellates, dinoflagellates, diatoms, chlorophytes and blue-green algae. ▪ Chlorophyll-a measurements taken at the surface, 0.5 m and 1 m depths, under typically high and low flow conditions using a recognised technique, e.g. spectrophotometer, HPLC or fluoroprobe. ▪ Intertidal and subtidal benthic chlorophyll-a measurements (four replicates each) using a recognised technique, e.g. sediment corer or fluoroprobe.	Quarterly for first two years and then low flow surveys. Every three years.	Along length of estuary minimum five stations (include stations in upper reaches of Brandwag and Moordkuil arms).
Macrophytes		
▪ In the field map the area covered by the different macrophyte habitats. Record boundaries and the total number of macrophytes species. 2013 was a rapid field survey and did not include detailed vegetation mapping and ground truthing. ▪ Assess extent of invasive species within the 5 m contour line. ▪ Locate the position of reed and sedge areas as indicators of future salinity changes. ▪ Identify supratidal salt marsh areas and their condition in terms of area of bareground. ▪ Map sensitive submerged macrophyte habitats such as *R. cirrhosa* and *Z. capensis* beds. ▪ Identify macroalgae present, their distribution and potential for future expansion (bloom formation) particularly under low flow conditions. ▪ Measure macrophyte and sediment characteristics along transects in the main salt marsh areas. Percentage plant cover measured in duplicate 1 m^2 quadrats along the transects and an elevation gradient from the water to the terrestrial habitat. ▪ Duplicate sediment samples collected in three zones along each transect to represent the lower intertidal, upper intertidal and supratidal salt marsh. Analysed in the laboratory for sediment moisture, organic content, electrical conductivity, pH and redox potential. In the field measure depth to water table and ground water salinity.	Every three years during summer.	Entire estuary.
Invertebrates		
▪ Collect duplicate zooplankton samples at night from mid-water levels using WP2 nets (190 µm mesh). ▪ Collect grab samples (five replicates) (day) from the bottom substrate in mid-channel areas at same sites as zooplankton (each samples to be sieved through 500 µm). ▪ Collect sled samples (day) at same zooplankton sites for hyper benthos (190 µm). ▪ Intertidal invertebrate hole counts using 0.25 m^2 grid (five replicates per site). Establish the species concerned using a prawn pump. ▪ Collect sediment samples using the grab for particle size analysis and organic content (at same sites as zooplankton).	Every two years in mid-summer.	Minimum of three sites along length of entire estuary. For hole counts – three sites in muddy substrata on eastern shore below N2 bridge.

Monitoring action	Temporal Scale (frequency and timing)	Spatial Scale (Number of stations)
Fish		
▪ Record species and abundance of fish, based on seine net and gill net sampling. Sampling with a small beam trawl for channel fish should also be considered. ▪ Seine net specifications: 30 m x 2m, 15 mm bar mesh seine with a 5 mm bar mesh with a 5 mm bar mesh 5 m either side and including the cod-end. ▪ Gill nets specifications: Set of gill nets each panel 30 m long by 2 m deep with mesh sizes of 44 mm, 48 mm, 51 mm, 54 mm, 75 mm, 100 mm and 145 mm. ▪ Trawl specification: 2 m wide by 3 m long, 10 mm bar nylon mesh in the main net body and a 5 mm bar in the cod-end.	Twice annually. Spring/Summer and autumn/winter.	Entire estuary (10 stations).
Birds		
Undertake counts of all non-passerine water birds, identified to species level (as for this study).	Annual winter and summer surveys.	Entire estuary including floodplain. Divide into sections: lower to N2; lower estuary adjacent marshes; middle to confluence including marshes; Moordkuils to top, Brandwag to top; upper floodplain wetlands (sections must be standardised).

7.5 WILDERNESS SYSTEM

Additional baseline studies that are important to the improvement of the confidence of the Wilderness System EWR study are provided in **Table 7.9.** These components are all important to improve the confidence overall, priority components are highlighted. Especially, data needs to be collected to improve the relationship between hydrology, mouth condition, and breaching levels. The recommended long-term monitoring programme, the purpose of which is to test for compliance with EcoSpecs and TPC and to continuously improve understanding of ecosystem function, is presented in **Table 7.10**. While all components in the long-term monitoring programme remain important, certain primary (abiotic) data, as highlighted in **Table 7.10**, is of highest priority.

Table 7.9 Additional baseline surveys to improve confidence of EWR study on the Wilderness System (priority components are highlighted)

Monitoring action	Temporal Scale (frequency and timing)	Spatial Scale (Number of stations)
Sediment dynamics		
Monitoring berm height using appropriate technologies.	Quarterly.	Mouth.
Bathymetric surveys: Series of cross section profiles and a longitudinal profile collected at fixed 300 m intervals, but in more detail in mouth including berm (every 100 m). Vertical accuracy at least 5 cm.	Once-off.	Entire estuary. All three connecting channels.
Bathymetric survey lines extending from the entrance of the western connecting channel to the entrance of the eastern connecting channel (or eastern bank), as well as a survey line from the southern to northern banks through the approximate centre of each lake.	Once-off.	Each of the three lakes (exact position of survey lines to be confirmed during baseline survey).
Collect sediment grab samples (at cross section profiles) for analysis of particle size distribution and organic content (and ideally origin, i.e. microscopic observations).	Once-off.	Entire estuary and each of the three lakes.
Water quality		
Collect samples for pesticides/herbicide and metal determinations in river inflow.	Once-off.	Near head of estuary in: Touw River (K3H5) Duiwe River (K3H11) Langspruit River
Measure pesticides/herbicides and metal accumulation in sediments (for metals investigate establishment of distribution models – refer to Newman and Watling, 2007).	Once-off.	Entire estuary and lakes, including depositional areas (i.e. muddy areas).
Collect surface and bottom water samples for inorganic nutrients (and organic nutrient) and suspended solid analysis, together the in situ salinity, temperature, pH, DO and turbidity profiles.	Quarterly, preferably over two years.	Entire estuary (nine stations). All lakes and connecting channels (including stations in deeper middle, and shallower peripheral areas of lakes).
Microalgae		
▪ Record relative abundance of dominant phytoplankton groups, i.e. flagellates, dinoflagellates, diatoms, chlorophytes and blue-green algae. ▪ Chlorophyll-a measurements taken at the surface, 0.5 m and 1 m depths, under typically high and low flow conditions using a recognised technique, e.g. spectrophotometer, HPLC or fluoroprobe. ▪ Intertidal and subtidal benthic chlorophyll-a measurements (four replicates each) using a recognised technique, e.g. sediment corer or fluoroprobe.	Quarterly, preferable over two years.	Entire estuary (minimum three stations). All lakes, including stations in deeper middle, and shallower peripheral areas of lakes (minimum five stations each).

Monitoring action	Temporal Scale (frequency and timing)	Spatial Scale (Number of stations)
Macrophytes		
▪ Ground-truthed maps to update changes over time in emergent vegetation after the SANParks 1997 assessment (Russell, 2003). ▪ Measurement of area covered by submerged macrophytes, SANParks annual field assessment to be included in vegetation map. ▪ Assess and map extent of invasive plants within the 5 m contour line.	Once-off.	Entire estuary and lakes.
Invertebrates		
▪ Collect duplicate zooplankton samples at night from mid-water levels using WP2 nets (190 µm mesh) along estuary. ▪ Collect grab samples (five replicates) (day) from the bottom substrate in mid-channel areas at same sites as zooplankton (each samples to be sieved through 500 µm). ▪ Collect sled samples (day) at same zooplankton sites for hyper benthos (190 µm). ▪ Intertidal invertebrate hole counts using 0.25 m^2 grid (five replicates per site). Establish the species concerned using a prawn pump. Check for the presence of mudprawn in muddy intertidal substrate in the lower estuary. ▪ Collect sediment samples using the grab for particle size analysis and organic content (at same sites as zooplankton)	Quarterly, preferable over two years.	Minimum of three sites along length of entire estuary and one site in each of the lakes For hole counts - three sites in Touw Estuary near the N2 bridge.

Table 7.10 Recommended long-term monitoring programme for the Wilderness System (priority components are highlighted)

Monitoring action	Temporal Scale (frequency and timing)	Spatial Scale (Number of stations)
Hydrodynamics		
Record water levels.	Continuous.	Touw Estuary (K3T006). Eilandvlei (K3R005). Langvlei (K3R004). Rondevlei (K3R003).
Measure freshwater inflow into the estuary.	Continuous.	Near head of estuary in: Touw River (K3H005). Duiwe River (K3H011). Langspruit River.
Aerial photographs or high resolution satellite imagery (5 x 5 m) of estuary.	Every three years.	Entire estuary.

Monitoring action	Temporal Scale (frequency and timing)	Spatial Scale (Number of stations)
Sediment dynamics		
Monitoring berm height using appropriate technologies.	Quarterly.	Mouth.
Bathymetric surveys: Series of cross section profiles and a longitudinal profile collected at fixed 300 m intervals, but in more detail in mouth including berm (every 100 m). Vertical accuracy at least 5 cm.	Every three years (and after large resetting event).	Entire estuary. All three connecting channels.
Bathymetric survey lines extending from the entrance of the western connecting channel to the entrance of the eastern connecting channel (or eastern bank), as well as a survey line from the southern to northern banks through the approximate centre of each lake.	Every three years (and after large resetting event).	Each of the three lakes (exact position of survey lines to be confirmed during baseline survey).
Collect sediment grab samples (at cross section profiles) for analysis of particle size distribution and organic content (and ideally origin, i.e. microscopic observations).	Every three years.	Entire estuary and each of the three lakes.
Water quality		
Collect data on conductivity, temperature, suspended matter/turbidity, DO, pH, inorganic nutrients and organic content in river inflow.	Monthly, continuous.	Near head of estuary in: Touw River (K3H5). Duiwe River (K3H11). Langspruit River. Also in lakes: Eilandvlei (K3R005). Langvlei (K3R004). Rondevlei (K3R003).
Collect in situ continuous salinity data with mini CTD probe at a depth of about 1 m.	Continuous.	Six sites - At the mouth, Ebb en flow, head of the estuary, Eilandvlei, Langvlei and Rondevlei.
Collect samples for herbicides and pesticides in river inflow.	Every three-six years.	Near head of estuary in: Touw River (K3H5). Duiwe River (K3H11). Langspruit River.
Record in situ salinity, temperature, pH, DO, turbidity profiles.	Seasonally, every year.	Entire estuary (nine stations). All lakes and connecting channels (including stations in deeper middle, and shallower peripheral areas of lakes).

Monitoring action	Temporal Scale (frequency and timing)	Spatial Scale (Number of stations)
Collect surface and bottom water samples for inorganic nutrients (and organic nutrient) and suspended solid analysis, together the in situ salinity, temperature, pH, DO and turbidity profiles.	Every three years (high flow and low flow) or when significant change in WQ expected.	Entire estuary (nine stations). All lakes and connecting channels (including stations in deeper middle, and shallower peripheral areas of lakes).
Measure pesticides/herbicides and metal accumulation in sediments (for metals investigate establishment of distribution models – refer to Newman and Watling, 2007).	Every three – six years.	Entire estuary and lakes, including depositional areas (i.e. muddy areas).
Microalgae		
▪ Record relative abundance of dominant phytoplankton groups, i.e. flagellates, dinoflagellates, diatoms, chlorophytes and blue-green algae. ▪ Chlorophyll-a measurements taken at the surface, 0.5 m and 1 m depths, under typically high and low flow conditions using a recognised technique, e.g. spectrophotometer, HPLC or fluoroprobe. ▪ Intertidal and subtidal benthic chlorophyll-a measurements (four replicates each) using a recognised technique, e.g. sediment corer or fluoroprobe.	Every three years during low flow.	Entire estuary (minimum three stations). All lakes, including stations in deeper middle, and shallower peripheral areas of lakes (minimum five stations each).
Macrophytes		
Map the area covered by the different macrophyte habitats. Compile a species list and check for expansion of invasive plants, reed, sedges and grass areas.	Summer surveys. Every three years.	Entire estuary and lakes.
SANParks to continue their monitoring including that of submerged macrophytes which includes four littoral transects around each lake and five transects in the Touw Estuary for biomass measurements. At the same time assessments of area covered should be made.	Bi-annually.	Entire estuary and lakes.
Invertebrates		
▪ Collect duplicate zooplankton samples at night from mid-water levels using WP2 nets (190 µm mesh) along estuary. ▪ Collect grab samples (five replicates) (day) from the bottom substrate in mid-channel areas at same sites as zooplankton (each samples to be sieved through 500 µm). ▪ Collect sled samples (day) at same zooplankton sites for hyper benthos (190 µm). ▪ Intertidal invertebrate hole counts using 0.25 m^2 grid (five replicates per site). Establish the species concerned using a prawn pump. Check for the presence of mudprawn in muddy intertidal substrate in the lower estuary. ▪ Collect sediment samples using the grab for particle size analysis and organic content (at same sites as zooplankton).	Every two years mid-summer.	Minimum of three sites along length of entire estuary and one site in each of the lakes. For hole counts – three sites in Touw Estuary near the N2 bridge.

Monitoring action	Temporal Scale (frequency and timing)	Spatial Scale (Number of stations)
Fish		
As per SANParks detailed monitoring programme.		
Birds		
Undertake counts of all water associated birds, identified to species level.	Continued winter and summer counts. A series of monthly counts carried out for two years each decade.	Entire system, divided into its component sections (estuary, Serpentine, three lakes)

7.6 KEURBOOMS ESTUARY

A monitoring programme was proposed for the Keurbooms Estuary as part of the 2008 EWR study (CSIR, 2008), but was re-assessed as part of the GRDS. Additional baseline studies that are important to the improvement of the confidence of the EWR study are provided in **Table 7.11**. These components are all important to improve the confidence overall, priority components are highlighted. Specifically the following crucial actions should continue/commence as soon as possible:

- Continuous water level recordings at the mouth and at the N2 Bridge in the Keurbooms Estuary to monitoring mouth state and tidal variation.
- Proper gauging of the river flow and water quality from the Keurbooms and Bitou rivers for at least a **three - five year period that includes both extreme low flow periods and high flow event.**
- Monitoring of salinity structure and water quality (e.g. nutrients and dissolved oxygen) under various river flow conditions **for at least a three - five year period, especially covering extreme low flow periods in both the Keurbooms and Bitou arms.**
- Bathymetric survey of the Keurbooms Estuary between the N2 bridges and the mouth, as well as the Bitou flood plain.
- Invertebrates and fish surveys including both the Bitou and Keurbooms arms.

The recommended long-term monitoring programme, the purpose of which is to test for compliance with EcoSpecs and TPC and to continuously improve understanding of ecosystem function, is presented in **Table 7.12**. While all components in the long-term monitoring programme remain important, certain primary (abiotic) data, as highlighted in **Table 7.12**, is of highest priority.

Table 7.11 Additional baseline surveys to improve confidence of EWR study on the Keurbooms Estuary (priority components are highlighted)

Action	Temporal Scale	Spatial Scale
Hydrology		
For larger systems record river inflow at head of estuary (smaller systems hydrology to be simulated every 10 years).	Continuous.	Head of estuary in Bitou tributary (to be refined and confirmed through future monitoring) and Keurbooms tributary (K6H19).
Hydrodynamics		
Record water levels (to record mouth state and tidal variation).	Continuous.	Near mouth (K6T018).
Aerial photography (or using high resolution satellite imagery i.e. 5 x 5 m pixel size, e.g. Google Pro or BirdEye) (e.g. to map mouth position over time).	Once-off.	Entire estuary.
Sediment dynamics		
Monitoring berm height using appropriate technologies.	Once-off.	Mouth.
Bathymetric surveys: Series of cross section profiles and a longitudinal profile collected at fixed 500 m intervals, but in more detail in the mouth including the berm (every 100 m). Vertical accuracy at least 5 cm.	Once-off.	Entire estuary.
Collect sediment grab samples (at cross section profiles) for analysis of particle size distribution and organic content (and ideally origin, i.e. microscopic observations).	Once-off.	Entire estuary.
Water quality		
Electrical conductivity, pH, inorganic nutrients and organic content (e.g. Total P and Kjeldahl N) in river inflow (preferably also suspended solids and temperature).	Monthly, continuous (as in DWS monitoring programme).	Head of estuary in Bitou tributary (to be refined and confirmed through future monitoring) and Keurbooms tributary (K6H19).
Salinity and temperature profiles (and any other *in situ* measurements possible e.g. pH, DO, and turbidity).	Monthly, for one year.	12 - 15 stations along length of estuary (e.g. see CSIR, 2008, Figure A1, but include additional station into the Bitou arm towards head of estuary).
Inorganic nutrient concentrations (together with above).	Once-off (high and low flows).	12 - 15 stations along length of estuary (e.g. see CSIR, 2008, Figure A1, but include additional station into the Bitou arm towards head of estuary).

Action	Temporal Scale	Spatial Scale
Measure pesticides/herbicides and metal accumulation in sediments (for metals investigate establishment of distribution models – refer to Watling and Newman, 2007).	Once-off.	Entire estuary, including depositional areas (i.e. muddy areas).
Microalgae		
▪ Record relative abundance of dominant phytoplankton groups, i.e. flagellates, dinoflagellates, diatoms, chlorophytes and blue-green algae. ▪ Chlorophyll-a measurements taken at the surface, 0.5 m and 1 m depths, under typically high and low flow conditions using a recognised technique, e.g. spectrophotometer, HPLC or fluoroprobe. ▪ Intertidal and subtidal benthic chlorophyll-a measurements (four replicates each) using a recognised technique, e.g. sediment corer or fluoroprobe.	Quarterly, for two years.	Along length of estuary minimum five stations.
Macrophytes		
▪ Map area covered by different macrophyte habitats using recent imagery. Conduct field survey to record total number of macrophytes habitats, identification and total number of macrophytes species, number of rare or endangered species, or those with limited populations. Assess extent of invasive species in Estuary Functional Zone (EFZ). ▪ Where there are salt marsh areas greater than 1 ha measure % plant cover along elevation gradient. Sediment samples collected along the transect and analysed in the laboratory for sediment moisture, organic content, EC, pH and redox potential. In the field measure depth to water table and ground water salinity.	Once-off.	Entire estuary (mapping). Where there is salt marsh (minimum three transect sites).
Invertebrates		
▪ Collect duplicate zooplankton samples at night from mid-water levels using WP2 nets (190 µm mesh) along estuary. ▪ Collect sled samples (day) at same zooplankton sites for hyper benthos (190 µm). ▪ Collect grab samples (five replicates) (day) from the bottom substrate in mid-channel areas at same sites as zooplankton (each samples to be sieved through 500 um). ▪ Intertidal invertebrate hole counts using 0.25 m^2 grid (five replicates per site). ▪ Establish the species concerned *(C. kraussi* or *U. africana*) using a prawn pump. ▪ Collect sediment samples using the grab for particle size analysis and organic content (at same sites as zooplankton) (preferably link with sediment dynamics).	Quarterly, for two years.	Minimum of three sites along length of entire estuary including the Keurbooms and Bitou arms. For hole counts - three sites in each of muddy or sandy areas.

Action	Temporal Scale	Spatial Scale
Fish		
▪ Record species and abundance of fish, based on seine net and gill net sampling. Sampling with a small beam trawl for channel fish should also be considered. ▪ Seine net specifications: 30 m x 2 m, 15 mm bar mesh seine with a 5 mm bar mesh with a 5 mm bar mesh 5 m either side and including the cod-end. ▪ Gill nets specifications: Set of gill nets each panel 30 m long by 2 m deep with mesh sizes of 44 mm, 48 mm, 51 mm, 54 mm, 75 mm, 100 mm and 145 mm. ▪ Gill net sampling can be replaced by a large mesh seine (44 mm stretch mesh, 100 m x 2 m). ▪ Trawl specification: 2 m wide by 3 m long, 10 mm bar nylon mesh in the main net body and a 5 mm bar in the cod-end.	Quarterly, over at least one year to account for the seasons.	12 - 15 stations along length of estuary (e.g. see CSIR, 2008, Figure A1, but include additional station into the Bitou arm towards head of estuary).
Birds		
Undertake counts of all non-passerine waterbirds, identified to species level.	Quarterly, over at least one year to account for the seasons.	Entire estuary (approximately seven sections).

Table 7.12 Recommended long-term monitoring programme for the Keurbooms Estuary (priority components are highlighted)

Monitoring action	Temporal Scale (frequency and timing)	Spatial Scale (Number of stations)
Hydrology		
For larger systems record river inflow at head of estuary (smaller systems hydrology to be simulated every 10 years).	Continuous.	Head of estuary in Bitou tributary (to be refined and confirmed through future monitoring) and Keurbooms tributary (K6H19).
Hydrodynamics		
Record water levels (to record mouth state and tidal variation).	Continuous.	Near mouth (K6T018).
Aerial photography (or using high resolution satellite imagery i.e. 5x5 m pixel size, e.g. Google Pro or BirdEye) (e.g. to map mouth position over time).	Annual.	Entire estuary.
Sediment dynamics		
Monitoring berm height using appropriate technologies.	Quarterly.	Mouth.
Bathymetric surveys: Series of cross section profiles and a longitudinal profile collected at fixed (e.g. 300 – 500 m intervals) but in more detail in mouth including berm (every 100 m). Vertical accuracy at least 5 cm.	Every three years (and after large resetting event).	Entire estuary.
Set sediment grab samples (at cross section profiles) for analysis of particle size distribution (and ideally origin, i.e. microscopic observations).	Every three years.	Entire estuary.

Monitoring action	Temporal Scale (frequency and timing)	Spatial Scale (Number of stations)
Water quality		
Electrical conductivity, pH, inorganic nutrients and organic content (e.g. Total P and Kjeldahl N) in river inflow (preferably also suspended solids and temperature).	Monthly, continuous (as in DWS monitoring programme).	Head of estuary in Bitou tributary (to be refined and confirmed through future monitoring) and Keurbooms tributary (K6H19).
Salinity and temperature profiles (and any other in situ measurements possible e.g. pH, DO, turbidity).	Quarterly.	12 - 15 stations along length of estuary (e.g. see CSIR, 2008, Figure A1, but include additional station into the Bitou arm towards head of estuary).
Inorganic nutrient concentrations (together with above).	Every three years (high and low flows) or when significant change in WQ expected.	12 - 15 stations along length of estuary (e.g. see CSIR, 2008, Figure A1, but include additional station into the Bitou arm towards head of estuary).
Measure pesticides/herbicides and metal accumulation in sediments (for metals investigate establishment of distribution models – refer to Newman and Watling, 2007).	Every three – six years, if results show contamination.	Entire estuary, including depositional areas (i.e. muddy areas).
Microalgae		
▪ Record relative abundance of dominant phytoplankton groups, i.e. flagellates, dinoflagellates, diatoms, chlorophytes and blue-green algae. ▪ Chlorophyll-a measurements taken at the surface, 0.5 m and 1 m depths, under typically high and low flow conditions using a recognised technique, e.g. spectrophotometer, HPLC or fluoroprobe. ▪ Intertidal and subtidal benthic chlorophyll-a measurements (four replicates each) using a recognised technique, e.g. sediment corer or fluoroprobe.	Low flow surveys. Every three years.	Along length of estuary minimum five stations.
Macrophytes		
Map area covered by different macrophyte habitats using recent imagery. Conduct field survey to record total number of macrophytes habitats, identification and total number of macrophytes species, number of rare or endangered species, or those with limited populations. Assess extent of invasive species in EFZ. Where there are salt marsh areas greater than 1 ha measure % plant cover along elevation gradient. Sediment samples collected along the transect and analysed in the laboratory for sediment moisture, organic content, EC, pH and redox potential. In the field measure depth to water table and ground water salinity.	Every three years, in summer.	Entire estuary (mapping). Where there is salt marsh (minimum three transect sites).

Monitoring action	Temporal Scale (frequency and timing)	Spatial Scale (Number of stations)
Invertebrates		
▪ Collect duplicate zooplankton samples at night from mid-water levels using WP2 nets (190 µm mesh) along estuary. ▪ Collect sled samples (day) at same zooplankton sites for hyper benthos (190 µm). ▪ Collect grab samples (five replicates) (day) from the bottom substrate in mid-channel areas at same sites as zooplankton (each samples to be sieved through 500 µm). ▪ Intertidal invertebrate hole counts using 0.25 m^2 grid (five replicates per site). ▪ Establish the species concerned *(C. kraussi* or *U. africana*) using a prawn pump. ▪ Collect sediment samples using the grab for particle size analysis and organic content (at same sites as zooplankton) (preferably link with sediment dynamics).	Every two years, mid-summer.	Minimum of three sites along length of entire estuary including the Keurbooms and Bitou arms. For hole counts – three sites in each of muddy or sandy areas.
Fish		
Record species and abundance of fish, based on seine net and gill net sampling. Sampling with a small beam trawl for channel fish should also be considered. Seine net specifications: 30 m x 2m, 15 mm bar mesh seine with a 5 mm bar mesh with a 5 mm bar mesh 5 m either side and including the cod-end. Gill nets specifications: Set of gill nets each panel 30 m long by 2 m deep with mesh sizes of 44 mm, 48 mm, 51 mm, 54 mm, 75 mm, 100 mm and 145 mm. Gill net sampling can be replaced by a large mesh seine (44 mm stretch mesh, 100 m x 2 m). Trawl specification: 2 m wide by 3 m long, 10 mm bar nylon mesh in the main net body and a 5 mm bar in the cod-end.	Twice annually, spring/ summer and autumn/ winter,	12 - 15 stations along length of estuary (e.g. see CSIR, 2008, Figure A1, but include additional station into the Bitou arm towards head of estuary).
Birds		
Undertake counts of all non-passerine waterbirds, identified to species level.	Twice annually, summer and winter.	Entire estuary (approximately seven sections).

7.7 OTHER ESTUARIES

A generic baseline and long-term monitoring programme to improve the confidence of the preliminary reserve determination in the estuaries assessed as part of the desktop assessment, as well as other estuaries in the WMA for which such programmes have not been provided previously, is presented in **Tables 7.13** and **7.14**, respectively (priority components are highlighted).

Table 7.13 Generic baseline surveys to improve confidence in the preliminary reserve determination of estuaries in the Gouritz WMA (highest priorities are highlighted)

Monitoring action	Temporal Scale (frequency and timing)	Spatial Scale (Number of stations)
Hydrology		
For larger systems record river inflow at head of estuary (smaller systems hydrology to be simulated every 10 years).	Continuous.	Install recorder near head of estuaries.
Hydrodynamics		
Record water levels Large system (permanent recorder DWS levelled to mean sea level). Smaller systems (small in situ probe).	Continuous.	Near mouth.
Aerial photography (or using high resolution satellite imagery i.e. 5x5 m pixel size, e.g. Google Pro or BirdEye).	Once-off.	Entire estuary.
Sediment dynamics		
Monitoring berm height using appropriate technologies.	Quarterly.	Mouth.
Bathymetric surveys: Series of cross section profiles and a longitudinal profile collected at fixed 500 m intervals, but in more detail in the mouth including the berm (every 100 m). Vertical accuracy at least 5 cm.	Once-off.	Entire estuary.
Collect sediment grab samples (at cross section profiles) for analysis of particle size distribution and organic content (and ideally origin, i.e. microscopic observations).	Once-off.	Entire estuary.
Water quality		
Electrical conductivity, pH, inorganic nutrients and organic content (e.g. Total P and Kjeldahl N) in river inflow (preferably also suspended solids and temperature).	Monthly (as in DWS monitoring programme).	Include monitoring station near head of estuary.
Salinity and temperature profiles (and any other in situ measurements possible e.g. pH, DO, and turbidity).	Quarterly, preferably for two years.	Along entire length of estuary (at least three station covering all zones).
Inorganic nutrient concentrations (together with above).	Quarterly, preferably for two years.	Along entire length of estuary (at least three station covering all zones).
Measure pesticides/herbicides and metal accumulation in sediments (for metals investigate establishment of distribution models – refer to Newman and Watling, 2007)	Once-off.	Entire estuary, including depositional areas (i.e. muddy areas).
Microalgae		
▪ Record relative abundance of dominant phytoplankton groups, i.e. flagellates, dinoflagellates, diatoms, chlorophytes and blue-green algae. ▪ Chlorophyll-a measurements taken at the surface, 0.5 m and 1 m depths, under typically high and low flow conditions using a recognised technique, e.g. spectrophotometer, HPLC or fluoroprobe. ▪ Intertidal and subtidal benthic chlorophyll-a measurements (four replicates each) using a recognised technique, e.g. sediment corer or fluoroprobe.	Quarterly preferably for two years.	Along length of estuary minimum five stations.

Monitoring action	Temporal Scale (frequency and timing)	Spatial Scale (Number of stations)
Macrophytes		
▪ Map area covered by different macrophyte habitats using recent imagery. Conduct field survey to record total number of macrophytes habitats, identification and total number of macrophytes species, number of rare or endangered species, or those with limited populations. Assess extent of invasive species in EFZ. ▪ Where there are salt marsh areas greater than 1 ha measure % plant cover along elevation gradient. Sediment samples collected along the transect and analysed in the laboratory for sediment moisture, organic content, EC, pH and redox potential. In the field measure depth to water table and ground water salinity	Once-off, in summer.	Entire estuary (mapping). Where there is salt marsh (minimum three transect sites).
Invertebrates		
▪ Collect duplicate zooplankton samples at night from mid-water levels using WP2 nets (190 µm mesh) along estuary ▪ Collect sled samples (day) at same zooplankton sites for hyper benthos (190 µm) ▪ Collect grab samples (five replicates) (day) from the bottom substrate in mid-channel areas at same sites as zooplankton (each samples to be sieved through 500 µm). ▪ Intertidal invertebrate hole counts using 0.25 m^2 grid (five replicates per site). ▪ Establish the species concerned *(C. kraussi* or *U. africana*) using a prawn pump. ▪ Collect sediment samples using the grab for particle size analysis and organic content (at same sites as zooplankton) (preferably link with sediment dynamics).	Quarterly, preferably for two years.	Minimum of three sites along length of entire estuary. For hole counts – three sites in each of muddy or sandy areas.
Fish		
▪ Record species and abundance of fish, based on seine net and gill net sampling. Sampling with a small beam trawl for channel fish should also be considered. ▪ Seine net specifications: 30 m x 2m, 15 mm bar mesh seine with a 5 mm bar mesh with a 5 mm bar mesh 5 m either side and including the cod-end. ▪ Gill nets specifications: Set of gill nets each panel 30 m long by 2 m deep with mesh sizes of 44 mm, 48 mm, 51 mm, 54 mm, 75 mm, 100 mm and 145 mm. ▪ Gill net sampling can be replaced by a large mesh seine (44 mm stretch mesh, 100 m x 2 m). ▪ Trawl specification: 2 m wide by 3 m long, 10 mm bar nylon mesh in the main net body and a 5 mm bar in the cod-end.	Once-off, in spring/ summer and autumn/ winter.	Larger system (> 5 km): 10 - 15 stations along length of estuary) (~ length/10). Small systems (< 5 km): 3 - 5 stations (mouth, mid, top).
Birds		
Undertake count of all water birds.	Once-off. Hartenbos, and Groot (Wes): Annual and divide estuary into upper middle lower) must be sensible divisions.	Entire estuary. Hartenbos and Groot (Wes): Divide estuary into upper middle lower sections.

Table 7.14 Generic long-term monitoring programme for estuaries in the Gouritz WMA (highest priorities are highlighted)

Monitoring action	Temporal Scale (frequency and timing)	Spatial Scale (Number of stations)
Hydrology		
For larger systems record river inflow at head of estuary (smaller systems hydrology to be simulated every 10 years).	Continuous.	At station near head of estuary.
Hydrodynamics		
Record water levels. Large system (permanent recorder DWS levelled to mean sea level). Smaller systems (small in situ probe).	Continuous.	Near mouth.
Aerial photography (or using high resolution satellite imagery i.e. 5 x 5 m pixel size, e.g. Google Pro or BirdEye).	Every three years.	Entire estuary.
Sediment dynamics		
Monitoring berm height using appropriate technologies	Quarterly.	Mouth.
Bathymetric surveys: Series of cross section profiles and a longitudinal profile collected at fixed (e.g. 300 – 500 m intervals) but in more detail in mouth including berm (every 100 m). Vertical accuracy at least 5 cm.	Every three years (and after large resetting event).	Entire estuary.
Set sediment grab samples (at cross section profiles) for analysis of particle size distribution (and ideally origin, i.e. microscopic observations)	Every three years.	Entire estuary.
Water quality		
Electrical conductivity, pH, inorganic nutrients and organic content (e.g. Total P and Kjeldahl N) in river inflow *(*preferably also suspended solids and temperature).	Monthly.	At station near head of estuary.
Salinity and temperature profiles (and any other in situ measurements possible e.g. pH, DO, turbidity).	Seasonally, annually.	Along entire length of estuary (at least three station covering all zones).
Inorganic nutrient concentrations (together with above).	Every three years (high flow and low flow) or when significant change in WQ expected.	Along entire length of estuary (at least three station covering all zones).
Measure pesticides/herbicides and metal accumulation in sediments.	Every three – six years, if results show contamination.	Entire estuary, including depositional areas (i.e. muddy areas).
Microalgae		
▪ Record relative abundance of dominant phytoplankton groups, i.e. flagellates, dinoflagellates, diatoms, chlorophytes and blue-green algae. ▪ Chlorophyll-a measurements taken at the surface, 0.5 m and 1 m depths, under typically high and low flow conditions using a recognised technique, e.g. spectrophotometer, HPLC or fluoroprobe. ▪ Intertidal and subtidal benthic chlorophyll-a measurements (four replicates each) using a recognised technique, e.g. sediment corer or fluoroprobe.	Every three years.	Along length of estuary minimum five stations.

Monitoring action	Temporal Scale (frequency and timing)	Spatial Scale (Number of stations)
Macrophytes		
▪ Map area covered by different macrophyte habitats using recent imagery. Conduct field survey to record total number of macrophytes habitats, identification and total number of macrophytes species, number of rare or endangered species, or those with limited populations. Assess extent of invasive species in EFZ. ▪ Where there are salt marsh areas greater than 1 ha measure % plant cover along elevation gradient. Sediment samples collected along the transect and analysed in the laboratory for sediment moisture, organic content, EC, pH and redox potential. In the field measure depth to water table and ground water salinity.	Every three years, in summer.	Entire estuary (mapping). Where there is salt marsh (minimum three transect sites).
Invertebrates		
▪ Collect duplicate zooplankton samples at night from mid-water levels using WP2 nets (190 µm mesh) along estuary. ▪ Collect sled samples (day) at same zooplankton sites for hyper benthos (190 µm). ▪ Collect grab samples (five replicates) (day) from the bottom substrate in mid-channel areas at same sites as zooplankton (each samples to be sieved through 500 µm). ▪ Intertidal invertebrate hole counts using 0.25 m^2 grid (five replicates per site). ▪ Establish the species concerned *(C. kraussi* or *U. africana*) using a prawn pump. ▪ Collect sediment samples using the grab for particle size analysis and organic content (at same sites as zooplankton) (preferably link with sediment dynamics).	Every two years, in mid-summer	Minimum of three sites along length of entire estuary. For hole counts - three sites in each of muddy or sandy areas.
Fish		
▪ Record species and abundance of fish, based on seine net and gill net sampling. Sampling with a small beam trawl for channel fish should also be considered. ▪ Seine net specifications: 30 m x 2m, 15 mm bar mesh seine with a 5 mm bar mesh with a 5 mm bar mesh 5 m either side and including the cod-end. ▪ Gill nets specifications: Set of gill nets each panel 30 m long by 2 m deep with mesh sizes of 44 mm, 48 mm, 51 mm, 54 mm, 75 mm, 100 mm and 145 mm. ▪ Gill net sampling can be replaced by a large mesh seine (44 mm stretch mesh, 100 m x 2 m). Trawl specification: 2 m wide by 3 m long, 10 mm bar nylon mesh in the main net body and a 5 mm bar in the cod-end.	Twice annually, spring/ summer and autumn/ winter.	Larger system (> 5 km): 10 - 15 stations along length of estuary) (~ length/10). Small systems (< 5 km): 3 - 5 stations (mouth, mid, top).
Birds		
Undertake count of all water birds.	Every two years, mid-summer. Hartenbos, and Groot (Wes): Annual and divide estuary into upper middle lower) must be sensible divisions.	Entire estuary. Hartenbos and Groot (Wes): Divide estuary into upper middle lower sections.

8 WETLAND MONITORING

8.1 MONITORING AND ECOSPECS

There are thousands of wetlands in South Africa, and it would be difficult, if not impossible, to map every single wetland as many are small (i.e. beyond a reasonable mapping scale), some are cryptic (i.e. not be easily identified) and others have been extensively modified, thus making their identification and delineation difficult. Even if all the wetlands within a region could be identified and mapped, their sheer number would preclude a site-specific approach to wetland management.

Monitoring and EcoSpecs, as outlined in **Sections 2.1** to **2.3** of this report applies to wetlands except that TPCs are not applicable at present for wetlands. This is mainly due to depauperate data availability which in turn does not allow for defining wetland specific TPCs.

8.2 DIFFERENT LEVELS OF MONITORING

Monitoring programmes have generally in South Africa failed due to amongst others the following reasons:

- The lack of a monitoring DSS and an Adaptive Management Framework.
- The perceived high cost associated with the application of an EWR monitoring programme.

In wetlands, the monitoring programmes that are suggested are relatively cheap desktop approaches, with limited field verification if budget and expertise permits. The design of a cost-effective monitoring programme is based on different levels of monitoring as follows:

- EcoSpecs for priority wetlands; and
- EcoSpecs for key catchments.

8.3 PRINCIPLES OF EWRM AND ECOSPECS

Monitoring in this report focusses on measuring the ecological state, i.e. the EC. EcoSpecs therefore describe the PES and/or the REC for each of the biota and habitat indicators. The key principles and concepts are the following:

- The data collated during desktop and field surveys form the baseline.
- Future monitoring must compare conditions to the baseline.
- For wetlands, the EcoSpecs describe the baseline so monitoring can determine whether one is maintaining the PES, further degrading the system, or achieving the REC if different from the PES.
- Monitoring should be initiated soon after the baseline data has been collated to ensure that this data represents the recent baseline.
- Monitoring must be applied within an Adaptive Management Framework.
- If the EcoSpecs are not met, management actions will be necessary.

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 land use objectives for the non-flow related aspects of the wetland EcoSpecs.

8.4 APPROACH

Of the thirty-three potential priority wetlands identified in the WMA, two of the highest priority wetlands were selected for field assessments. The purpose of the field assessments was to verify the desktop data and information, to determine the EcoStatus (PES, EIS and REC) of the priority wetlands, to identify the threats and achievable management actions which could be implemented to halt or reverse degradation, and to provide field-based wetland assessment training opportunities to DWS national and regional staff (DWS, 2015f).

The two priority wetlands selected were the Duiwenhoks valley bottom wetland and Bitou floodplain. Although the Goukou wetland complex scored slightly higher in the priority ranking, the issues in the Goukou system are very similar to those in the immediately adjacent Duiwenhoks system in that there are large degraded, eroding palmiet valley bottom wetlands in both catchments. By including the assessment of the Bitou wetland, it offered the opportunity to assess a similarly high priority wetland, but to examine and understand a different wetland type with different management challenges to the Duiwenhoks (and Goukou) wetlands (DWS, 2015f).

This approach outlined below is for desktop monitoring of priority and key wetlands in the study area. The best available wetlands maps should be used in conjunction with Google Earth or other similar available landcover records to evaluate the condition of invasive alien vegetation, erosion and landuse encroachment within wetland areas. Compare the baseline (2015) records with the most recent available imagery.

At present the SANBI National Wetland Map is the most up to date national wetland map available, and is periodically updated. The DWS should regularly consult with local municipalities and the National DEA (current contact as at November 2015: Namhla Mbona (N.Mbona@sanbi.org.za)) to ensure that any updated wetland maps of the region are obtained to be consulted during the monitoring phases. This will ensure that the most up to date information on known wetland extent is used for the monitoring procedures.

8.5 DUIWENHOKS WETLAND: PRIORITY WETLAND 1

8.5.1 PES and EIS

The Duiwenhoks wetland is located in the H80A quaternary catchment. The upper catchment is within the Southern Fold Mountain EcoRegion, but where the river flows out into the flatter coastal belt. The subsequent deposition of alluvium derived from the steep mountainous streams, and associated growth of vegetation upon this alluvium, resulted in the creation of extensive valley bottom wetlands. The Duiwenhoks wetland was once a very large wetland system characterised by unchannelled and weakly channelled valley bottom wetlands which would have been dominated by palmiet and *Phragmites* vegetation.

The large wetlands which were present in this basin, and the adjacent Goukou catchment, once represented good examples of large valley bottom palmiet wetlands which are present in the foothill valleys of the Western Cape and parts of the Eastern Cape provinces. Ecological Importance and Sensitivity of the Duiwenhoks are estimated to be Moderate, in that the conservation of this large

wetland is likely to be locally to regionally in terms of its ecology, and its strong flood attenuation and sediment trapping functions would be important for the downstream catchment (DWS, 2015f).

Although in the upperwestern section of the basin, some large intact wetland patches remain, even here the wetland is impacted by invasive alien vegetation and, most importantly, an extensive, actively eroding donga. For the remainder of the basin, the situation is far worse, with a large erosion donga having impacted the wetlands for many decades. The erosion of the wetland and diversion of flows into the eroded donga channel has caused reduced flows on the wetland (valley bottom), resulting in desiccation and degradation of remaining wetland areas. The encroachment of agricultural areas, and construction of dykes, drains and road crossings, all serve to further reduce and degrade the remaining wetland areas. The concentrated flows in the eroded channel cause high flow velocities and this has resulted in the continued erosion of the bed and banks of the dongas. Once the protective, binding layer of vegetation is eroded off the wetland surface, the erosion process is advanced and very expensive, to stop or contain. The eroded nature of the wetland, together with invasive woody vegetation and encroachment of agricultural areas into the wetlands, are the main causes of the PES, which was assessed to be in a D EC (largely modified). Based on the site visit, study results, expert opinion and the diversion from the natural state this wetland is on a negative trajectory and requires management intervention. The REC for this wetland, given its moderate EIS, should be to maintain the current condition of the D Category. This will require the stabilisation and remediation of the current impacts, most notably erosion, to halt the negative trajectory of change (DWS, 2015f).

8.5.2 Monitoring approach

- Monitor the extent of erosion dongas using Google Earth. The erosion dongas should not extend further than the 2015 (baseline) conditions.
  Action: Stabilise erosion dongas; work in conjunction with DAFF, Working for Wetlands (WfWetlands).
- Monitor the extent of invasive alien vegetation within and alongside wetlands. Invasive alien vegetation, especially woody vegetation, within and alongside wetlands must reduce (to reverse the negative trend) relative to the baseline (2015) conditions.
  Action: Invasive alien vegetation should be actively managed to reduce extent and prevent further loss and degradation of wetland habitats.
- Prevent landuse encroachment in to wetlands. Ensure that Water Use Licence Applications (WULAs) and all proposed developments adjacent to wetlands include a wetland delineation to confirm the footprint of the wetland.
  Action: For WULAs where activities which pose high risk of degradation to wetlands are considered, wetland delineation is recommended.

8.5.3 EcoSpecs

Monitoring should ensure that:

- There is no additional erosion in intact wetland sections.
- There is no encroachment of agricultural areas in to wetlands.

- There is removal and control of invasive alien vegetation within and along margins of the wetland. The draining of the wetland areas and/or diverting of flows have already initiated widespread erosion in former pristine wetland areas and further degradation of this type must be prevented; and
- The EC must achieve or exceed the 2015 baseline. Baseline scores for EC are provided in **Table 8.1**.

Table 8.1 Baseline (2015) PES of the Duiwenhoks wetland

Metric	PES	Confidence rating
Driving Processes:		
Hydrology	C/D	3.4
Geomorphology	E	4.0
Water quality	A	3.0
Wetland Landuse Activities:		
Vegetation Alteration Score	C	4.0
Overall PES Category (%)		**D (57%)**

8.6 BITOU FLOODPLAIN: PRIORITY WETLAND 2

The Bitou floodplain is located in quaternary catchment K60F upstream of the confluence of the Bitou River with the Keurbooms estuary. The upper reaches of the floodplain are characterised by a meandering alluvial channel through a floodplain which is extensively under agricultural uses. This gradually changes to an increasingly estuarine-influenced system towards the confluence with the Keurbooms (DWS, 2015f).

The indigenous vegetation on the estuary floodplain is Endangered Shale Fynbos which has been designated as a CBA in the Bitou, but most of this vegetation has been lost in the conversion to agriculture. The floodplains and salt marshes of the Bitou have historically been subjected to reclamation for agricultural purposes, but on the lower reaches, this was not successful due to the presence of saline groundwater (Bornman, 2004). Bird species numbers and total counts for the Bitou Estuary have decreased and this has been attributed to pollution from effluent, pesticides and fertilizers, damage by livestock, siltation of the estuary, reed encroachment and residential development (Taylor *et al*., 1999). In addition, alien tree species, most notably *Acacia melanoxylon*, *Acacia saligna* and *Acacia mearnsii*, have invaded sections of the floodplains.

Ecological Importance and Sensitivity of the Bitou wetlands is estimated to be Moderate. Although the floodplain and associated wetlands flow into the much larger Keurbooms estuary, which is ranked as the 18th most important estuary in South Africa, the Bitou catchment is small and contribution of flows are small. In addition, the Bitou floodplain has been extensively transformed by agricultural activities, but the lower lying areas and estuarine wetlands are more intact. Large numbers of birds are associated with the area, including Blue Cranes (IUCN Vulnerable species).

The flood attenuation and sediment trapping functions of intact wetlands afford a moderate importance to the hydrological functions of this floodplain. The area is largely composed of residential smallholdings and commerical farms, so subsistence use and direct dependence on the wetland for a subsistence livelihood (direct human benefits) is expected to be low. Overall, importance of the wetland is thus Moderate, indicating a local to regional importance for the wetland.

The PES of the Bitou wetland is rated as a C category, partially due to catchment issues, such as reduced flows, but also due to direct impacts on the floodplain itself. In particular, the alteration (conversion) of floodplain vegetation to agricultural pastures has had the biggest impact upon the PES. Large pine plantations within the catchment are expected to have slightly reduced baseflows. On the floodplain and margins thereof, the intensive agricultural activities have reduced the condition of the floodplain through:

- Loss of wetland habitat due to some small areas of infilling.
- Extensive conversion of vegetation from indigenous species to pasture grasslands.
- Overgrazing and bank destabilisation; and
- Nutrient-rich runoff from agricultural lands.

Invasive alien vegetation and encroachment of residential and other infrastructure on the floodplain have also further reduced the ecological condition of the system. There is reduced hydrological connectivity across the floodplain due to road crossings (small culverts) and bridges, as well as levees and excavated canals/channels which facilitate drainage.

In 1961 there were 45 ha of freshwater wetlands above the Wittedrif Bridge on the Bitou system, but by 2006 these had been reduced to less than 30 ha. Reduced flows, infrastructure impacts, development encroachment and land use conversion have all impacted upon the floodplain and its wetlands (DWS, 2015f).

8.6.1 Monitoring approach

- Monitor the extent of invasive alien vegetation within and alongside wetlands. Invasive alien vegetation, especially woody vegetation within and alongside wetlands, must not expand relative to the baseline (2015) conditions. Invasive woody alien vegetation should be removed from the floodplain wherever possible, and must be removed from all riparian zones along the river channel. This will promote an increase in the indigenous vegetation through reduced shading.
  Action: Invasive alien vegetation should be actively managed to prevent further loss and degradation of wetland habitats.
- Prevent landuse encroachment into wetlands. Ensure WULAs and all proposed developments adjacent to wetlands include a wetland delineation to confirm the footprint of the wetland.
  Action: For WULAs where activities which pose high risk of degradation to wetlands are considered, wetland delineation is recommended.

8.6.2 EcoSpecs

Monitoring should focus on the key impacts which affect the wetlands and place at risk the achievement of the REC:

- No encroachment of agricultural or residential areas in to wetlands.
- Removal and control of invasive alien vegetation within and along margins of the wetland. The draining of the wetland areas and/or diverting of flows have already initiated widespread degradation and further degradation of this type must be prevented.
- The EC must achieve or exceed the 2015 baseline. Baseline scores for EC are provided in **Table 8.2**.

Table 8.2 Baseline (2015) PES of the upper Bitou floodplain

Metric	PES	Confidence rating
Driving Processes:		
Hydrology	C	2.2
Geomorphology	C	3.0
Water quality	C	1.9
Wetland Landuse Activities:		
Vegetation Alteration Score	D	3.0
Overall PES Category (%)		**C (63%)**

An additional recommendation would be to promote the vegetation of buffer areas along streams and natural canals. This would assist to reduce turbidity and sediment losses from the floodplain through stabilised stream and canal banks. The vegetation may also assist with some nutrient trapping and thus a potential reduction in nutrient-rich runoff from the agricultural areas.

8.7 WETLANDS IN KEY CATCHMENTS OF THE GOURITZ WMA

The average EIS and PES of wetlands for assessed catchments in the study area are provided in **Table 8.3**. High and Very High EIS catchments are noted in bold and where the REC is higher than the PES, REC is highlighted.

8.7.1 Monitoring approach

The design of a cost-effective catchment-scale monitoring programme can be based on different priorities for monitoring as follows:

- Level 1a: Desktop approaches at a moderate frequency (e.g. every two to three years) focussing on the High and Very High EIS catchments (see **Table 8.3**).
- Level 1b: Desktop approaches at a moderate frequency (e.g. every two to three years) focussing on the Moderate EIS catchments (see **Table 8.3**).

The monitoring of important quaternary catchments should ensure that:

- Invasive alien vegetation, especially woody vegetation, within and alongside wetlands does not expand from the baseline (2015) conditions.
    - For quaternary catchments K30B, K50B and K80A where the REC is higher than the baseline condition, the extent of invasive alien vegetation should decline relative to the baseline condition.
- Erosion dongas, which desiccate wetlands and cause the degradation of wetland habitats, should not expand from the baseline (2015) conditions. The unchecked expansion of erosion dongas will cause wetlands to be degraded and lost. Rehabilitation interventions can be implemented in conjunction with the DAFF, DEA and WfWetlands.
- Residential, industrial and agricultural landuse encroachment in to wetlands should not take place.
- The average EC for the catchment achieves the REC (**Table 8.3**).

Table 8.3 The average EIS and PES of wetlands for assessed catchments in the Study Area

Quaternary catchment	EIS	PES	REC	How to achieve the REC
K10A	Moderate	C	C	Control invasive alien vegetation, erosion and landuse encroachment.
K10B	Moderate	C	C	
K10C	Moderate	B/C	B/C	
K10D	Moderate	B/C	B/C	
K10E	Moderate	B/C	B/C	
K10F	Moderate	C	C	
K20A	Moderate	C	C	
K30A	**High**	C	C	
K30B	**High**	D	C/D	Buffers in urban and agricultural areas, manage water quality, erosion and invasive vegetation.
K30C	Moderate	D	D	Control invasive alien vegetation, erosion and landuse encroachment.
K30D	**Very High**	B	B	
K40A	Moderate	D	D	
K40B	Moderate	C	C	
K40C	Moderate	C	C	
K40D	**Very High**	B	B	
K40E	Moderate	B/C	B/C	
K50A	Moderate	b/c	B/C	
K50B	**High**	C/D	C	No net loss or degradation of remaining wetland patches, control invasive vegetation.
K60A	Moderate	B	B	Control invasive alien vegetation, erosion and landuse encroachment.
K60B	Moderate	B	B	
K60C	Moderate	B	B	
K60D	**High**	A	A	
K60E	**High**	C	C	
K60F	**High**	C	C	
K60G	Moderate	C	C	
K70A	Moderate	C	C	

Quaternary catchment	EIS	PES	REC	How to achieve the REC
K70B	Low	A	A	
H80A	**High**	C/D	C	
H80B	Moderate	C	C	
H80C	Moderate	D	D	
H80D	Moderate	D	D	
H80E	Moderate	C/D	C/D	
H90A	Moderate	C	C	
H90B	Moderate	D	D	Control invasive alien vegetation, erosion and landuse encroachment.
H90C	Moderate	D	D	
H90D	Moderate	C	C	
H90E	Moderate	C/D	C/D	
J11D	Low	C	C	
J11F	Moderate	C	C	
J11G	Moderate	B	B	
J12A	Moderate	B	B	
J12B	Moderate	B	B	
J12J	Moderate	B	B	
J12K	Moderate	B	B	
J12L	Moderate	C	C	
J21A	Moderate	B/C	B/C	
J21B	Moderate	B	B	
J22B	Moderate	B	B	
J22G	Moderate	B	B	
J22K	Low	B/C	B/C	
J23E	Low	C	C	
J23J	Moderate	B	B	
J24F	Low	C	C	
J25A	Low	B	B	
J33B	Low	C	C	
J33E	Low	C	C	
J34C	Low	C	C	
J34D	Low	C	C	
J34E	Low	C/D	C/D	
J34F	Low	D	D	
J40B	Low	B	B	
J40C	Moderate	C/D	C/D	
J40D	Moderate	D	D	
J40E	**High**	C	C	

8.7.2 EcoSpecs

The monitoring of important quaternary catchments should ensure that:

- Invasive alien vegetation, especially woody vegetation, within and alongside wetlands does not expand from the baseline (2015) conditions.
    - For quaternary catchments K30B, K50B and K80A where the REC is higher than the baseline condition, the extent of invasive alien vegetation should decline relative to the baseline condition.
- Erosion dongas, which desiccate wetlands and cause the degradation of wetland habitats, should be stabilised through rehabilitation structures. The unchecked expansion of erosion dongas will cause wetlands to be degraded and lost. Rehabilitation interventions can be implemented in conjunction with the DAFF, DEA and WfWetlands.
- Residential, industrial and agricultural landuse encroachment in to wetlands should not take place.
- The EC must achieve or exceed the 2015 baseline, and meet the REC (**Table 8.1**).

8.8 GAPS AND RECOMMENDATIONS FOR ADDITIONAL DATA

Current available maps of the wetlands of the GRDS study area are the NFEPA maps which have been developed by the SANBI, which is now absorbed within the national DEA. These maps provide an indication of likely wetland presence and extent across the study area, but are not highly accurate in terms of exact wetland number and extent. The SANBI wetland map is periodically updated to incorporate improved regional and national wetland coverage data. More accurate, detailed maps of wetland extent would improve the quality of monitoring (of impacts within wetlands) and thus wetland resource protection. ***The DWS should regularly consult with local municipalities, the Provincial and National DEA andSANBI*** (current contact as at November 2015: Namhla Mbona (N.Mbona@sanbi.org.za)) to ensure that any updated wetland maps of the region are obtained. This will ensure that the most up to date information on known wetland extent is used for the monitoring procedures described above.

Several stakeholders have highlighted the limited understanding on the recharge of groundwater to the Bitou wetland, the discharge of groundwater and surface water to the Keurbooms Estuary and impact of current water abstractions for agriculture. To anticipate the data requirements to ensure an adequate understanding of the links to the estuary and enable sustainable allocation of water volumes when compulsory licencing comes in to play in this system, it is recommended that a water level and flow monitoring programme be considered for the Bitou system.

The estuary studies undertaken in this project highlighted the need for improved baseflows for the Duiwenhoks Estuary (DWS, 2014c). To some extent, improved baseflows can be achieved through the rehabilitation and protection of wetlands within the catchment. The upper Duiwenhoks catchment still has some large wetland patches remaining, such as the priority site selected in the wetland assessment, and protection of this wetland could aid in maintaining some of the current baseflow regulation functions in the catchment. A strong focus on preventing draining of wetlands and, where possible, the plugging of existing drains/canals within floodplains and wetlands, would

aid in increasing water tables and baseflow regulation functions. Such actions would both improve wetland conditions at the site but also improve the reliability of baseflows.

9 GROUNDWATER MONITORING

9.1 BACKGROUND

Based on an assessment of the existing active DWS monitoring borehole network, the active network maintained and managed by DWS is well developed compared to networks in some of the other water management areas in South Africa. The spatial distribution of the actively monitored boreholes within the WMA is also generally good. **Figure 9.1** shows all of the DWS active monitoring borehole locations. Within the Gouritz WMA there are a total of 231 historic and active hydraulic head (groundwater level) monitoring boreholes. Of these hydraulic head monitoring boreholes, 106 are still in operation where head measurements are taken, in some cases automatically, by pressure transducers (level loggers). Basic physiochemical constituents are also determined from samples taken periodically at 17 active water quality monitoring boreholes. In addition, there are a number of private active monitoring boreholes of which details are not listed in the DWS active monitoring borehole database. Time-series water levels can date back to 1961 if the entire dataset of historic and active hydraulic head monitoring boreholes are considered. A robust monitoring protocol was implemented by DWS since May 2002, based on observation of inceased number of monitoring boreholes and frequency in DWS active groundwater monitoring data. **Table 9.1** provides a summary of the number of active monitoring boreholes per selected GRU and compares also where WULAs (July 2013; DWS, 2014d) were received and are pending.

According to an extensive recent review (DWS, 2015a) and mapping of all historic and active DWS monitoring boreholes in South Africa (DWS, 2015b) by AECOM, there are 81 active DWS groundwater level monitoring boreholes in the Gouritz WMA and 17 active groundwater quality monitoring boreholes (DWS, 2015b; **Table 9.2**). Their spatial distribution is shown in **Figure 9.2**. AECOM developed a ‘smart’ numbering system that indicates whether a station is open or closed, what kind of groundwater monitoring (level or quality) is being performed and how large the data gaps in the monitoring records are.

Data sources used for the AECOM monitoring borehole network evaluation are those of DWS, Agricultural Research Council (ARC) and the South African Weather Services (SAWS) (DWS, 2015a – Table 3.1).

The purpose of this component of the groundwater Reserve determination is to evaluate the current monitoring network, identify gaps if any and to suggest improvements and/or new monitoring borehole sites where deemed necessary.

9.2 LOCATIONS OF DWS ACTIVE MONITORING BOREHOLES

Locations of active monitoring boreholes are shown in **Figure 9.2**. Although a good coverage of the most important GRUs and selected Intermediate Reserve quaternaries is achieved with the existing active monitoring boreholes, there are still some areas in the Gouritz WMA where additional groundwater monitoring boreholes would be prudent. One observation of the active monitoring borehole network is that there are often concentrations of monitoring boreholes at specific towns while other towns have none. It is, however, also true that one has to consider for each town if groundwater level data is really necessary given the town's type of water use (surface- or groundwater-source).

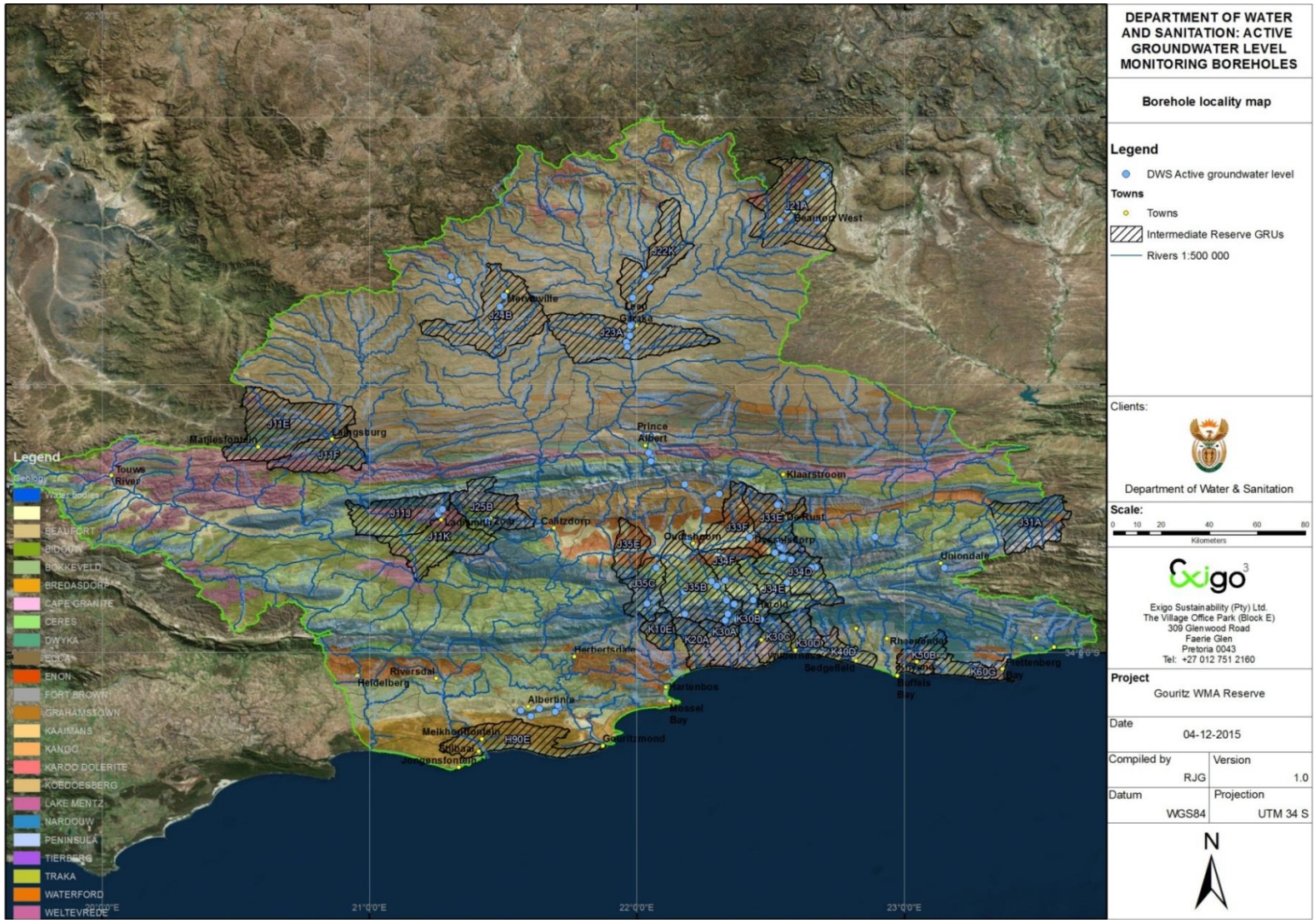

Figure 9.1 DWS historic and active hydraulic head monitoring network stations

Table 9.1 Gouritz active hydraulic head monitoring boreholes (DWS, 2015b)

Station	NGA_ID	Startdate	Enddate	Gap % total dataset	Label
H4N0051	3319DA00202	25/02/2004	27/09/2012	0%	H4N0051-GI-O-10yrs-0%
J1N0520	33864	20/02/2005	12/05/2014	0%	J1N0520-GI-O-9yrs-0%
J1N0522	GZ00324	14/11/2006	12/05/2014	0%	J1N0522-GI-O-7yrs-0%
J1N0523	GZ00325	20/09/2006	12/05/2014	0%	J1N0523-GI-O-8yrs-0%
J1N0524	GZ00326	20/09/2006	12/05/2014	0%	J1N0524-GI-O-8yrs-0%
J2N0550	029885B	15/04/1975	16/04/2014	0%	J2N0550-GI-O-39yrs-0%
J2N0552	3221CB00120	13/10/2004	22/01/2014	0%	J2N0552-GI-O-9yrs-0%
J2N0553	3221DA00064	28/02/2005	22/01/2014	0%	J2N0553-GI-O-9yrs-0%
J2N0557	3221CB00085	13/10/2004	25/04/2013	0%	J2N0557-GI-O-9yrs-0%
J2N0563	3221CB00087	15/02/2004	22/01/2014	0%	J2N0563-GI-O-10yrs-0%
J2N0572	3221DB00068	07/12/2004	23/01/2014	0%	J2N0572-GI-O-9yrs-0%
J2N0574	3221DD00048	17/11/2004	23/01/2014	8%	J2N0574-GI-O-9yrs-8%
J2N0575	3221DD00116	14/07/2004	23/01/2014	3%	J2N0575-GI-O-10yrs-3%
J2N0576	3221DD00150	17/11/2004	23/01/2014	15%	J2N0576-GI-O-9yrs-15%
J2N0577	3221DD00032	02/03/2005	23/01/2014	0%	J2N0577-GI-O-9yrs-0%
J2N0580	3322AC00114	02/03/2005	22/05/2014	0%	J2N0580-GI-O-9yrs-0%
J2N0582	3322AC00120	02/03/2005	22/05/2014	0%	J2N0582-GI-O-9yrs-0%
J2N0591	3222CA00121	06/07/2005	23/01/2014	0%	J2N0591-GI-O-9yrs-0%
J2N0592	3222CA00140	06/07/2005	23/01/2014	0%	J2N0592-GI-O-9yrs-0%
J2N0593	GZ00020	06/07/2005	23/01/2014	0%	J2N0593-GI-O-9yrs-0%
J2N0594	3221DD00188	21/06/2005	23/01/2014	0%	J2N0594-GI-O-9yrs-0%
J2N0596	029879BN	16/11/2004	28/01/2014	0%	J2N0596-GI-O-9yrs-0%
J2N0618	029898TA	15/11/2004	29/01/2014	4%	J2N0618-GI-O-9yrs-4%
J2N0620	3322AC00118	21/12/2006	22/05/2014	0%	J2N0620-GI-O-7yrs-0%
J2N0621	3322AC00113	19/03/2007	22/05/2014	3%	J2N0621-GI-O-7yrs-3%
J2N0623	029935A	05/08/2008	17/04/2014	0%	J2N0623-GI-O-6yrs-0%
J3N0014	3322DA00009	23/04/2008	20/05/2014	19%	J3N0014-GI-O-6yrs-19%
J3N0040	40173	12/07/2000	21/03/2013	9%	J3N0040-GI-O-13yrs-9%
J3N0042	40171	05/04/2000	20/05/2014	53%	J3N0042-GI-O-14yrs-53%
J3N0048	3322DA00392	14/02/2002	21/05/2014	0%	J3N0048-GI-O-12yrs-0%
J3N0049	3322DA00391	31/07/1996	20/05/2014	6%	J3N0049-GI-O-18yrs-6%
J3N0053	3322DA00145	17/11/2003	21/05/2014	0%	J3N0053-GI-O-11yrs-0%
J3N0054	046075A	27/11/2002	20/05/2014	10%	J3N0054-GI-O-11yrs-10%
J3N0056	46077	12/08/2003	20/03/2014	6%	J3N0056-GI-O-11yrs-6%
J3N0057	033800A	23/02/2005	20/05/2014	0%	J3N0057-GI-O-9yrs-0%
J3N0059	33803	23/02/2005	20/05/2014	0%	J3N0059-GI-O-9yrs-0%
J3N0061	33802	23/02/2005	20/05/2014	0%	J3N0061-GI-O-9yrs-0%
J3N0062	46043	23/02/2005	22/05/2014	0%	J3N0062-GI-O-9yrs-0%
J3N0063	3322BC00016	23/02/2005	22/05/2014	0%	J3N0063-GI-O-9yrs-0%
J3N0064	46078	20/11/2003	21/05/2014	2%	J3N0064-GI-O-10yrs-2%
J3N0065	46079	09/05/2002	21/05/2014	2%	J3N0065-GI-O-12yrs-2%
J3N0067	46080	02/05/2002	21/05/2014	2%	J3N0067-GI-O-12yrs-2%
J3N0069	46042	24/02/2005	21/05/2014	0%	J3N0069-GI-O-9yrs-0%
J3N0071	33614	24/02/2005	21/05/2014	0%	J3N0071-GI-O-9yrs-0%
J3N0076	46041	23/02/2005	22/05/2014	0%	J3N0076-GI-O-9yrs-0%
J3N0077	40156	23/02/2005	22/05/2014	0%	J3N0077-GI-O-9yrs-0%
J3N0090	3322CB00085	12/08/2003	20/05/2014	7%	J3N0090-GI-O-11yrs-7%
J3N0091	3322CD00061	18/10/2005	14/05/2014	15%	J3N0091-GI-O-9yrs-15%
J3N0098	GZ00034	18/07/2005	20/05/2014	3%	J3N0098-GI-O-9yrs-3%
J3N0099	3322CD00060	19/10/2005	14/05/2014	15%	J3N0099-GI-O-9yrs-15%
J3N0100	3322CD00062	18/10/2005	14/05/2014	14%	J3N0100-GI-O-9yrs-14%
J3N0101	3322CD00064	19/10/2005	14/05/2014	12%	J3N0101-GI-O-9yrs-12%
J3N0102	3322CD00063	18/10/2005	14/05/2014	18%	J3N0102-GI-O-9yrs-18%
J3N0103	GZ00161	11/04/2006	15/05/2014	0%	J3N0103-GI-O-8yrs-0%
J3N0104	GZ00162	11/04/2006	15/05/2014	0%	J3N0104-GI-O-8yrs-0%
J3N0105	GZ00028	25/11/2005	20/05/2014	0%	J3N0105-GI-O-8yrs-0%
J3N0106	GZ00031	19/10/2005	15/05/2014	3%	J3N0106-GI-O-9yrs-3%
J3N0107	GZ00032	18/07/2005	14/05/2014	1%	J3N0107-GI-O-9yrs-1%
J3N0108	GZ00033	24/08/2005	14/05/2014	12%	J3N0108-GI-O-9yrs-12%
J3N0109	GZ00035	17/11/2004	15/05/2014	6%	J3N0109-GI-O-9yrs-6%
J3N0111	GZ00037	29/11/2005	20/05/2014	0%	J3N0111-GI-O-8yrs-0%
J3N0112	3322AD00063	23/09/2005	20/05/2014	0%	J3N0112-GI-O-9yrs-0%
J3N0115	GZ00165	11/04/2006	15/05/2014	0%	J3N0115-GI-O-8yrs-0%
J3N0116	GZ00029	26/02/2006	05/03/2014	15%	J3N0116-GI-O-8yrs-15%
J3N0118	GZ00164	13/09/2006	21/05/2014	0%	J3N0118-GI-O-8yrs-0%
J3N0121	GZ00337	13/06/2007	15/05/2014	7%	J3N0121-GI-O-7yrs-7%
J3N0122	GZ00338	13/06/2007	15/05/2014	0%	J3N0122-GI-O-7yrs-0%
J3N0124	GZ00339A	02/03/2008	20/05/2014	16%	J3N0124-GI-O-6yrs-16%
J3N0125	GZ00335	20/11/2008	11/12/2013	17%	J3N0125-GI-O-5yrs-17%
J3N0126	GZ00336	19/11/2009	16/05/2014	5%	J3N0126-GI-O-4yrs-5%
J4N0005	GZ00327	10/07/2007	13/05/2014	4%	J4N0005-GI-O-7yrs-4%
J4N0006	GZ00328	21/12/2006	13/05/2014	0%	J4N0006-GI-O-7yrs-0%
J4N0007	GZ00329	21/12/2006	13/05/2014	7%	J4N0007-GI-O-7yrs-7%
J4N0008	GZ00330	21/12/2006	13/05/2014	0%	J4N0008-GI-O-8yrs-0%
J4N0009	GZ00331	21/12/2006	13/05/2014	0%	J4N0009-GI-O-7yrs-0%
J4N0010	GZ00332	21/12/2006	13/05/2014	7%	J4N0010-GI-O-7yrs-7%
J4N0011	GZ00333	10/04/2006	13/05/2014	0%	J4N0011-GI-O-8yrs-0%
J4N0012	GZ00334	10/07/2007	13/05/2014	0%	J4N0012-GI-O-7yrs-0%
J3N0127	EC/J32/002	14/01/2013	03/06/2014	14%	J3N0127-GI-O-1yrs-14%
J3N0128	EC/J31/029	14/01/2013	02/06/2014	19%	J3N0128-GI-O-1yrs-19%
J3N0129	EC/J31/038	07/08/2013	01/04/2014	51%	J3N0129-GI-O-1yrs-51%

Table 9.2 Summary of DWS active monitoring boreholes in selected GRU quaternary catchments (DWS, 2014d)

No	Quat/GRU[1]	No of active DWS level monitoring BHs[1]	GRU priority	Shallowest GW[2] level (mbgl[3])	Deepest GW level (mbgl)	Mean GW level (mbgl)	Dominant Aquifer type used	Pending WULAs[4]	Monitoring BH(s) applicable?
1	H90E	0	2				Alluvium; Bredasdorp Group	0	
2	J11E	0	2				Ecca; Dwyka; Q	1	No
3	J11F	0	3				Witteberg; Ecca	0	
4	J11J	3	3	1.9	4.8	2.9	Skurweberg; Witteberg; Bokkeveld	0	
5	J11K	0	2				Bokkeveld; Witteberg	0	
6	J21A	6	1	0.3	20.7	9.4	Alluvium, Dolerite; Adelaide Group	3	Yes
7	J22K	3	3	10.1	31.3	20.6	Adelaide, alluvium/ weathered zone	0	
8	J23A	6	2	0.0	15.4	8.1	Adelaide Group	0	
9	J24B	3	2	10.2	20.5	16.0	Adelaide, alluvium/ weathered zone	0	
10	J25B	1	2	10.3	10.3	10.3	Peninsula; Skurweberg	0	
11	J31A	2	1				Skurweberg; Peninsula; Nardouw	1	Yes
12	J33E	12	1	0.0	162.8	23.5	Peninsula; Skurweberg	0	
13	J33F	3	1	1.1	74.9	48.0	Alluvium/ regolith; Peninsula	0	
14	J34D	9	2	0.2	68.4	26.8	Skurweberg; Nardouw; calcrete/cave deposits	0	
15	J34E	0	4				Ceres Sub-Group	0	
16	J34F	4	2	0.0	83.9	25.7	Nardouw; Bokkeveld	0	
17	J35B	15	1	0.0	94.5	20.4	Peninsula Fm; Skurweberg Formation; Alluvium	1	Yes
18	J35C	2	1	20.2	25.1	22.7	Skurweberg; alluvium; Nardouw Sub-Group	0	
19	J35E	0	4				Alluvium; Nardouw Sub-Group; Skurweberg	0	
20	K10E	0	3				Peninsula; Skurweberg; Alluvium	0	
21	K20A	0	4				Peninsula; Quaternary	0	
22	K30A	0	4				Quaternary/weathered zone; Peninsula	0	
23	K30B	0	4				Quaternary/weathered zone; Peninsula	0	
24	K30C	0	4				Quaternary/weathered zone; Peninsula	0	
25	K30D	0	3				Quaternary/weathered zone; Peninsula	0	
26	K40D	0	3				Bredasdorp; Alluvium	0	
27	K50B	0	2				Bredasdorp; Nardouw Sub-Group	2	No
28	K60G	0	2				Peninsula; Bredasdorp	1	No

1 Bore holes 2 Groundwater 3 Metres below ground level 4 Pending WULAs - July 2013 (DWS, 2014d)

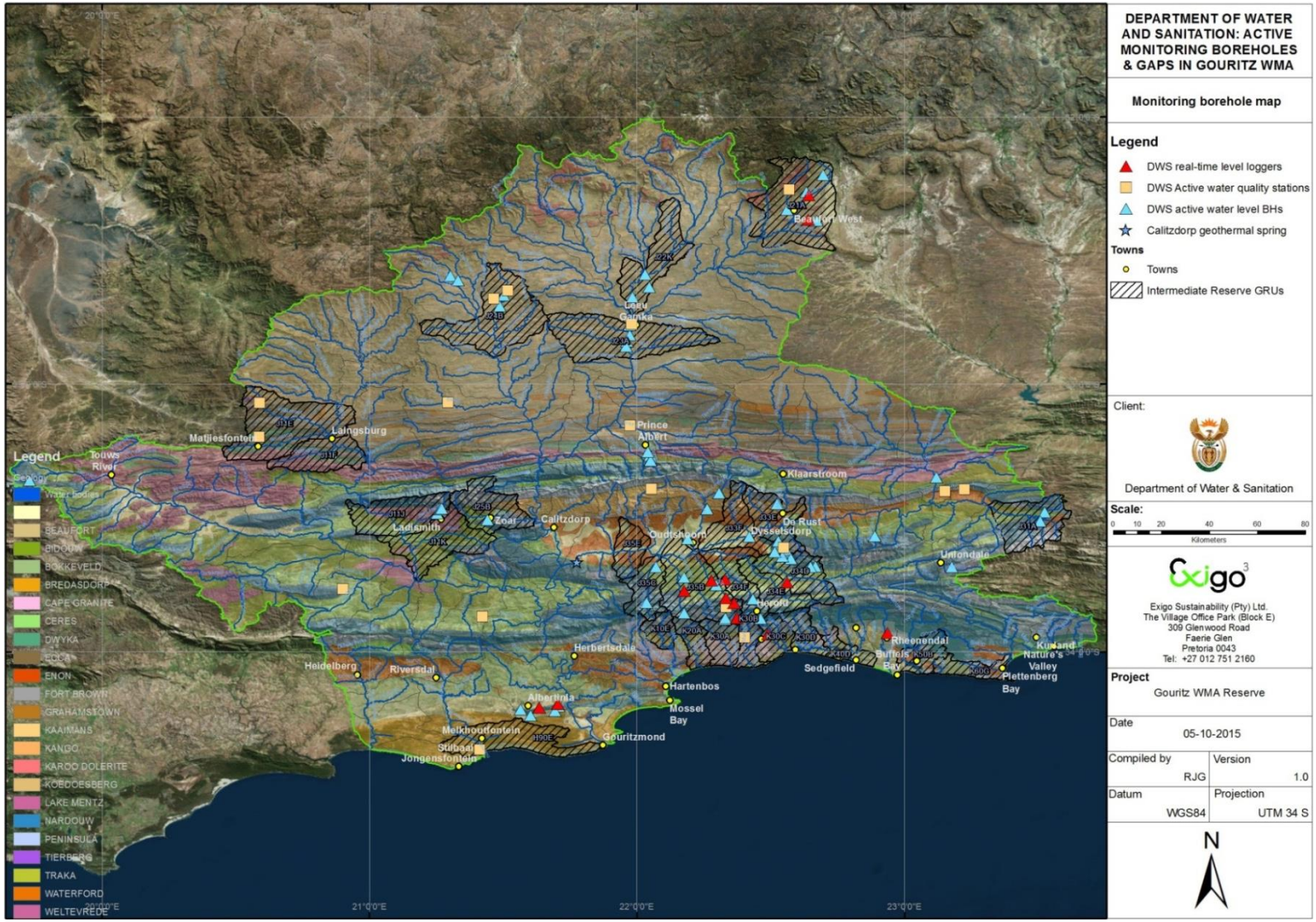

Figure 9.2 DWS real-time hydraulic head monitoring stations and active heads and quality monitoring (DWS, 2015a;b)

Based on these considerations the following areas have been identified

- The primary area for inclusion of hydraulic head monitoring data in DWS active monitoring boreholes database is the coastal region between George and Plettenberg Bay.
- A second area for consideration is the H90E Stilbaai, Jongensfontein/Gouritzmond coastal dune aquifers area. The reason being that some of the potable water for Stilbaai is supplied from groundwater from springs and boreholes. There are already a number of monitoring boreholes being actively monitored close by at Albertinia.

Although there are no DWS active monitoring boreholes at Laingsburg, Stilbaai or the J31A quaternary catchment, there is active monitoring taking place at these towns and major abstraction boreholes. This groundwater monitoring is handled by the regional local municipalities and in almost all cases contracted out to preferenced geohydrological service providers. In the case of the former mentioned municipalities the data was readily made available for this study by the geohydrological service providers (GEOSS, 2012a;b; GEOSS, 2013a).

Every attempt should be made by relevant municipalities to make the groundwater data accessible to service providers for evaluation, either directly on the website, a contact link to obtain via e-mail or as favoured method provide the data to the DWS in the correct format for inclusion in their active monitoring borehole database. In some rare cases data accessibility is problematic due to the involvement of consultants instead of the data being directly managed by the DWS.

Data from the specific wellfield developments and strategic GRU areas such as the Klein Karoo Rural Water Supply Scheme (KKRWSS) and the Deep Artesian Groundwater Exploration for Oudtshoorn Supply (DAGEOS) RUs are available and can be supplied upon request from the service providers involved via DWS. Evaluations of the hydraulic head and water quality data can be found in the respective wellfield groundwater specialist reports (GEOSS, 2014; Hartnady *et al.*, 2014).

Sedgefield and Ladismith have both had further groundwater development in the last three years and monitoring by the local municipalities should be strongly considered in order to sustainably manage the groundwater resources.

9.3 HYDRAULIC HEADS (GROUNDWATER LEVELS)

Snapshot groundwater levels are shown per selected intermediate GRU in **Table 9.2**. Some time series hydraulic head data is available for the selected Intermediate Reserve quaternary catchments/GRUs and examples are provided per wellfield below.

The KKRWSS is arguably the largest existing groundwater supply scheme in the Gouritz WMA and was designed to deliver 4.7 million m^3/a. The scheme has, however, encountered iron-bacteria encrustation problems on the pumps as well as borehole screened casing, reducing the yield to ±1.0 million m^3/a as reported in 2006 (Smith, 2006). The scheme currently supplies ±1.2 million m^3/a. A declining hydraulic head trend is apparent in the Vermaaks River wellfield, part of the KKRWSS in **Figure 9.3**. Cognisance has to be taken of the fact that any unimpacted wellfield initially starts with an almost steady state groundwater level and when abstraction starts, this level will initially sharply decline until a new groundwater level equilibrium is reached. This will then flatten out when the cone

of depression has expanded far enough. Over 25 years of operation, the KKRWSS data show how the initial sharp declining hydraulic head trend has almost reached a new steady state level. Since abstraction has started in 1989, there has been approximately 30 m drawdown in hydraulic head. Given that the boreholes are on average ± 200 m deep, this is a comparably small percentage of available drawdown. Some of the KKRWSS boreholes are situated in the Vermaaks River valley. In **Figure 9.3** below hydraulic heads and abstraction are both plotted to provide some indication of trends in the KKRWSS.

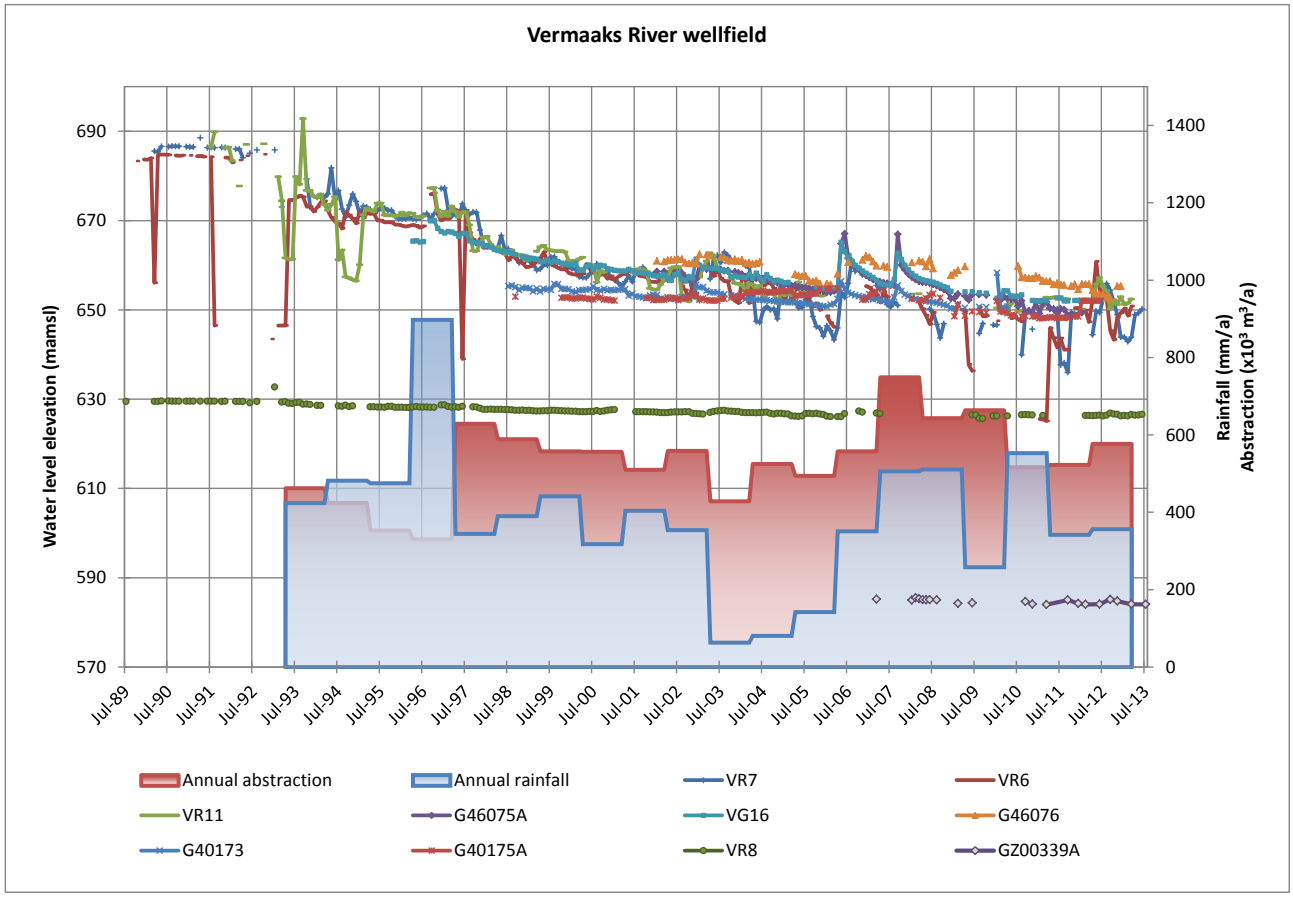

Figure 9.3 Rainfall, abstraction and hydraulic head data from GEOSS (2014)

In selected GRU J31A, groundwater level monitoring and abstraction monitoring is taking place at the farm Wanhoop, although this is not tied in with the Gouritz DWS active monitoring network data. The groundwater monitoring at Wanhoop farm is being performed by the Baviaans Municipality and monthly hydraulic heads and abstraction rates were received from the municipality. Only snapshot groundwater levels and abstraction were received by the municipality for 2014. For the 15 boreholes monitored in the scheme, the shallowest groundwater level is 1 mbgl, the deepest is 38 mbgl and a mean groundwater level is calculated to be 17 mbgl. According to the data, Grootkloof boreholes alone abstract some 315 360 m^3/a (10 l/s). In 2013, two DWS grounwater monitoring stations were established in the J31A catchment, with J3N0129 being very close to the Grootkloof abstraction. Only three hydraulic head measurements are available for J3N0129 in the National Groundwater Archive (NGA) database, namely 13.29 mbgl (March, 2008), 9.36 mbgl (November, 2011) and 16.18 mbgl (September, 2012). It is recommended that a logger be installed by the Baviaans Municipality at the Grootkloof and Wilgerkloof wellfields and that this data be made available on

request. Alternatively, DWS can decide if the want to install a logger at the Grootkloof wellfield to obtain better time series data.

Stilbaai's (H90E) groundwater monitoring data is collected by GEOSS and provided to DWS. This data again does not show on the DWS database and it would be highly advantageous for DWS to create a programme where monitoring data can be loaded onto the DWS database via a web browser. Data loaded by service providers must clearly state monitoring frequency and whether data has been checked or not as a quality control step.

9.4 MONITORING AND TRENDS IN SELECTED GRUS AND HOTSPOTS

9.4.1 Beaufort West J21A, Groot Karoo

Beaufort West experienced a serious drought during 2009/2010. Groundwater was used as the emergency water resource and additional groundwater resource development was performed. In the 2011 wet season appreciable rain was received and the local groundwater level (hydraulic head) recovered. All of these events are clearly evident from the hydraulic head time series data in **Figure 9.4**.

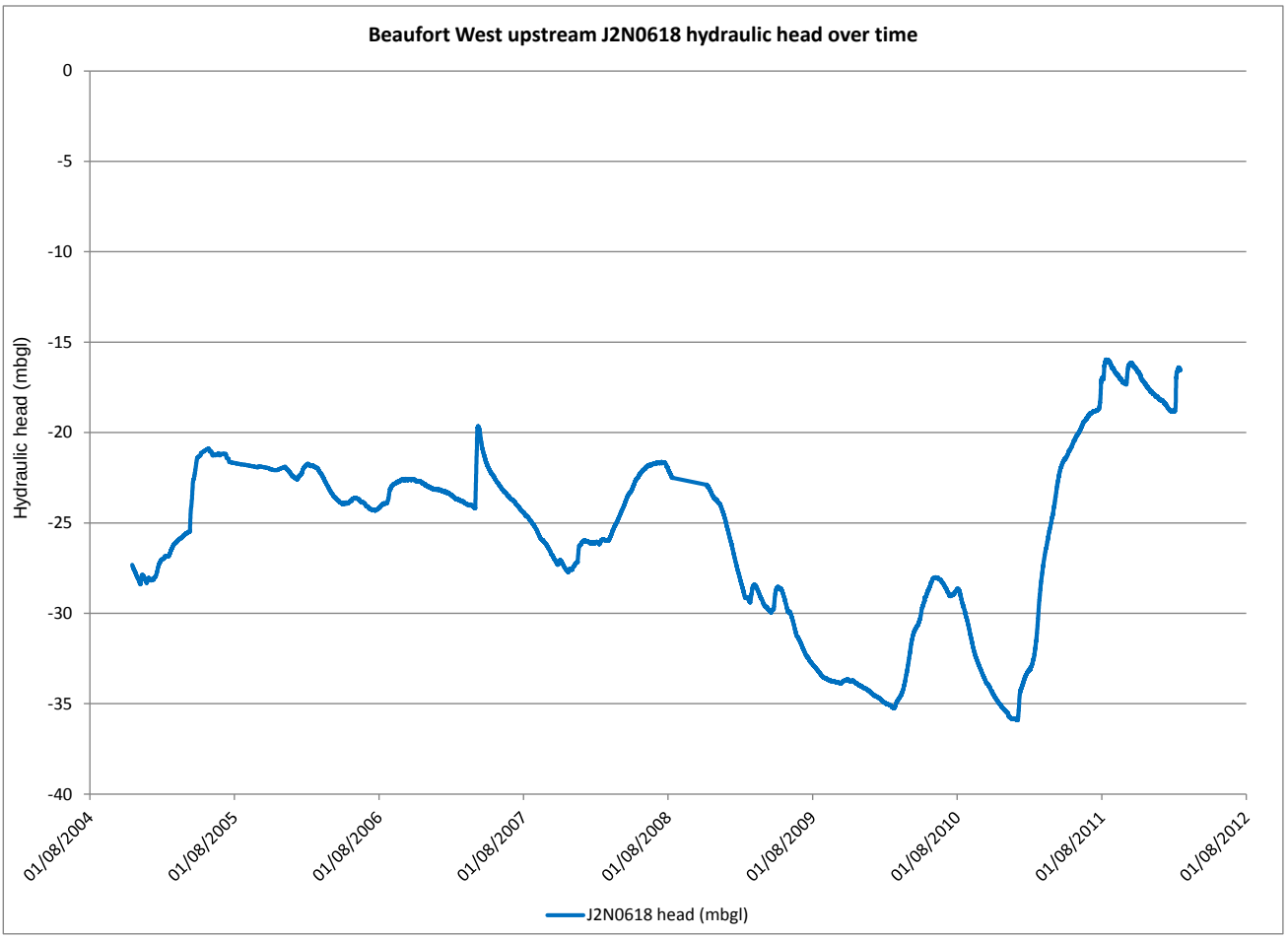

Figure 9.4 Hydraulic head monitoring station J2N0618 upstream of Beaufort West

9.4.2 KKRWSS

As can be observed in **Figure 9.3**, there is currently a decrease in yield at the Vermaaks River valley wellfield, due to iron-bacteria encrustation on the pumps and casing as well as intermittent over-abstraction. This affects hydraulic heads (groundwater levels) negatively and a decreasing trend is visible (GEOSS, 2014b). The groundwater level and quality monitoring at the KKRWSS is however excellent and it is the reason why this scheme can be proactively managed and yields adjusted, based on monitoring data.

9.4.3 DAGEOS

The DAGEOS Blossoms wellfield has not yet come into operation and there are currently aquifer tests and yield tests being conducted before the scheme starts with operation. **Figure 9.2** shows where key DAGEOS monitoring boreholes are located. The monitoring currently being performed for DAGEOS, based on existing monitoring and logger locations is good. Geothermal springs will also need to be monitored for this scheme.

9.4.4 Waboomskraal

Waboomskraal is a small catchment within the Outeniqua Mountains, but is very important due to the amount and quality of hops produced in the area. Waboomskraal requires groundwater monitoring due to the existing farmer's abstraction for the hops agriculture, but also due to future use of the underlying Peninsula Formation aquifer by the DAGEOS Blossoms groundwater wellfield. The DAGEOS project has, however, already identified and implemented groundwater loggers in at least three strategically located boreholes in Waboomskraal to monitor hydraulic head trends. The south-eastern Waboomskraal area groundwater level is shown in **Figure 9.5**. There is also at least one borehole being monitored for groundwater quality.

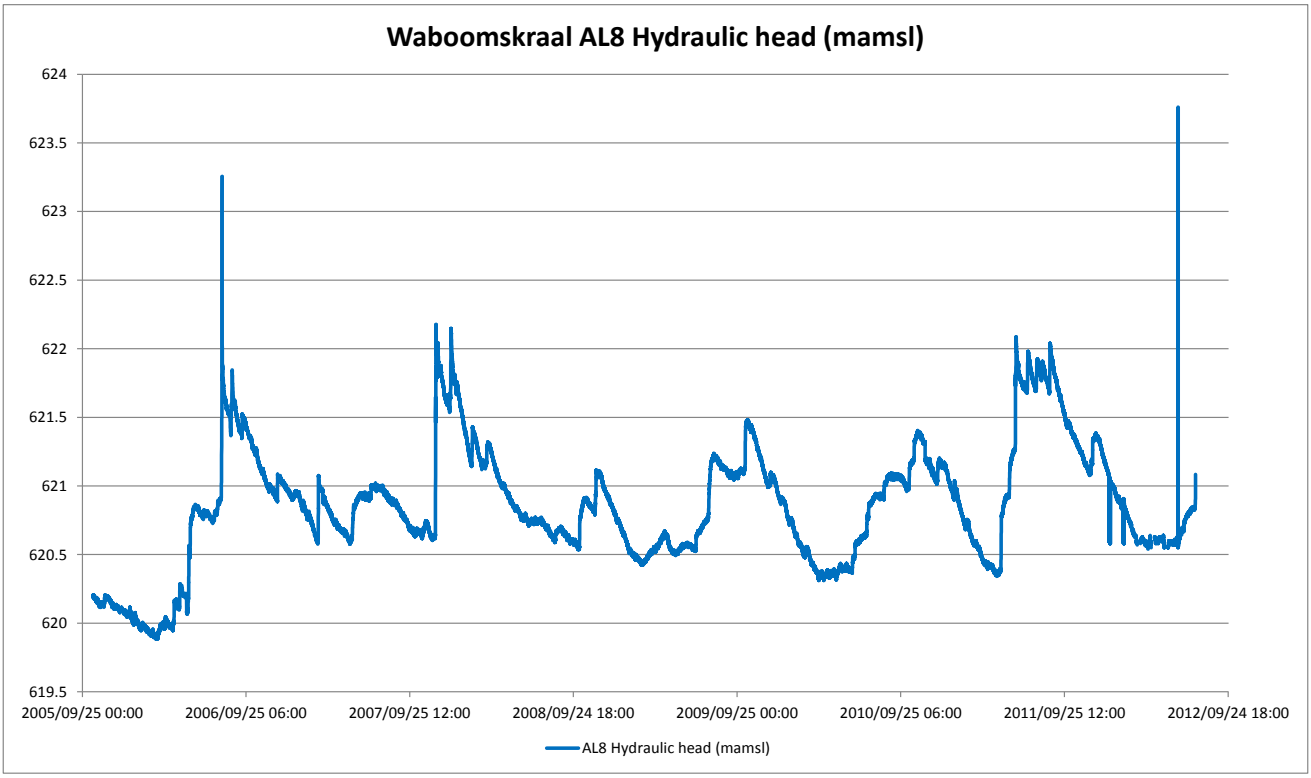

Figure 9.5 Hydraulic head (water level) fluctuation in south-east Waboomskraal

9.4.5 Groenvlei

Groenvlei is a uniquelacustrine wetland situated on the inland side of a high coastal dune, separating this wetland from the ocean, located about 5 km east of the holiday town of Sedgefield. Groenvlei is unique since it has no rivers flowing into it, yet it maintains its water level. There was some debate as to whether Groenvlei is actually fed by groundwater from the TMG aquifers or not. Extensive monitoring and research has been done by Dr. Roger Parsons for his PhD to determine the nature of groundwater contribution and based on the study no evidence could be found that Groenvlei is fed by the TMG aquifers (Parsons, 2014).

9.5 GROUNDWATER QUALITY MONITORING IN THE GOURITZ WMA AND TRENDS

The groundwater quality has been presented in some detail based on the groundwater monitoring work that is being conducted across the Gouritz WMA (DWS, 2014d; Section 2.5). Aquifer types and associated groundwater qualities are also discussed in the groundwater quality section. In this monitoring section a summary is presented including a map of general water quality to provide an overview of water quality monitoring in the WMA.

The groundwater quality in some of the key areas and Intermediate Reserve quaternary catchments are summarised in **Table 9.3**. Many of the groundwater quality were obtained from GEOSS (2012a,b; 2013a) since they perform a significant amount of groundwater monitoring in the Gouritz WMA for local municipalities. As can be observed from **Table 9.3** and the map in **Figure 9.6**, the

aquifer types and geographical setting determine to a large extent the water quality of each area where groundwater quality was monitored.

Table 9.3 Summary of groundwater quality from groundwater monitoring across Gouritz WMA

Quat	Location	Geosite ID	Overall Water quality Class	pH	EC (mS/m)	TDS (mg/l)	Ca (mg/l)	Mg (mg/l)	Na (mg/l)	K (mg/l)	CO_3 (mg/l)	HCO_3 (mg/l)	Cl (mg/l)	SO_4 (mg/l)	Fe (mg/l)
Stilbaai	H90E	GZ00167	Class 2	7.8	119.2	723.0	94.9	27.9	135.3	3.8	18.0	317.8	299.6	42.4	0.01
Stilbaai	H90E	MA02	Class 1	7.9	90.4	544.0	83.7	19.7	95.7	2.3	21.0	328.5	185.1	27.1	0.00
Laingsburg	J11E	LB_BH3	Class 2	7.4	200.0	0.0	112.9	62.3	385.8	16.4	0.0	708.9	409.7	346.0	0.00
Laingsburg	J11E	LB_BH4	Class 2	7.3	244.0	0.0	101.0	60.2	371.1	2.7	0.0	799.2	445.0	330.0	0.00
Merweville	J24B	ME2	Class 1	7.2	76.3	644.0	100.7	15.6	87.4	3.7	12.1	364.4	100.7	65.8	0.01
Merweville	J24B	ME3	Class 1	7.2	77.5	579.0	82.6	14.9	84.7	3.2	9.0	372.6	74.2	52.0	0.02
Beaufort West	J21A	Flagship BH	Class 2	7.6	170.0	1088.0	118.0	39.0	198.0	0.0	0.0	316.0	195.0	195.0	0.01
Beaufort West	J21A	HR15	Class 3	7.2	305.0	1952.0	320.0	79.0	203.0	9.5	0.0	277.0	605.0	399.0	0.00
Beaufort West	J21A	HR16	Class 3	7.2	302.0	1933.0	321.0	79.0	204.0	6.3	0.0	272.0	619.0	409.0	0.00
Beaufort West	J21A	SR9	Class 2	8.0	284.0	2130.0	148.4	59.3	345.3	2.8	18.1	425.7	370.1	368.4	0.03
Zoar	J25B	ZBH4	Class 2	5.7	5.0	32.0	4.8	2.5	3.4	1.0	0.0	18.3	13.6	6.0	3.23
Calitzdorp	J25D	GCS well	Class 2	6.3	38.0	243.0	11.0	8.0	38.0	9.0	0.0	31.0	68.0	31.0	4.30
KKRWSS west	J25E	KG1	Class 4	5.9	31.8	0.0	15.6	9.0	36.3	10.7	0.0	31.0	85.7	38.8	18.40
KKRWSS west	J25E	DL15	Class 2	7.2	44.5	0.0	12.0	10.0	37.0	14.2	0.0	89.9	90.0	20.0	3.41
KKRWSS east	J33E	J3N0014	Class 0	5.1	9.0	54.0	1.3	1.6	10.0	0.6	0.0	3.0	19.0	2.8	0.10
KKRWSS east	J33E	VR6	Class 0	5.1	8.0	52.0	1.7	1.5	13.0	0.4	0.0	4.3	22.0	2.2	0.10
DAGEOS	J35B etc.	C1b1 (Skwbg)	Class 2	8.0	23.0	0.0	19.5	1.3	16.8	7.2	0.0	0.0	14.3	7.0	1.62
DAGEOS	J35B	C1b3 (Ope)	Class 0	8.2	22.8	0.0	20.1	3.8	9.2	12.8	0.0	0.0	11.2	16.0	0.21
DWA drinking WQ guidelines 1998															
Class 0: Ideal water quality				*5.0<pH<9.5*	*70*	*450*	*80*	*70*	*100*	*25*	*N/A*	*N/A*	*100*	*200*	*0.5*
Class 1: Good water quality				*5.0>pH>9.5*	*150*	*1000*	*150*	*100*	*200*	*50*			*200*	*400*	*1*
Class 2: Marginal water quality				*4.5>pH>10.0*	*370*	*2400*	*300*	*200*	*400*	*100*			*600*	*600*	*5*
Class 3: Poor water quality				*4.0>pH>10.5*	*520*	*3400*	*300+*	*400*	*1000*	*500*			*1200*	*1000*	*10*
Class 4: Unacceptable water quality				*3.0>pH>11.0*	*520+*	*3400+*		*400+*	*1000+*	*500+*			*1200+*	*1000+*	*10+*

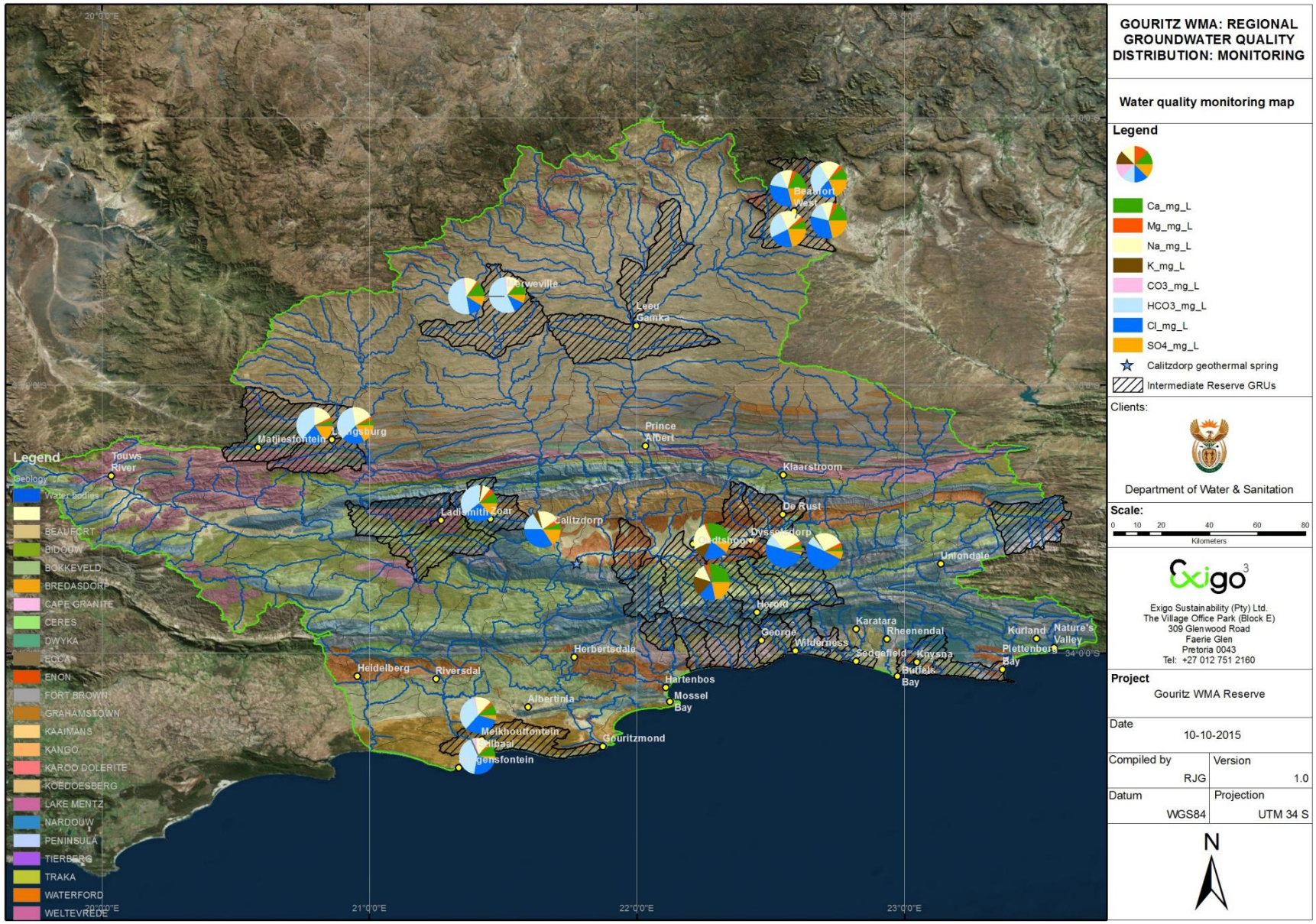

Figure 9.6 Groundwater macro constituents for various areas in the Gouritz WMA from groundwater monitoring

9.6 CONCLUSIONS

There should be an attempt to include current active monitoring conducted by service providers into the DWS active monitoring boreholes database so that the data is readily available from DWS for any groundwater assessments that need to be performed in specific areas. At the simplest level, geosite identifiers or borehole numbers with coordinates of active monitoring boreholes should be included by DWS in the list/table of active monitoring boreholes. A column (field) can be added to include which organisation is performing the monitoring so that the groundwater investigator can at least know whom to contact for this data. The complete list of active monitoring boreholes will also then provide a complete picture of all active groundwater monitoring taking place. It is recommended that data supply from consultants be realised through an easy to use web-upload interface with registration of the service providers assisting the DWS with monitoring or a specific project that requires access to the data. Those only accessing the data can have read-only rights to the database. Given the simplest level of monitoring, service provider participation in the DWS active monitoring borehole database, as mentioned above, is essential and would require minimal database maintenance effort from both DWS and the service provider.

10 REFERENCES

Bell, E.M., Lockyear, J.F., McPherson, J.M., Marsden, A.D, and Vincent A.C.J. 2003. First field studies of an endangered South African seahorse, *Hippocampus capensis*. Environmental Biology of Fishes. 67: 35-46.

Blinn, D.W. 1993. Diatom Community Structure Along Physicochemical Gradients in Saline Lakes. *Ecology* 74 (4): 1246-1263.

Bornman, T.G. 2004. Vegetation survey of the wetland component of the proposed Hanglip development. Institute for Environmental and Coastal Management, University of Port Elizabeth. IECM Report No. C99. 26 pp.

Bornman T.G., van Niekerk, L., Adams, J.B., Whitfield, A.K., Wooldridge, T. and Snow, G. 2007a. RDM Technical Report: Matjies Estuary. DWAF Directorate: Resource Directed Measures, Pretoria. 68pp.

Bornman T.G., van Niekerk, L., Adams, J.B., Whitfield, A.K., Wooldridge, T. and Snow, G. 2007b. RDM Technical Report: Sout Estuary. DWAF Directorate: Resource Directed Measures, Pretoria. 77pp.

CEMAGREF 1982. Etude des methodes biologiques quantitatives d'appreciation de la qualite des eaux. Rapport Division Qualité des Eaux Lyon - Agence Financiere de Bassin Rhône-Méditerranée- Corse. Pierre-Benite.

Cormier, S.M. and Suter, G.W. 2008. A framework for fully integrating environmental assessment. Environmental Management 42:543–556.

Council for Scientific and Industrial Research (CSIR). 2008. Rapid Ecological Reserve Determination. Technical Report. Keurbooms Estuary (Version 2). Report prepared for the Bitou Municipality through Ninham Shand. CSIR Report No CSIR/NRE/ECO/ER/2008/0086/C. Stellenbosch.

Dallas H.F., and Day J.A. 2004 The Effect of Water Quality Variables on Aquatic Ecosystems: A Review. WRC Report No TT224/04. Water Research Commission, Pretoria.

Dean, W.R.J., and S.J. Milton. 1999. The Karoo. Ecological patterns and processes. Cambridge University Press, Cambridge.

Department of Water Affairs and Forestry (DWAF). 1995. South African Water Quality Guidelines for Coastal Marine Waters. Volume 1: Natural Environment. Pretoria.

Department of Water Affairs and Forestry (DWAF), South Africa. 1996. South African water quality guidelines. Volume 7: Aquatic Ecosystems.

Department of Water Affairs and Forestry (DWAF). 2008a. Methods for determining the water quality component of the Ecological Reserve. Report prepared for Department of Water Affairs and Forestry, Pretoria, South Africa by P-A Scherman of Scherman Consulting.

Department of Water Affairs and Forestry (DWAF). 2008b. Resource Directed Measures for Protection of Water Resources: Methodologies for the determination of ecological water requirements for estuaries. Version 2. Pretoria.

Department of Water Affairs and Forestry (DWAF), South Africa. 2008c. Maintenance and Updating of Hydrological and System Software Phase 3: Procedural Manual for the Water Resources Simulation Model (WRSM) compiled for the Department of Water Affairs and Forestry by the consulting team consisting of Hydrosol (Pty) Ltd and WRP Consulting Engineers (Pty) Ltd.

Department of Water Affairs (DWA), South Africa. 2009a. Reserve Determination studies for selected surface water, groundwater, estuaries and wetlands in the Outeniqua (Groot Brak and other water resources, excluding wetlands) catchment: Ecological Water Requirements Study - Estuarine RDM Report: Maalgate, Gwaing and Kaaimans Assessment. Report No. RDM/K10-K30, K40E/00/ CON/05407. Department of Water Affairs, Pretoria.

Department of Water Affairs (DWA), South Africa. 2009b. Reserve Determination studies for selected surface water, groundwater, estuaries and wetlands in the Outeniqua (Groot Brak and other water resources, excluding wetlands) catchment: Ecological Water Requirements Study - Estuarine RDM Report: Goukamma Assessment. Report No. RDM/K10-K30, K40E/00/ CON/0407. Department of Water Affairs, Pretoria.

Department of Water Affairs (DWA). South Africa. 2009c. Operationalise the Reserve: Main Report. Prepared by Water for Africa. Compiled by D Louw and S Louw. RDM Report no. RDM/NAT/05/CON/0907.

Department of Water Affairs (DWA), South Africa. 2009d. Operationalise the Reserve: Rapid Habitat Assessment Model Manual. Prepared by Water for Africa. Authored by D Louw and CJ Kleynhans. Report no RDM/ Nat/00/CON/0707.

Department of Water Affairs (DWA). South Africa. 2010. Comprehensive Reserve Determination Study for Selected Water Resources (Rivers, Groundwater and Wetlands) in the Inkomati Water Management Area, Mpumalanga. Sabie and Crocodile Systems: EcoSpecs Report. Prepared by Water for Africa, edited by Louw, MD and Koekemoer, S. RDM Report no 26/8/3/10/12/012.

Department of Water Affairs (DWA). 2012. Green Drop Report: Western Cape – Chapter 13.

Department of Water Affairs, (DWA). 2013. Review and update of the Desktop Present Ecological State (PES) and Ecological Importance (EI) - Ecological Sensitivity (ES) of South African Rivers according to sub-quaternary catchments: Breede/Berg/Gouritz WMAs. Prepared by Southern Waters.

Department of Water Affairs (DWA). 2014a. Reserve Determination Studies for the Selected Surface Water, Groundwater, Estuaries and Wetlands in the Gouritz Water Management Area: Delineation Report, Volume 2. Prepared by Scherman Colloty and Associates. Report no. RDM/WMA16/00/CON/0313, Volume 2.

Department of Water Affairs (DWA). 2014b. Reserve Determination Studies for the Selected Surface Water, Groundwater, Estuaries and Wetlands in the Gouritz Water Management Area: Desktop EcoClassification Report. Prepared by Scherman Colloty & Associates cc. Report no. RDM/WMA16/00/CON/0213.

Department of Water and Sanitation (DWS). 2014a. Reserve Determination Studies for Surface Water, Groundwater, Estuaries and Wetlands in the Gouritz Water Management Area: Rivers RDM Report – Rapid Assessment. Prepared by Scherman Colloty & Associates cc. Report no. RDM/WMA16/01/CON/1113.

Department of Water and Sanitation (DWS). 2014b. Reserve Determination Studies for Surface Water, Groundwater, Estuaries and Wetlands in the Gouritz Water Management Area: Estuaries RDM Report – Rapid Assessment, Volume 2 (Wilderness System). Prepared by the Council for Scientific and Industrial Research (CSIR). Report no. RDM/WMA16/04/CON/0713, Volume 2.

Department of Water and Sanitation (DWS). 2014c. Reserve Determination Studies for Surface Water, Groundwater, Estuaries and Wetlands in the Gouritz Water Management

Area: Estuaries RDM Report – Intermediate Assessment Volume 1 (Duiwenhoks Estuary). Prepared by the Council for Scientific and Industrial Research (CSIR). Report no. /WMA16/04/CON/0813, Volume 1.

Department of Water and Sanitation (DWS). 2014d. Reserve Determination Studies for the Selected Surface Water, Groundwater, Estuaries and Wetlands in the Gouritz Water Management Area: Groundwater Report. Prepared by Scherman Colloty & Associates cc. Report no. RDM/WMA16/02/CON/0413.

Department of Water Affairs and Sanitation (DWS). 2015a. Review, evaluation and optimisation of the South African water resources monitoring network. Network inventory: Volume 1: Main Report. Prepared by AECOM. April 2015. DWS Project number: WP10871.

Department of Water Affairs and Sanitation (DWS). 2015b. Review, evaluation and optimisation of the South African water resources monitoring network. Network inventory: Volume 2: Map book. Prepared by AECOM.

Department of Water and Sanitation (DWS). 2015c. Reserve Determination Studies for the Selected Surface Water, Groundwater, Estuaries and Wetlands in the Gouritz Water Management Area: Rivers RDM Report – Intermediate Assessment. Prepared by Scherman Colloty & Associates cc. Report no. RDM/WMA16/00/CON/1013.

Department of Water and Sanitation (DWS). 2015d. Reserve Determination Studies for Surface Water, Groundwater, Estuaries and Wetlands in the Gouritz Water Management Area: Estuaries RDM Report – Intermediate Assessment, Volume 3 (Goukou Estuary). Prepared by the Council for Scientific and Industrial Research (CSIR). Report no. RDM/WMA16/04/CON/0813, Volume 3.

Department of Water and Sanitation (DWS). 2015e. Reserve Determination Studies for Surface Water, Groundwater, Estuaries and Wetlands in the Gouritz Water Management Area: Estuaries RDM Report – Intermediate Assessment, Volume 2 (Gouritz Estuary). Prepared by the Council for Scientific and Industrial Research (CSIR) for Scherman Colloty & Associates cc. Report no. RDM/WMA16/04/CON/0813, Volume 2.

Department of Water and Sanitation (DWS) 2015f. Reserve Determination Studies for Surface Water, Groundwater, Estuaries and Wetlands in the Gouritz Water Management Area: Wetland Report. Prepared by Fluvius Environmental Consultants for Scherman Colloty & Associates cc. Report no. RDM/WMA16/03/CON/0513.

Dickens, C.W.S., and Graham, P.M. 2002. The South African Scoring System (SASS) Version 5 Rapid Bioassessment Method for Rivers. African Journal of Aquatic Science 27:1-10.

Driver, A., Sink, K.J., Nel, J.L., Holness, S., Van Niekerk, L., Daniels, F., Jonas, Z., Majiedt, P.A., Harris, L. and Maze, K. 2012. National Biodiversity Assessment 2011: An assessment of South Africa's biodiversity and ecosystems. Synthesis Report. South African National Biodiversity Institute and Department of Environmental Affairs. Pretoria. South Africa.

Elzinga, C.L., Salzer, D.W., and Willoughby, J.W. 1998. Measuring and monitoring plant populations. BLM Technical Reference 1730-1, BLM/RS/ST-98/005+1730.

Geographical and Spatial Solutions cc (GEOSS). 2012a. Water Use Licence Application-Geohydrological assessment: Beaufort West Municipality, Beaufort West. Prepared for Worley Parsons RSA & Beaufort West Municipality. Prepared by D. Barrow, J. Conrad & L. Gibson. Stellenbosch.

Geographical and Spatial Solutions cc (GEOSS). 2012b. Water Use Licence Application- Geohydrological assessment: Laingsburg and Matjiesfontein. Prepared for Laingsburg Municipality. Prepared by C. Lasher & J. Conrad. Stellenbosch.

Geographical and Spatial Solutions cc (GEOSS). 2013. Still Bay waste water treatment works: groundwater monitoring November 2012 to August 2013. Prepared for Worley Parsons RSA & Still Bay Municipality. Prepared by D. Barrow, J. Conrad & L. Soltau. Stellenbosch.

Geographical and Spatial Solutions cc (GEOSS). 2014. Klein Karoo Rural Water Supply Scheme – Annual groundwater monitoring report for the monitoring period end June 2014. Prepared for the Department of Water Affairs and Sanitation (DWS). Prepared by J. Conrad & M. Carstens. Stellenbosch.

Hartnady, C.J.H, Hay, E.R., Riemann, K. 2014. Strategy for groundwater development in a confined artesian basin, Oudtshoorn area, South Africa. Draft article. Groundwater Division (GWD) of the Geological Society of South Africa (GSSA). http://gwd.org.za/sites/gwd.org.za/files/01 CJH Hartnady_DAGEOS.pdf.

Hughes, D.A., Louw, D., Desai, A.Y., Birkhead, A.L. 2011. Development of a revised desktop model for the determination of the Ecological Reserve for Rivers. WRC report No 1856/1/11.

Kasperovičienė J. and Vaikutienė G. 2007. Long-term changes in diatom communities of phytoplankton and the surface sediments in the Curonian Lagoon (Lithuanian part) Transit. Waters Bull. 1:27-37.

Kelly, M.G. and Whitton, B.A. 1995. The Trophic Diatom Index: a new index for monitoring eutrophication in rivers, Journal of Applied Phycology 7, 433- 444.

Kleynhans, C.J. 2007. Module D: Fish Response Assessment Index in River EcoClassification: Manual for EcoStatus Determination (version 2) Joint Water Research Commission and Department of Water Affairs and Forestry report. WRC Report No. TT 330/08.

Kleynhans, C.J. and Louw, D. 2007. Reference frequency of occurrence of fish species in South Africa. Report produced for the Department of Water Affairs and Forestry (Resource Quality Services) and the Water Research Commission. Report produced for the Department of Water Affairs and Forestry (Resource Quality Services) and the Water Research Commission.

Kleynhans, C.J., Mackenzie, J. and Louw, M.D. 2007. Module F: Riparian Vegetation Response Index. In River EcoClassification: Manual for EcoStatus Determination (version 2) Water Research Commission Report No. TT 333/08. Joint Water Research Commission and Department of Water Affairs and Forestry report, Pretoria, South Africa.

Kleynhans, C.J., Louw, M.D., Birkhead, A.L., Thirion, C., Deacon, A., Angliss, M., Maseti, P., Rodgers, S and Weston, B. 2009. On the way to implementation: Ecological reserve Monitoring. International Conference on Implementing Environmental Water Allocations (IEWA), Port Elizabeth – South Africa 23-26 February 2009.

Kershner, J.L., Bischoff, C.M., Horan, D.L. 1997. Population, habitat, and genetic characteristics of Colorado River cutthroat trout in wilderness and non-wilderness stream sections in the Uinta Mountains of Utah and Wyoming. North American Journal of Fisheries Management 17, 1134-1143.

Lecointe, C., Coste, M. and Prygiel, J. 1993. “Omnidia”: Software for taxonomy, calculation of diatom indices and inventories management. Hydrobiologia 269/270: 509-513.

Lockyear, J.F., Kaiser, H., Hecht, T. and Teske, P.R. 2006. The distribution and abundance of the endangered Knysna seahorse, *Hippocampus capensis* (Pisces: Syngnathidae) in South African estuaries. Africal Journal of Aquatic Science 31: 275-283.

Luís, A.T., Teixeira, P., Almeida, S.F.P., Ector, L., Matos, J.X. and Ferreira da Silva, A. 2008. Impact of Acid Mine Drainage (AMD) on Water Quality, Stream Sediments and Periphytic Diatom Communities in the Surrounding Streams of Aljustrel Mining Area (Portugal). Water Air Soil Pollution. DOI 10.1007/s11270-008-9900-z.

Milton, S.J. and Dean, W.R.J. 1995. http://www.greatkarooconservancy.co.za/aerial-inspection-tour-of-the-upper-seacow-river-valley, accessed October 214.

ORASECOM, 2013. EFR Monitoring Programme. Research Project on Environmental Flow Requirements of the Fish River and the Orange-Senqu River Mouth. UNDP-GEF: Orange-Senqu Strategic Action Programme (Atlas Project ID 71598). Orange Senqu River Commission Report No. TR35. Prepared by Rivers for Africa, e-Flows Consulting (PTY) LTD.

Newman, B.K. and Watling, J. 2007. Definition of baseline metal concentrations for assessing metal enrichment of sediment from the south-eastern Cape coastline of South Africa. Water SA, vol 33, no. 5, pp. 675-692.

Philibert, A., Gell, P., Newall, P., Chessman, B. and Bate, N. 2006. Development of diatom-based tools for assessing stream water quality in south-eastern Australia: assessment of environmental transfer functions. Hydrobiologia 572: 103–114.

Rogers, K.H. and Bestbier, R. 1997. Development of a protocol for the definition of the desired state of riverine systems in South Africa. Department of Environmental Affairs and Tourism, Pretoria.

Russell, I. 2003. Changes in the distribution of emergent aquatic plants in a brackish South African estuarine-lake system. African Journal of Aquatic Science 28: 103-122.

Scherman, P-A. 2015. Personal Communication, January 2015

Smith, M. 2006. Prediction, control and rehabilitation of iron encrustation in water supply boreholes, Western Cape, South Africa: A geochemical approach. Ph.D. Thesis. University of Cape Town. Cape Town, South Africa.

Smuts, T.N. 2012. An archaeological perspective on the nineteenth century development of land, landscape and sheep farming in the Karoo. Thesis submitted for the Degree of Master of Science in the Department of Archaeology, Science Faculty, University of Cape Town.

Taylor, J.C., Harding, W.R. and Archibald, C.G.M. 2007a. A methods manual for the collection, preparation and analysis of diatom samples. Water Research Commission Report TT281/07. Water Research Commission. Pretoria.

Taylor, J.C., Harding, W.R. and Archibald, C.G.M. 2007b. An illustrated guide to some common diatom species from South Africa. Water Research Commission Report TT282/07. Water Research Commission. Pretoria.

Taylor, P.B., Navarro, R.A., Wren-Sargent, M., Harrison, J.A. & Kieswetter, S.C. (1999). CWAC Report. Co-ordinated Waterbird Counts in South Africa, 1992 – 1997. Avian Demography Unit, University of Cape Town. 251 pp.

Thirion, C. 2007. Module E: Macroinvertebrate Response Assessment Index in River EcoClassification: Manual for EcoStatus Determination (version 2). Joint Water Research Commission and Department of Water Affairs and Forestry report. WRC Report No. TT330/08.

UNEP/Nairobi Convention Secretariat and CSIR (2009) Guidelines for the Establishment of Environmental Quality Objectives and Targets in the Coastal Zone of the Western Indian Ocean (WIO) Region, UNEP, Nairobi, Kenya, 169p.

Van Dam, Mertens, A., and Sinkeldam, J. 1994. A coded checklist and ecological indicator values of freshwater diatoms from the Netherlands. Netherlands Journal of Aquatic Ecology 28(1): 177-133.

APPENDIX A: COMMENTS AND RESPONSE REGISTER

Section	Report Statement	Comments	Addressed in Report?	Author Comment
Comments: Andrew Gordon - DWS WC : Resource Protection, received 24 November 2015				
Entire document		Editorial an grammatical comments	Yes	
Exec summary; Table 6.1	Institute bi-monthly monitoring (every second month) at EWR sites with no water quality gauging weir in place.	Bimonthly usually means every two months (although sometimes used to mean twice monthly). What is meant In this instance - twice monthly? Best to be explicit in this regard	Yes	Clarified statement.
Section 2.2	The broad objectives of monitoring are to:	Isn't monitoring the outcome of the two points below??	Yes	Clarified statement.
Hydrology EcoSpecs		For clarity it would be good to include (MCM) after "Low flows" in the tables for all the EWR sites. I would suggest a quick description of what this means. I presume it is a percentiles of a flow duration curve. Perhaps just state this as superscript point 4.	Yes	
4.3.2 Hydrology EcoSpecs		Is there not a low flow minimum than can be monitored? Or is the river ephemeral – in which case it helps for clarity to say the river is expected to cease flowing from month A to month B.	No	The hydrological definitions of the various non-perennial states are controversial and it is safer not to attach a state to the report. The reasons for zero flow recommendations are in the intermediate report. It will not be valid to monitor a minimum flow as there is no such thing as a minimum flow. In this case there is a gauge close by and the gauged record will serve adequately for monitoring and comparing to the EWR rule.
Table 4.2: Water quality EcoSpecs and TPC	Sodium TPC: The 95th percentile of the data must be 300 - 380 mg/L.	Suggest rephrase as "is between" for all TPCs. To me the phrase "must be" suggests a goal or an objective. Whereas the TPC is more of a warning, heading towards something undesirable. This suggestion is just a personal preference. Thinking about it wouldn't a TPC be any value greater than 300mg/L?.	Yes	A range is defined for the TPC as it indicates the values before the category would change, hence the use of the word PROBABLE or POTENTIAL concern. If the values exceeded 380 mg/L (for sodium, for example), the category would have changed and the TPC would no longer be a warning light.

Section	Report Statement	Comments	Addressed in Report?	Author Comment
	pH EcoSpec: The 5th percentile of the data must be 5.9 – 6.5, and the 95th percentile 8.0 - 8.8. pH TPC: The 5th percentile of the data must be < 6.1 and > 6.3, and the 95th percentile must be < 8.2 and > 8.6.	But if you did measure a pH of 7 wouldn't that be a good thing, indicating that water quality (in terms of pH) is even better than you were hoping for? I know that the benchmark values for pH are structured as presented in this table, but for the purpose of EcoSpecs would it not be clearer just to say "The 5th percentile must be ≥ 5.9, and the 95th percentile ≤ 8.8"? Similarly, if the 5th percentile is 7 surely it is not a TPC? What if you have WQ improvement at a site through interventions? Instead of recognising the improvement, the current TPC's would highlight a problem. The TPC for pH could be phrased as "The 5th percentile of the data is ≤ 6.1 and the 95th percentile is ≥ 8.6" ?	Yes	Remember that the Ecospecs define the category that the pH is in, and that two summary statistics are used for pH (i.e. the 5th and 95th percentiles) which are analysed separately. If the 5th percentile was stated as ≥ 5.9 (for example), it would suggest that even a pH of 8.2 would be suitable, which would be incorrect as the category would then have changed. However, I do agree that the standard methods for pH are clumsy and difficult to understand. Revision and review is recommended, with your recommendation being a good one. For ease of monitoring and understanding, pH Ecospecs and TPCs have been checked and revised throughout the report. Agreed. The standard method linking the TPC to the Ecospecs for that category does not then include an improved state. TPCs have been checked and revised throughout the report where necessary.
Diatom EcoSpecs for all sites		I don't understand how this threshold indicator would work. As it stands I read it as: ≥ 10 is scores of 10 and higher, and <12 as scores of 11 and lower. So that means all scores are an indicator? Would an indicator/general threshold not be something like < 10 ?	Yes	Clarified thresholds.
Table 4.11 Table 4.39	All five of the expected indigenous fish species estimated to still be present in the reach under PES (only *Monodactylus falciformis* (MFAL)) sampled during EWR survey).	Is it realistic (an attainable EcoSpec) to expect all indigenous species to be present if bass occur in the system – and the survey undertaken for this Reserve Study only sampled 1 indigenous species? Maybe this can be addressed when RQOs developed during Classification.	No	Due to the fact that there was only one survey, it is also risky to base the assumption on that that the indigenous species are not present Yes, this could be further clarified during Classification.
Table 5.7	The EcoSpecs and TPCs representative of the REC (Category B/C) for the Maalgate Estuary are presented in Table 5.7.	In table 17.1 of the Main Report (report 13) the REC for the Maalgate is listed as B.	Yes	Corrected
Table 5.8		In table 17.1 of the Main Report (report 13) the REC for the Maalgate is listed as C.	No	The main report is incorrect and was corrected.

Section	Report Statement	Comments	Addressed in Report?	Author Comment
Comments: Thapelo Machaba – DWS: CD: SWRR, received 4 December 2015				
Whole report		Grammatical errors	Yes	
Table 8.1		Are these applicable to wetlands and not rivers?		Yes, just for wetlands. This is stated in the Table heading.
Table 9.1		Increase the font of the Table. Info is not clear	No	This is a cut and paste from another report
Comments: Esther Lekalake, received 3 December 2015				
Acronyms	Invert abbreviations	Should they not be in italics	No	Invert taxa are provided and not genus and species detail. No italics required.
1.2		Is this for Breede-Gouritz or only for Gouritz? Please correct.	No	Intro paragraph states that the focus is only on the Gouritz WMA, therefore the Study Area overview has been written in this context.
1.2.2	Within this WMA, 11 estuaries have been assessed a part of previous EWR studies and the Gouritz Reserve Determination Study (GRDS) therefore focused on the remaining 10 estuaries	Is it possible to give reference to such studies here?	Yes	
2.2	Resource Quality Objectives (RQOs) are specified during Water Resource Classification (WRC), with EcoSpecs defined during Reserve studies forming the ecological input to the RQOs.	Try to fix this, because during classification process RQOs are not determined.	Yes	
	Detailed RQOs (which include EcoSpecs) must be provided as the output of the Classification process.	Also try to fix this as well.	Yes	
4.5.2	Hydrology references.	Correct references.	Yes	
Table 5.5	▪ DIN > 200 µg/L average (to be confirmed). ▪ DIP > 50 µg/L average (to be confirmed).	Confirmed how?	Yes	