INKOMATI-USUTHU

CATCHMENTMANAGEMENTAGENCY

ECOSTATUS OF THE ELANDS RIVER CATCHMENT

BIOMONITORING REPORT 2016

www.iucma.co.za

VISION

Water for all in Inkomati-Usuthu

MISSION

Our mission is of a pioneering catchment management system that empowers stakeholders to engage in consensual and adaptive decision making, to achieve reform, and to promote persistent social, economic, and environmental justice across the Inkomati-Usuthu catchment.

- The Inkomati-Usuthu CMA supports the co-operative management of the Inkomati basin as an internationally shared water course
- The decision-making environment of the Inkomati-Usuthu CMA, including delegated functions, enables collaborative action towards equity, sustainability and efficiency in a continually evolving socio-economic system
- The Inkomati-Usuthu CMA manages the resources adaptively, co-operatively and progressively to achieve social, economic and environmental justice, and promote healthy living

VALUES

- The Inkomati-Usuthu CMA acknowledges the interdependence of our responsibilities for caring for the resource and there is explicit recognition of the diversity achieved by what individual/ group contributes to promoting equity, efficiency, and sustainability as defined in the National Water Act
- Decisions, actions and outcomes are subject to performance evaluation against measurable goals, indicators and timeframes
- The Inkomati-Usuthu CMA strives for a trusting, transparent and corrupt-free system of catchment management that is cognisant of existing agreements and promotes fairness before the law, environment and economic development
- Management is adaptive, open to critique and outcomes driven, with solutions being practical, achievable and implement able
- The Inkomati-Usuthu CMA practices problem solving that embraces:
- Ethics of Ubuntu (our humanity is defined by how others experience our behaviour), Simunye (we are one) and Batho-pele (people first)
- Consensus driven stakeholder participation
- Decision within our mandate are made and are justified on the basis of the best available social, technical, economic, environmental and governance knowledge

ELANDS RIVER CATCHMENT BIOMONITORING REPORT 2016

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Inkomati-Usuthu Catchment Management Agency

Web: www.iucma.co.za

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ABSTRACT

The need to sample the mainstem of the Elands River during the 2016 drought conditions was identified as critical, since at present the Elands River is rated as one of the most impacted rivers in the Crocodile River Catchment.These surveys conducted will complement the larger Ecostatus of the Crocodile River Report to be conducted in 2017. Biomonitoring, using aquatic macro-invertebrates and fish, was carried out in September – October 2016 at 17 sampling locations in the Elands River catchment, Mpumalanga Province, South Africa. The results of this biomonitoring are briefly presented, and problem areas and issues identified in the field are listed. Preliminary results indicate changes in water quality and flow, both recognized drivers of aquatic systems, with resultant negative responses of sensitive biota. Changes in the stream community from sensitive to tolerant taxa indicates impaired conditions. Drought conditions, over-abstraction, and water quality pollution are considered the main sources of impairment during field sampling. Large volumes of poorly treated domestic waste water enter the upper Elands River at Machadodorp and Waterval Boven, while over-abstraction was noted between Malaga and Ngodwana. Stream flow increased considerably directly up- and downstream from Ngodwana Mill, as water from underground eyes and irrigated effluent enters the river. Levels of chlorides and sulphates were found to increase considerably in this area, and correlated with the absence or low abundances of specific families of aquatic macro-invertebrates (e.g. Tricorythidae) and several fish species (e.g. *Chiloglanis bifurcus, Amphilius uranoscopus and Labeobarbus polylepis*).

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Abbreviations

ASPT	=	Average Score Per Taxon
FRAI	=	Fish Response Assessment Index
IBI	=	Index of Biological Integrity
IUCMA	=	Inkomati-Usuthu Catchment Management Agency
LIFE	=	Lotic Invertebrate Index for Flow Evaluation
MTPA	=	Mpumalanga Tourism and Parks Agency
NEH	=	North Eastern Highlands
NEM	=	Northern Escarpment Mountains
PSI	=	Pollution Sensitivity Index
RHAM	=	Rapid Habitat Assessment Model
SASS5	=	South African Scoring System, Version 5

1. INTRODUCTION

The Mpumalanga Tourism and Parks Agency (MTPA) (Scientific Services:Aquatic and Herpetofauna) were tasked in August 2016 to carry out an assessment to determine the in-stream conditions of the Elands River, based on biological indicators (macro-invertebrates and fish). The Elands River as one of the most impacted rivers in the Crocodile Catchment (Incomati basin), which is based on a water quality assessment of certain variables in the Crocodile and Olifants Rivers in the Mpumalanga and Limpopo provinces carried out in 2013-14, (Griffin et al. 2014). Due to the extreme drought conditons in 2016, as well as numerous developments in the catchment, along with an application by Sappi Ngodwana applying for an increased water use license, it was deemed necessary to do a comprehensive biotic survey in the Elands River mainstem. These surveys conducted will complement the larger Ecostatus of the Crocodile River Report to be conducted in 2017.

Biological data gathering in the Incomati system's Elands River have been relatively good, with the most active data collection up- and downstream from Ngodwana Pulp & Paper Mill after a spill in September 1989 (James & Barber 1991; Kleynhans et al. 1991; Kleynhans et al. 1992). Biological data collection prior to the spill was carried out since the late 1960's onwards, although the frequency of sampling has, following the spill, has decreased (Gaigher 1967; Kleynhans 1986; Kleynhans 1999; Matthew 1968). Several recent biological studies have been carried out in the Elands River to determine conditions (RHP 1998; RHP 2001; O'Brien 2005; Ferreira et al. 2008; Roux & Selepe 2012; Diedericks & Roux 2014). Some of these studies which focused on the Elands River from source included (RHP1998; RHP 2001; Roux & Selepe 2012), while the others were mainly focused on the impact of the pulp and paper mill (O'Brien 2005; Ferreira et al. 2008; Diedericks & Roux 2014). The studies focused on stream conditions (O'Brien2015; Ferreira et al. 2008) indicated the conditions in the Elands River as relatively good (A to B category), although recent studies of the conditions up- and downstream from the pulp and paper mill indicate moderate to severely impaired conditions (Diedericks & Roux 2014).

1.1 OBJECTIVES OF THE STUDY

The main aim of this study was to determine in-stream conditions during low flow conditions in the drought period (September 2016) based on the aquatic macro-invertebrate and fish community. Biomonitoring in the Elands River was carried out starting upstream from Machadodorp and ending close to the Elands' confluence with the Crocodile River. A total of 17 sites were sampled, of which 15 are in the Elands River, and two in the Ngodwana Catchment. The two additional sites in the Ngodwana catchment were sampled primarily to assess the health and abundance of the population of IUCN critically endangered *Chiloglanis bifurcus* species (Roux & Hoffmann 2017, In Prep). This report briefly summarises the results from the fieldwork determining the Fish Ecostatus and Macro-Invertebrate Ecostatus within the Elands River mainstem, as well as indicating problems identified.

1.2. STUDY AREA

The Elands River rises in a gentle sloping Highveld zone near the town of Machadodorp at an elevation of 1,904 m a.m.s.l., flowing first in a southerly and then in an easterly direction towards its confluence with the Crocodile River at an elevation of 772 m a.m.s.l., located downstream from Montrose Falls and have a steeper gradient for most of its length. The total length of the Elands River is 118km from its source to its confluence with the Crocodile River. There are two natural barriers on the Elands River in the form of waterfalls, one at the Waterval Boven Tunnel between Waterval Boven and Waterval Onder, and one downstream from Ngodwana, before the river merges with the Crocodile (see Figure 1 and Table 2). The waterfall at Waterval Boven is an outstanding geomorphological feature of this river reach. It forms a natural, physical barrier to upstream migrating fish species. The river section from Waterval Boven to Ngodwana can be characterised by exceptional riffle and rapid habitats. The total Elands River Catchment area is 1,573 km^2, of which 22 % was reported as afforested and 0.8 % irrigated in 1994 (Midgley et al. 1994).

2. METHODS

The general approach used for this study was based on the rapid assessment appraisal methods recommended by the Department of Water Affairs in their guidelines for Resource Directed Measures for the Protection of Water Resources. Aquatic biomonitoring was implemented using aquatic macro-invertebrates and fish as indicators, *in situ* measurements of water quality variables were taken, and chemical samples were collected for laboratory analyses. The SASS5 (aquatic macro-invertebrate) and fish results are summarised and then discussed per sampling site.

2.1 MACRO-INVERTEBRATES

Aquatic invertebrates were sampled using a standard SASS net and identified to at least family level according to the SASS5[5] sampling technique (Dickens & Graham 2002). Species that were easy to identify were also noted. The results were classified into one of six Present Ecological State categories, ranging from Natural (Category A), to Critically Modified (Category F). The interpretation of values can differ significantly for different eco-regions in the country (Davies & Day 1998). Because SASS was developed for application in the broad synoptic assessment required for the River Health Program (RHP), it does not have a particularly strong cause-effect basis.

The MIRAI (Macro-Invertebrate Assessment Index) was also used to interpret the Ecological Condition of the macro invertebrate for the sites. The MIRAI is a rule-based model recently developed by DWAF (Thirion 2008). It integrates the ecological requirements of the invertebrate taxa in a community or assemblage to their response to modified habitat conditions.

[5] SASS5, or South African Scoring System (version 5), is a rapid method of quantifying the condition or health of a river, based on the presence of major invertebrate groups (mostly families), each of which have been allocated a "sensitivity" value (Dickens and Graham 2002). The values are summed to provide a Total Score, and divided by the total number of taxa to provide an Average Score per Taxon (ASPT).

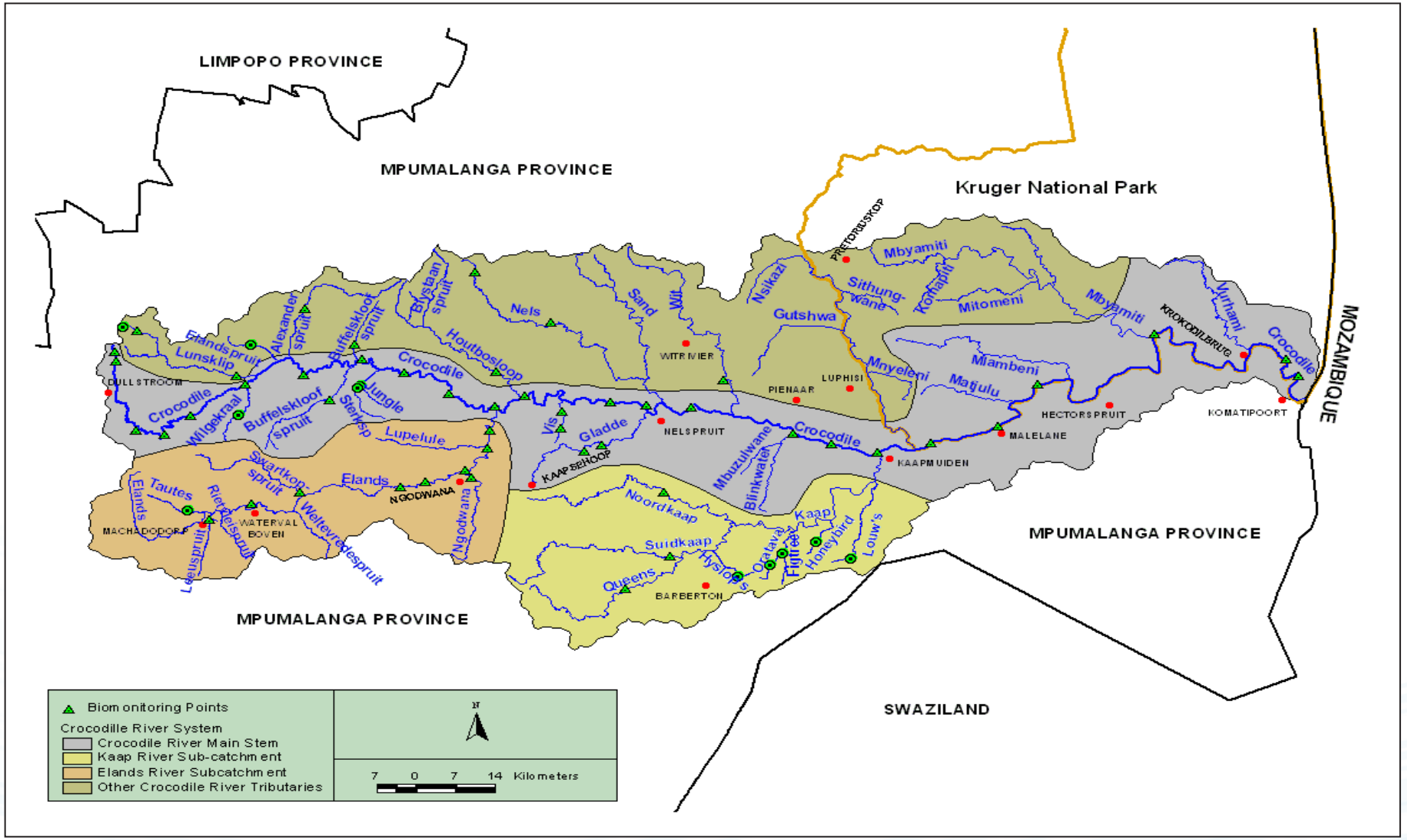

Figure 1: Map of the Elands River Catchment and Tributaries.

2.2 FISH

Fish were sampled using a 10mm-mesh scoop-net and a SAMUS DC electro shocking device. Electro shocking is highly effective and entails the use of an electronic device to rapidly catch fish. The sampling of fish by using an electro shocker is based on the flow of direct electric current (DC) in water causing an anode reaction (galvanotaxis) in fish. Apart from the critical electric parameters to be considered, the conductivity of waters (salinity), temperatures, surface of electrodes, species and the size of fish are also important parameters. These parameters can only be determined on site with a considerable degree of experience (Cowx 2001). All fish species were identified and anomalies and general age structure were recorded. Sampling effort (time electricity applied in water) per site was kept to about 30 minutes.

The presence, absence or abundance of fish species in comparison to the expected reference condition was based on all baseline data obtained and available habitat at each site during the survey. Fish assemblage diversity and abundance vary depending on the season and the integrity of the available habitat. This data was used in the Fish Response Assessment Index (FRAI) and Reference Frequency of Occurrence (FROC) (Kleynhans et al. 2008) to evaluate changes from reference conditions. The FRAI is a rule-based model recently developed by DWAF (Kleynhans 2008) and is an assessment index based on the environmental intolerances and preferences of the reference fish assemblage and the response of the constituent species of the assemblage to particular groups of environmental determinants or drivers.

These intolerance and preference attributes are categorized into metric groups with constituent metrics that relates to the environmental requirements and preferences of individual species. Assessment of the response of the species metrics to changing environmental conditions occur either through direct measurement (surveys) or are inferred from changing environmental conditions (habitat). Evaluation of the derived response of species metrics to habitat changes are based on knowledge of species ecological requirements. Usually the FRAI is based on a combination of fish sample data and fish habitat data (Kleynhans 2008).

Changes in environmental conditions are related to fish stress and form the basis of ecological response interpretation and to determine the “Present Ecological Category” of the fish assemblage.

2.3 CHEMICAL AND PHYSICAL WATER QUALITY MEASUREMENTS

At each biomonitoring site, water quality samples were collected in 1L treated bottles for analysis at Regen Waters Laboratory[6]. In addition to water quality samples, *in situ* water quality parameters (i.e. temperature, pH and conductivity) were recorded using a Eutech CyberScan PC10 and AZ8403 dissolved oxygen meter (concentration in mg/L and % saturation). The water quality constituents that were measured at the sites on the Elands River are listed in Table 1 below. In situ measurements and water quality samples collected in straight reaches with uniform flow stable bottom contours, and where constituents were considered to be well mixed along the cross section, as described in (U.S. Geological Survey, 2006).

Table 1. List of chemical and physical variables measured and analysed.

Variable	Measure		Units
Physical			
Colour	Absorbance of light		
Specific conductance (EC)	Electric carrying capacity		mS/m
Dissolved Solids (TDS)	Concentration of solids < a given filter pore size		mg/L
Temperature	Thermal energy		°C
Transparency	Light transmission		Cm
Chemical			
Aggregate	Hardness	(divalent cations) [Ca^{2}]+[Mg^{2}]	mg/L as $CaCO_3$
Inorganic	Major cations	Calcium	mg/L as Ca^{2}
		Magnesium	mg/L as Mg^{2}
		Sodium	mg/L as Na^{+}
		Potassium	mg/L as K^{+}
	Major anions	Sulphate	mg/L as SO^{2}_{4}
		Chloride	mg/L as Cl^{-}
	Minor ions	Aluminium	mg/L as Al
		Fluoride	mg/L as F
	Hydrogen (H^{+} - pH)		
Dissolved Gasses	Oxygen		mg/L & % O_2
Nutrients	Ammonium (NH_4)		mg/L as N
	Ammonia (NH_3)		mg/L as N
	Nitrite (NO_2)		mg/L as N
	Nitrate (NO_3)		mg/L as N
	Orthophosphate (H_2PO_4)		mg/L as P
	Silica ($Si(OH)_4$)		mg/L as Si

2.4 SAMPLING SITES

A total of 17 sites were sampled, of which 15 were located on the Elands River mainstem, and two on tributaries. The bulk of the sites were located upstream from Ngodwana Pulp & Paper Mill.

[6]Regen Waters Laboratory, 4 Woltemade Street, Emalahleni, 1035, Tel: 013-690-1487; Email: regenlab@mweb.co.za

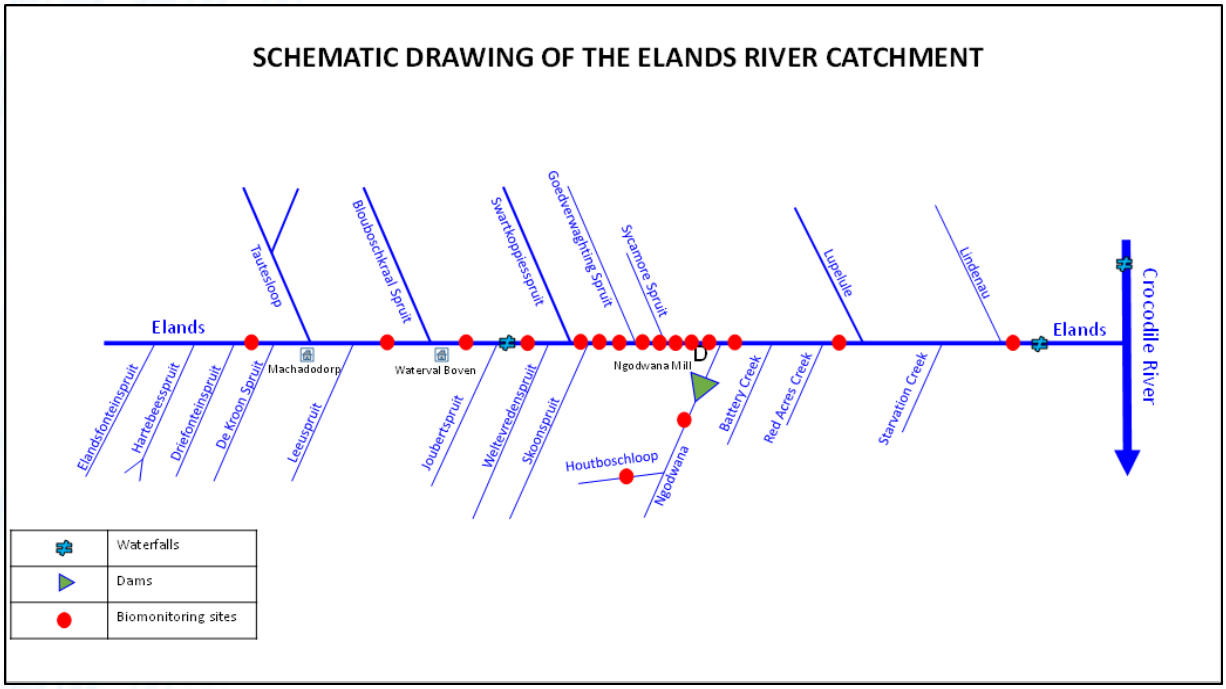

Figure 2: Schematic drawing of the Elands River, roughly indicating site locations.

Table 2: A list of sites sampled during the 2016 survey, including details such as site code, quaternary sub-catchment (QC), PESEIS Reach Code, River, GPS location and elevation, EWR site highlighted in orange.

Aquatic Ecoregion	RU (resource unit)	Site Code	QC	Reach Code	River	Geomorphological Zone	GPS[7] (dd.ddddd)		Elevation[8]
							S	E	(m a.s.l.)
10: Northern Escarpment Mountains	RU 1	X2ELAN-DEGOE	X21F	X21F-01046	Elands	D: Upper Foothills	-25.68720	30.19924	1,576
		X2ELAN-QUARY	X21G	X21G-01037		D: Upper Foothills	-25.64855	30.28933	1,469
		X2ELAN-WATER (EWR1)				C: Transitional	-25.63188	30.32415	1,373
	RU 2	X2ELAN-DOORN				C: Transitional	-25.64621	30.37673	1,208
		X2ELAN-KINDE	X21J	X21J-01013		D: Upper Foothills	-25.61180	30.41679	1,132
		X2ELAN-MALAG				D: Upper Foothills	-25.59706	30.44719	1,103
		X2ELAN-ELAND				D: Upper Foothills	-25.60372	30.48327	1,051
		X2ELAN-WELTE				D: Upper Foothills	-25.60571	30.52707	1,013
		X2ELAN-HEMLO				D: Upper Foothills	-25.60033	30.55953	984
		X2ELAN-RAYTO				D: Upper Foothills	-25.59517	30.59258	950
		X2ELAN-GELUK				D: Upper Foothills	-25.58729	30.61307	935
		X2ELAN-GROOT				D: Upper Foothills	-25.57241	30.65061	908
		X2ELAN-ROODE	X21K	X21K-01035		D: Upper Foothills	-25.56873	30.66285	892
		X2ELAN-GOEDG				D: Upper Foothills	-25.52798	30.69784	852
		X2ELAN-EHOEK		X21K-00997		D: Upper Foothills	-25.49434	30.70218	828
		X2HOUT-UITZI	X21H	Not allocated	Houtboschloop	D: Upper Foothills	-25.67886	30.65769	1,119
		X2NGOW-NOOIT	X21H	X21H-01060	Ngodwana	D: Upper Foothills	-25.66244	30.67263	1,064

[7] Map Datum = WGS84

[8] The elevation was obtained from a Garmin Oregon 650, with Garmap's Southern Africa TOPO 2013 PRO, run on Garmin Base Camp Version 4.4.7.

3. RESULTS

The SASS5 results based on the aquatic macro-invertebrates encountered, the fish species and the community composition are presented for all the sites sampled in 2016. Water samples were collected for chemical analysis, but the results will only be presented in the final report.

3.1 SASS5

SASS5 results recorded at the 17 sites during the 2016 field surveys are presented in Table4 that follows.

Table 3: 2016 SASS5 results for sites located in the Elands River Catchment.

SITE	SQ REACH	SS	FAM	ASPT	% SEN	MIRAI %	CATEGORY
X2ELAN-DEGOE	X21F-01046	199	32	6.2	11	70.9	C
X2ELAN-QUARY	X21G-01037	191	35	5.5	13	62.9	C
X2ELAN-WATER	X21G-01037	187	33	5.7	14	60.8	C/D
X2ELAN-DOORN	X21J-01013	175	31	5.6	23	57.2	D
X2ELAN-KINDE	X21J-01013	141	26	5.4	43	56.2	D
X2ELAN-MALAG	X21J-01013	198	31	6.4	55	67.1	C
X2ELAN-ELAND	X21J-01013	191	32	6.0	32	70.0	C
X2ELAN-WELTE	X21J-01013	174	29	6.0	19	62.1	C
X2ELAN-HEMLO	X21J-01013	151	26	5.8	21	51.6	D
X2ELAN-RAYTO	X21J-01013	174	26	6.7	13	51.6	D
X2ELAN-GELUK	X21J-01013	147	24	6.1	57	50.2	D
X2ELAN-GROOT	X21J-01013	211	32	6.6	37	65.7	C
X2ELAN-ROODE	X21K-01035	180	30	6.0	21	61.1	C
X2ELAN-GOEDG	X21K-01035	195	31	6.3	32	60.1	C/D
X2ELAN-EHOEK	X21K-00997	175	30	5.8	37	60.6	C/D

SITE	SQ REACH	SS	FAM	ASPT	% SEN	MIRAI %	CATEGORY
X2HOUT-UITZI	Not on Reach	202	30	6.7	48		
X2NGOD-NOOIT	X21H-01060	222	32	6.9	57		

Tolerant taxa are dominant in headwater streams, with improvements at some downstream sites, but overall deterioration. The lowest percentage of sensitive taxa were recorded in the headwaters of the Elands River, X2ELAN-DEGOE, X2ELAN-QUARY, X2ELAN-WATER, and then further downstream at X2ELAN-WELTE, X2ELAN-RAYTO, and X2ELAN-ROODE.

The best conditions based on the SASS5 results were recorded in the tributary of the Ngodwana River, X2HOUT-UITZI and in the Ngodwana River.

3.2 FISH

Based on historical results dating back to 1968, 10 indigenous fish species have been recorded in the Elands River. These species are listed in black font in Table 5 that follows. Species listed in red font are either exotic invasive or indigenous species outside its normal distribution range.

Table 4: List of sites sampled in the Elands River, indicating species expected, recorded, numbers and catch per unit efforts.

FISH SPECIES	SAMPLING SITES																
	X2ELAN-DEGOE	X2ELAN-QUARY	X2ELAN-WATER	X3ELAN-DOORN	X3ELAN-KINDE	X2ELAN-MALAG	X2ELAN-SALAG	X2ELAN-WELTE	X2ELAN-HEMLO	X2ELAN-RAYTO	X2ELAN-GELUK	X2ELAN-GROOT	X2ELAN-ROODE	X2ELAN-GOEDG	X2ELAN-EHOEK	TOTAL	SCPUE
ANGUILLIDAE (Freshwater Eels)																	
Anguilla mossambica					1		3	1			1					**6**	**0.01**
KNERIIDAE (Knerias)																	
Kneria kwena							2									**2**	**0.00**
CYPRINIDAE (Barbs, yellowfishes, labeos)																	
Enteromius anoplus				4												**4**	**0.01**
Enteromius crocodilensis					39		21	31	36	24	64	43	37	39	33	**367**	**0.63**
Barbus paludinosus				7			41									**48**	**0.08**
Labeobarbus marequensis										1						**1**	**0.00**
Labeobarbus polylepis				16	24	9	14	16		2	7					**88**	**0.15**
CHARACIDAE (Characins)																	
Micralestes acutidens							17	4	783	96	59	3		17	14	**993**	**1.70**
AMPHILIIDAE (Mountain catfishes)																	
Amphilius uranoscopus		2	6	3	17	41	29	9	53	29	27	9		4	5	**234**	**0.40**
MOCHOKIDAE (Squeakers, suckermouth catlets)																	
Chiloglanis bifurcus					4							7	3	4	2	**20**	**0.03**
Chiloglanis pretoriae				32	77	113	74	78	89	103	327	29	19	22	49	**1012**	**1.74**
SALMONIDAE (Trouts)																	
Oncorhynchus mykiss																**0**	**0.00**
POECILIIDAE (Live-bearers)																	
Gambusia affinis																**0**	**0.00**
CENTRARCHIDAE (Basses and sunfishes)																	
Micropterus salmoides																**0**	**0.00**
CICHLIDAE (Cichlids)																	
Pseudocrenilabrus philander	7	7	29	14	9	14	7	7	4	3	14	2	5		7	**129**	**0.22**
Tilapia sparrmanii	36	24	14	3	21		33	13	59	42	68	8	16	7	25	**369**	**0.63**
NO. OF SPECIES	**2**	**3**	**3**	**7**	**8**	**4**	**10**	**8**	**6**	**8**	**8**	**7**	**5**	**6**	**7**	**16**	
NUMBER OF INDIVIDUALS	**43**	**33**	**49**	**79**	**192**	**177**	**241**	**159**	**1024**	**300**	**567**	**101**	**80**	**93**	**135**	**3273**	
ELECTRO-FISHING TIME (min)	**31**	**39**	**32**	**43**	**39**	**43**	**49**	**35**	**38**	**36**	**42**	**35**	**42**	**38**	**41**	**583**	
CPUE	**1.39**	**0.85**	**1.53**	**1.84**	**4.92**	**4.12**	**4.92**	**4.54**	**26.95**	**8.33**	**13.50**	**2.89**	**1.90**	**2.45**	**3.29**	**5.61**	

Table 5: List of reaches surveyed during 2016 in the Elands River mainstem and tributaries.

REACH	SITE	No. Spp.	No. Ind.	EF (min)	CPUE	FRAI	
						%	CATEGORY
X21F-01046	X2ELAN-DEGOE	2	43	31	1.39	78.2	B/C
X21G-01037	X2ELAN-QUARY	3	33	39	0.85	74.6	C
X21G-01037	X2ELAN-WATER	3	49	32	1.53	69.1	C
X21G-01037	X2ELAN-DOORN	7	79	43	1.84	80.7	B
X21J-01013	X2ELAN-KINDE	8	192	39	4.92	86.9	B
X21J-01013	X2ELAN-MALAG	4	177	43	4.12	75.8	C
X21J-01013	X2ELAN-ELAND	10	241	49	4.92	85.6	B
X21J-01013	X2ELAN-WELTE	8	159	35	4.54	78.5	B/C
X21J-01013	X2ELAN-HEMLO	6	1024	38	26.95	77.2	C
X21J-01013	X2ELAN-RAYTO	8	300	36	8.33	78.0	B/C
X21J-01013	X2ELAN-GELUK	8	547	42	13.02	79.7	B/C
X21J-01013	X2ELAN-GROOT	7	101	35	2.89	77.8	C
X21K-01035	X2ELAN-ROODE	5	80	42	1.90	72.8	C

X21K-01035	X2ELAN-GOEDG	6	93	38	2.45	80.0	B/C
X21K-01035	X2ELAN-EHOEK	7	135	41	3.29	79.1	B/C

REACH	SITE	No. Spp.	No. Ind.	EF (min)	CPUE	FRAI	
						%	CATEGORY
X21H not allocated	X2HOUT-UITZI	6	205	50	4.10	75.2	C
X21H-01060	X2NGOW-NOOIT	7	1044	88	11.86	87.2	B

The last survey of the Elands River on record took place in September 2014, with new records of species during this survey including *Kneria kwena, Labeobarbus marequensis* and *Micralestes acutidens*. The species *Micralestes acutidens* was first recorded by Neels Kleynhans at the X2ELAN-ROODE site in August 2000. The lowest diversity (CPUE) were recorded at headwater sites, and the site downstream from Ngodwana Pulp & Paper Mill (X2ELAN-ROODE).

3.3 WATER QUALITY

Results are presented for the Elands River and all the data for each site is included in Table 7.

Table 6: Summary of Chemical Analysis of Water Quality results for the Elands River Mainstem and Tributaries.

SITE CODE	SAMPLE DATE	WATER SAMPLE CODE	TDS	Nitrate & Nitrite as N	Nitrate NO_3 as N	Nitrite NO_2 as N	Chlorides as Cl	Total Alkalinity as $CaCO_3$	Fluoride as F	Sulphate as SO_4	Calcium as Ca	Magnesium as Mg	Sodium as Na	Potassium as K	Conductivity at 25° C in mS/m	pH-Value at 25 ° C	Ortho Phosphate PO_4 as P	Silicon as Si	Free & Saline Ammonia as N	Ammonium as N	Zinc as Zn	Aluminium as Al
X2ELAN-DEGOE	11-Oct-16	EC16	100	<0.1	<0.1	<0.1	3.72	88	<0.20	2.56	12.30	14.2	5.42	1.69	18.4	8.27	<0.1	7.04	<0.20	<0.20	<0.01	0.06
X2ELAN-QUARY	11-Oct-16	EC17	150	<0.1	<0.1	<0.1	10.00	110	0.20	7.33	13.40	16.3	17.40	2.14	24.9	8.40	<0.1	9.41	<0.20	<0.20	0.02	0.03
X2ELAN-WATER	11-Oct-16	EC15	150	0.31	0.31	<0.1	9.22	98	<0.20	13.30	12.90	15.8	17.50	2.16	23.9	8.39	<0.1	7.05	<0.20	<0.20	<0.01	0.02
X2ELAN-DOORN	11-Oct-16	EC14	170	0.54	0.54	<0.1	13.20	107	<0.20	19.80	15.60	17.0	20.80	2.13	27.3	8.43	<0.1	6.29	<0.20	<0.20	<0.01	0.03
X2ELAN-KINDE	11-Oct-16	EC13	130	<0.1	<0.1	<0.1	8.02	85	<0.20	10.10	12.60	12.0	15.30	1.50	21.3	8.26	<0.1	6.83	<0.20	<0.20	<0.01	0.02
X2ELAN-MALAG	29-Sep-16	EC07	126	<0.1	<0.1	<0.1	8.23	94	<0.20	9.54	12.40	12.7	14.50	1.55	20.8	8.37	<0.1	7.25	<0.20	<0.20	<0.01	0.03
X2ELAN-ELAND	29-Sep-16	EC08	138	<0.1	<0.1	<0.1	7.78	107	0.25	8.42	15.50	16.5	14.30	1.21	25.1	8.17	<0.1	11.10	<0.20	<0.20	0.01	0.10
X2ELAN-WELTE	29-Sep-16	EC09	130	<0.1	<0.1	<0.1	7.60	93	<0.20	7.48	17.40	14.1	9.30	1.00	19.8	8.64	<0.1	10.30	<0.20	<0.20	<0.01	0.02
X2ELAN-HEMLO	28-Sep-16	EC03	118	<0.1	<0.1	<0.1	7.28	84	<0.20	7.05	10.90	12.5	13.40	1.09	20.0	8.50	<0.1	10.20	<0.20	<0.20	0.01	0.02
X2ELAN-RYTON	28-Sep-16	EC04	98	<0.1	<0.1	<0.1	6.07	76	<0.20	5.86	13.60	10.4	7.94	0.76	16.3	8.63	<0.1	9.32	<0.20	<0.20	<0.01	0.05
X2ELAN-GELUK	10-Oct-16	EC11	486	<0.1	<0.1	<0.1	39.70	110	<0.20	188.00	28.00	23.2	104.00	1.95	72.9	8.07	<0.1	8.31	<0.20	<0.20	<0.01	0.06
X2ELAN-GROOT	10-Oct-16	EC10	612	0.53	0.53	<0.1	98.50	139	<0.20	200.00	51.90	36.4	96.40	1.40	96.5	8.09	<0.1	8.65	<0.20	<0.20	0.02	0.04
X2ELAN-ROODE	28-Sep-16	EC05	750	0.14	0.14	<0.1	116.00	158	<0.20	248.00	57.20	46.9	130.00	1.84	116.0	8.17	<0.1	9.55	<0.20	<0.20	<0.01	0.07
X2ELAN-GOEDG	28-Sep-16	EC06	642	0.13	0.13	<0.1	105.00	145	<0.20	222.00	48.30	33.8	99.70	1.51	108.0	7.98	<0.1	8.72	<0.20	<0.20	<0.01	0.06
X2ELAN-EHOEK	10-Oct-16	EC12	602	<0.1	<0.1	<0.1	91.50	137	<0.20	203.00	49.00	41.3	102.00	1.67	96.1	8.07	<0.1	8.00	<0.20	<0.20	<0.01	0.03
X2HOUT-UITZI	27-Sep-16	EC02	54	<0.1	<0.1	<0.1	1.00	45	<0.20	1.23	9.40	5.95	1.80	0.29	9.65	8.55	<0.1	7.09	<0.20	<0.20	<0.01	0.04
X2NGOD-NOOIT	27-Sep-16	EC01	58	<0.1	<0.1	<0.1	1.25	51	<0.20	1.25	9.53	5.78	5.11	0.38	10.7	8.387	<0.1	10.3	<0.20	<0.20	<0.01	0.09

3.4 RESOURCE UNIT 1 (RU1): Elands River Catchment upstream from Waterfall Boven waterfall

The Elands River originates at an elevation of approximately 1,920 m a.s.l., with the main channel flowing for 52.2 km towards the Waterval Boven Waterfall at an elevation of 1,340 m a.s.l. The catchment upstream from the waterfall is approximately 514.2 km^2, draining mainly grassland areas with numerous small farm dams stocked with exotic trout and bass. The main towns in the catchment area are Machadodorp and Waterval Boven, both with poorly managed wastewater treatment works (Deparment of Water Affairs and Sanitation 2014). The main tributaries within this portion of the catchment are Hartebeesspruit; Driefonteinspruit; Tautesloop; Leeuspruit and Blouboskraalspruit.

Aquatic macro-invertebrates

Based on the available data a total of 54 SASS taxa have been recorded at sites in the Elands River and its tributaries located upstream from the Waterval-Boven Waterfall, which includes the exotic gastropod, Physidae. In a 2000 specialists report, Thirion & Todd (2000) indicated that the RU1 had a rich and diverse invertebrate fauna.

Fish

Historically (since 1967), six fish species (of which four are indigenous) have been recorded in the main channel of the Elands River upstream from the Waterval Boven Waterfall. The indigenous species are:

- *Enteromius anoplus* (Chubby-head Barb);
- *Amphilius uranoscopus* (Mountain Catfish);
- *Pseudocrenilabrus philander* (Southern Mouthbrooder), and;
- *Tilapia sparrmanii* (Banded Tilapia).

Two invasive exotic species have been recorded, namely *Oncorhynchus mykiss* (Rainbow Trout) and *Micropterus salmoides* (Largemouth Bass). Most of the *M. salmoides* records are from tributaries.

Three sites were sampled on the main channel within this “upper” portion of the catchment, namely X2ELAN-DEGOE, X2ELAN-QUARY and X2ELAN-WATER. More detailed information on the location of each site are included in Appendix A.

RIVER		TRIBUTARY OF		
Elands		Crocodile		
SITE NUMBER		**QUATERNARY SUB-CATCHMENT**		**REACH**
X2ELAN-DEGOE		X21F		X21F-01046
GPS CO-ORDINATES (WGS84 – dd.ddddd):	**Latitude**	**Longitude**	**Elevation (m. a.m.s.l.)**	**Geomorphological Zone**
	-25.68720	30.19924	1576	Upper Foothills
AQUATIC ECOREGION	**Level I**			**Level II**
	10. Northern Escarpment Mountains			10.03

Figure A-01. Upstream view of the De Goede Hoop site on the Elands River, X2ELAN-DEGOE (11 October 2016, G. Diedericks).

Figure A-02. Downstream view of the De Goede Hoop site on the Elands River, X2ELAN-DEGOE (11 October 2016, G. Diedericks).

3.4.1 X2ELAN-DEGOE– X21F-01046

Site Description

The De Goede site (X3ELAN-DEGOE) is located on the Elands River at an elevation of 1,576 m a.s.l, and is categorised as a 5th order stream at the sampling point. The site is located approximately 25 km downstream from its source (1,920 m a.s.l.), draining a catchment area of 168.1 km^2. The surrounding area is dominated with grasslands, and there are several small dams located on the main river and its tributaries. The site represented the highest upstream point during the 2016 sampling event. A dam is located 4.4 km upstream from the sampling point, and Milly's fuel station and restaurants are located downstream. The stream falls within the upper foothills geomorphological zone, dominated by alluvial bedrock, cobble-bed, riffles, runs, glides, and pools.

In 2016, the stream banks were scoured, and the riparian zone was dominated by grasses, herbaceous plants, shrubs, and invasive weeds. The stream canopy can be described as open. Invasive plants are abundant with *Acacia mearnsii* dominant. The degree of infestation was estimated as 20 – 40%.

Aquatic Macro-invertebrates

A total of five SASS sampling events are listed on the Rivers Database for this site. These surveys were carried out in May, July, and September 1999, in June 2000 and September 2016. MIRAI was applied for each sampling event. Based on the available MIRAI results, stream conditions improved. The sampling intensity increased between the SASS4 and SASS5 versions, which would partially explain the differences in results.

X2ELAN-DEGOE	ELANDS RIVER	DATE				
		May-99	Jul-99	Sep-99	Jun-00	Oct-16
Total SASS Score		105	107	129	192	197
No. of SASS Families		17	18	22	28	32
Average Score Per Taxon		6.2	5.9	5.9	6.9	6.2

Low flow conditions in 2016 affect the available instream habitat (i.e. flow velocities, water depth) and alters water quality (e.g. water temperature, dissolved oxygen). Several of the taxa previously recorded and expected, e.g. Perlidae, Aeshnidae, Gomphidae, Naucoridae, Philopotamidae and Leptophlebiidae were absent from the 2016 sample. When comparing the two sampling events, there is an overall decrease in sensitive taxa between 2000 and 2016, but this is attributed to the seasonality and low flow conditions, which results in less water, higher temperature fluctuation, less flow and available habitat.

Based on MIRAI, stream conditions were categorised as a category C (71% = moderately modified), with low flow conditions resulting in less available and altered instream habitat conditions, and changes in water quality, all the main drivers of change. The low flow conditions are linked to the 2016 drought, with numerous small upstream weirs and dams adding to human induced reduced flows.

Fish

Five species have been recorded in the reach upstream from Waterval Boven Falls, of which one, *Oncorhynchus mykiss* (Rainbow Trout) is an exotic invasive. In 2016, only two species, *Pseudocrenilabrus philander* (Southern-mouth Brooder) and *Tilapia sparrmanii* (Banded Tilapia) were recorded at the De Goede site. The two expected indigenous species, *Enteromius anoplus* (Chubby-head Barb) and *Amphilius uranoscopus* (Mountain Catfish) were absent from this stretch. This was the only site done for the upper reach of the Elands River.

Table 7: Fish species expected based on the PESEIS Reach Code (X21F-01046) are listed, and the numbers of fish species present during the surveys indicated.

SPECIES	EXP	DATE	
		2011	10/2016
Cyprinidae (Barbs, Yellow-fishes and Labeos)			
Enteromius (Barbus) anoplus	x		-
Cichlidae (Cichlids)			
Pseudocrenilabrus philander	x		7
Tilapia sparrmanii	x		36
Number of species expected	**3**		
Number of species recorded		**NS**	**2**
Number of individuals			**43**
Electro-fishing time (minutes)			**31**
Catch/Unit Effort (CPUE)			**1.39**

X - Expected
NS – Not sampled

The fish velocity depth classes present at this site were slow shallow habitat (moderate) and fast shallow in abundance. Riffles and runs were in abundance and boulders, large rocks and cobbles offered good substrate cover for fish. Some undercut banks were only present in the slow habitat where it provided some cover. No aquatic macrophytes were present and riparian grasses provided the overhanging vegetation cover for fish.

Two indigenous fish species were found of an expected three species. Both of these were limnophylic cichlids with *Tilapia sparrmanii* the most abundant fish species found during the survey.

The catch per unit effort (CPUE) was recorded at a low 1.39 individuals caught per minute.

A Fish Ecostatus rating of 78.2% was calculated for this site based on all available information, placing this site in an Ecological Category B/C (slightly to moderately impaired with a high to moderate diversity and abundance of species).

Impacts

Low flow conditions, bank scouring, and sediment inputs from a poorly drained and steep road approach impacts on this site. Flow regulation from the upstream dam, especially during drought conditions, will further impact negatively on flow conditions (Allan 2004; Dallas & Day 2004; Dallas 2008; Davies et al. 1993; Davies & Day 1998).

The riparian zone was infested with several invasive tree species (e.g. *Acacia mearnsii, Salix babylonica, Eucalyptus grandis, Gleditsia triacanthos,* and *Populus* sp.), with the degree of weed infestation rated as 20-40%.

RIVER			TRIBUTARY OF	
Elands			Crocodile	
SITE NUMBER		**QUATERNARY SUB-CATCHMENT**		**REACH**
X2ELAN-QUARY		X21G		X21G-01037
GPS CO-ORDINATES (WGS84 – dd.ddddd):	**Latitude**	**Longitude**	**Elevation (m. a.m.s.l.)**	**Geomorphological Zone**
	-25.64855	30.28933	1469	Upper Foothills
AQUATIC ECOREGION	**Level I**			**Level II**
	9. Eastern Bankenveld			9.02

Figure A-03. Upstream view of the Quarry site on the Elands River, X2ELAN-QUARY (11 October 2016, G. Diedericks).

Figure A-04. Downstream view of the Quarry site on the Elands River, X2ELAN-QUARY (11 October 2016, G. Diedericks).

3.4.2 X2ELAN-QUARY – X21F-01046

Site Description

The Quarry site (X3ELAN-QUARY) is located on the Elands River downstream from Machadodorp, the Goedgeluk Railway Station and the Machado Quarry. The sampling point is at an elevation of 1,469 m a.s.l., downstream from a weir and upstream from an off-channel trout hatchery. The size of the catchment increased to 406.7 km^2 (due to the site being further downstream), with the main tributaries contributing water being the De Kroonspruit, Tautesloop, Leeuspruit and Rietfonteinspruit.

The surrounding catchment area is dominated by grassland, and the riparian vegetation with shrubs and some exotic trees (e.g. *Salix babylonica*). The stream falls within the upper foothills geomorphological zone, dominated by alluvial bedrock, with cobbles limited. Hydraulic biotopes were represented by riffles, rapids, runs, glides, and pools.

Algal growth was extensive, clearly indicating high upstream inputs of nutrients. The Emthonjeni and Machadodorp WWTWs are located upstream from the sampling point. The stream canopy can be described as open to partially closed.

Aquatic Macro-invertebrates

The 2016 SASS sampling events at this site is the first on record.

Several of the sensitive taxa expected to occur in the reach based on habitat were absent. These included Perlidae, Baetidae >2Sp., Heptageniidae, Chlorocyphidae, Gomphidae, Crambidae and Philopotamidae. The Sewage Snail (*Physa acuta*) from the family Physidae was recorded in high numbers, with algal growth prolific. The absence of taxa sensitive to poor water quality and the high algal growths are attributed to increased nutrient inputs from upstream poorly managed Machadodorp and Emthonjeni WWTWs. Evidence of poor management of these WWTWs is documented in the 2014 Green Drop report (Department of Water Affairs and Sanitation 2014) and 2014/15 IUCMA report (IUCMA 2015).

Based on MIRAI, stream conditions were categorised as a class C (63% = moderately modified), with the stream community mostly affected and responding to the poor water quality (51%).

Fish

The site X2ELAN-QUARY is one of three sites sampled on reach X21G-01037. All of the fish velocity depth classes were available to survey at this site. Habitat for fish was mostly in the form of fast shallow habitat with the slow shallow habitat sparse. Slow deep and fast deep were moderately present. Cover was moderately present as overhanging vegetation with substrate (boulders, rocks and cobbles) providing the necessary in-stream cover for especially the flow dependent fish species.

Three indigenous fish species of an expected nine species were found at this site. Habitat for flow dependent fish was in abundance but only two flow dependent fish were collected. The limnophylic *Tilapia sparrmanii* was the most abundant species found during the survey.

Table 8: Fish species expected based on the PESEIS Reach Code (X21G-01037) are listed, and the numbers of fish species present during the surveys indicated.

SPECIES	EXP	DATE	
		2012	10/2016
Anguillidae (Freshwater Eels)			
Anguilla mossambica	x		-
Cyprinidae (Barbs, Yellow-fishes and Labeos)			
Enteromius (Barbus) anoplus	x		-
Enteromius (Barbus) crocodilensis	x		-
Labeobarbus polylepis	x		-
Amphiliidae (Mountain Catfishes)			
Amphilius uranoscopus	x		2
Mochokidae (Squeakers, suckermouth catlets)			
Chiloglanis bifurcus	x		-
Chiloglanis pretoriae	x		-
Cichlidae (Cichlids)			
Pseudocrenilabrus philander	x		7
Tilapia sparrmanii	x		24
Number of species expected	**9**		
Number of species recorded		**NS**	**3**
Number of individuals			**33**
Electro-fishing time (minutes)			**39**
Catch/Unit Effort (CPUE)			**0.85**

X - Expected
NS – Not sampled

The catch per unit effort (CPUE) was low at 0.85 individuals caught per minute.

A Fish Ecostatus rating of 74.6% was calculated for this site based on all available information, placing this site in an Ecological Category C (moderately modified indicating a loss and change of natural habitat).

Impacts

Algal growth during the 2016 site visit was extensive, covering most of the substrates in and out of current. Excessive algal growth is generally indicative of high nutrient inputs from upstream sources (e.g. phosphorous from WWTWs) (Dallas & Day 2004). The source of impairment is more than likely originating from the Emthonjeni-Machadodorp WWTW's sewage effluent. In the 2014 Green Drop report, the effluent quality compliance was rated as 35.4 % for microbial, 21.9 % for chemical compliance, suggeting a critical state needing urgent intervention (Department of Water Affairs and Sanitation 2014).

The riparian zone was infested with several invasive species (i.e. *Acacia mearnsii, Salix babylonica,* and *Sesbania punicea*), with the degree of weed infestation rated as 20-40%.

RIVER			TRIBUTARY OF	
Elands			Crocodile	
SITE NUMBER		**QUATERNARY SUB-CATCHMENT**		**REACH**
X2ELAN-WATER		X21G		X21G-01037
GPS CO-ORDINATES (WGS84 – dd.ddddd):	**Latitude**	**Longitude**	**Elevation (m. a.m.s.l.)**	**Geomorphological Zone**
	-25.63188	30.32415	1373	Transitional
AQUATIC ECOREGION	**Level I**			**Level II**
	10. Northern Escarpment Mountains			10.03

Figure A-05. Upstream view of the Waterval Boven site on the Elands River, X2ELAN-WATER (11 October 2016, G. Diedericks).

Figure A-06. Downstream view of the Waterval Boven site on the Elands River, X2ELAN-WATER (11 October 2016, G. Diedericks).

3.4.3 X2ELAN-WATER – X21G-01037 (EWR1)

Site Description

The Waterval Boven site (X3ELAN-WATER) is located on the Elands River in Waterval Boven, at an elevation of 1,373 m m.a.s.l. The site is also an Environmental Water Requirements site (EWR1), used for the determination of catchment water resource classes and associated resource quality objectives.

The catchment size upstream from the sampling point increased to 505.5 km2, and is located upstream from Waterval Boven's WWTWs. The main water quantity contributing tributary, Blouboskraalspruit, flows from northern side of the Elands River upstream from Waterval Boven (eNtokozweni).

The sampling site is located close to a cliff-face, which dominates a large portion of the left stream bank (facing downstream). Shrubs dominate the immediate riparian vegetation, and open grass dominated woodland the surrounding catchment area. The stream falls within the upper foothills geomorphological zone, dominated by alluvial bedrock, with cobbles and silt deposition in pools. Hydraulic biotopes were represented by cascades, rapids, riffles, runs, glides, and pools.

Algal growth was extensive, clearly indicating high upstream inputs of nutrients. The stream canopy can be described as partially closed.

Aquatic Macro-invertebrates

A total of four SASS sampling events at this site are listed on the Rivers Database, with 50 SASS5 taxa recorded. Sampling dates on record are October 1996, August 2000, September 2012, and October 2016. Based on the 2000 to 2016 SASS results, conditions deteriorated in terms of sensitivity (ASPT).

X2ELAN-WATER	ELANDS RIVER	DATE			
		Oct-96	Aug-00	Sep-12	Oct-16
Total SASS Score		99	171	184	181
No. of SASS Families		14	25	30	33
Average Score Per Taxon (ASPT)		7.1	6.8	6.1	5.1

Several of the sensitive taxa frequently recorded (e.g. Perlidae, Heptageniidae, Aeshnidae, and Athericidae) were absent from the 2016 sample. Taxa diversity was high but sensitive taxa poorly represented. The substrates were covered with algal growth, indicating high nutrient inputs.

Based on MIRAI, stream conditions in 2016 were categorised as a category C/D (moderately to largely modified), with the greatest respondents to poor water quality the absence of sensitive taxa.

Fish

Shallow habitat, both slow and fast were present in abundance with slow deep habitat which could be sampled, sparse. Most of the cover present was in the fast shallow habitat with overhanging vegetation, undercut banks and substrate as cover for fish. Large areas of bedrock were covered with silt and algae.

Three indigenous fish were found at this site out of an expected nine species during both the 2012 and 2016 surveys but the abundance of both the cichlids, *Pseudocrenilabrus philander* and *Tilapia sparrmanii,* was higher during the 2016 survey. During the 2016 survey the limnophylic, *Pseudocrenilabrus philander,* were the most abundant fish species collected.

The catch per unit effort (CPUE) of 1.53 was higher than the 2012 survey at a very low 0.26.

A Fish Ecostatus rating of 69.1% was calculated for this site based on all available information, placing this site in an Ecological Category C (moderately modified indicating a loss and change of natural habitat).

Table 9: Fish species expected based on the PESEIS Reach Code (X21G-01037) are listed, and the numbers of fish species present during the surveys indicated.

SPECIES	EXP	DATE	
		2012	06/2016
Anguillidae (Freshwater Eels)			
Anguilla mossambica	x	-	-
Cyprinidae (Barbs, Yellow-fishes and Labeos)			
Enteromius (Barbus) anoplus	x	-	-
Enteromius (Barbus) crocodilensis	x	-	-
Labeobarbus polylepis	x	-	-
Amphiliidae (Mountain Catfishes)			
Amphilius uranoscopus	x	2	6
Mochokidae (Squeakers, suckermouth catlets)			
Chiloglanis bifurcus	x	-	-
Chiloglanis pretoriae	x	-	-
Cichlidae (Cichlids)			
Pseudocrenilabrus philander	x	1	29
Tilapia sparrmanii	x	8	14
Number of species expected	**9**		
Number of species recorded		**3**	**3**
Number of individuals		**11**	**49**
Electro-fishing time (minutes)		**43**	**32**
Catch/Unit Effort (CPUE)		**0.26**	**1.53**

X - Expected

Impacts

Algal growth during the 2016 site visit was extensive, covering most of the substrates in and out of current. The algal growth is indicative of high nutrient inputs from upstream sources (Dallas & Day 2004). The source of impairment is more than likely originating from the Waterval Boven WWTW's sewage effluent. In the 2014 Green Drop report, the effluent quality compliance was rated as 35.4 % for microbial, 21.9% for chemical compliance, suggesting a critical state needing urgent intervention (Department of Water Affairs and Sanitation 2014).

The riparian zone was infested with several invasive species (i.e. *Acacia mearnsii, Salix babylonica,* and *Sesbania punicea*), with the degree of weed infestation rated as 20-40%.

3.5 RESOURCE UNIT 2: Elands River downstream from Waterval Boven Waterfall to the Lindenau Waterfall

This middle portion of the catchment includes the Elands River downstream from the Waterval Boven Waterfall at an elevation of approximately 1,340m m.a.s.l. towards the Lindenau Waterfall at an elevation of 800 m m.a.s.l. The length of the Elands River between these two waterfalls is 61.8 km, with the overall geomorphology categorised as upper foothills. Upper foothills are characterised as moderately steep, dominated by cobble-beds and mixed bedrock-cobble bed channels, with plain-bed, pool-riffle, and pool-rapid reach types (Freeman & Rowntree 2005).

The natural vegetation in the catchment between the two waterfalls can be described as woodland dominated grasslands, climaxing towards thickets in lower lying areas. Commercial forestry, the Ngodwana Pulp, and Paper Mill, the Ngodwana community, nurseries, Ngodwana Dam, numerous citrus crops, and new agricultural developments are dominant land-uses. The main tributaries within this portion of the catchment are:

- Nooitgedaghtspruit;
- Joubertspruit;
- Weltevredenspruit;
- Swartkoppiespruit;
- Skoonspruit;
- Goedverwachtingspruit;
- Rietspruit;
- Red Acres;
- Masjonamienspruit;
- Ngodwana River;
- Battery Creek;
- Starvation Creek and;
- Lupelule.

All these tributaries play a considerable role in terms of freshwater inputs and refugia, affecting the intensity of impacts in the main Elands River channel.

Aquatic macro-invertebrates

Based on the available data a total of 66 SASS taxa have been recorded at sites in the Elands River and its tributaries located downstream from the Waterval Boven Waterfall, which includes the exotic gastropods, Physidae and Thiaridae. In a 2000 specialists report, Thirion & Todd (2000) indicated that the RU2 was in relatively good condition, with characteristic taxa Baetidae, Heptageniidae, Simuliidae and Ancylidae.

Fish

Historically (since 1967), a total of 17 fish species have been recorded in the main channel of the Elands River between the Waterval Boven Waterfall and Lindenau Waterfall. Of these 17 species, two are exotic invasives, and six are indigenous species outside their normal distribution range. These extra-limital distribution of these species can often be related to extreme drought conditions when low flow conditions and the modified in-steam conditions facilitate movement of these species to new areas. The species indigenous to the Eland River in this reach are:

- *Anguilla mossambica* (Longfin Eel);

- *Enteromius anoplus* (Chubby-head Barb);
- *Enteromius crocodilensis* (Rosefin Barb);
- *Labeobarbus polylepis* (Bushveld Small-scale Yellowfish);
- *Amphilius uranoscopus* (Mountain Catfish);
- *Chiloglanis bifurcus* (Incomati Suckermouth);
- *Chiloglanis pretoriae* (Short-spine Suckermouth);
- *Pseudocrenilabrus philander* (Southern Mouthbrooder), and;
- *Tilapia sparrmanii* (Banded Tilapia).

The indigenous species outside their normal distribution range recorded included:

- *Kneria kwena* (Southern Kneria) – first record 2016;
- *Enteromius paludinosus* (Straight-fin Barb) – first records 2012;
- *Labeobarbus marequensis* (Lowveld Large-scale Yellow-fish) – first record 1991;
- *Micralestes acutidens* (Silver Robber) – first records 2000;
- *Clarias gariepinus* (Sharp-tooth Catfish) – first records 1992, and;
- *Oreochromis mossambicus* (Mozambique Tilapia).

Two invasive exotic species have been recorded, namely *Gambusia affinis* (Mosquitofish) and *Micropterus salmoides* (Largemouth Bass). *Oncorhynchus mykiss* (Rainbow Trout) was recorded in the Ngodwana River and a tributary of the Ngodwana River (Houtboschloop) upstream from the Ngodwana Dam. The *Micropterus salmoides* were not caught during electro-fishing in 2016, but was observed hunting in deeper pools.

Twelve sites were sampled on the main channel within this mid portion of the catchment.

RIVER			TRIBUTARY OF	
Elands			Crocodile	
SITE NUMBER		**QUATERNARY SUB-CATCHMENT**		**REACH**
X2ELAN-DOORN		X21G		X21G-01037
GPS CO-ORDINATES (WGS84 – dd.ddddd):	**Latitude**	**Longitude**	**Elevation (m. a.m.s.l.)**	**Geomorphological Zone**
	-25.64621	30.37673	1208	Transitional
AQUATIC ECOREGION	**Level I**			**Level II**
	10. Northern Escarpment Mountains			10.03

Figure A-07. Upstream view of the Doornhoek site on the Elands River, X2ELAN-DOORN (11 October 2016, G. Diedericks).

Figure A-08. Downstream view of the Doornhoek site on the Elands River, X2ELAN-DOORN (11 October 2016, G. Diedericks).

3.5.1 X2ELAN-DOORN – X21J-01013

Site Description

The Doornhoek site (X2ELAN-DOORN) is located on the Elands River, 5.1 km downstream from the Waterval Boven Waterfall, at an elevation of 1,208 m a.s.l. The catchment size upstream from the sampling point increased to 540.9 km^2.

Shrubs with grasses, reeds and herbaceous vegetation dominate the immediate riparian vegetation, and an open grass dominated woodland the surrounding catchment area. The stream falls within the upper foothills geomorphological zone, dominated by alluvial bedrock, with cobbles and silt deposition in pools. Hydraulic biotopes were represented rapids, riffles, runs, glides, and pools.

Aquatic grasses and algae are extensive, indicating high upstream organic loads still affects the river. The stream canopy can be described as partially closed.

Aquatic Macro-invertebrates

A total of four SASS sampling events at this site are listed on the Rivers Database, with 40 SASS5 taxa recorded during these four events. Sampling dates on record are October 1996, August 2000, September 2012, and October 2016. Based on the SASS results, conditions vary, with tolerant taxa dominant during the majority of sampling events.

X2ELAN-DOORN	ELANDS RIVER	DATE			
		Oct-96	Aug-00	Sep-12	Oct-16
Total SASS Score		99	130	184	169
No. of SASS Families		14	23	30	29
Average Score Per Taxon (ASPT)		7.1	5.7	6.1	5.8

Sensitive taxa either frequently recorded or expected in 2016 but notably absent at the site included Perlidae, and Aeshnidae. Some of the taxa were present but at lower abundance than previously recorded, e.g. Heptageniidae, and Leptophlebiidae. The 2016 results also highlight an increase in taxa diversity and the number of tolerant taxa. Based on MIRAI, stream conditions were categorised as a category D (largely modified), with community response mostly to poor water quality, followed by flow and to a lesser extent habitat. The poor water quality is likely a product of low flow conditions in 2016, combined with high inputs of polluted waters from upstream communities (e.g. Machadodorp and Waterval Boven).

Fish

This site is just downstream from the waterfall and the third site sampled for the reach. The fish velocity depth classes that were present at this site during the recent survey was slow deep (sparse), slow shallow (moderate) and fast shallow (abundant). Overhanging vegetation was very abundant with undercut banks and root wads only present in the fast shallow habitat. Riffles and runs were in abundance and the boulders, rocks and cobbles offered good substrate cover for fish.

Table 10: Fish species expected based on the PESEIS Reach Code (X21G-01037) are listed, and the numbers of fish species present during the surveys indicated.

SPECIES	EXP	DATE	
		2012	06/2016
Anguillidae (Freshwater Eels)			
Anguilla mossambica	x		-
Cyprinidae (Barbs, Yellow-fishes and Labeos)			
Enteromius (Barbus) anoplus	x		4
Enteromius (Barbus) crocodilensis	x		-
Enteromius (Barbus) paludinosus			7
Labeobarbus polylepis	x		16
Amphiliidae (Mountain Catfishes)			
Amphilius uranoscopus	x		3
Mochokidae (Squeakers, suckermouth catlets)			
Chiloglanis bifurcus	x		-
Chiloglanis pretoriae	x		32
Cichlidae (Cichlids)			
Pseudocrenilabrus philander	x		14
Tilapia sparrmanii	x		3
Number of species expected	**9**		
Number of species recorded		**NS**	**7**
Number of individuals			**79**
Electro-fishing time (minutes)			**43**
Catch/Unit Effort (CPUE)			**1.84**

X - Expected
NS – Not sampled

Six of the expected nine indigenous fish species were collected during the present survey with an additional indigenous species, a small barb *Enteromius paludinosus*, which is extra-limital. This was also the only site where the small barb, *Enteromius anoplus* was found. The flow dependent *Chiloglanis pretoriae* was the most abundant fish species collected.

The catch per unit effort (CPUE) was recorded as 1.84 individuals caught per minute.

A Fish Ecostatus rating of 80.7% was calculated for this site based on all available information, placing this site in an Ecological Category B/C (slightly to moderately impaired with a high to moderate diversity and abundance of species).

RIVER			TRIBUTARY OF	
Elands			Crocodile	
SITE NUMBER		**QUATERNARY SUB-CATCHMENT**		**REACH**
X2ELAN-KINDE		X21J		X21J-01013
GPS CO-ORDINATES (WGS84 – dd.ddddd):	**Latitude**	**Longitude**	**Elevation (m. a.m.s.l.)**	**Geomorphological Zone**
	-25.61180	30.41679	1132	Upper Foothills
AQUATIC ECOREGION	**Level I**			**Level II**
	10. Northern Escarpment Mountains			10.03

Figure A-09. Upstream view of the Kindergoed site on the Elands River, X2ELAN-KINDE (11 October 2016, G. Diedericks).

Figure A-10. Downstream view of the Kindergoed site on the Elands River, X2ELAN-KINDE (11 October 2016, G. Diedericks).

3.5.2 X2ELAN-KINDE– X21J-01013

Site Description

The Kindergoed site (X2ELAN-KINDE) is located on the Elands River, 6.6 km downstream from the Doornhoek site, and 63.9 km downstream from its source. The site is located at an elevation of 1,132 m a.s.l., and the catchment size upstream from the sampling point is 763.5 km^2.

The main tributaries contributing water quantity to the Elands River after the Doornhoek site are the Joubertspruit, Weltevredenspruit and Swartkoppiespruit. The Joubertspruit and Weltevredespruit drain from the southern parts of the Elands and the Swartkoppiespruit from the northwest.

Shrubs with grasses, reeds, trees, and herbaceous vegetation dominate the immediate riparian vegetation, and grass dominated woodland the surrounding catchment area. The stream falls within the upper foothills geomorphological zone, dominated by alluvial bedrock, with cobbles and silt deposition in pools. Hydraulic biotopes present were rapids, riffles, runs, glides, and pools.

There was a noticeable reduction in aquatic grasses when compared to the upstream site (X2ELAN-DOORN) in 2016, with algal growth noticeable in slow flowing portions of the stream. The stream canopy can be described as partially open.

Aquatic Macro-invertebrates

Based on SASS sampling on record, the Kindergoed site was sampled for the first time in 2016. Several of the taxa expected to occur were absent. Of the taxa absent, those regarded as sensitive based on SASS5 included the families Perlidae, Heptageniidae, Leptophlebiidae, Chlorocyphidae, Aeshnidae, Gomphidae, Philopotamidae, Elmidae, Psephenidae, and Athericidae.

Based on MIRAI, stream conditions were categorised as a category D (largely modified), with the absence of taxa sensitive to poor water quality. It was expected that the site will indicate improvement at this site in terms of flow and water quality, since the site is located downstream from the Swartkoppiespruit, which contributes a large proportion of water to the Elands. The community, based on MIRAI, however still indicated impairments caused by water quality, and low flow. The instream habitat was more affected by the low flow than the disturbance is physical (e.g. altered substrates due to increased sediment deposition).

Fish

All of the fish velocity depth classes were available to survey at this site. Habitat for fish was mostly in the form of shallow habitat with the slow habitat sparsely present and fast rapid and riffle habitat in abundance. Cover was moderately to abundantly present as overhanging vegetation with some canopy cover also present. Undercut banks and root wads were only present in the slow habitat but substrate (boulders, rocks and cobbles) provided the necessary in-stream cover for especially the flow dependent fish species.

Table 11: Fish species expected based on the PESEIS Reach Code (X21J-01013) are listed, and the numbers of fish species present during the surveys indicated.

SPECIES	EXP	DATE	
		2012	10/2016
Anguillidae (Freshwater Eels)			
Anguilla mossambica	x		1
Cyprinidae (Barbs, Yellow-fishes and Labeos)			
Enteromius (Barbus) anoplus	x		-
Enteromius (Barbus) crocodilensis	x		39
Labeobarbus polylepis	x		24
Amphiliidae (Mountain Catfishes)			
Amphilius uranoscopus	x		17
Mochokidae (Squeakers, suckermouth catlets)			
Chiloglanis bifurcus	x		4
Chiloglanis pretoriae	x		77
Cichlidae (Cichlids)			
Pseudocrenilabrus philander	x		9
Tilapia sparrmanii	x		21
Number of species expected	**9**		
Number of species recorded		**NS**	**8**
Number of individuals			**192**
Electro-fishing time (minutes)			**39**
Catch/Unit Effort (CPUE)			**4.92**

X - Expected
NS – Not sampled

Eight indigenous fish species of an expected nine were collected during the present survey with only *Enteromius anoplus* not collected. Four *Chiloglanis bifurcus* were collected at a CPUE of 0.1 individuals per minute, which is a high number for this critically endangered fish species. Another flow dependent species, *Chiloglanis pretoriae,* was the most abundant species collected for this survey.

The catch per unit effort (CPUE) was recorded at a higher 4.92 individuals caught per minute.

A Fish Ecostatus rating of 86.9% was calculated for this site based on all available information, placing this site in an Ecological Category B (largely natural with few modifications).

RIVER			TRIBUTARY OF	
Elands			Crocodile	
SITE NUMBER			**QUATERNARY SUB-CATCHMENT**	**REACH**
X2ELAN-MALAG			X21J	X21J-01013
GPS CO-ORDINATES (WGS84 – dd.ddddd):	**Latitude**	**Longitude**	**Elevation (m. a.m.s.l.)**	**Geomorphological Zone**
	S -25.59706	E 30.44719	1,103	Upper Foothills
AQUATIC ECOREGION	**Level I**			**Level II**
	10. Northern Escarpment Mountains			10.03

Figure A-10. Upstream view of the site on the Elands River at Malagate, X2ELAN-MALAG (29 September 2016, G Diedericks).

Figure A-11. Downstream view of the site on the Elands River at Malagate, X2ELAN-MALAG (29 September 2016, G Diedericks).

3.5.3 X2ELAN-MALAG– X21J-01013

Site Description

The Malaga site (X2ELAN-MALAG) is located on the Elands River, 3.9 km downstream from the Kindergoed site, and 67.8 km downstream from its source. The site is located at an elevation of 1,132 m m.a.s.l., and the catchment size upstream from the sampling point is 763.5 km^2.

The main tributary feeding water between the Kindergoed and Malaga sampling points is the Schoonspruit, draining from the northern slopes of the Elands River.

Shrubs with trees and herbaceous vegetation dominate the immediate riparian vegetation, and woodlands the surrounding catchment area. A high diversity of invasive exotic plants was recorded in the riparian zone. The stream falls within the upper foothills geomorphological zone, dominated by alluvial bedrock, with cobbles and silt deposition in pools. The site is located upstream from the Malaga Weir, and hydraulic biotopes represented were rapids, riffles, runs, glides, and pools. The stream canopy can be described as partially shaded.

Commercial forestry, citrus orchids, and small communities are the main upstream land-uses.

Aquatic Macro-invertebrates

A total of four previous SASS sampling events are listed on the Rivers Database for the Malaga site. These are May, July and September 1999, and September 2016. Based on the SASS results, taxa diversity increased considerably in 2016 compared to previous years, with ASPT ranging between 6.4 and 7.1.

X2ELAN-MALAG	ELANDS RIVER	DATE			
		May-99	Jul-99	Sep-99	Sep-16
Total SASS Score		135	142	126	198
No. of SASS Families		20	20	20	31
Average Score Per Taxon (ASPT)		6.8	7.1	6.3	6.4

Compared to the upstream site, X2ELAN-KINDE, stream conditions based on the taxa recorded, showed improvement in 2016. This improvement is based on the flow, habitat, and water quality preferences of taxa recorded. Based on previous records for this Malaga site, 2016 is the first record of the family Atyidae (fresh water shrimps), and they were abundant (>100), suggesting increased availability of nutrients.

Based on MIRAI, stream conditions were categorised as a category C (moderately modified), with a slight improvement in flow and water quality, and consequently instream habitat.

Fish

The Fish velocity depth classes recorded for this reach were slow shallow (moderate), slow deep (moderate) and fast shallow (abundant). No fast deep habitat was present. Cover was moderately present as overhanging vegetation and undercut banks with root wads and rocks, cobbles and pebbles as substrate cover.

Table 12: Fish species expected based on the PESEIS Reach Code (X21J-01013) are listed, and the numbers of fish species present during the surveys indicated.

SPECIES	EXP	DATE 2012	DATE 09/2016
Anguillidae (Freshwater Eels)			
Anguilla mossambica	x		-
Cyprinidae (Barbs, Yellow-fishes and Labeos)			
Enteromius (Barbus) anoplus	x		-
Enteromius (Barbus) crocodilensis	x		-
Labeobarbus polylepis	x		9
Amphiliidae (Mountain Catfishes)			
Amphilius uranoscopus	x		41
Mochokidae (Squeakers, suckermouth catlets)			
Chiloglanis bifurcus	x		-
Chiloglanis pretoriae	x		113
Cichlidae (Cichlids)			
Pseudocrenilabrus philander	x		14
Tilapia sparrmanii	x		-
Number of species expected	**9**		
Number of species recorded		**NS**	**4**
Number of individuals			**177**
Electro-fishing time (minutes)			**43**
Catch/Unit Effort (CPUE)			**4.12**

X - Expected
NS – Not sampled

A total of only four of the expected nine reference indigenous fish species were recorded during the present survey. The four species were *Labeobarbus polylepis,Amphilius uranoscopus,Pseudocrenilabrus philander,* and*Chiloglanis pretoriae* which was the most abundant fish species collected at a CPUE of 2.63 for the species.The overall CPUE calculated for this site was 4.12 individuals caught per minute.

A Fish Ecostatus rating of 75.8% was calculated for this reach based on all available information, placing this reach in an Ecological Category C (moderately impaired with low diversity and abundance of species).

RIVER			TRIBUTARY OF	
Elands			Crocodile	
SITE NUMBER			**QUATERNARY SUB-CATCHMENT**	**REACH**
X2ELAN-ELAND			X21J	X21J-01013
GPS CO-ORDINATES (WGS84 – dd.ddddd):	**Latitude**	**Longitude**	**Elevation (m. a.m.s.l.)**	**Geomorphological Zone**
	S -25.60372	E 30.48327	1,051	Upper Foothills
AQUATIC ECOREGION	**Level I**			**Level II**

Figure A-12. Upstream view of the site on the Elands River at Saragassa, X2ELAN-SARAG (29 September 2016, G Diedericks).

Figure A-13. Downstream view of the site on the Elands River at Saragassa, X2ELAN-SARAG (29 September 2016, G Diedericks).

3.5.4 X2ELAN-ELAND – X21J-010103

Site Description

The Elandshoek site (X2ELAN-ELAND) is located on the Elands River, 5.3 km downstream from the Malaga site, and 73.1 km downstream from its source. The site is located at an elevation of 1,051 m m.a.s.l., and the catchment size upstream from the sampling point is 892.6 km^2.

The main tributaries adding to water quantity between the Malaga and Elandshoek sampling points are the Goedverwagting and Sycamore streams. These two streams drain mainly commercial forestry areas from the southern slopes of the Elands River. The Malaga Weir diverts water into a man-made channel supplying irrigation water to downstream citrus crops (160.8 ha). The water levels in the Elands River noticeably drops downstream from this abstraction point.

Shrubs with grasses, trees, and herbaceous vegetation dominate the immediate riparian vegetation, and woodlands and irrigated crops the surrounding catchment area. A high diversity of invasive exotic plants was recorded in the riparian zone. The stream falls within the upper foothills geomorphological zone, dominated by alluvial bedrock, with cobbles and silt deposition in pools. Flow in 2016 was noticeably reduced compared to the Malaga site, with hydraulic biotopes were represented with riffles, runs, glides, and pools. The stream canopy can be described as partially open.

Commercial forestry, citrus orchids, and small communities are the main upstream land-uses.

Aquatic Macro-invertebrates

Based on SASS sampling on record, the Elandshoek site was sampled for the first time in 2016. Several of the taxa expected to occur were absent. Of the taxa absent, those regarded as sensitive based on SASS5 included the families Perlidae, Philopotamidae, and Naucoridae.

Based on MIRAI, stream conditions were categorised as a category C (moderately modified), with the dominance of taxa tolerantlinked to poor water quality. Conditions in 2016 however, based on MIRAI, improved when compared to the upstream site (X2ELAN-MALAG).

Fish

The habitat surveyed at this site had a high habitat diversity comprising of a large but shallow pool with a dense growth of aquatic plants providing both slow shallow (moderate) and slow deep (sparse) habitat. Rapids and riffles with boulders and large rocks provided both fast shallow (abundant) and fast deep (sparse) habitat with adequate substrate cover for fish. Overhanging vegetation provided moderate cover at both the slow shallow and fast shallow habitats.

Seven of the nine expected indigenous fish species were collected together with three other indigenous fish species, *Micralestes acutidens*, *Kneria* sp. nova 'South Africa' and *Enteromius paludinosus* which were not expected to occur. The *Kneria* sp. is the first recorded ever for the Elands River. The most abundant expected fish species was the flow-dependent *Chiloglanis pretoriae.*

The CPUE recorded for the survey is 4, 92 individuals collected per minute.

A Fish Ecostatus rating of 85.6% was calculated for this site based on all available information, placing this site in an Ecological Category B (largely natural with few modifications).

Table 13: Fish species expected based on the PESEIS Reach Code (X21J-01013) are listed, and the numbers of fish species present during the surveys indicated.

SPECIES	EXP	DATE	
		2012	09/2016
Anguillidae (Freshwater Eels)			
Anguilla mossambica	x		3
Kneriidae (Knerias)			
Kneria sp. nova 'South Africa'			2
Cyprinidae (Barbs, Yellow-fishes and Labeos)			
Enteromius (Barbus) anoplus	x		-
Enteromius (Barbus) crocodilensis	x		21
Enteromius (Barbus) paludinosus			41
Labeobarbus polylepis	x		14
Characidae (Characins)			
Micralestes acutidens			17
Amphiliidae (Mountain Catfishes)			
Amphilius uranoscopus	x		29
Mochokidae (Squeakers, suckermouth catlets)			
Chiloglanis bifurcus	x		-
Chiloglanis pretoriae	x		74
Cichlidae (Cichlids)			
Pseudocrenilabrus philander	x		7
Tilapia sparrmanii	x		33
Number of species expected	**9**		
Number of species recorded		**NS**	**10**
Number of individuals			**241**
Electro-fishing time (minutes)			**49**
Catch/Unit Effort (CPUE)			**4.92**

X - Expected
NS – Not sampled

RIVER			TRIBUTARY OF	
Elands			Crocodile	
SITE NUMBER			**QUATERNARY SUB-CATCHMENT**	**REACH**
X2ELAN-WELTE			X21J	X21J-01013
GPS CO-ORDINATES (WGS84 – dd.ddddd):	**Latitude**	**Longitude**	**Elevation (m. a.m.s.l.)**	**Geomorphological Zone**
	S -25.60571	E 30.52707	1,013	Upper Foothills
AQUATIC ECOREGION	**Level I**			**Level II**
	10. Northern Escarpment Mountains			10.02

Figure A-14. Upstream view of the Weltevreden site on the Elands River, X2ELAN-WELTE (29 September 2016, G Diedericks).

Figure A-15. Downstream view of the Weltevreden site on the Elands River, X2ELAN-WELTE (29 September 2016, G Diedericks).

3.5.5 X2ELAN-WELTE – X21J-01013

Site Description

The Weltevreden site (X2ELAN-WELTE) is located on the Elands River, 6.1 km downstream from the Elandshoek site, and 79.2 km downstream from its source. The site is located at an elevation of 1,031 m a.s.l., and the catchment size upstream from the sampling point is 958.4 km^2.

The Rietspruit is the main tributary adding to water quantity between the Elandshoek and Weltevreden sampling points. The water level in the Elands River at the Weltevreden sampling point was still very low in 2016, affected by the abstraction from the upstream Malaga Weir.

Shrubs with reeds, grasses, trees, and herbaceous vegetation dominate the immediate riparian vegetation, and woodlands and irrigated crops the surrounding catchment area. The stream falls within the upper foothills geomorphological zone, dominated by alluvial bedrock, with cobbles and silt deposition in pools. Hydraulic biotopes represented were riffles, runs, glides, and large pools. The stream canopy can be described as partially open.

Commercial forestry, citrus orchids, and small communities are the main upstream land-uses.

Aquatic Macro-invertebrates

A total of three previous SASS sampling events are listed on the Rivers Database for the Malaga site. These are October 1996, August 2000, and September 2016. Data on the families recorded in August 2000 were not available to include in this report. Based on the SASS results, taxa diversity increased considerably from October 1996 to September 2016, with a decrease in sensitive taxa (ASPT decrease from 6.7 to 6.0). More data than two sampling events are however required to suggest change with any confidence.

X2ELAN-WELTE	ELANDS RIVER	DATE		
		Oct-96	Aug-00	Sep-16
Total SASS Score		160	No data	174
No. of SASS Families		24		29
Average Score Per Taxon (ASPT)		6.7		6.0

Compared to the upstream site, X2ELAN-ELAND, stream conditions based on the taxa recorded indicated similar conditions.

Based on MIRAI, stream conditions were categorised as a category C (moderately modified), with flow and water quality responses similar to those at the upstream site, X2ELAN-ELAND.

Fish

All fish velocity depth classes were available at the site with the exception of fast deep habitat. Classes were slow deep and slow shallow moderately present provided by the big pool areas. The fast shallow class was abundantly present in the form of shallow riffles with rocks and pebbles providing the necessary substrate cover for especially the flow dependent fish. Aquatic macrophytes with their associated root wads also provided cover for the limnophylic fish species.

Table 14: Fish species expected based on the PESEIS Reach Code (X21J-01013) are listed, and the numbers of fish species present during the surveys indicated.

SPECIES	EXP	DATE	
		2012	09/2016
Anguillidae (Freshwater Eels)			
Anguilla mossambica	x		1
Cyprinidae (Barbs, Yellow-fishes and Labeos)			
Enteromius (Barbus) anoplus	x		-
Enteromius (Barbus) crocodilensis	x		31
Labeobarbus polylepis	x		16
Characidae (Characins)			
Micralestes acutidens			4
Amphiliidae (Mountain Catfishes)			
Amphilius uranoscopus	x		9
Mochokidae (Squeakers, suckermouth catlets)			
Chiloglanis bifurcus	x		-
Chiloglanis pretoriae	x		78
Cichlidae (Cichlids)			
Pseudocrenilabrus philander	x		7
Tilapia sparrmanii	x		13
Number of species expected	**9**		
Number of species recorded		**NS**	**8**
Number of individuals			**159**
Electro-fishing time (minutes)			**35**
Catch/Unit Effort (CPUE)			**4.54**

X - Expected
NS – Not sampled

Of the expected nine indigenous species of fish a total of seven were collected as well as one indigenous species not expected to occur. The flow dependent *Chiloglanis pretoriae* was the most abundant species present with the small barb, *Enteromius crocodilensis*, a larger barb *Labeobarbus polylepis* and a cichlid, *Tilapia sparrmanii* in double digit numbers. The CPUE was calculated at 4.54 individuals per minute.

A mean Fish Ecostatus rating of 78.5% was calculated for this reach based on all available information, placing this reach in an Ecological Category B/C (slightly to moderately impaired with a high to moderate diversity and abundance of species).

RIVER			TRIBUTARY OF	
Elands			Crocodile	
SITE NUMBER			**QUATERNARY SUB-CATCHMENT**	**REACH**
X2ELAN-HEMLO			X21J	X21J-01013
GPS CO-ORDINATES (WGS84 – dd.ddddd):	**Latitude**	**Longitude**	**Elevation (m. a.m.s.l.)**	**Geomorphological Zone**
	S -25.60033	E 30.55953	984	Upper Foothills
AQUATIC ECOREGION	**Level I**			**Level II**
	10. Northern Escarpment Mountains			10.02

Figure A-16. Upstream view of the Hemlock site on the Elands River, X2ELAN-HEMLO (28 September 2016, G Diedericks).

Figure A-17. Downstream view of the Hemlock site on the Elands River, X2ELAN-HEMLO (28 September 2016, G Diedericks).

3.5.6 X2ELAN-HEMLO – X21J-01013

Site Description

The Hemlock site (X3ELAN-HEMLO) is located on the Elands River at an elevation of 984 m a.s.l., between the X3ELAN-WELGE site (4 km upstream) and the X2ELAN-RYTON site, a further 4.7 km downstream. The catchment upstream from the sampling point is 1,017.4 km^2, with the Masjonamien the main tributary contributing to water quantity. The catchment of the Masjonamien is dominated by commercial forestry.

The Hemlock site is situated downstream from a weir. A substantial amount of water from the Elands River at the Hemlock Weir, is diverted into a ground-based channel. The water flows for 4.076 m in an east by southerly direction (96°) towards a pump house on the farm Vlakplaats 476 JT. There is no means of closing the off-take, so all water diverted from the Elands River is continuously flowing towards the pump house. Stream flow at the Hemlock site in 2016 was reduced to a trickle because of over abstraction.

The stream falls within the upper foothills geomorphological zone, dominated by alluvial cobble-bed, riffles, runs, glides, and pools.

The riparian zone is dominated by reeds, invasive weeds, grasses, herbaceous plants, shrubs, and trees, and the stream canopy can be described as partially shaded. Invasive plants are abundant, with the degree of infestation estimated as 20 - 40%.

Commercial forestry, citrus orchids, and small communities are the main upstream land-uses.

Aquatic Macro-invertebrates

A total of 18 SASS sampling events at this site are listed on the Rivers Database, starting July 1993. Of these, three sampling events occurred in autumn, six in winter and ten in spring. Overall the results seem to indicate lower taxa diversity in winter, with most sensitive taxa recorded in autumn.

DATE	SASS5 Total Score	No. SASS Families/Taxa	ASPT
Jul-93	147	22	6.7
Aug-93	138	23	6.0
Oct-93	112	20	5.6
Jun-94	114	19	6.0
Sep-94	186	29	6.4
Jun-95	161	22	7.3
Oct-96	176	24	7.3
Sep-98	171	28	6.1
May-99	182	26	7.0
Jul-99	177	28	6.3
Nov-99	240	34	7.1
Oct-01	123	20	6.2
Mar-05	151	20	7.6
Jun-05	241	36	6.7
Sep-12	192	29	6.6
Sep-13	197	31	6.4
Apr-14	247	35	7.1
Sep-16	151	26	5.8

In October 2016, stream flow downstream from the off-take (Hemlock weir) was extremely low. The low flow conditions affect the available instream habitat (i.e. flow velocities, water depth) and alters water quality (e.g. water temperature, dissolved oxygen) (Gordon et al. 2008). Several of the taxa frequently recorded (e.g. Perlidae, Leptophlebiidae, Tricorythidae, Naucoridae, Hydroptilidae, Athericidae, and Ceratopogonidae) were absent from the 2016 sample. Some of the taxa were present but at lower abundance than previously recorded, e.g. Heptageniidae and, Philopotamidae. Based on the previous data dating back to July 1993, the family Atyidae was absent from this point in the river, with the first record from September 2012 onwards. It is worth to note that there is a 10-year sampling gap between October 2001, prior to which there are no records of Atyidae, and September 2012 where a B-abundance (10-100 individuals) were recorded. Another taxon only recently recorded is the family Corbiculidae (clams). The presence of these taxa is attributed to increased nutrient inputs from upstream poorly managed waste water treatment works.

Based on MIRAI, stream conditions were categorised as a category D (largely modified), with extremely low flow, less available and altered instream habitat, and water quality the main drivers of change. The low flow conditions are linked to the 2016 drought, but the extremity of the low flow event is directly because of over abstraction.

Fish

Incredibly high numbers of *Micralestes acutidens* (introduced species) were recorded at the site, obviously benefiting from the slow flow conditions enforced by over abstraction.

Table 15: Fish species expected based on the PESEIS Reach Code (X21J-01013) are listed, and the numbers of fish species present during the surveys indicated.

SPECIES	EXP	DATE			
		2012	2013	2014	09/2016
Anguillidae (Freshwater Eels)					
Anguilla mossambica	x	-	-	-	-
Cyprinidae (Barbs, Yellow-fishes and Labeos)					
Enteromius (Barbus) anoplus	x	-	-	-	-
Enteromius (Barbus) crocodilensis	x	52	82	71	36
Labeobarbus polylepis	x	28	6	7	-
Characidae (Characins)					
Micralestes acutidens		-	-	-	783
Amphiliidae (Mountain Catfishes)					
Amphilius uranoscopus	x	7	28	11	53
Mochokidae (Squeakers, suckermouth catlets)					
Chiloglanis bifurcus	x	-	-	3	-
Chiloglanis pretoriae	x	13	107	88	89
Cichlidae (Cichlids)					
Pseudocrenilabrus philander	x	3	5	14	4
Tilapia sparrmanii	x	11	12	9	59
Number of species expected	**9**				
Number of species recorded		**6**	**6**	**7**	**6**
Number of individuals		**114**	**240**	**203**	**1024**
Electro-fishing time (minutes)		**40**	**30**	**32**	**38**
Catch/Unit Effort (CPUE)		**2.85**	**8.00**	**6.34**	**26.95**

X - Expected

The habitat surveyed at this site had very low habitat diversity comprising of a large pool silted up with a few riffles and runs with some aquatic macrophytes. Only shallow habitat was present at the time of the present survey with slow shallow habitat in abundance and the fast shallow habitat moderately abundant. The fish cover present was mainly provided by the aquatic macrophytes with some boulders, rocks and cobbles providing substrate cover. Five of the nine expected indigenous fish species were collected together with another indigenous fish species, *Micralestes acutidens*, which was not expected to occur but collected in very high numbers. The most abundant expected fish species was the flow-dependent *Chiloglanis pretoriae* concentrated in the few riffles present. During the 2013 and 2014 surveys *C. pretoriae* wasalso the most abundant species but during the 2012 survey it was the small barb, *Enteromius crocodilensis.*

The relative high CPUE recorded for the present survey (26.95) was due to the large numbers of extra-limital *Micralestes acutidens*.

A Fish Ecostatus rating of 77.2% was calculated for this site based on all available information, placing this site in an Ecological Category C (moderately modified indicating a loss and change of natural habitat).

Impacts

The main impact at this site is the reduction of flow, caused by an upstream weir. The sluice gates opening and closing functionality was disabled, resulting in thediversion of most of the river water into the earth channel during the September 2016 site visit. The permanent diversion allows river water to continuously flow into the diversion channel.

The riparian zone is severely infested with known high water using species (i.e. *Eucalyptus* spp.), but several other invasive species were also present. The degree of weed infestation was rated as 20-40%.

RIVER			TRIBUTARY OF	
Elands			Crocodile	
SITE NUMBER		**QUATERNARY SUB-CATCHMENT**		**REACH**
X2ELAN-RAYTO		X21J		X21J-01013
GPS CO-ORDINATES (WGS84 – dd.ddddd):	**Latitude**	**Longitude**	**Elevation (m. a.m.s.l.)**	**Geomorphological Zone**
	S -25.59517	E 30.59258	950	Upper Foothills
AQUATIC ECOREGION	**Level I**			**Level II**
	10. Northern Escarpment Mountains			10.02

Figure A-18. Upstream view of the Rayton site on the Elands River, X2ELAN-RAYTO (28 September 2016, G Diedericks).

Figure A-19. Downstream view of the Rayton site on the Elands River, X2ELAN-RAYTO (28 September 2016, G Diedericks).

3.5.7 X2ELAN-RAYTO – X21J-01013

Site Description

The Ryton site (X3ELAN-RYTON) is located on the Elands River at an elevation of 950 m a.s.l., 4.5 km downstream from the Hemlock site and 87.7 km downstream from its source. The catchment upstream from the sampling point increased to 1,054.4 km^2, with no major tributaries contributing to water quantity.

More water is diverted from the river into a man-made channel between the Hemlock and Ryton sites, and there is a pump in the river downstream from the Ryton sampling point. The pump was operational while sampling was carried out in 2016. Stream flow at the Ryton site in 2016 was reduced to a trickle because of over abstraction.

The stream falls within the upper foothills geomorphological zone, dominated by alluvial cobble-bed, riffles, runs, glides, and pools.

The riparian zone is dominated by reeds, invasive *Eucalyptus* trees (high water use), grasses, herbaceous plants, shrubs, and trees, and the stream canopy can be described as partially shaded. Invasive plants are abundant, with the degree of infestation estimated as 20 - 40%.

Commercial forestry, citrus orchids, and small communities are the main upstream land-uses.

Aquatic Macro-invertebrates

A total of four previous SASS sampling events are listed on the Rivers Database for the Ryton site. These are October 1996, March and June 2005, and September 2016. Based on the SASS results, changes are relatively small, with ASPT between 6.6 and 7.4.

X2ELAN-RYTON	ELANDS RIVER	DATE			
		Oct-96	Mar-05	Jun-05	Sep-16
Total SASS Score		171	186	225	174
No. of SASS Families		24	25	34	26
Average Score Per Taxon (ASPT)		7.1	7.4	6.6	6.7

Compared to the upstream site, X2ELAN-HEMLO, stream conditions based on the taxa recorded showed a decrease in taxa diversity from June 2005 to September 2016. More data is needed to meaningfully interpret site specific changes.

Based on MIRAI, stream conditions in 2016 were categorised as a category D (severely modified). This indicates a decrease in flow sensitive taxa, specifically for those associated with fast and moderate flows, with an increase in those taxa associated with slow to stagnant water.

Fish

A high abundance of *Micralestes acutidens* (introduced species) was recorded at the site, benefiting from the slow flow conditions enforced by over abstraction.

Table 16: Fish species expected based on the PESEIS Reach Code (X21J-01013) are listed, and the numbers of fish species present during the surveys indicated.

SPECIES	EXP	DATE 2012	DATE 06/2016
Anguillidae (Freshwater Eels)			
Anguilla mossambica	x		-
Cyprinidae (Barbs, Yellow-fishes and Labeos)			
Enteromius (Barbus) anoplus	x		-
Enteromius (Barbus) crocodilensis	x		24
Labeobarbus marequensis			1
Labeobarbus polylepis	x		2
Characidae (Characins)			
Micralestes acutidens			96
Amphiliidae (Mountain Catfishes)			
Amphilius uranoscopus	x		29
Mochokidae (Squeakers, suckermouth catlets)			
Chiloglanis bifurcus	x		-
Chiloglanis pretoriae	x		103
Cichlidae (Cichlids)			
Pseudocrenilabrus philander	x		3
Tilapia sparrmanii	x		42
Number of species expected	**9**		
Number of species recorded		**NS**	**8**
Number of individuals			**300**
Electro-fishing time (minutes)			**36**
Catch/Unit Effort (CPUE)			**8.33**

X - Expected
NS – Not sampled

Fish velocity depth classes present during the survey were slow deep (sparse), slow shallow (moderate) and fast shallow (abundant) with fast deep habitat absent. The available cover was also very poor with imbedded rocks and pebbles the only available substrate cover in the riffles and a single large rock in a deep pool provided some cover for fish. No aquatic macrophytes provided any cover.

The reference expected indigenous fish species comprise of nine expected species of which six were collected. A further two indigenous fish species (*Labeobarbus marequensis* and *Micralestes acutidens*) were collected which were not expected to occur. The most abundant species recorded were the flow dependent *Chiloglanis pretoriae*

The CPUE calculated was 8.33 (300 individuals; 36 minutes) indicating a high abundance within the species collected.

A Fish Ecostatus rating of 78.0% was calculated for this reach based on all available information, placing this reach in an Ecological Category B/C (slightly to moderately impaired with a high to moderate diversity and abundance of species).

RIVER			TRIBUTARY OF	
Elands			Crocodile	
SITE NUMBER		**QUATERNARY SUB-CATCHMENT**		**REACH**
X2ELAN-GELUK		X21J		X21J-01013
GPS CO-ORDINATES (WGS84 – dd.ddddd):	**Latitude**	**Longitude**	**Elevation (m. a.m.s.l.)**	**Geomorphological Zone**
	S -25.58729	E 30.61307	935	Upper Foothills
AQUATIC ECOREGION	**Level I**			**Level II**
	10. Northern Escarpment Mountains			10.02

Figure A-20. Upstream view of the Geluk site on the Elands River, X2ELAN-GELUK (10 October 2016, G Diedericks).

Figure A-21. Downstream view of the Geluk site on the Elands River, X2ELAN-GELUK (10 October 2016, G Diedericks).

3.5.8 X2ELAN-GELUK – X21J-01013

Site Description

The Geluk site (X3ELAN-GELUK) is located on the Elands River close to the Ngodwana Airstrip, at an elevation of 935 m a.s.l., 3.2 km downstream from the Ryton site and 87.7 km downstream from its source. The catchment upstream from the sampling point is 1,076.2 km^2, with no major tributaries contributing to water quantity.

Stream flow at the Geluk site in 2016 was reduced to a trickle because of over abstraction.

The stream falls within the upper foothills geomorphological zone, dominated by alluvial bedrock, cobble-bed, riffles, runs, glides, and pools.

The exotic invasive *Arundo donax* dominate large portions of the immediate riparian zone, with grasses, herbaceous plants, shrubs, and trees, dominating the rest. The stream canopy can be described as partially open. Commercial forestry, citrus orchids, and small communities are the main upstream land-uses.

Aquatic Macro-invertebrates

Based on SASS sampling on record, the Geluk site was sampled for the first time in 2016. Several of the taxa expected to occur were absent. Of the taxa absent, those regarded as sensitive based on SASS5 included the families Heptageniidae, Tricorythidae, Chlorocyphidae, Naucoridae, and Philopotamidae

Based on MIRAI, stream conditions were categorised as a category D (moderately modified), with taxa with a preference for slow to stagnant water and marginal vegetation dominant, despite the abundant presence of riffles (see site photos). Poor conditions are attributed to the extremity of low flow conditions encountered during the sampling period.

Fish

The site (X2ELAN-GELUK) was one of eight sites sampled for the reach X21J-01013 with all fish velocity depth classes present and the fast shallow habitat in abundance. The fish cover present was overhanging vegetation only at the slow deep habitat, no undercut banks and aquatic macrophytes only present at the slow deep habitat. A few large boulders with rocks and cobbles provided good substrate cover for fish.

In this reach, nine indigenous fish species were expected to occur according to the reference conditions. During the 2016 survey eight fish species were collected, four more than the 2012 survey. One indigenous species, *Micralestes acutidens*, not expected to occur was found at this site for the first time and in large numbers. During the present survey (2016) it was *Chiloglanis pretoriae,* a rheophylics, which was the most abundant species collected, but the presence of the limnophylic cichlids also increased in numbers with *Pseudocrenilabrus philander* collected for the first time at this site. The CPUE for the present survey (13.02) was very much higher than recorded for the 2012 survey (0.53) which can be related to the very low flow conditions experienced during the latest survey which made the habitat easier to access.

A Fish Ecostatus rating of 79.7% was calculated for this site based on all available information, placing this site in an Ecological Category B/C (slightly to moderately impaired with a high to moderate diversity and abundance of species).

Table 17: Fish species expected based on the PESEIS Reach Code (X21J-01013) are listed, and the numbers of fish species present during the surveys indicated.

SPECIES	EXP	DATE	
		2012	10/2016
Anguillidae (Freshwater Eels)			
Anguilla mossambica	x	-	1
Cyprinidae (Barbs, Yellow-fishes and Labeos)			
Enteromius (Barbus) anoplus	x	-	-
Enteromius (Barbus) crocodilensis	x	7	44
Labeobarbus polylepis	x	-	7
Characidae (Characins)			
Micralestes acutidens		-	59
Amphiliidae (Mountain Catfishes)			
Amphilius uranoscopus	x	6	27
Mochokidae (Squeakers, suckermouth catlets)			
Chiloglanis bifurcus	x	-	-
Chiloglanis pretoriae	x	3	327
Cichlidae (Cichlids)			
Pseudocrenilabrus philander	x	-	14
Tilapia sparrmanii	x	2	68
Number of species expected	**9**		
Number of species recorded		**4**	**8**
Number of individuals		**18**	**547**
Electro-fishing time (minutes)		**34**	**42**
Catch/Unit Effort (CPUE)		**0.53**	**13.02**

X - Expected

RIVER			TRIBUTARY OF	
Elands			Crocodile	
SITE NUMBER			**QUATERNARY SUB-CATCHMENT**	**REACH**
X2ELAN-GROOT			X21J	X21J-01013
GPS CO-ORDINATES (WGS84 – dd.ddddd):	**Latitude**	**Longitude**	**Elevation (m. a.m.s.l.)**	**Geomorphological Zone**
	S -25.57241	E 30.65061	908	Upper Foothills
AQUATIC ECOREGION	**Level I**			**Level II**
	10. Northern Escarpment Mountains			10.02

Figure A-22. Upstream view of the Grootfontein site on the Elands River, X2ELAN-GROOT (10 October 2016, G Diedericks).

Figure A-23. Downstream view of the Grootfontein site on the Elands River, X2ELAN-GROOT (10 October 2016, G Diedericks).

3.5.9 X2ELAN-GROOT – X21J-01013

Site Description

The Grootfontein site (X3ELAN-GROOT) is located on the Elands River close to Sappi Grootgeluk Office, at an elevation of 908 m a.s.l. The site is located 5.3 km downstream from the Geluk site and 96.2 km downstream from its source. The catchment upstream from the sampling point is 1,108.8 km^2, with no major tributaries contributing to water quantity. Despite this, the volume of water in 2016 at this point in the river was considerably higher than at the Geluk site, where flow was a trickle. Between the Geluk (X2ELAN-GELUK) and Grootgeluk (X2ELAN-GROOT) sites, stream flow increased as a spring (Fraser's Eye) contributes water quantity at an average of 0.259 m^3/s (standard deviation = 0.087).

Stream flow at the Grootgeluk site in 2016 was therefore relatively high in comparison to flow in the rest of the upstream catchment, attributed to the contribution of Fraser's Eye's spring and return flow from Ngodwana Mill's irrigated waste water.

The stream falls within the upper foothills geomorphological zone, dominated by alluvial bedrock, cobble-bed, riffles, runs, glides, and pools.

Reeds, shrubs, and herbaceous plants with grasses dominate large portions of the immediate riparian zone, with commercial Eucalyptus trees (left bank facing downstream) in the riparian zone. The stream canopy can be described as partially open.

Return flow from Ngodwana Pulp and Paper Mill irrigated effluent, the Ngodwana villages, commercial forestry, nursery, and citrus orchids are the main upstream land-uses.

Aquatic Macro-invertebrates

A total of six previous SASS sampling events are listed on the Rivers Database for the Grootgeluk site. These are September 1998, November 1999, October 2001, October 2003, January 2007 and September 2016. This represents five spring surveys and one summer survey. Based on the SASS results, conditions noticeably vary, with ASPT ranging between 6.0 and 7.2.

X2ELAN-GROOT	ELANDS RIVER	DATE					
		Sep-98	Nov-99	Oct-01	Oct-03	Jan-07	Oct-16
Total SASS Score		176	161	209	190	143	211
No. of SASS Families		25	27	30	28	20	32
Average Score Per Taxon (ASPT)		7.0	6.0	7.0	6.8	7.2	6.6
% Sensitive Taxa		44	35	50	39	59	37

River flow volumes increased considerably when compared to those recorded at the upstream site (X2ELAN-GELUK) during the 2016 survey. The increase in volume improves instream habitat conditions and habitat diversity (e.g. different velocities at different depths)(Dewson et al. 2007; Gordon et al. 2008).

The Ephemeroptera family Tricorythidae, was absent from the 2016 sample, having been recorded during all previous sampling events (from 1998 to 2007). The most noticeable difference between the different surveys is the sudden appearance (recorded Sep 2016) of the exotic invasive gastropod from the family Thiaridae, *Tarebia granifera* (Quilted melania). The species was first recorded downstream at the Roodewal site (X2ELAN-ROODE) during a March 2005 survey (Ferreira et al. 2008). It is highly likely that the species was accidentally introduced, either with the introduction of fishes into Ngodwana Dam and/or through waterfowl. Rocha-Miranda & Martins-Silva (2006) indicated that *Melanoides tuberculatis* from the Gastropod family Thiaridae, was most likely introduced from aquarium releases. Based on increases in abundance since first recorded in 2005, the species successfully established over time as it encountered favourable environmental conditions downstream from the return flow of Ngodwana Mill's irrigated effluent.

Based on MIRAI, stream conditions in 2016 were categorised as a category C (moderately modified). The taxa composition and preferences in the application of the model suggests an improvement in flow, habitat, and water quality, especially when compared to those recorded at the upstream site, X2ELAN-RAYTO.

Fish

The only fish velocity depth classes present during the survey were slow shallow moderately present and fast shallow very abundant. Both slow deep and the fast deep habitat were absent. The available cover wasrestricted to rocks and pebbles as substrate cover in the riffles with some aquatic macrophytes with associated root wads providing some cover for fish.

The reference expected indigenous fish species comprise of nine expected species of which six were collected. The indigenous *Micralestes acutidens* were also collected which was not expected to occur. Seven individuals of the critically endangered *Chiloglanis bifurcus* were also collected at a CPUE of 0.2 individuals per minute, the highest since 2012. The most abundant species recorded was the flow dependent *Chiloglanis pretoriae.*

The CPUE calculated was 2.89 (101 individuals; 35 minutes).

A Fish Ecostatus rating of 79.8% was calculated for this reach based on all available information, placing this reach in an Ecological Category C (moderately impaired with low diversity and abundance of species).

Table 18: Fish species expected based on the PESEIS Reach Code (X21J-01013) are listed, and the numbers of fish species present during the surveys indicated.

SPECIES	EXP	DATE	
		2012	10/2016
Anguillidae (Freshwater Eels)			
Anguilla mossambica	x		-
Cyprinidae (Barbs, Yellow-fishes and Labeos)			
Enteromius (Barbus) anoplus	x		-
Enteromius (Barbus) crocodilensis	x		43
Labeobarbus polylepis	x		-
Characidae (Characins)			
Micralestes acutidens			3
Amphiliidae (Mountain Catfishes)			
Amphilius uranoscopus	x		9
Mochokidae (Squeakers, suckermouth catlets)			
Chiloglanis bifurcus	x		7
Chiloglanis pretoriae	x		29
Cichlidae (Cichlids)			
Pseudocrenilabrus philander	x		2
Tilapia sparrmanii	x		8
Number of species expected	**9**		
Number of species recorded		**NS**	**7**
Number of individuals			**101**
Electro-fishing time (minutes)			**35**
Catch/Unit Effort (CPUE)			**2.89**

X - Expected
NS – Not sampled

Impacts

The main impact at this site is the change in chemical water quality linked to return flow from Ngodwana Mill's irrigated effluent.

On the left stream bank, large portions of commercial Eucalyptus compartments are established in the riparian zone and riparian buffer (see site photos).

RIVER			TRIBUTARY OF	
Elands			Crocodile	
SITE NUMBER		**QUATERNARY SUB-CATCHMENT**		**REACH**
X2ELAN-ROODE		X21K		X21K-01035
GPS CO-ORDINATES (WGS84 – dd.ddddd):	**Latitude**	**Longitude**	**Elevation (m. a.m.s.l.)**	**Geomorphological Zone**
	S -25.56873	E 30.66285	892	Upper Foothills
AQUATIC ECOREGION	**Level I**			**Level II**
	10. Northern Escarpment Mountains			10.02

Figure A-24. Upstream view of the Roodewal site on the Elands River, X2ELAN-ROODE (28 September 2016, G Diedericks).

Figure A-25. Downstream view of the Roodewal site on the Elands River, X2ELAN-ROODE (28 September 2016, G Diedericks).

3.5.10 X2ELAN-ROODE – X21K-01035

Site Description

The Roodewal site (X3ELAN-ROODE) is located on the Elands River downstream from the Bambi Bridge and Ngodwana mill and the Ngodwana River. The site is also an Environmental Water Requirements site (EWR2), used for the determination of catchment water resource classes and associated resource quality objectives for resource unit 2.

The site is located at an elevation of 982 m a.s.l., 1.6 km downstream from the Grootgeluk site and 97.8 km downstream from its source. The catchment upstream from the sampling point is 1,355.3 km^2, with the Ngodwana River the major tributary contributing to water quantity. The Ngodwana River was however, mostly stagnant when fieldwork was carried out in 2016. Despite this, the volume of water in 2016 at the Roodewal site was considerably higher than at the upstream Geluk and Grootgeluk sites. Stream flow at the Roodewal site during the 2016 sampling event was therefore relatively high, attributed to return flow from Ngodwana Mill's irrigated waste water through four known spring locations, Eye X, Eye Y, Northern Eye, and Allen's Eye. No flow data for Allen's Eye was available, but contributions from the remaining springs can be summarised as follows:

Spring	Average (m^3/s)	Standard Deviation (DV)
Eye X	0.104	0.045
Eye Y	0.014	0.006
Northern Eye	0.080	0.011

The stream falls within the upper foothills geomorphological zone, dominated by alluvial bedrock, cobble-bed, riffles, runs, glides, and pools. The cobble-bed was covered in a green-like algae (not filamentous), with prolific filamentous green algae growth in the slow flowing portions of the river.

Reeds, shrubs, and herbaceous plants with grasses dominate large portions of the immediate riparian zone. Commercial pine trees (right bank facing downstream) are located within the riparian zone. The stream canopy can be described as open.

The Ngodwana Pulp and Paper Mill, the Ngodwana villages, commercial forestry, and citrus orchids are the main upstream land-uses.

Aquatic Macro-invertebrates

A total of eight previous SASS sampling events are listed on the Rivers Database for the Roodewal site. These are October 1996, August 2000, March and June 2005, September 2012 and 2013, April 2014 and September 2016. This represents two autumn surveys, two winter, and four spring surveys. Based on the SASS results, conditions noticeably vary, with ASPT ranging between 6.0 and 7.2. The highest differences are in the percentage sensitive taxa, which were the lowest during the March and June 2005, and September 2016 surveys.

DATE	SASS5 Total Score	No. SASS Families/Taxa	ASPT	% Sensitive Taxa
Oct-96	172	24	7.2	68
Aug-00	233	33	7.1	39
Mar-05	122	18	6.8	10
Jun-05	211	32	6.6	27
Sep-12	193	29	6.7	47
Sep-13	160	25	6.4	43
Apr-14	164	23	7.1	81
Sep-16	180	30	6.0	28

The Ephemeroptera family Tricorythidae, was absent in the last three samples (September 2013, April 2014, and September 2016), having been recorded during previous sampling events (from 1996 to 2012). The exotic invasive Gastropod from the family Thiaridae, *Tarebia granifera* (Quilted melania) was recoded at a D-abundanceat this site in March 2005.

Based on MIRAI, stream conditions in 2016 were categorised as a category C (moderately modified). The taxa composition and preferences in the application of the model suggests aslight improvement in flow-habitat in 2016 when compared to those recorded at the upstream site, X2ELAN-GROOT, but deterioration in terms of water quality preferences. Most of the substrate was covered in algae, and the abundances of taxa rated as sensitive was low.

Fish

The velocity depth classes that were present at this site were limited to slow shallow and fast shallow habitat with fast shallow habitat in abundance. The most prominent cover for fish was the substrate in the form of rocks and cobbles with some overhanging vegetation and undercut banks present. Five of the nine expected indigenous fish species were collected during the recent survey in low abundances with the small barb, *Enteromius crocodilensis,* being the most abundant species.

Amphilius uranoscopus was not recorded at this site since 2012 and the absence of this flow dependent sensitive fish species, found at all of the other sites sampled during the recent survey, may be indicative of poor water quality. The flow dependent *Chiloglanis bifurcus,* an endemic fish species of the Elands River and upper Crocodile River, is an endangered fish species which has recently been reassessed to critically endangered, was recorded for this site although in very low numbers.

Table 19: Fish species expected based on the PESEIS Reach Code (X21K-01035) are listed, and the numbers of fish species present during the surveys indicated.

SPECIES	EXP	DATE			
		2012	2013	2014	09/2016
Anguillidae (Freshwater Eels)					
Anguilla mossambica	x	-	-	-	-
Cyprinidae (Barbs, Yellow-fishes and Labeos)					
Enteromius (Barbus) anoplus	x	-	-	-	-
Enteromius (Barbus) crocodilensis	x	8	120	7	37
Labeobarbus polylepis	x	-	-	-	-
Characidae (Characins)					
Micralestes acutidens		-	-	-	-
Amphiliidae (Mountain Catfishes)					
Amphilius uranoscopus	x	3	-	-	-
Mochokidae (Squeakers, suckermouth catlets)					
Chiloglanis bifurcus	x	2	-	-	3
Chiloglanis pretoriae	x	9	7	10	19
Cichlidae (Cichlids)					
Pseudocrenilabrus philander	x	-	3	-	5
Tilapia sparrmanii	x	-	18	8	16
Number of species expected	**9**				
Number of species recorded		**4**	**4**	**3**	**5**
Number of individuals		**22**	**148**	**25**	**80**
Electro-fishing time (minutes)		**40**	**40**	**35**	**42**
Catch/Unit Effort (CPUE)		**0.55**	**3.70**	**0.71**	**1.90**

X - Expected
NS – Not sampled

The relatively low CPUE recorded since 2012 except for 2013 when high numbers of a single species influenced it, indicate the possibility of negative impacts close to and/or at the site.

A Fish Ecostatus rating of 72.8% was calculated for this site based on all available information, placing this site in an Ecological Category C (moderately modified indicating a loss and change of natural habitat).

Impacts

The main impact at this site is the change in chemical water quality linked to return flow from Ngodwana Mill's irrigated effluent.

On the right stream bank, large portions of commercial Pinus-compartments are established in the riparian buffer (see site photos), while the riparian zone is infested with exotic invasive plants.

RIVER			TRIBUTARY OF	
Elands			Crocodile	
SITE NUMBER			QUATERNARY SUB-CATCHMENT	REACH
X2ELAN-GOEDG			X21K	X21K-01035
GPS CO-ORDINATES (WGS84 – dd.ddddd):	Latitude	Longitude	Elevation (m. a.m.s.l.)	Geomorphological Zone
	S -25.52798	E 30.69784	852	Upper Foothills
AQUATIC ECOREGION	Level I			Level II
	10. Northern Escarpment Mountains			10.02

Figure A-26. Upstream view of the Goedgeluk site on the Elands River, X2ELAN-GOEDG (29 September 2016, G Diedericks).

Figure A-27. Downstream view of the Goedgeluk site on the Elands River, X2ELAN-GOEDG (29 September 2016, G Diedericks).

3.5.11 X2ELAN-GOEDG – X21K-01035

Site Description

The Goedgeluk site (X3ELAN-GOEDG) is located on the Elands River, 9.2 km downstream from the Roodewal site and 106 km downstream from its source. The site is located at an elevation of 852 m a.s.l. The catchment upstream from the sampling point is 1,416.6 km^2. The Battery Creek, and Red Acres are the major tributaries contributing to water quantity, both flowing from the eastern side of the Elands.

The stream falls within the upper foothills geomorphological zone, dominated by alluvial cobble-bed, rapids, riffles, runs, glides, and pools. Reeds, shrubs, trees, and herbaceous plants with limited grasses dominate large portions of the immediate riparian zone. Large *Eucalyptus* trees (high water using) with several other weed species dominate the rest of the riparian zone. The stream canopy can be described as partially open.

Eucalyptus compartments, old citrus orchids, small settlement, commercial forestry, and the Pulp and Paper Mill are the main upstream land-uses.

Aquatic Macro-invertebrates

A total of 12 previous SASS sampling events are listed on the Rivers Database for the Goedgeluk site. These are listed below, representing two autumn, one winter, eight spring, and one summer survey. Based on the SASS results, conditions noticeably vary, with ASPT ranging between 6.3 and 8.6. The highest differences are in the percentage sensitive taxa, which were the lowest during the October 2001 and 2003, and September 2016 surveys.

DATE	SASS5 Total Score	No. SASS Families/Taxa	ASPT	% Sensitive Taxa
Oct-96	129	15	8.6	65
Oct-98	184	26	7.1	39
Nov-99	162	24	6.8	40
Oct-01	175	27	6.5	28
Oct-03	181	29	6.2	30
Mar-05	138	20	6.9	66
Jun-05	191	28	6.8	75
Jan-07	164	24	6.8	46
Sep-12	239	36	6.6	39
Sep-13	220	32	6.9	52
Apr-14	159	21	7.6	66
Sep-16	195	31	6.3	33

The Ephemeroptera family Tricorythidae, was present in six samples over 12 sampling events, mostly at low abundance (1 – A). The family was absent in the last three samples (September 2013, April 2014, and September 2016), having been recorded during previous sampling events (from 1996 to 2012). The exotic invasive Gastropod from the family Thiaridae, *Tarebia granifera* (Quilted melania) was recoded at a D-abundance at this site in March 2005.

Based on MIRAI, stream conditions in 2016 were categorised as a category C (moderately modified). The taxa composition and preferences in the application of the model suggests a slight improvement in flow-habitat in 2016 when compared to those recorded at the upstream site, X2ELAN-GROOT, but deterioration in terms of water quality preferences. Most of the substrate is covered in algae, and taxa abundances of taxa rated as sensitive is low.

Ngodwana Mill Sites

These are the Hemlock, Roodewal and Goedgeluk site (X2ELAN-HEMLO, X2ELAN-ROODE and X2ELAN-GOEDG), located upstream, downstream, and further downstream from the mill's influence. The table that follows indicate the averaged percentage of sensitive taxa from the stream community at each of the sites over different seasons.

Site	Autumn	Winter	Spring
X2ELAN-HEMLO	66% n = 3	54% n = 6	42% n = 10
X2ELAN-ROODE	46% n = 2	33% n = 2	48% n = 3
X2ELAN-GOEDG	66% n = 2	75% n = 1	43% n = 7

n = number of site visits.

The percentage of sensitive taxa in the stream community decreased considerably at the Roodewal site (X2ELAN-ROODE) during autumn and winter surveys. In spring, during the lowest flow period, results are similar.
The number of samples per site per season is however very low, suggesting interpretation with caution. What is clear, is that SASS5 biomonitoring has merely highlighted the impact of the mill, but more detailed information and scientific data should be collated to quantify the impacts more objectively e.g. with species level data.
The family Tricorythidae is most noticeably absent at sites influenced by the mills irrigated run-off.

SITES	% FROC Tricorythidae
X2ELAN-HEMLO	90% n = 20
X2ELAN-ROODE	63% n = 8
X2ELAN-GOEDG	50% n = 12

In a study on the effect of effluent from the mill on Tricorythidae under controlled conditions, negative responses to selected concentrations of the effluent high in sulphate salts were recorded (Zokufa et al. 2001). The authors stated that "high electrical conductivity has been found to be a major contributor to" Tricorythidae: *Tricorythus tinctus*"mortality with sulphate having a synergistic and calcium an antanogistic effect".

Fish

Fish velocity depth classes present during the survey were slow deep (sparse), slow shallow (moderate) and fast shallow (abundant) with fast deep habitat absent. Overhanging vegetation and undercut banks with root wads as

well as a large dead tree provided some cover for fish. A well-developed rapid and riffle section with some boulders, rocks and pebbles provided good substrate cover for fish. Aquatic macrophytes also provided some cover.

Table 20: Fish species expected based on the PESEIS Reach Code (X21K-01035) are listed, and the numbers of fish species present during the surveys indicated.

SPECIES	EXP	DATE			
		2012	2013	2014	09/2016
Anguillidae (Freshwater Eels)					
Anguilla mossambica	x	-	-	-	-
Cyprinidae (Barbs, Yellow-fishes and Labeos)					
Enteromius (Barbus) anoplus	x	-	-	-	-
Enteromius (Barbus) crocodilensis	x	60	66	16	39
Labeobarbus polylepis	x	1	14	9	-
Characidae (Characins)					
Micralestes acutidens		-	-	-	17
Amphiliidae (Mountain Catfishes)					
Amphilius uranoscopus	x	24	3	4	4
Mochokidae (Squeakers, suckermouth catlets)					
Chiloglanis bifurcus	x	1	-	1	4
Chiloglanis pretoriae	x	19	34	14	22
Cichlidae (Cichlids)					
Pseudocrenilabrus philander	x	-	-	6	-
Tilapia sparrmanii	x	2	8	6	7
Number of species expected	**9**				
Number of species recorded		**6**	**5**	**6**	**6**
Number of individuals		**107**	**126**	**50**	**93**
Electro-fishing time (minutes)		**52**	**30**	**30**	**38**
Catch/Unit Effort (CPUE)		**2.06**	**4.20**	**1.67**	**2.45**

X - Expected

Five of the nine expected indigenous fish species were collected together with another indigenous fish species, *Micralestes acutidens*, which was not expected to occur but collected. This is the site where the critically endangered *Chiloglanis bifurcus* is often found but still in low numbers. The most abundant fish species, not only for the recent survey but also since 2012 was the small barb, *Enteromius crocodilensis.*

The CPUE recorded for the present survey (2.45) was very much the same as previous surveys except for 2013 when a CPUE of 4.20 was recorded.

A Fish Ecostatus rating of 80.0% was calculated for this site based on all available information, placing this site in an Ecological Category B/C (slightly to moderately impaired with a high to moderate diversity and abundance of species).

Impacts

The riparian zone is severely infested with high water using invasive species (see site photos), which also replace and outcompete indigenous vegetation (Bromilow 2010; Henderson 2001).

RIVER			TRIBUTARY OF	
Elands			Crocodile	
SITE NUMBER			**QUATERNARY SUB-CATCHMENT**	**REACH**
X2ELAN-EHOEK			X21K	X21K-00997
GPS CO-ORDINATES (WGS84 – dd.ddddd):	**Latitude**	**Longitude**	**Elevation (m. a.m.s.l.)**	**Geomorphological Zone**
	S -25.49434	E 30.70218	828	Upper Foothills
AQUATIC ECOREGION	**Level I**			**Level II**
	10. Northern Escarpment Mountains			10.02

Figure A-28. Upstream view of the Elandshoek site on the Elands River, X2ELAN-EHOEK (10 October 2016, G Diedericks).

Figure A-29. Downstream view of the Elandshoek site on the Elands River, X2ELAN-EHOEK (10 October 2016, G Diedericks).

3.5.12 X2ELAN-EHOEK – X21K-00997

Site Description

The Lindenau site (X3ELAN-EHOEK) is located on the Elands River, 4 km downstream from the Goedgeluk site and 110 km downstream from its source. The site is located at an elevation of 828 m a.s.l. The catchment upstream from the sampling point increased to 1,556.5 km^2. The Lupelule, and Starvation Creek are the major tributaries contributing to water quantity, with the Lupelule flowing from the western side and the Starvation Creek from the eastern side of the Elands.

The stream falls within the upper foothills geomorphological zone, dominated by alluvial cobble-bed, rapids, riffles, runs, glides, and pools. Reeds, shrubs, trees, and herbaceous plants with limited grasses dominate large portions of the immediate riparian zone. A shrub-tree thicket dominates parts of the riparian zone, with open tall grasses dominating the right stream bank (facing downstream). A small community lives in the vicinity, with large quantities of litter such as plastic, paper, batteries, tins and more dumped in the river. The stream canopy can be described as open.

Citrus orchids, rural settlements, commercial forestry, and the Pulp and Paper Mill are the main upstream land-uses.

Aquatic Macro-invertebrates

A total of 11 SASS sampling events at this site are listed on the Rivers Database, starting July 1993. Of these, one sampling event occurred in autumn, five in winter and five in spring. The low number of sampling events per season limits seasonal interpretations.

DATE	SASS5 Total Score	No. SASS Families/Taxa	ASPT	% SEN
Jul-93	139	22	6.3	54
Aug-93	135	23	5.9	36
Oct-93	152	26	5.8	41
Jun-94	105	19	5.5	11
Sep-94	160	24	6.7	47
Jun-95	180	27	6.7	41
Oct-96	200	27	7.4	54
Mar-05	137	19	7.2	31
Jun-05	232	35	6.6	51
Sep-12	230	36	6.4	33
Oct-16	175	30	5.8	37

Several of the taxa frequently recorded (e.g. Perlidae, Leptophlebiidae, and, Tricorythidae) were absent, and with more than 2 species of Hydropsychidae expected, only one species was recorded in 2016 at low abundance (A). The family Tricorythidae was last recorded during the October 1996 survey. A high abundance (C) of Atyidae was recorded in the October 2016 sample, with the earliest records at this site in September 2010. Atyidae are categorised as shredders, filtering-gathering collectors and omnivorous, and a preference for slow flowing to

stagnant waters (Hart et al. 2001). Environmetal conditions in terms of food availability and flow conditions are therefore atributed to the presence and abundance of Athyidae in 2016.

Based on MIRAI, stream conditions were categorised as a category C/D (largely modified), with taxa associated with slow to moderate flows dominant. Flow conditions were not necessarily lower that at the Grootgeluk, Roodewal and Goedgeluk sites, with the riffle-rapid biotopes well represented. The absence of some of the sensitive taxa are therefore attributed to chemical water quality.

Fish

Only one site (X21K-00997) was sampled for this reach and was characterised by a large and deep pool just upstream from the river crossing which was not sampled with shallow pools downstream from the crossing with inter-connective rapids, riffles and runs. All fish velocity depth classes were present at the time of the present survey except for fast deep habitat with slow deep and slow shallow moderately present and fast shallow very abundant. The fish cover present was overhanging vegetation, undercut banks and aquatic macrophytes with boulders, rocks and cobbles providing good substrate cover, especially in the rapids and riffles.

Six of the expected nine indigenous fish species were collected, which is the same as collected during the 2011 survey but with a different species assemblage. Two extra-limital indigenous species were recorded at this site, *Enteromius paludinosus* during the 2012 survey and *Micralestes acutidens* for the present survey.

Table 21: Fish species expected based on the PESEIS Reach Code (X21K-00997) are listed, and the numbers of fish species present during the surveys indicated.

SPECIES	EXP	DATE	
		2012	10/2016
Anguillidae (Freshwater Eels)			
Anguilla mossambica	x	-	-
Cyprinidae (Barbs, Yellow-fishes and Labeos)			
Enteromius (Barbus) anoplus	x	-	-
Enteromius (Barbus) crocodilensis	x	7	33
Enteromius (Barbus) paludinosus		17	-
Labeobarbus polylepis	x	3	-
Micralestes acutidens		-	14
Amphiliidae (Mountain Catfishes)			
Amphilius uranoscopus	x	3	5
Mochokidae (Squeakers, suckermouth catlets)			
Chiloglanis bifurcus	x	-	2
Chiloglanis pretoriae	x	13	49
Cichlidae (Cichlids)			
Pseudocrenilabrus philander	x	4	7
Tilapia sparrmanii	x	3	25
Number of species expected	**9**		
Number of species recorded		**7**	**7**
Number of individuals		**50**	**135**
Electro-fishing time (minutes)		**43**	**41**
Catch/Unit Effort (CPUE)		**1.16**	**3.29**

X - Expected

The most abundant expected fish species recorded was the rheophylics *Chiloglanis pretoriae* for both the 2012 and 2016 surveys.

A greater number of fish were collected during the present survey and the CPUE for the present survey (3.29) was higher than the effort for the 2011 survey (1.16). The higher number of fish collected during the present survey can be attributed to low flow conditions and easy accessibility of the habitat.

A Fish Ecostatus rating of 79.1% was calculated for this reach based on all available information, placing this reach in an Ecological Category B/C (slightly to moderately impaired with a high to moderate diversity and abundance of species).

RIVER			TRIBUTARY OF	
Houtboschloop			Ngodwana	
SITE NUMBER			QUATERNARY SUB-CATCHMENT	REACH
X2HOUT-UITZI			X21H	Not allocated
GPS CO-ORDINATES (WGS84 – dd.ddddd):	Latitude	Longitude	Elevation (m. a.m.s.l.)	Geomorphological Zone
	S -25.67886	E 30.65769	1119	Upper Foothills
AQUATIC ECOREGION	Level I			Level II
	10. Northern Escarpment Mountains			10.02

Figure A-30. Upstream view of the Uitzicht site on the Houtboschloop, a tributary of the Ngodwana River, X2HOUT-UITZI (27 September 2016, G Diedericks).

Figure A-31. Downstream view of the Uitzicht site on the Houtboschloop, a tributary of the Ngodwana River, X2HOUT-UITZI (27 September 2016, G Diedericks).

3.6 TRIBUTARIES OF THE ELANDS RIVER CATCHMENT

3.6.1 X2HOUT-UITZ– NOT ON REACH (X21H)

Site Description

The Uitzight site (X2HOUT-UITZI) is located on the Houtboschloop, a tributary of the Ngodwana River, merging with the Ngodwana River a few kilometres upstream from Ngodwana Dam. A large portion of the upper catchment drains commercial forestry land, with the lowest portion mostly natural vegetation stocked with cattle. The sampling point is located 13.5 km downstream from its source, within the cattle ranch. The source is at an elevation of approximately 1,885 m a.s.l., while the site is at 1,119 m a.s.l. The catchment upstream from the sampling point was measured as 51.4 km^2. The Houtboschloop firstly flows in a south-easterly direction and then a north-easterly direction towards the Ngodwana River.

The site falls within the upper foothills geomorphological zone, dominated by alluvial cobble-bed, rapids, riffles, runs, glides, and pools. Trees, shrubs, and herbaceous plants dominate the marginal zone, with grassland and scattered trees and shrubs the surrounding landscape. Stream bank scouring and high silt deposition provides evidence of increased peak flows linked to high road network densities in upstream commercial forestry land (Diedericks 2011; Eastaugh et al. 2008; Fiener & Auerswald 2003; Furniss et al. 1998; Harris et al. 2008; Haskins & Mayhood 1997; Meghan & Kidd 1972; Wemple 1996; Wemple et al. 2001).

There is evidence of cattle trampling of stream banks, which will be more problematic should grazing pressure increase (Armour et al. 2002; Davies 1982; Fleishner 1994; Gumbert et al. 2009; Kauffman 2002; Kauffman & Krueger 1984).

Aquatic Macro-invertebrates

A total of seven SASS sampling events at this site are listed on the Rivers Database, starting October 1998. Of these, one sampling event occurred in autumn, one in winter and five in spring. The low number of sampling events per season limits meaningful seasonal interpretations.

Most of the taxa frequently recorded was present, with sensitive taxa prominent. Pool areas are larger as a result of the low flow, associated with increased deposition (Dewson et al. 2007; Gordon et al. 2008). Cummins et al. (2008) described that "the key features of habitat organisation appear to be physical-chemical differences among erosional, depositional, and semi-aquatic conditions". As depositional zones increase during low flow conditions, so will the aquatic community composition respond in terms of the available habitat and environmental conditions. Based on MIRAI, stream conditions were categorised as a category B/C (slightly to moderately modified), with taxa associated with fast to moderate flows still dominant. Some of the sensitive taxa are present at lower abundances, which is considered natural since flow conditions provided a habitat template with more depositional zones and less deep-fast flowing riffles-rapids.

Fish

The site was characterised by a narrow shallow stream and the only fish velocity depth classes present were both slow and fast shallow habitat with fast shallow very abundant. Lots of marginal grass and other aquatic plants provided cover for fish and the marginal trees formed a canopy in some areas. The substrate was mostly sand and mud with some rocks, cobbles and pebbles as substrate cover.

During the survey five indigenous species of fish of an expected nine species were collected as well as a single female rainbow trout (*Oncorhynchus mykiss*) filled with eggs. This exotic alien and invasive species is a predatory species which will have a negative impact on the indigenous fish species present.

Table 22: Fish species expected based on the PESEIS Reach Code (X21H-Not on Reach) are listed, and the numbers of fish species present during the surveys indicated.

SPECIES	EXP	DATE 2012	DATE 09/2016
Anguillidae (Freshwater Eels)			
Anguilla mossambica	x		-
Cyprinidae (Barbs, Yellow-fishes and Labeos)			
Enteromius (Barbus) anoplus	x		31
Enteromius (Barbus) crocodilensis	x		79
Labeobarbus polylepis	x		5
Amphiliidae (Mountain Catfishes)			
Amphilius uranoscopus	x		29
Mochokidae (Squeakers, suckermouth catlets)			
Chiloglanis bifurcus	x		-
Chiloglanis pretoriae	x		60
Salmonidae (Trouts)			
Oncorhynchus mykiss			1
Cichlidae (Cichlids)			
Pseudocrenilabrus philander	x		-
Tilapia sparrmanii	x		-
Number of species expected	**9**		
Number of species recorded		**NS**	**5 + 1**
Number of individuals			**205**
Electro-fishing time (minutes)			**50**
Catch/Unit Effort (CPUE)			**4.10**

X - Expected
NS – Not sampled
Exotic in red

RIVER			TRIBUTARY OF	
Ngodwana			Elands	
SITE NUMBER			**QUATERNARY SUB-CATCHMENT**	**REACH**
X2NGOD-NOOIT			X21H	X21H-01060
GPS CO-ORDINATES (WGS84 – dd.ddddd):	**Latitude**	**Longitude**	**Elevation (m. a.m.s.l.)**	**Geomorphological Zone**
	S -25.66244	E 30.67263	1064	Upper Foothills
AQUATIC ECOREGION	**Level I**			**Level II**
	10. Northern Escarpment Mountains			10.02

Figure A-32. Upstream view of the Nooitgedacht site on the Ngodwana River, X2NGOW-NOOIT (27 September 2016, G Diedericks).

Figure A-33. Downstream view of the Nooitgedacht site on the Ngodwana River, X2NGOW-NOOIT (27 September 2016, G Diedericks).

3.6.2 X2NGOW-NOOIT– X21H-01060

Site Description

The Nooitgedacht site (X2NGOD-NOOIT) on the Ngodwana River, is located approximately 8.5 km upstream from the Ngodwana Dam, and 12 km downstream from the river's source. The upper portion of the catchment drains commercial forestry land, with the lower portions flowing mostly through natural vegetation stocked with cattle. The source is at an elevation of approximately 1,650 m m.a.s.l., while the site is at 1,064 m m.a.s.l. The catchment upstream from the sampling point was measured as 127.3 km^2. The Ngodwana River firstly flows in an easterly direction before flowing in a northerly direction past Ngodwana Pulp and Paper Mill towards the Elands River.

The site falls within the upper foothills geomorphological zone, dominated by alluvial cobble-bed, rapids, riffles, runs, glides, and pools. Trees, shrubs, herbaceous plants, and grasses dominate the marginal zone, with commercial forestry and grassland with scattered trees and shrubs in the surrounding landscape. Stream bank scouring and high sand deposition suggests that one of the upstream dams could have collapsed a few years ago. The property could not be accessed to verify this.

Aquatic Macro-invertebrates

A total of seven SASS sampling events at this site are listed on the Rivers Database, starting from October 1998. Of these, one sampling event occurred in autumn, one in winter and five in spring. The low number of sampling events per season limits meaningful seasonal interpretations. Most of the taxa expected were present, with sensitive taxa dominant. Based on MIRAI, stream conditions were categorised as a category B/C (slightly to moderately modified), with taxa associated with cobbles and fast to moderate flows dominant.

Fish

Most of the fish velocity depth classes were present with slow deep (sparse), slow shallow (abundant) and fast shallow (abundant). No fast deep habitat was present. Overhanging vegetation as well as undercut banks were sparse and most of the fish cover was provided by rocks, cobbles and pebbles as substrate cover.

During the survey six indigenous species of fish of an expected nine species were collected as well as a single exotic alien and invasive rainbow trout (*Oncorhynchus mykiss*). The small barb, *Enteromius crocodilensis*, was the most abundant fish species collected (489) but the rheophylics *Chiloglanis pretoriae* was also collected in abundance (410). None of the cichlids species expected to occur were found. The CPUE calculated is a very high 11.86 (1044 individuals; 88 minutes).

Table 23: Fish species expected based on the PESEIS Reach Code (X21H-01060) are listed, and the numbers of fish species present during the surveys indicated.

SPECIES	EXP	DATE 2012	DATE 06/2016
Anguillidae (Freshwater Eels)			
Anguilla mossambica	x		-
Cyprinidae (Barbs, Yellow-fishes and Labeos)			
Enteromius (Barbus) anoplus	x		27
Enteromius (Barbus) crocodilensis	x		489
Labeobarbus polylepis	x		11
Amphiliidae (Mountain Catfishes)			
Amphilius uranoscopus	x		103
Mochokidae (Squeakers, suckermouth catlets)			
Chiloglanis bifurcus	x		3
Chiloglanis pretoriae	x		410
Salmonidae (Trouts)			
Oncorhynchus mykiss			1
Cichlidae (Cichlids)			
Pseudocrenilabrus philander	x		-
Tilapia sparrmanii	x		-
Number of species expected	**9**		
Number of species recorded		**NS**	**6 + 1**
Number of individuals			**1044**
Electro-fishing time (minutes)			**88**
Catch/Unit Effort (CPUE)			**11.86**

X - Expected

NS – Not sampled

Exotic in red

A Fish Ecostatus rating of 87.2% was calculated for this reach based on all available information, placing this reach in an Ecological Category B (largely natural with few modifications).

4. DISCUSSION

4.1 FLOW

Stream flow in the Elands River during the Sep-Oct 2016 low flow survey varied considerably at each site, with unknown quantities of water abstracted at specific points along the river (e.g. dysfunctional sluice gate at Hemlock weir).

Rivers and streams in summer rainfall areas of southern Africa naturally experience high summer flows and low winter flows (Davies & Day 1998). Instream habitat conditions change under different flow regimes, and the severity of changes is related to its location within the catchment (e.g. headwater stream or lowlands river).

Dewson et al. (2007) summarised the consequences of decreased flow on instream habitat and macroinvertebrates as follows:

- Decreased water velocity;
- Decreased water depth;
- Decreased wetted channel width;
- Increased sedimentation;
- Changes in thermal regime and water chemistry;
- Increases or decreases in invertebrate abundances; and
- Decreases in invertebrate community richness linked to habitat diversity decreases.

Gordon et al. (2004) highlighted increases in water temperature, salinity, and plant growth during low flows. Where population movement is limited as a result of low flows, increased predation and competition further regulates stream communities (Dallas & Day 2004; Dallas 2008; Davies *et al*. 1993; Davies & Day 1998; Dewson et al. 2007; Gordon et al. 2008).

Low flows are a normal phenomenon in streams during years of low precipitation, with droughts generally referred to as extended periods of low flow (Davies et al. 1993; Gordon et al. 2008). Aquatic species have adapted to seasonal high and low flow conditions over eons, but extremely low flows with high quantities of polluted water inputs exacerbate the long term impact. The appearance of the Gastropod *Tarebia granifera* and the Cyprinid *Micralestes acutidens* is testament to current pressures experienced in the system, with low flows and polluted water likely providing ideal environmental conditions to establish succesfully. The low number of large dams (only Ngodwana Dam) on the Elands River leads to the false perception that low stream flow in the Elands River is natural.

Unregulated overabstraction (e.g. Hemlock Weir), ongoing land clearing to establish irrigated crops, and the high degree of high water using invasive plant species in riparian zones raises further concerns on the current management and future ecological status of a system previously regarded as being close to natural.

4.2 WATER QUALITY

A plethora of historical chemical data are available, with current chemical water data being generated by the IUCMA, WWTW's, and the Sappi Ngodwana Pulp & Paper Mill. This data needs to be captured and continuously interrogated on a catchment basis to compliment the use and interpretation of biological responses of indicator species over time.

Water quality within the catchment, based on historical and long term data analysed, are clearly deteriorating (Griffin et al. 2014). Actions to rectify this trend in deterioration should therefore focus on ensuring the collection of the adequate data and the interpretation of the data.

4.3. SASS5

The stream community in 2016 were affected by low flow conditions, but also pollutants entering the river downstream from Machadodorp, Waterval Boven, agricultural lands, the Ngodwana Pulp & Paper Mill, and the villages at the edge of the Elands River downstream from the mill. There are noticeable differences in the volume of water in the river at each site, with several diversion channels and water pumps reducing stream flow considerably. Maintenance of flow conditions (in a downstream direction)are as a result of water input from tributaries and water entering the river from Ngodwana Mill's irrigated fields.

The results from the 2016 SASS5 survey suggests that overall conditions in the catchment are deteriorating, but the more detailed monitoring information on the aquatic macroinvertebrates are needed as indicator species to better quantify deterioration or improvements (see section 6. Future Monitoring).

4.4 FISH

The flow dependent *Chiloglanis bifurcus* is an endemic fish species of the Elands River and tributaries as well as upper Crocodile River and some tributaries. This true rheophylics is an endangered fish species which has recently been reassessed to critically endangered. It was recorded on the Elands River mainstem at five of the fifteen sites sampled during the present intensively done survey and in very low numbers. CPUE for the species varied between 0.05 and 0.20 individuals caught per minute.

The flow dependent *Amphilius uranoscopus* is also a very sensitive species and intolerant to water quality changes. This species was found at all the Elands River mainstem sites surveyed (12 sites) between the Waterfall Boven waterfall and Lindenau waterfall except at site X2ELAN-ROODE and the absence of this species cannot be because of flow problems at this site and is rather water quality related.

Introduced species and indigenous fish species occurring outside their natural distribution range will have a serious effect on the system's natural fish assemblage. The sudden occurrence of large numbers of *Micralestes acutidens* (30% of total number of individuals recorded), which was not recorded in any survey between 1968 and 2005 is of

concern. *Kneria* sp. nov. 'South Africa' was also collected in the Elands River mainstem, but this species is not a mainstem river species and will migrate back into tributaries. One individual of *Labeobarbus marequensis* was also recorded during the present survey. Other extra-limital species recorded are *Clarias gariepinus*, *Enteromius paludinosus* and *Oreochromis mossambicus*. The introduction of fish species into river systems, exotic or indigenous, is a great risk to the overall biological diversity, uniqueness, and integrity of our aquatic ecosystems (Cucherousset & Olden 2011).

Based on the fish communities encountered, the results also reflect the considerable changes in flow conditions and water quality.

5. PROBLEMS IDENTIFIED

5.1 OVER ABSTRACTION

Water is abstracted from the river without consideration for low flow conditions. Water diversions in channels (some soil based) from Hemlock appears to have no sluice gates to control offtake quantities. The same quantities of water cannot be abstracted or diverted from rivers during drought conditions. Restrictions will have to be implemented and enforced for the sake of all catchment users directly and further downstream from the Elands River, both in terms of water quantity and quality.

5.2 LAND CLEARING

Large areas of vegetation are cleared along the Elands River, and replaced by more water demanding crops (i.e. irrigation). These extra demands on the water resource and the implications for downstream water quantity requirements (Mbombela water use) and water quality (drinking water treatment) needs to be considered for the entire catchment. The legality of these new developments should be investigated, and current registered water use should be inspected and verified.

5.3 INVASIVE PLANT SPECIES

The extent of invasive weed species in the entire catchment area is considered severe, with numerous species recordedin high abundance. Negative impacts of alien invader plants include e.g. the replacement of indigenous vegetation, decreased biodiversity, increased fire risk, increased water use, and access problems (dense vegetation) (Bosch & Smith 1989; Bromilow 2010; Calder & Dye 2001; Chamier et al. 2012; Dye & Poulter 1995a; Everson et al. 2007; Gordon 1998; Görgens & Van Wilgen 2004; Groeneveld & Griepentrog 1985; Le Maitre et al. 2000).

5.4 PLANTING DISTANCES

Exotic trees in commercial forestry areas were recorded in riparian zones, which is in contravention of national legislation (National Water Act, National Environmental Management Act, Conservation of Agricultural Resources Act), as well as the forest industry standards and best practice guidelines.

The conservation and maintenance of riparian zones is of critical importance to the functioning of our critically endangered freshwater ecosystems. Poorly managed riparian zones have negative implications on water quantity (Dye & Poulter 1995a; Le Maitre et al. 2000; Scott & Lesch 1997; Scott et al. 1998; Versfeld et al. 1998), water quality (Fiener & Auerswald 2003), biodiversity (Dos Santos et al. 2015; Graça et al. 2002; Harrison et al. 1999; Whiles & Wallace 1997) and economic sustainability (Everson, et al. 2007; Gordon 1998).

5.5 DOMESTIC WASTE

High volumes of domestic waste were generally encountered downstream from villages, towns, urban areas, and rural communities. The worst cases of domestic waste discarded into rivers were recorded downstream from Machadodorp, Waterval Boven, and at Elandshoek located downstream from Ngodwana Pulp & Paper Mill.

5.6 SEWAGE POLLUTION

Although water samples were not analysed for microbial contamination, high algal growth and sewage odours were recorded in the Elands River downstream from the Machadodorp- and Waterval Boven Waste Water Treatment Works (WWTW). The IUCMA (2015) report on water quality of the Elands River indicated high levels of pollution from several of the WWTWs. Results from both SASS and fish sampled in 2016 indicated a deterioration in conditions downstream from these sampling locations.

6. RECOMMENDATIONS

Based on problems encountered during the Sep-Oct 2016 field visit, the following catchment actions are recommended:

Water Quantity:

- Compliance monitoring of water users in the catchment focusing on water use licences, whether they exist and whether the terms of these licences are met, and;
- Detailed monthly flow monitoring at specific points along the Elands River is required, aiming to ensure environmental flow requirements are met throughout the main channel.

Water Quality:

- Collate all catchment chemical and microbial water quality data, and continuously interpret and report on the status of the river based on the chemical water quality, and;
- Improved management of WWTWs through training and ensuring the budgets allocated and spent to support day to day operational activities within WWTWs are met.

Land clearing:

- Audit the catchment and ensure all legal procedures (e.g. Environmental Impact Assessments) are followed in terms of bush clearing, water use, changing land use, and more.

Invasive Plants:

- The riparian zones overall are severely infested with invasive exotic plants that are recognised as high water users and a threat to biodiversity. Weed control and regular follow-ups is necessary,
- Category 1 declared alien invader plants are illegal, and Category 2 and 3 plants are illegal within 30 meters of the 1:50 year flood line of natural water bodies (CARA[9], No. 43 of 1983; NEMBA[10], No. 10 of 2004). Compliance to these regulations by all land-users should be enforced, and;
- Reactivate the Elands River Conservancy to plan and co-ordinate a catchment-based weed control effort. Land-owners should receive tax benefits for applying best management practices with managing riparian zones (see section 37C of the Income Tax Act[11]), and be held accountable for allowing the degradation of riparian zones.

Planting distances:

- Catchment audit of crops (i.e. commercial forestry and agricultural crops) planting distances from riparian zones. Several infringements into the riparian zone were noted during the 2016 site visits, and;
- Land users infringing on riparian zones and wetlands should be issued with directives to mitigate and correct these infringements.

Domestic waste:

- A national effort in educating and improving people's knowledge of river ecosystems and their functioning is crucial, and the initiative should be driven by the Department of Water and Environmental Affairs and supported by industry, municipalities, communities, and other catchment land-users.

7. FUTURE MONITORING

Specific biological indicators need to be identified and monitored frequently to ensure that the changes in water quantity and quality, and the responses of the aquatic biota is adequately measured. The report on the trends in historical water chemistry data clearly highlighted the deterioration of the Elands River(Griffin et al. 2014).

Biomonitoring tools such as SASS, are designed as rapid assessment methods, meant to cost-effectively flag problems. If there are signs of deterioration based on SASS results, more detailed monitoring is required to identify and resolve-address causes. In the case of the Elands River, regular long term monitoring of flow, water chemistry and aquatic biota is required. With aquatic biomonitoring, the aquatic macroinvertebrate and fish species which clearly indicate responses to changes in water quantity and quality should be used in regular long term monitoring.

[9]Conservation of Agricultural Resources Act 1983, Act No. 43 of 1983
[10]National Environmental Management: Biodiversity Act, Act No. 10 of 2004.
[11]The act provides an incentive for land-users and farmers to engage in environmental conservation and maintenance.

7.1 WATER QUANTITY

Detailed monthly flow monitoring at specific points along the Elands River is required, aiming to ensure environmental flow requirements are met throughout the main channel. The application of a Flow Health Index (Gippel et al. 2012) could provide detailed information on annual high and low flows, highest and lowest monthly flows, the persistence of high and low flows, seasonal flow shifts and flood flow intervals. Theecological significance of these indicators are summarised from Gippel et al. (2012) in the table that follows.

<table>
<tr><th>INDICATORS</th><th colspan="2">RATIONALE</th></tr>
<tr><td>High and Low Flows (HF & LF)</td><td colspan="2">A total seasonal volume will reflect the prevailing hydrological conditions (specifically, highlighting particularly dry years) and indicate any major reductions in total flow volume (and hence gross habitat area availability) due to flow regulation. Significant regulation impacts would tend to be characterised by a sustained reduction in HF, perhaps also with a sustained reduction in LF</td></tr>
<tr><td>Highest Monthly Flow (HM)</td><td>The HM sub-indicator relates to the magnitude of flood flows which are critical for inundating wetlands, cuing fish spawning behaviour, facilitating fish migration and mobilising sediment for creation of physical habitat.</td><td rowspan="2">HM and LM are not determined for the high flow and low flow seasons respectively, but for the entire year. This is since the occurrence of a month of very low flow can be problematic for the biota at any time of the year, and a significant flood or flow pulse event (associated with the month of highest flow) can be beneficial to the biota at any time of year. The benefit of a flow pulse may be greater in certain months, and in some months a pulse might have a negative impact on the biota. If the highest flow month is a-seasonal, this will be detected by the HF, LF, and SFS sub-indicators.</td></tr>
<tr><td>Lowest Monthly Flow (LM)</td><td>Related to the magnitude of the lowest flow of the year, when minimum flows are required for survivalin the reporting year.</td></tr>
<tr><td>Persistently Higher (PH)</td><td colspan="2">Relates to the situation of flows being artificially regulated at significantly higher than reference magnitude for long periods through the natural low flow period. This can reduce light penetration to the bed, and hence reduce primary production of benthic algae. Higher than normal flows in the low flow period can also stress riparian vegetation by waterlogging root zones, or preventing recruitment in exposed soils. In some places this may hinder recruitment of fish species dependent on slack-waters and warm temperatures associated with low flows. Persistently elevated low flows might also mean that invertebrates are not seasonally stressed, which could be a natural disturbance process that plays a role in maintaining diversity.</td></tr>
<tr><td>Persistently Lower (PL)</td><td colspan="2">Relates to the depression of flows for long periods, either in the low or high flow season. This sub-indicator would usually indicate persistently depressed low flow season flows, which would have implications for gross habitat area availability for fish and macroinvertebrates. This flow condition would potentially allow colonisation of the stream bed by invasive vegetation, or accumulation of fine sediments that settle out during periods of low flow.</td></tr>
<tr><td>Persistently Very Low (PVL)</td><td colspan="2">Relates to the artificialregulation of flows at very low levels for long periods. The consequences of this drying or near-drying of the channel can be critical for all organisms in the stream. Very low flows are often associated with the loss of riffle habitats, crowding of organisms in pools, and degraded water quality, such as temperature extremes and increased risk of hypoxia and high salinity.</td></tr>
<tr><td>Seasonal Flow Shifts (SFS)</td><td colspan="2">Relates to the situation of the seasonal pattern of flows being reversed, or partly reversed, due to storage of flows in reservoirs in the natural high flow season, and release of water for downstream supply in the natural low flow season. The consequences of this can be disruption of the natural timing of flow pulses and baseflows that stimulate the behaviour of aquatic organisms whose life cycle has adapted to a seasonal pattern of flow.</td></tr>
<tr><td>Flood Flow Interval (FFI)</td><td colspan="2">Relates to the occurrence of floods that inundate floodplain wetlands. In some rivers such floods might also play an important role in scouring hardy plants from channels and re-shaping channel morphology. During the interval between floods, wetlands can dry out, riparian vegetation can become stressed, succession processes give rise to changes in the composition of floodplain plant communities, plants that rely on regular floods for seed dispersal and propagation do not regenerate, and channels can become overgrown due to lack of disturbance.</td></tr>
</table>

7.2 WATER QUALITY

There is easily accessible information on water quality along the Elands River, indicating long term changes and linking existing and future data collected to a Water Quality Index model, which should continuously improve as the data sets increase.

7.3 BIOLOGICAL INDICATORS

7.3.1 Aquatic Macroinvertebrates

Several aquatic invertebrate species have been identified in detailed studies as good indicators, noticeably responding to specific impacts, such as flow alteration (Palmer 2000; Palmer 2007; Skoroszewski & de Moor 1999). In the Elands River, Thirion & Todd (2000) suggested the use of the following as indicators.

Family:Species	Indicator/Habitat Preference	Notes
Leptophlebiidae: *Adenophlebia sylvatica*	Hard substrates at slow (<0.2 m/s) flow	Target indicators for site EL1 (upstream of the waterfall)
Baetidae: *Demoreptus natalensis*	Stones in current and bedrock at moderate to fast flows (0.5 – 1.4 m/s)	
Prosopistomatidae: *Prosopistoma* sp.	Stones in current between 0.2 – 1.4 m/s	Target indicators for EL (sites up to Ngodwana confluence)
Baetidae: *Pseudocloeon* sp.	Vegetation out of and in current between 0.2 – 1.4 m/s.	
Heptageniidae: *Afronurus* sp.	Fast flowing unpolluted water	All sites
Psephenidae	Fast flowing unpolluted water	
Perlidae:	Fast flowing unpolluted water	
Planorbidae:	Extended periods of slow – stagnant waters (<0.3 m/s)	
Physidae: *Physa aculata*	Tolerant of high levels of organic pollution, commonly recorded downstream from WWTWs.	

In addition to the Thirion & Todd (2000) indicator invertebrate species, four additional taxa are recommended. These are:

- Tricorythidae: *Tricorythus tinctus;*
- Philopotamidae: *Chimarra* sp.;
- Hydropsychidae: *Hydropsyche longifurca, Macrostemum capense, and Polymorphanisus bipunctatus,*and;
- Thiaridae: *Tarebia granifera*.

Tricorythidae: *Tricorythus tinctus*–indicative of water pollution, since it appears that water quality currently negatively affects the species. The species also responded negatively to the mill effluent in previous studies (Palmer & Scherman 2000;Palmer et al. 2004; Zokufa et al. 2001).

Philopotamidae: *Chimarra* sp. –numbers generally increase with increases in fine suspended particulate organic matter (Gullan & Cranston 2010), but the species is currently either absent or present at very low abundances downstream from where the irrigated effluent re-enters the river.

Hydropsychidae: All three species (*Hydropsyche longifurca, Macrostemum capense,* and *Polymorphanisus bipunctatus*) have been recorded from the Hemlock site in a downstream direction. Their regular absence at sites located downstream from the pulp and paper mill flags them as potential indicators of river condition.

Thiaridae: *Tarebia granifera* – The sudden appearance in 2005 and their rapid increase in numbers downstream from the influence of the mill effluent, suggests the species could bea good indicator. The species is known for its tolerance to high salinities, and should environmental conditions become more "natural", the species should disappear or only be present in very low numbers.

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