environmental affairs

Department:
Environmental Affairs
REPUBLIC OF SOUTH AFRICA

DETAILS OF SPECIALIST AND DECLARATION OF INTEREST

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Application for authorisation in terms of the National Environmental Management Act, 1998 (Act No. 107 of 1998), as amended and the Environmental Impact Assessment Regulations, 2010

PROJECT TITLE

The proposed hydropower station and associated infrastructure at Boegoeberg Dam on the Orange River, near Groblershoop, Northern Cape

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The specialist appointed in terms of the Regulations

I, James MacKenzie, declare that

- I act as the independent specialist in this application
- I will perform the work relating to the application in an objective manner, even if this results in views and findings that are not favourable to the applicant;
- I declare that there are no circumstances that may compromise my objectivity in performing such work;
- I have expertise in conducting the specialist report relevant to this application, including knowledge of the Act, regulations and any guidelines that have relevance to the proposed activity;
- I will comply with the Act, regulations and all other applicable legislation;
- I have no, and will not engage in, conflicting interests in the undertaking of the activity;
- I undertake to disclose to the applicant and the competent authority all material information in my possession that reasonably has or may have the potential of influencing - any decision to be taken with respect to the application by the competent authority; and - the objectivity of any report, plan or document to be prepared by myself for submission to the competent authority;
- all the particulars furnished by me in this form are true and correct; and
- I realise that a false declaration is an offence in terms of Regulation 71 and is punishable in terms of section 24F of the Act.

Signature of the specialist:

MacKenzie Ecological & Development Services

Name of company (if applicable):

15 November 2013

Date:

AQUATIC SPECIALIST INPUT TO THE PROPOSED HYDROPOWER STATION AND ASSOCIATED INFRASTRUCTURE AT BOEGOEBERG DAM ON THE ORANGE RIVER, NEAR GROBLERSHOOP, NORTHERN CAPE

October 2013

DRAFT

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EXECUTIVE SUMMARY

Boegoeberg Hydro Electric Power (Pty) Ltd (Boegoeberg Hydro) intends to construct a hydropower facility with an approximate capacity of 15 Megawatt (MW) on the Orange River approximately 26km south east of Groblershoop in the Northern Cape. The proposed facility would be a run-of-river hydropower scheme using natural flow and drop in elevation of the Orange River, and diverting the flow and passing it through turbines that spin generators. There will be no storage of water off-stream and the power station would thus be subject to seasonal river flows, and would not operate during low flow periods.

The objectives of this aquatic specialist study are to:

- Undertake an initial desktop study of reputable sources to provide background information for the aquatic ecological assessment;
- Collect primary data from the Orange River and side channels on site to provide information regarding riparian and in-stream sensitivity and importance;
- Provide a description of the aquatic ecology of the candidate sites and surrounding wetlands/riparian zones and streams;
- Provide delineation of riparian zones or wetlands;
- Conduct an assessment of the ecological state, importance and sensitivity of aquatic and riparian ecosystems on the site, using standard methods (such as the EcoClassification method);
- Evaluate the the potential direct and indirect impacts of construction, operation and maintenance of the proposed development on aquatic resources, as well as outline mitigation for said impacts.

The assessed area occurs directly downstream of the Boegoeberg Dam wall (Fig. 2.2) and is a mere 5km upstream of EFR site 2, which is the site that was used for the Reserve determination conducted in 2010 (Louw & Koekemoer (eds), 2010). This means that all data and information from the site are relevant to this project. The Boegoeberg Dam wall does not have a fish ladder. Below the wall, there are varied and complex hydraulic habitats ranging from rapids and runs to deeper slow pools. The main channel comprises several mid-channel bars with smaller channels in-between, but the site can be generally described by 3 main sub-channels (labelled 1 through 3 in Fig. 2.2). The left and centre channels (labelled 1 and 2 in Fig. 2.2) are bedrock dominated with fast flowing, rocky habitats, while the right channel (labelled 3 in Fig. 2.2) is characterised by slower deeper flows and mainly alluvial in nature, other than at the dam wall where rapids occur. The proposed hydro scheme development is like to increase water delivery to the right alluvial channel and decrease flow in the bedrock channels. This is likely to scour the right channel. The riparian vegetation in dominated by reeds and woody vegetation (labelled r and w in Fig 2.2 respectively, and where w1 is high density woody vegetation and w2 low density) and is characterised as Lower Gariep Alluvial Vegetation (Mucina & Rutherford, 2006), which is considered to be an endangered unit. Features described above are photographically shown in Table 2.1.

The Present Ecological State (PES) and Ecological Importance and Sensitivity (EIS) are summarised below for various components of the riverine environment, as well as an integrated Ecological Status (Ecostatus) for the reach downstream of the Boegoeberg Dam. The PES is in a stable trend (indicated by 0) and because the EIS is high the Recommended Ecological Category (REC) for the reach is better than the PES. The current Ecostatus for the reach is a category C, which means that the system is moderately modified i.e loss and change of natural habitat and biota have occurred, but the basic ecosystem functions are still predominantly unchanged. A HIGH for EIS is generally defined as quaternaries / delineations (reach in this instance) that are considered to be unique on a national scale due to biodiversity (habitat diversity, species diversity, unique species, rare and endangered species). These rivers (in terms of biota and habitat) may be sensitive to flow modifications but in some cases, may have a substantial capacity for use.

Boegoeberg

EIS: HIGH

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

PES: C

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

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

Potential impacts of the proposed activity have two main components. Those pertaining to the aquatic or instream environment are mainly flow related, while those pertaining to the riparian / wetland environment are mainly non-flow related.

The main impact to the instream environment is the potential loss of spawning habitats characterised by bedrock substrates and fast flowing water which are important to rheophilic fish species such as yellowfish. Other fish such as the Orange River mudfish, and the rock catfish also utilise these habitats for spawning. Maintenance of these habitats requires certain minimum flows as well as the correct frequency and timing of small floods. The diversion of water from Boegoeberg Dam before it spills has the potential to reduce flows that are required for habitat maintenance directly downstream of the dam wall. Mitigation potential of this impact is high and outlined in detail as specific flows required for each month of the year (see Table below). These flows were determined as part of the Reserve determination study conducted in 2010 (Louw & Koekemoer (eds)).

Desktop version:		**2**	**Virgin MAR (MCM)**	**10573.7**
BFI	**0.329**	**Distribution type**	**Vaal**	
MONTH	**LOW FLOWS**		**HIGH FLOWS**	
	Maintenance (m^3/s)	**Drought (m^3/s)**	**Daily average (m^3/s) on top of base flow**	**Duration (days)**
OCTOBER	28.211	0.627		
NOVEMBER	36.708	13.665	150	6
DECEMBER	39.92	19.512	150	6
JANUARY	47.269	21.408	150	6
FEBRUARY	61.393	31.478	350	8
MARCH	60.014	31.051	850	12
APRIL	53.153	11.705		
MAY	39.716	10.906		

Desktop version:		2	Virgin MAR (MCM)		10573.7
BFI	**0.329**	**Distribution type**		**Vaal**	
MONTH	**LOW FLOWS**		**HIGH FLOWS**		
	Maintenance (m^3/s)	**Drought (m^3/s)**	**Daily average (m^3/s) on top of base flow**		**Duration (days)**
JUNE	30.813	11.3			
JULY	24.956	10.919			
AUGUST	23.653	10.171			
SEPTEMBER	24.231	6.115			
TOTAL MCM	1230.5	467.2	566.4		
% OF VIRGIN	11.64	4.42	5.36		
Total IFR	1797				
% of MAR	16.99				

The main impacts to the riparian environment are the removal and disturbance of indigenous riparian vegetation and the promotion of invasion of disturbed sites by alien perennial species such as *Prosopis glandulosa*. The current riparian zone is characterised as Lower Gariep Alluvial Vegetation (Mucina & Rutherford, 2006), which is considered to be an endangered unit. While it is unlikely that removal will be avoidable for the offtake and outflow structures, the routing of the power transmission lines so as to not be within the riparian zone (except where direct crossing is unavoidable) will mitigate this impact significantly. Where direct crossing of riparian zones or drainage channels is required, mitigation would be to not (as far as is possible) place towers within these areas, but to span them. Mitigation for invasion by alien vegetation species would require physical removal on site after construction and for the first few years of operation.

The impact of the proposed hydro power station will only be local, and the river should again attain its current integrity downstream of the tailrace of the plant. It is, however, important to protect rare spawning areas and ensure its functioning in order to ensure the survival of our already scarce and endangered fish species such as the largemouth yellowfish and the rock catfish.

1 INTRODUCTION

1.1 BACKGROUND

Boegoeberg Hydro Electric Power (Pty) Ltd (Boegoeberg Hydro) intends to construct a hydropower facility with an approximate capacity of 15 Megawatt (MW) on the Orange River approximately 26km south east of Groblershoop in the Northern Cape. The proposed facility would be a run-of-river hydropower scheme using natural flow and drop in elevation of the Orange river, and diverting the flow and passing it through turbines that spin generators. There will be no storage of water off-stream and the power station would thus be subject to seasonal river flows, and would not operate during low flow periods.

The proposed hydropower station would consist of the following components:

1. An off-take structure above the existing Boegoeberg weir to facilitate the abstraction of water;
2. Water conveyance infrastructure comprising a combination of either an open canal, a pipeline and/or culverts to convey the water to the head pond;
3. A head pond;
4. Steel (or other suitable pipeline material) penstocks to transfer the water to the power chamber;
5. A power chamber to house the turbines and generation equipment;
6. Outlet channel (tailrace) to return the abstracted water back into the river; downstream of the power chamber;
7. A switchroom and transformer yard;
8. A high voltage (HV) distribution line to evacuate the power to a nearby Fibre Substation; and
9. Access roads to the site.

Energy generated by the proposed hydropower station would be evacuated from the site transformer yard *via* a proposed transmission line of not more than 132 kilovolt (kV) capacity to a nearby Eskom substation. The overhead transmission line would connect the powerhouse to Fibre Substation where it would feed into the national grid. New gravel access roads of 4m in width would be constructed to follow the transmission servitude, where existing roads do not exist for construction and maintenance purposes.

1.2 OBJECTIVES OF THE STUDY

The objectives of this aquatic specialist study are to:

- Undertake an initial desktop study of reputable sources to provide background information for the aquatic ecological assessment;
- Collect primary data from the Orange River and side channels on site to provide information regarding riparian and in-stream sensitivity and importance;
- Undertake the requisite field work and compile a report that considers the following aspects:
  - Broad description of the aquatic ecology of the candidate sites and surrounding wetlands/riparian zones and streams including aquatic assessment and habitat classification;

- o Delineation of riparian zones or wetlands;
- o Assessment of the consequences of the various release options on the ecological state of the river should these be given;
- o Assessment of the ecological state, importance and sensitivity of aquatic ecosystems on the site, together with an assessment of the ecological services provided by these ecosystems, using standard methods (such as the EcoClassification method);
- o General comment on whether ecosystem processes would be affected (including comment on how these would be affected);
- o Evaluate the the potential direct and indirect impacts, including cumulative impacts, of construction, operation and maintenance of the proposed development (including the canal / pipelines, power-house, transmission lines and associated infrastructure) on aquatic resources, in terms of the scale of impact (local, regional, national), magnitude of impact (low, medium or high) and the duration of the impact (construction, up to 10 years after construction (medium term), more than 10 years after construction (long term));
- o Take cognisance of any guidelines which may be relevant including the Department of Environmental Affairs and Development Planning guideline: “Guideline for involving biodiversity specialists in EIA processes” (Brownlie, 2005).

1.3 SPECIALIST DETAILS

Specialist	Affiliation	Relevant expertise
James MacKenzie	M.E.D.S.	Riparian Vegetation: Environmental Flow Requirements (EFR); EcoClassification (VEGRAI); Riparian and wetland delineation; Ecological Importance and Sensitivity
Johan Koekemoer	Koekemoer Aquatic Services	Aquatic Health Specialist. Fish Specialist - Environmental Flow Requirements (EFR); EcoClassification (FRAI); Ecological Importance and Sensitivity

1.4 DATA AVAILABILITY

Data availability for the aquatic assessment is shown in Table 1.1:

Table 1.1 Data availability for the sites at Boegoeberg Dam.

Boegoeberg Dam	
Fish	Site visits and fish sampling during June 2010. Site visit and visual survey during October 2013. Various previous fish surveys in region. Atlas of Southern African Freshwater fishes (Scott *et al*., 2006). SAIAB Data base (2006). Reference Fish Frequency of Occurrence Report (Kleynhans *et al.,* 2007). A Complete Guide to the Freshwater Fishes of Southern Africa: Skelton (1993).
Vegetation, including wetland and riparian	Satellite images (Google earth) of the respective reach and aerial photos (1964, 1974, 1984, 2004, 2010). Hydraulic cross-section (profile) near the site together with surveyed key vegetation points.

Boegoeberg Dam	
vegetation	Hydrology specialist questionnaire near the site. Ecoregion class and associated information. Geomorphic Zone classification and Geomorphological Assessment Index (GAI). IHI segments / impacts. Biomes and vegetation types of South Africa: (Rutherford & Westfall, 1986; van Wyk & van Wyk, 1997; Mucina & Rutherford, 2006). SANBI Plant of Southern Africa online database (based on several herbaria collections). Data collected during field visits (June 2010 and October 2013).

2 STUDY AREA

2.1 STUDY AREA DESCRIPTION

The study area occurs in the Northern Cape near the town of Globlershoop within the D73B quaternary catchment and the Lower Orange DWA water management. The study area lies within the Nama Karoo Level 2 Ecoregion (26.05) described by Kleynhans et al. (2005, 2007), the Namib-Karoo-Kaokoveld Deserts and Shrublands WWF Terrestrial Ecosystems (Olson et al., 2004). Surrounding vegetation is azonal and endangered: Lower Gariep Alluvial Vegetation (Mucina & Rutherford, 2006). Mean annual precipitation is approximately 133mm with peaks in late summer, usually March (Fig 2.1, Mucina & Rutherford, 2006).

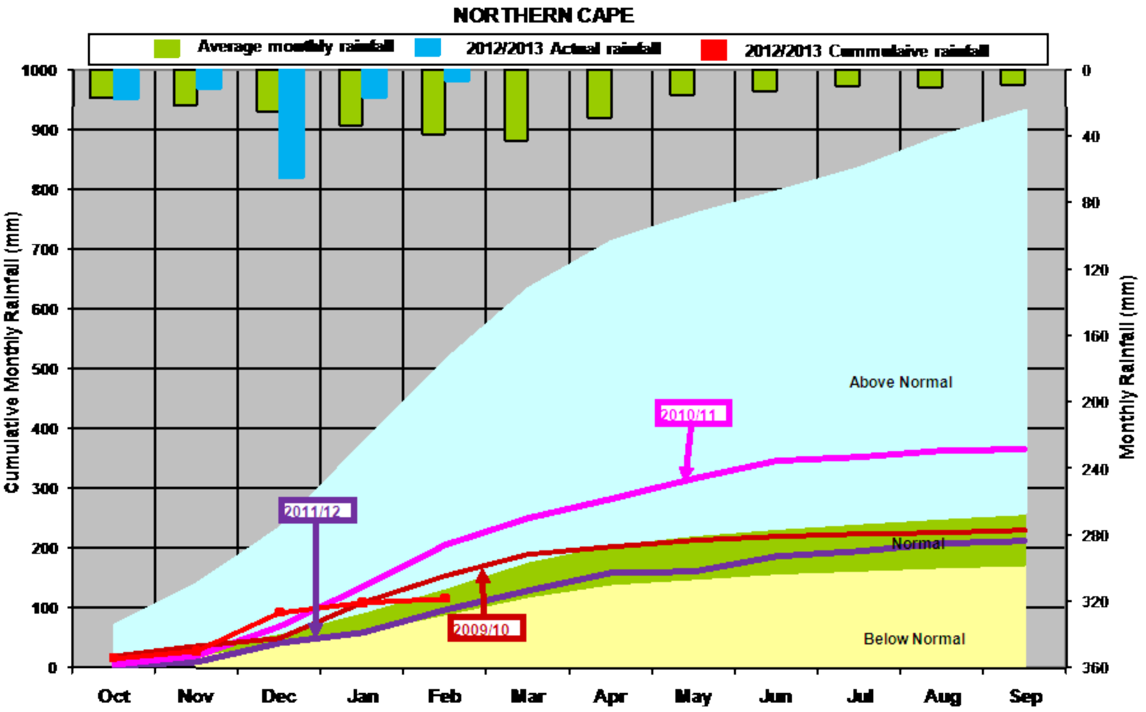

Figure 2.1 Rainfall summary and characteristics of the Northern Cape in general (Department of Water Affairs data)

2.2 SITE DESCRIPTION

The assessed area occurs directly downstream of the Boegoeberg Dam wall (Fig. 2.2) and is a mere 5km upstream of EFR site 2, which is the site that was used for the Reserve determination conducted in 2010 (Louw & Koekemoer (eds), 2010). This means that all data and information from the site are relevant to this project. The Boegoeberg Dam wall does not have a fish ladder. Below the wall, there are varied and complex hydraulic habitats ranging from rapids and runs to deeper slow pools. The main channel comprises several mid-channel bars with smaller channels in-between, but the site can be generally described by 3 main sub-channels (labelled 1 through 3 in Fig. 2.2). The left and centre channel (labelled 1 and 2 in Fig. 2.2) are bedrock dominated with fast flowing, rocky habitats, while the right channel (labelled 3 in Fig. 2.2) is characterised by slower deeper flows and mainly alluvial in nature, other than at the dam wall where rapids occur. Bedrock dominated habitats are indicated in Fig. 2.2 by yellow circular areas. The proposed hydro scheme development is like to increase water delivery to the right alluvial channel and decrease flow in the bedrock channels. This is likely to scour the right channel. The riparian vegetation in dominated by reeds and woody vegetation (labelled r and w in Fig 2.2 respectively, and where w1 is high density woody vegetation and w2 low density) and is characterised as Lower Gariep Alluvial Vegetation (Mucina & Rutherford, 2006), which is considered to be an endangered unit. Features described above are photographically shown in Table 2.1.

Figure 2.2 Aerial view of the site to be impacted by the proposed development, showing 3 channels that comprise the main Orange River downstream of the dam wall, and the proposed alignment of the hydro scheme (dark blue line).

Table 2.1 Photographs taken during October 2013 showing instream and riparian habitats downstream of the Boegoeberg Dam wall

 Channel 1 in Fig 2.2	 Channel 2 in Fig 2.2

 Channel 3 in Fig. 2.2	 Reed banks (r in Fig 2.2)
 Dense woody riparian vegetation (w1 in Fig 2.2)	 Sparce woody vegetation and sandy banks / bars (w2 in Fig. 2.2)
 Rapid and fast deep instream habitats downstream of dam wall	 Slow deep habitats in channel 3 (Fig. 2.2)

2.3 FISH: BACKGROUND FROM 2010 STUDY

Various sub-sites were sampled in the Boegoeberg area (Kotze and Koekemoer (Eds), 2010). The habitat of each sub-site is described and the sampling effort provided in Table 2.2. Different sub-sites were sampled to include habitats and fish representative of the Boegoeberg area.

Table 2.2 Description of fish sub-sites sampled in Boegoeberg area during 2010.

Sub-Site	Description	Sampling effort
Sub-site 1a	Fast deep (FD) and fast shallow (FS) with overhanging vegetation, instream vegetation and substrate (bedrock and boulders), reeds and grass.	60min EW (total for 2 samplers)
Sub-site 1b	FD and FS over bedrock and boulders (white water).	
Sub-site 1c	Slow shallow (SS) (below FS) with rocks and vegetation.	
Sub-site 1d	SS over bedrock.	
Sub-site 1e	FD and slow deep (SD) with overhanging vegetation (reeds), logs over bedrock and boulders.	
Sub-site 2a	SS and slow very shallow (SVS) over rocks (silted) and with instream vegetation as cover.	75min EW (total for 2 samplers)
Sub-site 2b	FS and FD over rocks (bedrock and boulders).	
Sub-site 2c	SS, SD and FD with instream and overhanging vegetation over rocks (bedrock).	
Sub-site 3	FD and FS over rocks.	15 min EW
Sub-site 4	SD, SS in and upstream of weir, with abundant reeds as cover, sand banks and rocky habitats (bedrock, cobble and boulders).	40min EB
Sub-site 5	FS and FD (rapid) over rocks (boulder, cobble and bedrock).	12min EB Angling

EW: Electrofishing by wading. EB: Electrofishing from boat

Table 2.3 indicates the different velocity depth classes sampled at each site and the abundance of cover at each sub-site (Kotze and Koekemoer (Eds), 2010).

Table 2.3 Fish habitat assessment (sampled) at each sub-site (2010).

Velocity-Depth Category	SLOW-DEEP					SLOW-SHALLOW				
SUB-SITE:	**1**	**2**	**3**	**4**	**5**	**1**	**2**	**3**	**4**	**5**
ABUNDANCE:	1	3	0	4	0	2	3	0	1	1
Overhanging vegetation	3	3	0	3	0	3	2	0	1	1
Undercut banks and root wads	2	1	0	2	0	2	1	0	0	0
Substrate	3	3	0	2	0	3	3	0	1	3
Instream vegetation	2	3	0	2	0	2	2	0	1	0
Water Column	3	3	0	5	0	1	1	0	1	1
Velocity-Depth Category	**FAST-DEEP**					**FAST-SHALLOW**				
SUB-SITE:	**1**	**2**	**3**	**4**	**5**	**1**	**2**	**3**	**4**	**5**
ABUNDANCE:	3	2	4	2	4	2	2	2	0	2
Overhanging vegetation	3	2	1	2	1	3	3	1	0	0
Undercut banks and root wads	1	2	1	0	0	1	1	1	0	0
Substrate	3	4	5	2	4	3	4	5	0	4
Instream vegetation	1	2	2	2	0	1	2	2	0	0
Water Column:	3	3	3	3	3	1	1	1	0	1

0 – absent; 1 – rare; 2 – sparse; 3 – common; 4 - abundant; 5 – very abundant

Table 2.4 provides a habitat profile for each of the fish species sampled or observed for the Boegoeberg area, and indicates the general habitat preferences of the fish species in this reach (Kotze and Koekemoer, 2010).

It is important to note for this report that most fish species were sampled in habitat with substrate i.e. rocky habitat or rocky substrate.

Table 2.4 Fish habitat profile where different fish species were observed or sampled at site EFR O2: Boegoeberg, 2010.

Habitat	SLOW-DEEP	SLOW-SHALLOW	FAST-DEEP	FAST-SHALLOW
Overhanging vegetation (reeds and trees)	*Barbus trimaculatus* *Labeo capensis*			
Undercut banks and root wads		Roots: *Tilapia sparrmanii* *Pseudocrenilabrus philander* *Barbus trimaculatus*		
Substrate	*Labeo capensis* (J&A) *Barbus trimaculatus* (J&A) *Clarias gariepinus* (J) *Ctenopharyngodon idella** (J)	*Cyprinus carpio** (J) *Pseudocrenilabrus philander* *Tilapia sparrmanii* (A) (with veg. & rocks) *Barbus paludinosus* (veg. & sand)	*Labeobarbus aeneus* (J&A) *Labeo capensis* (J&A) *Barbus trimaculatus* (A) *Austroglanis sclateri* (A)	*Barbus trimaculatus* (A&J) *Labeo capensis* (J)
Instream vegetation	*Pseudocrenilabrus philander* (J&A) *Tilapia sparrmanii* (J&A) *Barbus paludinosu*s (A), *Gambusia affinis**	Sand & veg.: *Gambusia affinis ** *Tilapia sparrmanii* *Barbus paludinosus*		Sand & veg.: *Tilapia sparrmanii* *Barbus trimaculatus*
Water column	*Labeobarbus aeneus* *Clarias gariepinus* *Barbus trimaculatus* *Labeo capensis*			

*Alien species; J- juvenile; A - adult

General comments:

- Right bank of EFR site downstream of dam has abundant gravel-cobble beds that will be suitable as a yellowfish spawning site.
- Good spawning habitat is present for most of the fish species in the side channels in the area.
- Boegoeberg Dam is a migration barrier to fish, and no functional fish ladders were present or observed during the surveys.

FISH HABITAT:

Flow sensitive habitats for fish (FS and FD) are well represented at the Boegoeberg area/reach. High habitat diversity occurs within various secondary canals in the reach (Kotze and Koekemoer, 2010). Rheophilic fish species are absent in the Orange River system, and large semi-rheophilic species will be the next indicator group for fast flowing habitats. Various large semi-rheophilic species are expected and some were sampled in the reach below Boegoeberg Dam in fast flowing habitats, and this guild will be an important indicator group for fast-flowing habitats. Representatives of the small-rheophilic and limnophilic guilds are also present at the site.

During the October 2013 survey the fish habitat directly below the Boegoeberg Dam was assessed as this is the area that will be affected the most by the proposed development. The reach and habitat suitability further downstream of the dam was also assessed for suitability for fish.

Semi-rheophilic refers to fish species that has a preference or need for fast flowing water, substrate and sometimes submerged cover in the form of vegetation during some stages of their life cycle, usually during spawning season. Some species such as the **yellowfishes, labeos and rock catfish** have adapted and have a higher preference for fast flowing waters with rocky substrate than others, and spend most of their life cycles in this type of habitat. These fishes have adapted to fast flowing habitat with rocky substrate in terms of cover, feeding and spawning.

Very good habitat (i.e. fast flow over substrate) for semi-rheophilic fish species currently exist directly downstream of the dam, especially in the left side of the river channel and towards the middle of the river (Channels 1 and 2 in Figure 2.2). Some smaller rocky rapids also occur in the right side of the river channel (Channel 3 in Figure 2.2). These rocky areas with rapids, riffles and runs are of importance mainly for successful spawning of the fish species as mentioned above.

Rocky substrate with fast flow over rocks, cobble and gravel beds is an especially important habitat type for the larger semi-rheophilic fish species. This renders the area directly below the dam wall as important and sensitive for the site in terms of spawning and breeding of fish. These rapids are expected be affected the most due to the impact of water abstraction for the hydropower plant. It is, therefore, important that the minimum flow requirements over the dam wall are met to facilitate successful fish spawning during the spawning season in the rapids and cobble beds below the dam wall.

Table 2.5 provides a summary of the spawning and migration specifications for the larger semi-rheophilic fish species (Skelton, 1993).

The rapids below the dam wall are, however, not unique to the reach and rapids and cobble beds also occur further downstream, but the loss of spawning habitat below the dam will have a negative impact on the spawning success of the fish in this reach, and these types of habitats need to be protected as they become less and less due to the impact of dams (inundation) and water abstraction from our rivers.

The loss of flow in the rapids directly below the dam wall will be of high significance for the immediate site (i.e. at the dam wall), but of lower significance to the reach.

Other habitats that occur below the dam wall such as the slow deep channel with marginal vegetation in the mid-section of the river will also be affected, but is of lesser importance as it is utilised to a lesser extent by fish. These habitats are also more abundant throughout the system.

Table 2.5 Summary of the spawning and migration specifications for the larger semi-rheophilic fish species (Skelton, 1993).

Species	Flow and habitat needed
BKIM (*Labeobarbus kimberleyensis* – Largemouth yellowfish)	Need gravel beds for spawning – mid to late summer. Eggs hatch within 2-3 days. Feed and free swimming 3-4 days later. Total flow duration needed for spawning: 5-7 days.
BAEN (*Labeobarbus aeneus* – Smallmouth – yellowfish)	Need gravel beds for spawning – mid to late summer. Eggs hatch within 2-8 days. Feed and free swimming 4-6 days later. Total flow duration needed for spawning: 6-14 days.
LCAP (*Labeo capensis* – Orange River Mudfish)	Need rocky rapids for spawning – summer. Eggs hatch within 3-4 days.

Species	Flow and habitat needed
	Feed and free swimming 4-5 days later. Total flow duration needed for spawning: 7-9 days. Rapid growth.
LUMB (*Labeo umbratus* – moggel)	Need shallow rocky areas or flooded grass banks for spawning – summer. Eggs hatch within 2 days. Feed and free swimming 2-4 days later. Total flow duration needed for spawning: 4-6 days. Rapid growth.
CGAR (*Clarias gariepinus* – Sharptooth catfish)	Need vegetation – shallow grassy verges for spawning – summer. Eggs hatch within 1-2 days. Feed and free swimming 2-3 days later. Total flow duration needed for spawning: 3-5 days. Rapid growth. Known to migrate up to 60km upstream in fish river catchment.
ASCL (*Austroglanis sclateri* – Rock catfish)	Not much known about this species. Lives in rocky habitat with flowing water, favouring rapids, where it most probably spawns.

3 ECOLOGICAL CLASSIFICATION

3.1 METHODS

The prescribed DWA EcoClassification process was followed according to the methods of Kleynhans and Louw (2007b).

EcoClassification refers to the determination and categorisation of the present ecological state (PES) (health or integrity) of various biophysical attributes of rivers compared to the natural (or close to natural) reference condition. The purpose of EcoClassification is to gain insight into the causes and sources of the deviation of the PES of biophysical attributes from the reference condition. This provides the information needed to derive desirable and attainable future ecological objectives for the river.

The state of the river is expressed in terms of biophysical components:

- Drivers (physico-chemical, geomorphology, hydrology), which provide a particular habitat template; and
- Biological responses (fish, riparian vegetation, riverine fauna (other than fish) and aquatic invertebrates).

Various models are used to assign a category (A→F; A = Natural, and F = critically modified) to each component. Ecological evaluation in terms of expected reference conditions, followed by integration of these components, represents the Ecological Status or EcoStatus of a river. Thus, the EcoStatus can be defined as the totality of the features and characteristics of the river and its riparian areas that bear upon its ability to support an appropriate natural flora and fauna (modified from: Iversen *et al*., 2000). This ability relates directly to the capacity of the system to provide a variety of goods and services.

The steps followed in EcoClassification are as follows:

- Determine reference conditions for each component.
- Determine the PES for each component, as well as for the integrated EcoStatus.
- Determine the trend for each component, as well as for the EcoStatus.
- Determine the reasons for the PES and whether these are flow or non-flow related.
- Determine the Ecological Importance and Sensitivity (EIS) for the biota and habitats.
- Considering the PES and the EIS, suggest a realistic Recommended Ecological Category (REC) for each component, as well as for the EcoStatus.
- Determine alternative Ecological Categories (ECs) for each component, as well as for the EcoStatus (not relevant for this study).

The Ecological Importance and Sensitivity (EIS) Model, developed by Dr CJ Kleynhans (DWAF, 1999) was used for this study. This approach estimates and classifies the EIS of the streams in a catchment by considering a number of components surmised to be indicative of these characteristics.

Fish were sampled in all available and representative habitats during 2010 (Kotze and Koekemoer, 2010) in the Boegoeberg area with SAMUS fish electro-shockers. A comprehensive fish study was conducted during 2010 and additional fish sampling was not deemed necessary for this study as ample fish data is available. A visual survey was conducted during October 2013 witch focused on the fish habitat availability and integrity. This was done to determine the impact of the proposed construction activities and proposed development in the area of the dam wall i.e. the construction of a hydropower facility with an approximate capacity of 15 Megawatt (MW). The aim was to identify sensitive habitats that may be affected by the construction of a hydropower plant and the impact it will have on the expected fish species.

A Fish Response Assessment Index (FRAI) (Kleynhans, 2007) was used to derive the reference conditions and present ecological status (PES) of the fish in the Boegoeberg area.

3.2 PRESENT ECOLOGICAL STATUS

3.2.1 REFERENCE CONDITION

The reference (or natural) conditions for the components at EFR O2 (Boegoeberg) are summarised below in Table 3.1 and are directly applicable to the Boegoeberg Site. Additional information specific to the Boegoeberg Dam site is also supplied.

Table 3.1 EFR O2: Reference (or natural) conditions at EFR O2 and also Boegoeberg for some components.

Component	Reference conditions
Hydrology	10573.7 nMAR
Geomorphology	The gross morphology of the site is close to reference conditions from the dam wall downstream. The site was a bedrock anatomising reach, characterised by multiple distributaries separated by very stable, vegetated bedrock core bars. Within the active channels, local slopes are steep and sediment deposition would be inhibited such that sandy sedimentary features would be limited to lee areas and low-energy marginal zones. Backwaters would be common.
Riparian vegetation (assessed at Boegoeberg)	**General**: The assessed area at Boegoeberg Dam occurs within an azonal vegetation type: the Lower Gariep Alluvial Vegetation. This vegetation type is poorly protected, with 5.8% under protection, and has only 50.3% of the type remaining. Consequently it has a conservation status of "Endangered", with the current conservation target set at 31%. (Mucina & Rutherford, 2006). Alluvial terraces and banks are dominated by woody riparian thickets (mainly *Acacia karoo* (Sweet thorn), *Ziziphus mucronata* (Buffalo thorn), *Searsia pendulina,* (White karee; endemic), *Combretum rythrophyllum* (River Bushwillow) or stands of reeds (Phragmites australis). Cobble or boulder features are characterised by *Gomphostigma virgatum* (River stars) and sedges (*Cyperus* spp.). Frequently flooded alluvia are open, grassed (*Cynodon dactylon* (Coach grass) mainly) or dominated by reedbeds, and *Salix mucronata* (Cape willow) is also common on frequently inundated alluvia. **Marginal Zone:** Expect a mix of open alluvia or cobble/boulder and vegetated areas. Vegetation, similarly, should be a mix of woody (*Gomphostigma virgatum, Salix mucronata*) and non-woody (*Phragmites*

Component	Reference conditions
	australis, Cyperus marginatus (Water reed)) vegetation. **Lower Zone**: Expect the same as the marginal zone with an emphasis on reeds and *S. mucronata.* **Upper Zone:** Terraces should be well vegetated with small percentage of open areas. Vegetation will be predominantly woody thickets (*Acacia karoo, Ziziphus mucronata, Searsia pendulina* and *Combretum erythrophyllum* (River Bushwillow)). **Macro Channel Banks (MCB):** Banks should be well vegetated and dominated by woody riparian thickets, with dominant species as outlined above, with the addition of *Acacia erioloba* (Camel thorn). **Island:** Should be similar to the Upper.
Fish	Eleven indigenous fish species [*Austroglanis sclateri* (Rock catfish),*Barbus anoplus* (Chubbyhead barb), *Labeobarbus aeneus* (Smallmouth yellowfish), *Labeobarbus kimberleyensis* (Largemouth yellowfish), *Barbus paludinosus* (Straightfin barb), *Barbus trimaculatus* (Three spot barb), *Clarias gariepinus* (Sharptooth catfish), *Labeo capensis* (Orange River mudfish), *Labeo umbratus* (Moggel), *Pseudocrenilabrus philander* (Southern mouthbrooder) and *Tilapia sparrmanii* (Banded tilapia)] have a high to definite probability of occurrence under reference (pre-disturbed) conditions. The expected FROC provided in Kleynhans *et al.* (2007c) for site D7ORAN-NEUSB (exact site under investigation) was broadly used to determine the reference FROC, with alterations made based on all available current information. Table 3.2 provides the reference FROC for the fish in the Boegoeberg area vs. the current observed and habitat derived FROC for the area. Fish sampled (observed), available habitat assessment (habitat integrity), specialist opinion, expertise and judgment were used to derive the EC or PES for the fish. Flow regulation and loss of substrate and fast shallow and fast deep habitat mostly contributed to reduced FROCs for the species.
Macroinvertebrates	Information on aquatic macroinvertebrate in the middle and lower Orange River before construction of Gariep Dam (in 1972) and Van der Kloof Dam (in 1977) is limited. A survey of aquatic invertebrates was collected at Prieska in December 1960 (Agnew 1965), and detailed data on the distribution of snails were collected in the catchment in the 1970's (de Kock *et al.* 1974, Pretorius *et al* 1974, Pitchford and Visser 1975). These data, together with professional judgement, were used to define the likely composition of aquatic invertebrates that would have occurred in the study area under natural conditions. Reference SASS5 Score is 179 and the ASPT is 6.6. The expected number of SASS5 taxa is 27.
Riverine Fauna (at Boegoeberg)	Potentially 95 animal species inhabited the riverine habitats. Open alluvia in marginal zone were utilized by waders. A variety of tree zones (from lower to macro channel bank) with different structural compositions act as refuge, shelter, breeding and feeding habitats, while the intact riparian corridor is used as a migration route for riverine fauna. Mudflats and alluvial soils, where they occur are used by burrowing and tunnelling fauna. Reeds and shrubs are also utilized as shelter, breeding and

Component	Reference conditions
	feeding habitats.

Table 3.2 Reference FROC vs. current observed and habitat derived FROC for the fish in the Boegoeberg area.

Abbreviations: reference species (introduced species excluded)	Scientific names: Reference species (introduced species excluded)	Reference Frequency of Occurrence	EC: Observed and Habitat derived Frequency of Occurrence
ASCL	*Austroglanis sclateri* (Boulenger, 1901)	3.00	2.00
BAEN	*Labeobarbus aeneus* (Burchell, 1822)	5.00	4.00
BANO	*Barbus anoplus* Weber, 1897	2.00	0.50
BKIM	*Labeobarbus kimberleyensis* Gilchrist & Thompson, 1913	3.00	1.50
BPAU	*Barbus paludinosus* Peters, 1852	4.00	3.50
BTRI	*Barbus trimaculatus* Peters, 1852	3.00	2.50
CGAR	*Clarias gariepinus* (Burchell, 1822)	3.00	2.50
LCAP	*Labeo capensis* (Smith, 1841)	5.00	4.50
LUMB	*Labeo umbratus* (Smith, 1841)	3.00	0.50
PPHI	*Pseudocrenilabrus philander* (Weber, 1897)	3.00	2.50
TSPA	*Tilapia sparrmanii* Smith, 1840	2.00	1.50

3.2.2 PRESENT CONDITION

The Present Ecological State (PES) reflects the changes in terms of the Ecological Category (EC) from reference conditions. The summarised information from the Reserve determination study (Louw & Koekemoer (eds), 2010) is provided in Table 3.3.

Table 3.3 EFR O2: Present Ecological State. All date are directly relevant to the Boegoeberg Dam site and are from Louw & Koekemoer (eds) 2010.

Component	PES Description	EC	Conf
Hydrology	4629.6 nMAR (44% of nMAR)	E	3
Physico-chemical	See Table 3.4	C	3.5
Geomorphology	Although the flows are critically reduced at the site, this has been in some ways compensated for by the reduced sediment loads (since much is trapped in upstream dams). The site is generally not very sensitive to the impacts of base flow and small flood changes, nor to small changes in sediment load. The key issue for this site is the loss of large floods that scour and maintain the distributary channels and beds. The very large dams now in place in the upstream catchment will probably prevent any sufficiently large scour events to occur in future, and thus stabilisation and increasing vegetation on the lower banks and bars will occur in the future.	C	3.5

Component	PES Description	EC	Conf
Riparian vegetation	Marginal: Cobble and bedrock areas have a vibrant population of *G. virgatum*. Other dominants however are *S. mucronata, P. australis Cyperus marginatus, Persicaria decipiens, P. lapathifolia* and *Cynodon dactylon.* Lower: Well wooded in places with *G. virgatum*, and *S. mucronata* mainly, but also with *Acacia karoo* recruits. Areas which are open (mainly cobble/boulder) or dominated by non-woody vegetation (*P. australis, Crinum bulbispermum, Cyperus marginatus, Persicaria x2* and *C. dactylon* mainly) make up the mosaic. Upper: The zone is predominantly woody with common species on both banks *T. usneoides, A. karoo, R. pendulina, Z. mucronata. D. lycioides, Lycium hirsutum A. erioloba, Prosopis glandulosa*, and *P. velutina*). A single specimen of *Combretum erythrophyllum* was found. Macro Channel Bank: similar to upper zone.	B	3.6
Fish	It is estimated that all the expected fish species are still present in this river reach albeit in a slightly to moderately reduced FROC. The changes responsible for deterioration in the fish assemblage are primarily associated with altered hydrology/flow modifications (due to large dams and flow regulation), causing habitat deterioration and water quality alterations. The impacts of migration barriers on the natural movement of fish is furthermore expected to impact the fish assemblage negatively in this river reach. Other impacts are related to water quality deterioration (especially impacts from dams on water temperature and oxygen content). Some loss of marginal zone overhanging vegetation due to an altered hydrological regime will also impact the fish assemblage negatively. The negative impacts associated with the alien species – *C. idella*, *G. affinis*, and *C. carpio* – include: loss of vegetation and habitat, bio-turbation and habitat loss, water quality alteration, and predation on native fish eggs and larvae.	C	3
Macroinvertebrates	A total of 20 SASS5 taxa was observed at the site, out of 27 expected (i.e. 74%). The observed SASS5 Score was 116 (65%), and the ASPT was 5.8 (87%). The most obvious change from natural has been outbreaks of pest blackflies (mainly *Simulium chutteri*) following impoundment. The bivalve *Corbicula fluminalis* was noticeably absent during the site-visit. This bivalve is particularly sensitive to elevated sediments, and its absence is probably associated with the periodic emptying of Boegoeberg Dam, which releases high concentrations of sediment. Other taxa that were expected but not observed included Heptageniidae, Ecnomidae, Hirudinea, Sisyridae, Corixidae and Ceratopogonidae. The most sensitive taxa recorded at the site were Atyidae, Tricorythidae and Leptophlebiidae. Elevated nutrients lead to excessive growth of epilithic algae, particularly during low-flow periods, and this reduces the suitability of substrates for colonisation of benthic invertebrates. The	C	4

Component	PES Description	EC	Conf
	chironomid *Cardiocladius africana* thrive under these conditions. Monthly data on aquatic invertebrates were collected at Gifkloof, near Upington, between 1991 and 1996 (Palmer 1997b). These data provide a reliable indication of the key ecological drivers that affect the diversity and abundance of benthic macroinvertebrates in the middle and lower Orange River: *Very Low Flows:* During very low flow (<16 m^3/s) the river was characterised by clear water (Secchi depth >47cm) and low concentrations of planktonic algae. The average number of macroinvertebrate taxa (29), the average number of SASS4 taxa (18), highest during these flow conditions. Taxa typically associated with very low flow included the filter-feeding midge *Rheotanytarsus fuscus*, the sponge *Ephydatia fluviatilis* and the blackflies *Simulium adersi* and *S. ruficorne*. *Low Flows:* During low flow (16 to 59 m^3/s) the river was characterised by moderate clarity (Secchi depth 25 to 47 cm) and moderate concentrations of planktonic algae. Numerous taxa were associated with low flows, including the mayflies *Afronurus peringueyi, Baetis glaucus* and *Euthraulus elegans*, and the blackflies Simulium damnosum s.l. and *S. mcmahoni.* *Moderate Flows:* During moderate flow (60 to 142 m^3/s) the probability of planktonic algal blooms was high. Taxa typically associated with moderate flows were the caddisfly *Amphipsyche scottae* and the blackflies *Simulium chutteri* and *S. gariepense.* The Average SASS4 Score per Taxon (ASPT) was highest under moderate flow conditions. *Very High Flows:* Dramatic changes in species composition and abundance were recorded after a flood in January 1996. Species whose abundance increased after the flood included the blackfly *S. chutteri*, the mayfly *Tricorythus discolor*, and the caddisflies *Cheumatopsyche thomasseti* and *Aethaloptera maxima*. Species that disappeared after the flood included the mayfly *A. peringueyi,* the caddisfly *Ecnomus thomasseti,* the sponge *E. fluviatilis,* the blackfly *S. mcmahoni* and the midge *R. fuscus*. *Fluctuating Flows:* Many invertebrates in the Orange River have life-history characteristics that buffer against unfavourable conditions. These include desiccation-resistant stages and rapid rates of development. Such characteristics are likely to promote the coexistence of species in fluctuating environments. This highlights the importance of disturbance in maintaining a diverse river ecosystem. Taxa whose abundance increased when flows fluctuated were the leech *Salifa perspicax,* the mayflies *T. discolor* and *B. glaucus*, the caddisflies *A. scottae* and *A. maxima* and the blackfly *S. chutteri*. The number of SASS4 families and total SASS4 scores were unaffected by flow variation, but invertebrate abundance dropped as flow variation increased. The lowest SASS4 score (indicating poor conditions) was		

Component	PES Description	EC	Conf
	recorded in June 1994, following a mid-winter period of unseasonally high flow. Taxa present during low flow were found throughout southern Africa, and were of little conservation importance. Taxa present during high flow, by contrast, included unusual species, endemic to large, turbid rivers. The maintenance of a healthy invertebrate fauna in the middle Orange River therefore depends on maintaining, or at least simulating, natural flow fluctuations. Simulating natural flow fluctuations would also help to conserve threatened species, such as the blackfly *S. gariepense*, and help reduce population outbreaks of the pest *S. chutteri.* *Stable Flows:* Stable flows caused by impoundment are detrimental to taxa adapted to either low or high flow. However, unseasonally high flows were shown to be detrimental to aquatic invertebrates. The pest blackfly *S. damnosum* became abundant during a long period of stable, low-flow conditions in 1993. Other taxa whose abundance increased during stable flow conditions were the stonefly *Neoperla spio,* Turbellaria and the midges *Cardiocladius africanus* and *R. fuscus*, the muscid fly *Xenomyiasp*. and the sponge *E. fluviatilis*. The overall abundance of caddisflies and predators started declining after 20 days of constant flow, whereas the abundance of gatherers started declining after 15 days of constant flow. *Water Temperature:* Water temperature had a significant impact on invertebrates. Of particular interest was an inverse relation between the abundance of blackflies and caddisflies as water temperatures changed: blackflies were more abundant than caddisflies during cold conditions, whereas caddisflies were more abundant than blackflies during warm conditions. *Benthic Algae:* Benthic algae were usually abundant in late winter to early spring (July to September). They were most abundant when the water was moderately clear (Secchi depth >18 cm) or when the flow was less than 130 m^3/s. There was a corresponding increase in the abundance of scrapers (mostly the midge *Cardiocladius africanus*) between August and October in most years. The ASPT was usually highest during low algal cover (<10 %). The middle and lower Orange River is mostly wide and the rapids are shallow. This means that primary production in most rapids in the Orange River is not limited at flows less than 130 m^3/s. *Planktonic Algae:* The abundance of planktonic algae was highly seasonal, with lowest values in winter (June to August), and highest values in autumn (March to May). The abundance of invertebrates increased as the abundance of planktonic algae increased. These changes had no significant influence on the SASS4 scores or the ASPT. However, in some years blooms of the blue-green algae *Microcystis* sp. developed in Lake		

Component	PES Description	EC	Conf
	Vanderkloof, particularly in autumn. There was a slight decline in the total number of invertebrate taxa as the abundance of *Microcytis* sp. increased, but these changes did not greatly affect SASS4 scores or the ASPT. Highest numbers of the pest blackfly *S. damnosum* were recorded in June 1995 following a *Microcystis* sp. bloom in the previous month. By contrast, the abundance of *S. chutteri* consistently declined during *Microcystis* blooms.		
Riverine Fauna	75 of the expected 95 animal species (79%) potentially can occur in this segment. This comprises 45 aquatic and semi-aquatic species, 11 marginal habitat species, and 19 riparian species. The riparian vegetation habitats have not changed much, as most of the riparian trees of diverse structures are still intact to act as refuge, shelter, breeding and feeding habitats, and a migration route. However, the changes in flows (removal of higher flows) resulted in the marginal zone being vegetated with reeds and hygrophilous shrubs, eliminating mudflats and alluvial sandbars.	C	3.6

Table 3.4 EFR O2: Present Ecological State: Physico-Chemical

RIVER	Orange River	**WATER QUALITY MONITORING POINTS**	
		RC	Orange River @ Boegoeberg Reserve (D73B; ecoregion II: 26.05) D7H008Q01 (1966 – 1979; n=43 - 57)
EFR SITE	O2 (D81B; ecoregion II: 28.01)	**PES**	1) Orange River @ Boegoeberg Reserve (D73B; ecoregion II: 26.05) D7H008Q01 (2000 – 2009; n=348) 2) Data from diatom sample collection in 2005, 2008, 2009, 2010
Confidence assessment	Moderate confidence. Although sufficient data for most variables, data gaps exist, particularly in the case of herbicides, pesticides and metal ions. Note that water quality and EFR sites are <u>not</u> in the same EcoRegion level II.		

Water Quality Constituents		**RC Value**	**PES Value**	**Category/Comment**
Inorganic salts (mg/L)	TEACHA was not used for data assessment, as salinity levels not elevated.			
Salt ions (mg/L)	Ca	37.40	34.06	Concentrations similar for the PES, except for sulphate, sodium and chloride which show increases from the RC, particularly sulphate and chloride.
	Cl	20.36	46.28	
	K	3.70	3.99	
	Mg	15.10	18.00	
	Na	23.70	35.36	
	SO_4	48.10	63.99	
Nutrients (mg/L)	SRP	0.014 *	0.022	A category
	TIN	0.14	0.22	A category
Physical Variables	pH (5^{th} + 95^{th} %ile)	7.05 + 7.91	7.71 + 8.60	A/B category
	Temperature	-	-	Site downstream of numerous dams upstream, with significant changes expected from natural.
	Dissolved oxygen	-	-	
	Turbidity (NTU)	-	Avg: 7.92 95^{th} %ile: 30.67	Levels not very significant. A/B category (qualitative assessment)
	Electrical conductivity (mS/m)	35.68 *	50.80	A/B category. RC shows slightly elevated natural salt levels.
Response variables	Chl a: periphyton (mg/m^2)	-	-	-
	Chl a: phytoplankton (µg/L)	-	46.5 (n=2; 2008) (Koekemoer, 2010)	E category
	Macroinvertebrates	ASPT: 6.6 SASS: 165	ASPT: 5.8 SASS: 116 MIRAI: 63.7%	C category (Palmer, 2010)
	Fish community score		FRAI: 66.9%	C category (Kotzé, 2010)

	Diatoms	-	SPI: avg – 12.9 (n=4; Boegoeberg + EFR O2)	B/C category (Koekemoer, 2010)
Toxics	Fluoride (mg/L)	0.452	0.260	A category
	Ammonia (mg/L)	0.002	0.011	A category
	Aluminium (mg/L)	0.02 **	0.166 (n=2; 2008) (Koekemoer, 2010)	D category
	Iron (mg/L)	-	0.110 (n=2; 2008) (Koekemoer, 2010)	No guideline + insufficient data
	Arsenic (mg/L)	0.02 **	297 (n=2; 2008) (Koekemoer, 2010)	E category
	Cadmium (mg/L)	0.000 3 **	0.005 (n=2; 2008) (Koekemoer, 2010)	E category
	Lead (mg/L)	0.002 **	0.011 (n=2; 2008) (Koekemoer, 2010)	E category
	Other	-	-	Impacts expected due to farming-related pesticides and fertilizer use.
OVERALL SITE CLASSIFICATION		**C: 69.34%** (from PAI model)		

* boundary value for the A category recalibrated - no data ** benchmark value, as no data

The reasons for changes from reference conditions must be identified and understood. These are referred to as causes and sources ((http://cfpub.epa.gov/caddis/)). The PES for the components at EFR O2 as well as the causes and sources for the PES are summarised in Table 3.5.

Table 3.5 Causes and Sources of the Present Ecological State.

	PES	Conf	Causes	Sources	F[1]/NF[2]	Conf
Hydro[3]	E	3	Increase in unseasonal releases of small floods, decrease of moderate and large floods.	Twice daily flood releases from Vanderkloof dam for hydro power, upstream dams.	F	5
			Increased base flows during drought and dry seasons and decreased base flows during the wet season.	Operation for irrigation and other users.	F	
Physico-chemical	C	3.5	Elevated nutrients and potential toxicant loads due to fertilizer and pesticide use.	Agriculture, resulting in some toxicant and nutrient loading expected.	NF	4
Geomorphology	C	3.5	Reduced frequency and size of large floods.	Large dams.	F	4
			Reduced sediment load.	Although upstream dams have reduced the sediment load, annual flushing of the upstream dam reintroduces some sediments.	F	2.5
Riparian vegetation	B	3.6	Increased vegetation cover.	Reduced base flows especially in summer and reduced moderate and large floods.	F	2.5
			Altered species composition.	Small percentage of perennial exotic species.	NF	4
Fish	C	3	Decreased overhanging vegetation as cover for fish result in decreased FROC of species with preference for these habitats. Loss of habitat (cover) also results in increased exposure to predators.	Increased bank erosion, flow modification and inundation. Farming: removal or change in riverine vegetation.	F NF	3.5
			Decrease in FROC and abundance of fish species with preference for fast habitats.	Decreased base flows.	F	

	PES	Conf	Causes	Sources	F[1]/NF[2]	Conf
			Decreased water quality.	Presence of toxics, agriculture, dams trapping silt altering water clarity, stratification in dams.	NF	
			Decreased species diversity and abundance.	Presence of alien predatory species (*G. affinis*) feeding on indigenous fish eggs and larvae.	NF	
			Increased turbidity and disturbed bottom substrates reduce bottom substrate quality and water quality for indigenous fish (especially impact on *Labeo umbratus* breeding habitats).	Presence of alien *C. carpio* which cause bio-turbation. Dams create habitat for undesirable species.	NF	
			Decreased native species diversity and abundance as result of presence of alien species.	Alien species will have negative impact on native species - *C. carpio* – bio-turbation; *G. affinis* - predation on eggs and fry; *C. idella* - loss of aquatic vegetation and habitat.	NF	
			Decreased abundance, and therefore FROC related to over utilization for human consumption.	Poaching and over-fishing of fish using nets (gill and seine nets, often home-made).	NF	
			Reduced spawning success resulting in decreased FROC of many species.	Flow modification: Absence of spring flushes, reduced habitat suitability and stimuli, flow pattern disrupts normal breeding cycle.	F	
			Presence of migration barriers reduces migration success (breeding, feeding and dispersal) of some species.	Some dams/weirs (incl. Boegoeberg Dam).	NF	
Macroinvertebrates	C	4	Elevated low flows.	Discharges to meet demands for winter power generation and irrigation demands.	F	4
			Water quality deterioration.	Agricultural return flows.	F	3
			Aseasonal releases.	Operation of Vanderkloof Dam.	F	4
			Pesticides.	Blackfly Control Programme.	NF/F	4
			Elevated sediment.	Periodic emptying of Boegoeberg Dam for maintenance, usually during winter (i.e. low flow).	NF	4
			Toxic algal blooms, such as *Microcystis.*	Annual overturn of Vanderkloof Dam, plus inputs from Harts River (Spitzkop Dam).	NF	2
Riverine Fauna	C	3.6	Reduced abundance. Loss of habitat diversity due to reduced flow volumes Reduced abundance in piscivorous species - Reduction in fish abundance (due to reduction of habitat) as a food base for piscivorous species.	Operation of the system.	F	3
			Impact adversely on instream biota that acts as food source for piscivores and invertivores.	Operation of the system.	F	
			Marginal zone invaded by reeds and shrubs, removing mudflat and alluvial sandbank habitats –habitat for waders.	Loss of frequency and magnitude of larger floods.	F	

1 Flow related 2 Non Flow related 3 Hydrology

The major issues that have caused the change from reference conditions are:

- Loss of frequency of large floods.
- Agricultural return flows.
- Higher low flows than natural in the dry season, drought and dry periods.
- Decreased low flows at other times.
- Annual release of sediment.
- Presence of alien fish species and barrier effects of dams.

- Presence of alien vegetation species.

3.2.3 ECOSTATUS

The summarised results of the EcoStatus are shown in Table 3.6. These results are from the 2010 Reserve determination study and were verified to still be the case at the Boegoeberg Dam site.

Table 3.6 Summary of EcoClassification results

Boegoeberg

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

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

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

3.3 ECOLOGICAL IMPORTANCE AND SENSITIVITY

The Ecological Importance and Sensitivity (EIS) evaluation results in a **HIGH** importance. The highest scoring matrices are:

- Riparian rare and endangered species such as clawless otter, black stork, African marsh harrier, Namaqua stream frog, straw-coloured fruit bat. Riparian vegetation: Two species listed as declining, *Acacia aerioloba, Crinum bulbispernum*.
- Unique riparian biota: Orange river white-eye and 6 endemic riparian vegetation species;
- Riparian biota – taxon richness: 75 species of riverine fauna present (79% of expected species).
- High diversity of riparian habitat types and features such as the abundance of riparian and marginal habitat available for riverine fauna.
- Critical riparian habitat and refugia: The lush riparian (large tree) habitat is a refuge for 19 true riparian species and 7 semi-aquatic species for nesting, roosting and shelter.
- Riparian habitat which is sensitive to flow changes: Rheophytes (such as *Gomphostigma virgatum*) sensitive to flow changes. Need fast flowing shallow water.
- Riparian migration corridor: A riparian band in the area annually inundated by high floods remains intact. This intact band forms a very important migration corridor for most of the riverine faunal species present in the area.
- Intolerant instream biota (fish) includes *L. kimberleyensis* and *A. sclateri* which prefer fast flowing habitat with substrate (rocks). This makes the fast flowing habitats with substrate (rocky habitat) important and sensitive to impacts in the area.

4 ENVIRONMENTAL FLOW REQUIREMENTS

4.1 METHODS

The Habitat Flow Stressor Response method (HFSR) (IWR S2S, 2004; O'Keeffe *et al*., 2002), a modification of the Building Block Methodology (BBM; King and Louw, 1998) was used to determine the low (base) flow EFRs (Louw & Koekemoer (eds), 2010). This method is an accepted DWA method for determining EFRs. The wettest and driest months were identified as March and September. Droughts are set at 95% exceedance (flow) and 5% exceedance (stress). Maintenance flows are set at 40% exceedance (flow) and at 60% exceedance (stress).

4.2 RESULTS

EFRs were determined as part of the Reserve determination study (Louw & Koekemoer (eds), 2010) study on the Orange River at EFR 2 (downstream of Boegoeberg Dam) and EFR 3 (downstream of Augrabies National Park). The EFRs determined for EFR 2 were the most appropriate and could be used as is for the Boegoeberg Dam site.

4.2.1 LOW FLOW REQUIREMENTS

The fish and macroinvertebrate flow requirements for different Ecological Categories (ECs) are provided in Table 4.1. The results are shown for the wet and dry season and the AEC is the Alternate Ecological Category i.e. one category worse than PES.

For easier reference the range of ECs are colour coded in the Table:
PES**: Purple** AEC↓: **Green**

Summarised motivations for the final requirements are provided in Table 4.2.

Table 4.1 Species and integrated stress requirements as well as the final integrated stress and flow requirement

Duration	LSR[1] stress	Integrated stress	FDI[2] stress	Integrated stress	FINAL (Integrated stress)	FLOW (m^3/s)
PES C ECOSTATUS		**FISH: C**		**MACROINVERTEBRATES: C**		
DRY SEASON						
5%	8.5	**8.5**	8.7	**8.7**	8.5	10.2
30%	7.3	**7.3**	7.4	**7.8**	7.3	22.7
60%	7.3	**7.3**	6.9	**6.9**	7.3	28.8
WET SEASON						
5%	7.2	**7.2**	6.8	**6.8**	6.8	30.8
30%	6.7	**6.8**	6.6	**6.6**	6.6	35.2
60%	5.1	**5.5**	5.4	**5.4**	5	60**
AEC↓ C ECOSTATUS		**FISH: D**		**MACROINVERTEBRATES: D**		
DRY SEASON						
5%	9.2	9.2	9.1	9.1	9.1	5.3

Duration	LSR[1] stress	Integrated stress	FDI[2] stress	Integrated stress	FINAL (Integrated stress)	FLOW (m^3/s)
30%	8.3	8.3	8.3	8.4	8.3	12.1
60%	7.6	7.6	7.3	7.7	7.6	19.2
WET SEASON						
5%	7.6	7.6	7.5	7.8	7.6	19.2
30%	7	7	6.8	7.1	7	27
60%	5.8	6.1	6.2	6.1	6.1	48

1 Large semi-rheophilic fish guild 2 Flow dependent invertebrates

Table 4.2 Summary of motivations for flow requirements.

Month	% Stress duration	Component stress	Integrated stress	Flow m^3/s	Comment
PES: EcoStatus FISH: C MACROINVERTEBRATES: C					
Sep	5% drought	8.5 LSR	8.5	10.2	Habitat suitability will be very low in terms of providing cover/abundance, connectivity and water quality, but adequate to allow survival and maintenance of PES during droughts.
	60% maintenance	7.3 LSR	7.3	28.8	Habitat suitability will generally be low in terms of proving cover/abundance, connectivity and water quality, but adequate to allow survival and maintenance of PES.
Mar	5% drought	6.8 FDI	6.8	30.8	This stress is slightly higher than the present-day flow, but will maintain the PES. The average current speeds at this stress are lower than that preferred by the indicator taxon, *Amphipsyche scottae*, but there is no justification for requesting more flow than present.
	60% maintenance			60	SEE TABLE 6.3
AEC↓: EcoStatus FISH: D MACROINVERTEBRATES: D					
Sep	5% drought	9.1 FDI	9.1	5.3	Natural stress will be introduced into the system. The stress-duration is higher than the natural stress, and significantly higher than the present-day stress. Elevated low-flows at this time of the year are the main reason leading to outbreaks of pest blackflies. The requested stress will therefore reduce outbreaks of pest blackflies.
	60% maintenance	7.6 LSR	7.6	19.2	Habitat suitability will generally be very low to low in terms of providing cover/abundance, connectivity and water quality, but lower than under present scenario, resulting in deterioration in the fish assemblage.
Mar	5% drought	7.6 LSR	7.6	19.2	Habitat suitability will generally be very low to low in terms of providing cover/abundance, connectivity and water quality and very low in terms of suitable spawning and nursery habitats, but lower than under present scenario, resulting in deterioration in the fish assemblage.
	60% maintenance	5.8 LSR	6.1	48	Habitat suitability will generally be low to low in terms of providing cover/abundance, connectivity, water quality nursery habitats and very low in terms of suitable spawning habitat, but lower than under present scenario, resulting in deterioration in the fish assemblage.

The low flow requirements determined by the instream biota is validated (and modified if necessary) by riparian vegetation requirements, specifically marginal zone vegetation and riverine fauna. This verification is summarised in Table 4.3.

Table 4.3 Verification of low flow requirements for instream biota to maintain riparian vegetation in the required EC.

PES						
Species	**Season**	**Duration**	**Flow (m^3/s)**	**Average Inundation / Height above water level (m)**		**Note**
				lower limit	**upper limit**	
G. virgatum	Dry	5%	10.2	0.52	1.51	Water stress is high and some mortality expected, especially along the upper limit of populations, but this is usual for drought, even in the dry season.
C. marginatus				0.54	1.62	
P. decipiens				0.55	1.01	
P. lapathifolia				0.65	1.49	
P. australis				0.70	1.62	
S. mucronata				0.76	1.36	
G. virgatum		60%	28.8	0.35	1.34	Water stress quite high, but normal for dry season and because plants reduce metabolic requirements, survival will be sufficient for PES to be unaltered.
C. marginatus				0.37	1.45	
P. decipiens				0.38	0.84	
P. lapathifolia				0.48	1.32	
P. australis				0.53	1.45	
S. mucronata				0.59	1.19	
G. virgatum	Wet	5%	30.8	0.33	1.33	Comparable to dry season base flows, but during the wet season these flows are likely to cause reproductive failure / abortion. Survival of existing vegetation is however likely to be high and not likely to change the PES.
C. marginatus				0.36	1.44	
P. decipiens				0.36	0.82	
P. lapathifolia				0.46	1.31	
P. australis				0.52	1.43	
S. mucronata				0.58	1.17	
G. virgatum		60%	60	0.11	1.11	On average most populations are not inundated, although up to 20 cm of inundation can occur at selected low points. These base flows are sufficient to facilitate survival and, together with small floods, reproduction. The PES is not likely to change.
C. marginatus				0.14	1.22	
P. decipiens				0.14	0.61	
P. lapathifolia				0.24	1.09	
P. australis				0.30	1.21	
S. mucronata				0.36	0.95	
Conclusion: Low flow requirements for instream fauna will maintain the PES for riparian vegetation (in a B class), provided that class I floods are provided. Riparian zone structure and functionality will remain predominantly unchanged from current.						

4.2.2 HIGH FLOW REQUIREMENTS

It is acknowledged that the proposed development is likely to have less of an impact on high (flood) flow requirements. Some of the smaller floods, the freshes (Class I flood) can be reduced and these flows should be allowed through as per the requirement (Table 4.4). Class 1 floods were set at 150 to 200 m^3/s and are required during summer to inundate 50% on average, of marginal and lower zone obligates (*Gomphostigma virgatum, Cyperus marginatus, and Phragmites australis*) and activate (just reaches the lower limit of) the *Salix mucronata* population. Also prevents the establishment of terrestrial and alien (especially *Prosopis glandulosa and Nicotiana glaucea*) species in the marginal and lower zones.

The high flow results are provided in Table 4.4 with detailed motivations shown in Table 4.5.

Table 4.4 The recommended number of high flow events required at the Boegoeberg site

FLOOD RANGE (m^3/s)	INVERTEBRATES	FISH	VEGETATION	GEOMORPHOLOGY	FINAL* (No of events)	MONTHS	DAILY AVERAGE (m^3/s)	DURATION
PES and REC: C								
150-200	3	3	3	2	3	Nov, Dec, Jan	150	6
300-400	1	1	1	1:2	1	Feb	350	8
850-1000	1:3		1:3	1:5	1:3	Mar	850	12
2000+			1:5+	1:10	1:5+	Late summer		
AEC↓: D								
150-200	1	2	2	1	2	Nov, Jan	150	6
300-400	1:1	0	1:1	1:3	1	Feb	350	8
850-1000			1:3	1:5	1:3	Mar	850	12
2000+			1:5+	1:10	1:5+			

Table 4.5 Identification of instream functions provided by the floods identified for geomorphology and riparian vegetation

FLOOD RANGE (m3/s) FLOOD CLASS (instantaneous peak)	Geomorphology and riparian vegetation motivation	Fish flood functions						Invertebrate flood functions				Riverine fauna		
		Migration cues & spawning	Migration habitat (depth etc.)	Clean spawning substrate	Create nursery areas	Resetting water quality	Inundate vegetation for spawning	Breeding and hatching cues	Clear fines	Scour substrate	Reach or inundate specific areas	Scour lower zone habitats	Create floodplain habitats	Invigorate riparian vegetation habitats
150 - 200	Required to inundate 50 to 60% of marginal and lower zone vegetation (*Gomphostigma virgatum, Cyperus marginatus, Persicaria decipiens, P. lapathifolia, Phragmites australis* and *Salix mucronata*). Prevents establishment of upper zone (*Acacia karoo*) and terrestrial species in the lower zone. Required to begin inundation of the *Crinum bulbispermum* population which will support reproductive demands. Required during growing season (spring to summer: Nov - Jan).	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓ 1	
300 - 400	Required to flood lower zone riparian species (*S. mucronata* and *P. australis*) and inundate about 50% of the *C. bulbispermum* population. This will flush sediment in seasonal channels and facilitate recruitment opportunities at higher levels, but create flooding disturbance at the lower limits which also maintains habitat and vegetative patchiness. These floods may cause some scour in the marginal zone, again, important for maintaining patchiness and similarly maintain seasonal channels. Required during summer (Nov - Jan).	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓ 2	
850 - 1000	Required to begin inundation of *Searsia pendulina* (which is where the tree line starts). Will facilitate recruitment and vigour of upper zone woody species, but also prevent their encroachment into the lower zone. Similarly, these floods are also useful for preventing terrestrialisation and expansion of exotic species such as *P. galndulosa*. Activation of the *Tamarix usneoides* population (i.e. no inundation, but sufficient soil moisture to facilitate recruitment and maintain reproductive outputs). Larger floods are also important to scour marginal and lower zone habitats and maintain open patches. Needed late in the growing season (Feb, Mar).	✓	✓	✓	✓	✓	✓	✓	□	□	□			✓[3]
2000 - 2500	Large and infrequent flood to inundate about 50% of the *T. usneoides* population. Important to maintain *T. usneoides* recruitment, but also to scour large sections of the macro-channel bed and maintain overall patchiness. Also creates flooding disturbance for upper zone and bank woody species such as *S. pendulina, A. karoo* and *Z. mucronata*. Useful to reduce exotic perennial species, especially *P. glandulosa.* Also activates lower limit of *A. erioloba.*	✓	✓	✓	✓	✓	✓	□	□	□	□			✓[4]
✓[1]	Inundate channels in anatomising area behind island on right hand bank. Supply a mosaic of habitats for fish and eventually for wetland fauna to forage in. Scour channels, supply embankments for nesting and tunnelling.													

FLOOD RANGE (m3/s) FLOOD CLASS (instantaneous peak)	Geomorphology and riparian vegetation motivation	Fish flood functions						Invertebrate flood functions				Riverine fauna		
		Migration cues & spawning	Migration habitat (depth etc.)	Clean spawning substrate	Create nursery areas	Resetting water quality	Inundate vegetation for spawning	Breeding and hatching cues	Clear fines	Scour substrate	Reach or inundate specific areas	Scour lower zone habitats	Create floodplain habitats	Invigorate riparian vegetation habitats
✓[2]	Larger floods are important to scour marginal and lower zone habitats and maintain open patches resulting in mudflats and alluvial sandbars as habitat.													
✓[3]	Main motivation for these flows is for the riparian vegetation to be invigorated, to which the riparian fauna will react accordingly.													
✓[4]	Main motivation for these flows is for the riparian vegetation to be invigorated, to which the riparian fauna will react.													

4.2.3 FINAL FLOW REQUIREMENTS

The low and high flows were combined to produce the final flow requirements for each EC as:

- An EFR table, which shows the results for each month for high flows and low flows separately (Table 4.7 – 4.8). Floods with a high frequency are not included in the modelled results as they cannot be managed.
- An EFR rule table which provides the recommended EFR flows as a duration table, linked to a natural trigger (natural modelled hydrology in this case). EFR rules are supplied for total flows as well as for low flows only (Table 4.9 – 4.10).

The low flow EFR rule table is useful for operating the system, whereas the EFR table must be used for operation of high flows.

Table 4.6 EFR table (final flows) for the PES (which is also the REC): C

Desktop version:		**2**	**Virgin MAR (MCM)**	**10573.7**
BFI	**0.329**	**Distribution type**		**Vaal**
MONTH	**LOW FLOWS**		**HIGH FLOWS**	
	Maintenance (m^3/s)	**Drought (m^3/s)**	**Daily average (m^3/s) on top of base flow**	**Duration (days)**
OCTOBER	28.211	0.627		
NOVEMBER	36.708	13.665	150	6
DECEMBER	39.92	19.512	150	6
JANUARY	47.269	21.408	150	6
FEBRUARY	61.393	31.478	350	8
MARCH	60.014	31.051	850	12
APRIL	53.153	11.705		
MAY	39.716	10.906		
JUNE	30.813	11.3		
JULY	24.956	10.919		
AUGUST	23.653	10.171		
SEPTEMBER	24.231	6.115		
TOTAL MCM	1230.5	467.2	566.4	
% OF VIRGIN	11.64	4.42	5.36	
Total IFR	1797			
% of MAR	16.99			

Table 4.7 EFR table (final flows) for the AEC↓: D

Desktop version:		**2**	**Virgin MAR (MCM)**	**10573.7**
BFI	**0.304**	**Distribution type**		**Vaal**
MONTH	**LOW FLOWS**		**HIGH FLOWS**	
	Maintenance (m^3/s)	**Drought (m^3/s)**	**Daily average (m^3/s) on top of base flow**	**Duration (days)**
OCTOBER	11	0.627		
NOVEMBER	17	10.459	150	6
DECEMBER	20	12.055		
JANUARY	25	15.286	150	6
FEBRUARY	34	20.908	350	8

MARCH	34	20.891	850	12
APRIL	29	11.705		
MAY	20	10.906		
JUNE	13	7.867		
JULY	11	5.475		
AUGUST	10	4.902		
SEPTEMBER	9	4.973		
TOTAL MCM	609.4	329.2	532.1	
% OF VIRGIN	5.76	3.11	5.03	
Total IFR	1141.5			
% of MAR	10.8			

Table 4.8 Assurance rules for PES and REC: C

Desktop Version 2, Printed on 2010/11/03
Summary of IFR rule curves for: EFRO2 Natural Flows
Determination based on defined BBM Table with site specific assurance rules.
Regional Type: Vaal PES and REC = C

Data are given in m^3/s mean monthly flow

% Points

Month	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	41.794	41.290	40.355	38.693	35.879	31.408	24.876	16.404	7.318	0.886
Nov	78.886	73.772	68.755	63.201	53.796	46.506	37.174	27.231	19.120	15.301
Dec	81.831	76.003	70.433	64.246	54.201	46.139	36.811	28.390	22.927	21.077
Jan	86.915	81.014	75.267	68.727	58.092	49.246	39.134	30.201	24.623	22.993
Feb	167.673	147.682	130.734	114.213	88.708	72.594	55.999	43.593	37.338	35.992
Mar	212.180	209.565	202.463	186.957	160.086	123.942	87.367	60.804	48.008	41.514
Apr	61.872	61.103	59.035	54.536	46.721	36.114	25.189	17.023	12.905	12.019
May	48.843	48.166	46.652	43.699	38.752	31.794	23.840	16.814	12.427	11.144
Jun	40.975	40.456	39.304	37.064	33.308	27.997	21.852	16.304	12.705	11.486
Jul	34.839	34.425	33.615	32.153	29.748	26.210	21.682	16.858	12.923	11.070
Aug	35.162	34.856	34.289	33.280	31.571	28.857	24.892	19.749	14.233	10.328
Sep	37.215	36.958	36.513	35.750	34.456	32.304	28.403	21.748	13.353	7.494

Reserve flows without High Flows

Oct	41.794	41.290	40.355	38.693	35.879	31.408	24.876	16.404	7.318	0.886
Nov	51.211	50.561	49.289	46.994	43.219	37.667	30.560	22.988	16.810	13.902
Dec	53.136	52.548	51.243	48.705	44.449	38.431	31.468	25.182	21.104	19.723
Jan	58.221	57.564	56.095	53.229	48.428	41.677	33.959	27.141	22.883	21.639
Feb	71.576	70.962	69.309	65.713	59.466	50.988	42.256	35.728	32.437	31.729
Mar	67.585	67.014	65.465	62.082	56.221	48.336	40.357	34.563	31.771	31.280
Apr	61.872	61.103	59.035	54.536	46.721	36.114	25.189	17.023	12.905	12.019
May	48.843	48.166	46.652	43.699	38.752	31.794	23.840	16.814	12.427	11.144
Jun	40.975	40.456	39.304	37.064	33.308	27.997	21.852	16.304	12.705	11.486
Jul	34.839	34.425	33.615	32.153	29.748	26.210	21.682	16.858	12.923	11.070
Aug	35.162	34.856	34.289	33.280	31.571	28.857	24.892	19.749	14.233	10.328
Sep	37.215	36.958	36.513	35.750	34.456	32.304	28.403	21.748	13.353	7.494

Natural Duration curves

Oct	631.571	345.904	243.160	171.151	109.282	82.788	63.762	40.931	25.336	5.780
Nov	918.985	673.117	500.725	372.319	254.479	224.730	170.517	136.802	59.047	17.191
Dec	1020.120	723.973	540.834	415.502	339.382	299.522	213.527	114.475	82.269	33.774
Jan	1270.557	903.875	638.303	521.184	395.508	298.484	227.173	172.547	96.210	43.003
Feb	2052.472	1278.741	891.353	538.802	436.872	319.498	273.276	229.588	135.235	45.705
Mar	1562.280	1034.289	698.014	607.411	468.765	335.738	252.647	200.396	126.176	41.514
Apr	899.541	636.867	406.590	319.606	288.630	238.515	170.093	119.487	75.598	29.344
May	353.271	265.091	197.431	133.277	106.732	82.154	72.353	47.551	34.606	11.470
Jun	192.647	140.895	91.454	71.937	60.683	56.296	43.534	33.029	22.477	11.617
Jul	149.578	100.896	84.569	67.040	47.525	39.221	32.818	26.329	19.108	15.084
Aug	152.337	106.582	83.796	60.140	50.881	34.069	27.770	23.466	18.246	14.445
Sep	229.946	126.123	86.844	65.251	48.935	39.734	28.403	21.748	13.353	8.333

Table 4.9 Assurance rules for AEC↓: D

Desktop Version 2, Printed on 2010/11/03
Summary of IFR rule curves for: EFRO2 Natural Flows
Determination based on defined BBM Table with site specific assurance rules.
Regional Type: Vaal AEC DOWN = D

Data are given in m^3/s mean monthly flow

% Points										
Month	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	22.801	22.479	21.853	20.697	18.696	15.507	10.986	5.642	1.168	0.767
Nov	59.802	54.879	50.194	45.190	36.677	30.819	23.717	16.949	12.561	11.995
Dec	35.148	34.698	33.665	31.625	28.223	23.566	18.534	14.519	12.429	12.200
Jan	70.158	64.401	58.946	52.944	43.228	35.820	27.693	21.023	17.373	16.805
Feb	148.597	128.716	112.039	96.084	71.588	56.976	42.191	31.453	26.280	25.369
Mar	221.525	218.605	210.676	193.365	163.364	123.010	82.176	52.518	38.233	35.716
Apr	44.741	44.225	42.824	39.766	34.465	27.335	20.120	14.880	12.356	11.912
May	33.158	32.734	31.768	29.864	26.686	22.301	17.490	13.543	11.382	11.046
Jun	22.846	22.555	21.885	20.561	18.355	15.334	12.070	9.465	8.110	7.961
Jul	20.775	20.471	19.859	18.731	16.870	14.189	10.938	7.840	5.831	5.572
Aug	20.786	20.555	20.107	19.279	17.845	15.561	12.322	8.494	5.290	5.002
Sep	20.517	20.360	20.072	19.549	18.617	17.002	14.325	10.255	5.071	5.071
Reserve flows without High Flows										
Oct	22.801	22.479	21.853	20.697	18.696	15.507	10.986	5.642	1.168	0.767
Nov	32.137	31.707	30.839	29.240	26.605	22.805	18.199	13.809	10.963	10.596
Dec	35.148	34.698	33.665	31.625	28.223	23.566	18.534	14.519	12.429	12.200
Jan	41.466	40.967	39.830	37.590	33.851	28.692	23.032	18.388	15.846	15.451
Feb	52.500	52.007	50.667	47.742	42.673	35.855	28.956	23.945	21.531	21.106
Mar	51.149	50.676	49.393	46.592	41.737	35.207	28.599	23.799	21.488	21.080
Apr	44.741	44.225	42.824	39.766	34.465	27.335	20.120	14.880	12.356	11.912
May	33.158	32.734	31.768	29.864	26.686	22.301	17.490	13.543	11.382	11.046
Jun	22.846	22.555	21.885	20.561	18.355	15.334	12.070	9.465	8.110	7.961
Jul	20.775	20.471	19.859	18.731	16.870	14.189	10.938	7.840	5.831	5.572
Aug	20.786	20.555	20.107	19.279	17.845	15.561	12.322	8.494	5.290	5.002
Sep	20.517	20.360	20.072	19.549	18.617	17.002	14.325	10.255	5.071	5.071
Natural Duration curves										
Oct	631.571	345.904	243.160	171.151	109.282	82.788	63.762	40.931	25.336	5.780
Nov	918.985	673.117	500.725	372.319	254.479	224.730	170.517	136.802	59.047	17.191
Dec	1020.120	723.973	540.834	415.502	339.382	299.522	213.527	114.475	82.269	33.774
Jan	1270.557	903.875	638.303	521.184	395.508	298.484	227.173	172.547	96.210	43.003
Feb	2052.472	1278.741	891.353	538.802	436.872	319.498	273.276	229.588	135.235	45.705
Mar	1562.280	1034.289	698.014	607.411	468.765	335.738	252.647	200.396	126.176	41.514
Apr	899.541	636.867	406.590	319.606	288.630	238.515	170.093	119.487	75.598	29.344
May	353.271	265.091	197.431	133.277	106.732	82.154	72.353	47.551	34.606	11.470
Jun	192.647	140.895	91.454	71.937	60.683	56.296	43.534	33.029	22.477	11.617
Jul	149.578	100.896	84.569	67.040	47.525	39.221	32.818	26.329	19.108	15.084
Aug	152.337	106.582	83.796	60.140	50.881	34.069	27.770	23.466	18.246	14.445
Sep	229.946	126.123	86.844	65.251	48.935	39.734	28.403	21.748	13.353	8.333

The flows set by the Reserve should be adequate to attain the specific EC for fish at the Boegoeberg Site, as the requirements for the different life-stages of the indicator guild (semi-rheophilic) are well documented and were strongly considered in determining the stress index for the site.

The floods recommended by the reserve will be adequate to ensure that all applicable flood requirements of the fish assemblages (including migration and spawning cues, flushing of sediment, etc.) will be provided for.

As a result of the absence of any true rheophilic fish species in this system, the large semi-rheophilic flow guild was selected as indicator group for setting flows. This group generally requires fast shallow, fast intermediate and fast deep flow-depth categories over good quality substrate (gravel and cobbles) for spawning (Table 4.10). Egg and embryo development also takes place in these habitats, while larvae prefer slow deep with substrate as optimal habitats. Juvenile and adult specimens have a high preference for slow deep, fast shallow, fast intermediate and fast deep habitats with substrate and water column as cover. Flows should furthermore remain adequate to allow migration between reaches, thus depth in riffle and rapids should remain adequate, especially during the wet season. Emphasis was placed on the requirements of the *Labeobarbus* species (*L. kimberleyensis* and *L. aeneus*) within this group in setting flows.

Table 4.10 Summarised habitat requirements for different life stage of the large semi-rheophilic indicator group (Louw and Koekemoer (Eds.), 2010).

Fish sp	Spawning	Egg and embryo development	Larvae	Juveniles	Adults
Labeobarbus aeneus	**FS, FI over substrate**. Spring to midsummer (September to January). Fast (>0.3m/s) with substrate (gravel and cobbles). flowing water, well oxygenated and low sediments loads. *L. aeneus* breeds from spring through to mid-summer after the first substantial rains of the season.	**FS with substrate (gravel/cobbles).** Flows to last long enough for eggs to hatch and embryos to develop. Sudden pulse after spawning may cause many of the eggs to be washed out of the spawning beds and die in the deeper less oxygenated pools and also be smothered by silt. Also if the flow subsides it could result in higher temperatures and lower oxygen thus killing the developing embryos or leaving them stranded. The fertilised eggs of BAEN incubate for 3 to 8 days at 18-21.5°C, where after the embryos remain in the gravel for a further period.	**SD with substrate.** (October to February). Cover, flow, oxygen and low silt loads. At swim-up they require suitable flows to move them away from the spawning beds to the nursery areas usually shallow backwaters which are warmer. If the backwaters are not there due to too high or too low flows the larval fish will die out as this is a very critical stage where they have to start eating. Larvae are initially inactive and sink to the bottom, not becoming mobile until 4 to 6 days after hatching. At this stage, they begin feeding on microscopic organisms.	**FS, FI and SS with substrates. SD at night.**	**SD, FD, FI and FS with substrates and water column.**
Labeobarbus kimberleyensis	**FS and FD with substrates** (**gravel, cobbles)** flowing water, well oxygenated and low sediments loads. The breeding season extends from mid to late summer. The species requires gravel beds in flowing water to spawn.	**FS and FI with substrate (gravel/cobbles).** Flows to last long enough for the embryos to develop and hatch out. The incubation period is 2 to 3 days and larvae become mobile after a further 3 to 4 days at 23-25°C.	**SD with substrate.**	**FI and SD with substrates.**	**SD, FD and FI with substrates and water column.**

Figure 4.1 Preference yellowfish feeding and spawning habitat below the dam wall at Boegoeberg.

Figure 4.1 shows the ideal spawning and living habitat for semi-rheophilic fish species such as the yellowfishes (i.e. fast flow over rocks and cobbles). Also note the marginal vegetation (instream marginally on island) in the background (sedges, reeds and grasses), which when inundated during spawning season create the ideal spawning habitat for fish species with a preference for these habitats.

Figure 4.2 Rapids on left side of channel.

Figure 4.2 shows ideal rapid habitat for semi-rheophilic fish species. This habitat may be lost at the site if the minimum flow requirements as set by the reserve are not administered.

5 IMPACT ASSESSMENT

5.1 METHODS

Assessment of predicted significance of impacts was done in accordance with standardised and internationally recognised methodology[1] as outlined by Aurecon S.A. requirements. Such methodology is applied in this study to assess the significance of the potential environmental impacts of the proposed HS development as follows:

For each impact, the EXTENT (spatial scale), MAGNITUDE (size or degree scale) and DURATION (time scale) are described Table 5.1). These criteria are used to ascertain the SIGNIFICANCE of the impact (Table 5.2), firstly in the case of no mitigation and then with the most effective mitigation measure(s) in place.

Table 5.1 Assessment criteria for the evaluation of impacts.

CRITERIA	CATEGORY	DESCRIPTION
Extent or spatial influence of impact	**National**	Within the country
	Regional	Within the province/recognised region
	Local	On site or within 1,000m of the impact site
***Magnitude of impact (at the indicated spatial scale)**	**High**	Social and/or natural functions and/ or processes are severely altered (i.e. function is severely hampered and processes are unlikely to function)
	Medium	Social and/or natural functions and/ or processes are notably altered (i.e. function is affected to a noticeable degree and processes struggle to function effectively)
	Low	Social and/or natural functions and/ or processes are slightly altered (i.e. while function is affected in a measurable way, processes are likely to function, albeit sub-optimally)
	Very Low	Social and/or natural functions and/ or processes are negligibly altered (i.e. function is slightly affected and processes are likely to function effectively)
	Zero	Social and/or natural functions and/ or processes remain unaltered
Duration of impact	**Long Term**	More than 10 years
	Medium Term	Up to 10 years

[1] As described, inter alia, in the South African Department of Environmental Affairs and Tourism's Integrated Environmental Management Information Series (Gov. of SA, 2002).

	Short term (construction period)	Up to 3 years

*NOTE: Where applicable, the magnitude of the impact has to be related to the relevant standard (threshold value specified and source referenced).
The magnitude of impact is based on specialist knowledge of that particular field.

The SIGNIFICANCE of an impact is derived by taking into account the temporal and spatial scales and magnitude. Such significance is also informed by the context of the impact, i.e. the character and identity of the receptor of the impact. The means of arriving at the different significance ratings is explained in Table 5.2 (developed by Ninham Shand in 1995).

Table 5.2 Definition of Significance ratings.

SIGNIFICANCE RATINGS	LEVEL OF CRITERIA REQUIRED
High	- High magnitude with a regional extent and long term duration - High magnitude with either a regional extent and medium term duration or a local extent and long term duration - Medium magnitude with a regional extent and long term duration
Medium	- High magnitude with a local extent and medium term duration - High magnitude with a regional extent and construction period or a site specific extent and long term duration - High magnitude with either a local extent and construction period duration or a site specific extent and medium term duration - Medium magnitude with any combination of extent and duration except site specific and construction period or regional and long term - Low magnitude with a regional extent and long term duration
Low	- High magnitude with a site specific extent and construction period duration - Medium magnitude with a site specific extent and construction period duration - Low magnitude with any combination of extent and duration except site specific and construction period or regional and long term - Very low magnitude with a regional extent and long term duration
Very low	- Low magnitude with a site specific extent and construction period duration - Very low magnitude with any combination of extent and duration except regional and long term
Neutral	- Zero magnitude with any combination of extent and duration

Once the significance of an impact has been determined, the PROBABILITY of this impact occurring as well as the CONFIDENCE in the assessment of the impact is determined using the rating systems outlined in the Tables 5.3 and 5.4 respectively.

Table 5.3 Definitions of Probability ratings

PROBABILITY RATINGS	CRITERIA
Definite	Estimated greater than 95% chance of the impact occurring.
Probable	Estimated 5% to 95% chance of the impact occurring.
Unlikely	Estimated less than 5% chance of the impact occurring.

Table 5.4 Definitions of Confidence ratings

CONFIDENCE RATINGS	CRITERIA
Certain	Wealth of information on and sound understanding of the environmental factors potentially influencing the impact.
Sure	Reasonable amount of useful information on and relatively sound understanding of the environmental factors potentially influencing the impact.
Unsure	Limited useful information on and understanding of the environmental factors potentially influencing this impact.

* The level of confidence in the prediction is based on specialist knowledge of that particular field and the reliability of data used to make the prediction.

Lastly, the REVERSIBILITY of the impact has been estimated using the rating system outlined in Table 5.5.

Table 5.5 Definitions of Reversibility ratings

REVERSIBILITY RATINGS	CRITERIA
Irreversible	The activity will lead to an impact that is permanent.
Reversible	The impact is reversible, within a period of 10 years.

5.2 POTENTIAL IMPACTS FOR CONSTRUCTION PHASE

5.2.1 Impacts

The proposed hydropower station would consist of the following components:

1. An off-take structure above the existing Boegoeberg weir to facilitate the abstraction of water;
2. Water conveyance infrastructure comprising a combination of either an open canal, a pipeline and/or culverts to convey the water to the head pond;
3. A head pond;
4. Steel (or other suitable pipeline material) penstocks to transfer the water to the power chamber;
5. A power chamber to house the turbines and generation equipment;
6. Outlet channel (tailrace) to return the abstracted water back into the river; downstream of the power chamber;
7. A switchroom and transformer yard;
8. A high voltage (HV) distribution line to evacuate the power to a nearby Fibre Substation; and
9. Access roads to the site (4-6m wide).

Components 1 through 7 are listed as HS Layout in assessments tables (Tables 5.6 and 5.7), component 8 as Transmission route 1 and component 9 as Roads.

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Based on the project design specifications that were given, the potential impacts for the construction phase are outlined and assessed in Table 5.6, together with mitigation measures (Table 5.7).

Table 5.6 Assessment of the potential impacts at the Boegoeberg Dam site during the construction phase of the proposed activity.

Project	Impact Reference	Key impacts	Extent	Magnitude	Duration	SIGNIFICANCE (Without mitigation)	SIGNIFICANCE (With Mitigation)	Probability	Confidence	Reversibility
HS Layout (preferred)	1	Riparian vegetation removal / clearing (Unit is considered Endangered) - (especially of *Acacia*	Local	Low	Long Term	Low	Low	Definite	Certain	Irreversible
Roads			Regional	Medium	Long Term	Medium	Low	Probable	Certain	Irreversible
Transmission Route 1			Regional	Medium	Long Term	Medium	Low	Probable	Certain	Irreversible

Project	Impact Reference	Key impacts	Extent	Magnitude	Duration	SIGNIFICANCE (Without mitigation)	SIGNIFICANCE (With Mitigation)	Probability	Confidence	Reversibility
		erioloba which is a long lived, slow growing species that is listed by SANBI as protected and has been assigned an IUCN status of "Declining" due to lack of recruitment, and *Searsia pendulina* which is endemic).								
HS Layout (preferred)	2	Sediment input into the river channel/s (deterioration of bottom substrate habitats for biota), elevated turbidity	Local	Medium	Short term	Medium	Low	Probable	Certain	Reversible
Roads			Local	Low	Short term	Low	Very Low	Probable	Certain	Reversible
Transmission Route 1			Local	Low	Short term	Low	Very Low	Probable	Certain	Reversible
HS Layout (preferred)	3	Water quality deterioration (increased turbidity, accidental spills, sanitation, erosion from stored aggregates), especially disturbance of fine sediments in the weir	Local	Medium	Short term	Medium	Low	Probable	Certain	Reversible
Roads			Local	Low	Short term	Low	Very Low	Probable	Certain	Reversible
Transmission Route 1			Local	Low	Short term	Low	Very Low	Probable	Certain	Reversible
HS Layout (preferred)	4	Increased invasion by alien plant species, especially perennial aggressive species such as *Prosopis glandulosa* and *Sesbanea punicea.*	Local	Medium	Long Term	Medium	Low	Probable	Certain	Reversible
Roads			Regional	Medium	Long Term	High	Low	Probable	Certain	Reversible
Transmission Route 1			Regional	Medium	Long Term	High	Low	Probable	Certain	Reversible
HS Layout (preferred)	5	Bank destabilisation	Local	Medium	Short term	Medium	Low	Probable	Certain	Reversible

Project	Impact Reference	Key impacts	Extent	Magnitude	Duration	SIGNIFICANCE (Without mitigation)	SIGNIFICANCE (With Mitigation)	Probability	Confidence	Reversibility
Roads		and erosion, especially given the alluvial nature of the majority of banks.	Local	Low	Short term	Low	Very Low	Probable	Certain	Reversible
Transmission Route 1			Local	Low	Short term	Low	Very Low	Probable	Certain	Reversible
HS Layout (preferred)	6	Noise and visual (increased activity of people and construction equipment) disturbance to riparian fauna.	Local	Medium	Short term	Low	Low	Probable	Certain	Reversible
Roads			Local	Medium	Short term	Low	Low	Probable	Certain	Reversible
Transmission Route 1			Local	Medium	Short term	Low	Low	Probable	Certain	Reversible
HS Layout (preferred)	7	Physical disturbance such as excavations and clearing, which may include blasting, in or near the river.	Local	Medium	Short term	Medium	Medium	Probable	Certain	Reversible
Roads			Local	Medium	Short term	Medium	Low	Probable	Certain	Reversible
Transmission Route 1			Local	Medium	Short term	Medium	Low	Probable	Certain	Reversible
HS Layout (preferred)	8	Waste reticulation and removal	Local	Low	Short term	Low	Very Low	Probable	Sure	Reversible
Roads			Local	Low	Short term	Very Low	Neutral	Probable	Sure	Reversible
Transmission Route 1			Local	Low	Short term	Very Low	Neutral	Probable	Sure	Reversible
HS Layout (preferred)	9	Cutting into rock and rock faces at site – loss of natural rock features. Area has recreational value – resorts around dam; deterioration of aesthetic value of area.	Local	Low	Short term	Low	Low	Probable	Sure	Reversible
Roads										
Transmission Route 1										
HS Layout (preferred)	10	Decreased overhanging vegetation for cover for fish result in decreased FROC of	Local	Low	Short term	Low	Low	Probable	Sure	Reversible
Roads										
Transmission Route 1										

Project	Impact Reference	Key impacts	Extent	Magnitude	Duration	SIGNIFICANCE (Without mitigation)	SIGNIFICANCE (With Mitigation)	Probability	Confidence	Reversibility
		species with preference for these habitats. Loss of habitat (cover) also results in increased exposure to predators.								
HS Layout (preferred)	11	Decreased abundance, and therefore FROC - related to over utilization of fish for human consumption. Especially during construction when foreign workers enter an area with good fishing potential. Poaching and over-fishing of fish using nets (gill and seine nets, often home-made).	Local	High	Short term	Medium	Low	Probable	Certain	Reversible
Roads										
Transmission Route 1										
HS Layout (preferred)	12	Reduced spawning success resulting in decreased FROC of many species, due to erosion and siltation	Local	Medium	Short term	Medium	Low	Probable	Certain	Reversible
Roads										
Transmission Route 1										

5.2.2 Mitigation

Proposed mitigation measures for impacts listed in Table 5.6 during the construction phase are shown in Table 5.7.

Table 5.7 Mitigation measures for potential impacts during the construction phase. Impact reference number refers to those listed in Table 5.6.

Impact Reference	Project	Mitigation Potential	Mitigation Measures
1	Layout (preferred)	Low	Minimise footprint by demarcation of impact zone (such as fencing / markers to limit access elsewhere); Minimise removal or disturbance of adult trees especially *A. erioloba* and *Searsia pendulina* specimens. Construction camps should be fenced and set back at least 32m from any watercourse. The collection of firewood by construction workers should be prohibited.
	Roads	Medium	As above. In addition – where the roads are to follow the Transmission line, please see below for re-routing options.
	Transmission Route 1	High	Minimise footprint by demarcation of impact zone (such as fencing / markers to limit access elsewhere); Minimise removal or disturbance of adult trees especially *A. erioloba* and *Searsia pendulina* specimens. Construction camps should be fenced and set back at least 32m from any watercourse. The collection of firewood by construction workers should be prohibited. Since much of the Transmission line occurs within the riparian zone along the Orange River, effective mitigation would be to reroute this portion so as traverse the terrestrial zone and f all outside the Orange River riparian zone.
2	Layout (preferred)	Medium	Use of erosion control measures to minimise erosion at excavation sites or aggregate storage sites. Construction activities to take place in dry season as far as possible.
	Roads	High	As above as well as keeping activities and aggregate storage outside of riparian zones / drainage channels.
	Transmission Route 1	High	As above
3	Layout (preferred)	High	Employ recognised best practices with respect to machinery washing and maintenance; procedures for discarding unused concrete; storage of hazardous materials; provision of sanitation facilities, erosion prevention, etc.
	Roads	High	As above
	Transmission Route 1	High	As above
4	Layout (preferred)	High	Removal of perennial alien species such as *Prosopis glandulosa* and *Sesbanea punicea* at sites disturbed or cleared by construction activities. Care should be taken not to introduce additional seed or propagules of alien species that may be present in aggregates brought to site. Vegetate areas that are not meant to stay clear as soon as possible after construction with a local indigenous species.
	Roads	High	As above
	Transmission Route 1	High	As above
5	Layout (preferred)	High	Best practices for design and prevention of bank erosion, especially since alluvium is fine on the right bank. Minimised vegetation removal on banks will help with stabilisation Vegetate areas that are not meant to stay clear as soon as possible after construction with a local indigenous species.
	Roads	High	As above
	Transmission Route 1	High	As above
6	Layout (preferred)	Low	Restrict unnecessary movement of people and plant in the riparian zone or drainage channels.

Impact Reference	Project	Mitigation Potential	Mitigation Measures
	Roads	Low	As above
	Transmission Route 1	Low	As above
7	Layout (preferred)	Low	Prevent unnecessary disturbance of substrates, fauna or flora.
	Roads	Low	As above
	Transmission Route 1	Low	As above
8	Layout (preferred)	High	Employ recognised best practices, and prevent spillage into the river, either directly or via soak aways.
	Roads	High	As above
	Transmission Route 1	High	As above
9	Layout (preferred)	Medium	Use of natural materials such as rock from site in the construction process of plant.
	Roads		As above
	Transmission Route 1		As above
10	Layout (preferred)	High	Rehabilitate marginal and riparian vegetation after construction where necessary.
	Roads		
	Transmission Route 1		
11	Layout (preferred)	High	Regulate fishing from start. Ban the use of fishing techniques other than angling i.e. ban gill nets if used by workers on site. Apply regulations firmly.
	Roads		
	Transmission Route 1		
12	Layout (preferred)	High	Minimise bank destabilisation, vegetation removal and erosion.
	Roads		
	Transmission Route 1		

5.3 POTENTIAL IMPACTS FOR OPERATIONAL PHASE

Based on the project design specifications that were given, the potential impacts for the operational phase are outlined and assessed in Table 5.8, together with mitigation measures (Table 5.9). Project components are as for construction phase.

5.3.1 Impacts

Table 5.8 Assessment of the potential impacts at the Boegoeberg Dam site during the operational phase of the proposed activity.

Project	Impact Reference	Key impacts	Extent	Magnitude	Duration	SIGNIFICANCE (Without mitigation)	SIGNIFICANCE (With Mitigation)	Probability	Confidence	Reversibility
HS Layout (preferred)	1	Potential erosion / bank destabilization at the outlet point.	Local	Low	Short Term	Low	Low	Probable	Sure	Irreversible
Roads										
Transmission Route 1										
HS Layout (preferred)	2	Decreased wet season flows in river section between the intake and outlet, especially bedrock habitats in channels 1 and 2 (Fig 2.2) i.e. left and central channels	Local	Medium	Long term	Medium	Low	Probable	Sure	Irreversible
Roads										
Transmission Route 1										
HS Layout (preferred)	3	Lack of capacity / commitment to manage operations in terms of environmental flow requirements.	Local	Medium	Long term	Medium	Low	Probable	Unsure	Reversible
Roads										
Transmission Route 1										
HS Layout (preferred)	4	Birds colliding with overhead power lines, which cut across riparian corridors.	Local	Low	Long Term	Low	Very Low	Probable	Certain	Reversible
Roads			Local	Low	Long Term	Low	Very Low	Probable	Certain	Reversible
Transmission Route 1			Local	Low	Long Term	Low	Very Low	Probable	Certain	Reversible
HS Layout (preferred)	5	Maintenance / clearing of vegetation in power								
Roads										

Project	Impact Reference	Key impacts	Extent	Magnitude	Duration	SIGNIFICANCE (Without mitigation)	SIGNIFICANCE (With Mitigation)	Probability	Confidence	Reversibility
Transmission Route 1		line servitudes.	Local	Medium	Long term	Medium	Low	Definite	Certain	Irreversible
HS Layout (preferred)	6	Open canal (should this option occur) acting as a barrier to faunal movement, and also as a drowning risk.	Local	Low	Long term	Low	Very Low	Probable	Certain	Reversible
Roads										
Transmission Route 1										
HS Layout (preferred)	7	Pulsed flows in the section of river between intake and outflow if turbines switched off frequently due to technicalities rather than flows becoming too low.	Local	Low	Long term	Low	Low	Probable	Sure	Reversible
Roads										
Transmission Route 1										
HS Layout (preferred)	8	Loss in abundance and diversity of especially fast instream habitats as result of decreased base flows.	Local	Medium	Long term and/or Intermittent during operation	Medium	Low	Probable	Sure	Reversible
Roads										
Transmission Route 1										
HS Layout (preferred)	9	Decrease in FROC and abundance of fish species with preference for fast habitats.	Local	Medium	Long term and/or Intermittent during operation	Medium	Low	Probable	Sure	Reversible
Roads										
Transmission Route 1										
HS Layout (preferred)	10	Reduced spawning success resulting in decreased FROC of many species.	Local	Medium	Long term and/or Intermittent during operation	Medium	Low	Probable	Sure	Reversible

Project	Impact Reference	Key impacts	Extent	Magnitude	Duration	SIGNIFICANCE (Without mitigation)	SIGNIFICANCE (With Mitigation)	Probability	Confidence	Reversibility
Roads										
Transmission Route 1										
HS Layout (preferred)	11	Flow modification: Absence of spring flushes, reduced habitat suitability and stimuli, flow pattern disrupts normal breeding cycle.	Local	Medium	Long term and/or Intermittent during operation	Medium	Low	Probable	Sure	Reversible
Roads										
Transmission Route 1										
HS Layout (preferred)	12	Increased turbidity and disturbed bottom substrates, reduced bottom substrate quality and water quality for indigenous fish (especially breeding habitats) due to bank destabilisation, veg removal and storm water run-off, and flow regulation.	Local	Medium	Long term and/or Intermittent during operation	Medium	Low	Probable	Sure	Reversible
Roads										
Transmission Route 1										

5.3.2 Mitigation

Proposed mitigation measures for impacts listed in Table 5.8 during the operational phase are shown in Table 5.9.

Table 5.9 Mitigation measures for potential impacts during the operational phase. Impact reference number refers to those listed in Table 5.8.

Impact Reference	Project	Mitigation Potential	Mitigation Measures
1	Layout (preferred)	Medium	Correct design and reinforcing to prevent bank cutting, especially at high flows. Conservation of as much vegetation cover as possible during construction will also mitigate in the longer term. Rehabilitation of vegetation after construction.
	Roads		
	Transmission Route 1		
2	Layout (preferred)	High	Ensure environmental flows occur before intake comes into operation. Allow small and moderate flood requirements to pass over the Dam wall in keeping with final flow requirements (Table 4.6).
	Roads		
	Transmission Route 1		
3	Layout (preferred)	High	Effective training and commitment to ensure capacity exists and operate to ensure environmental flow requirements are not compromised.
	Roads		
	Transmission Route 1		
4	Layout (preferred)	High	Use of bird flappers on powerlines. Keep power lines as high as reasonably possible, where crossing the river, as birds tend to fly at levels close to the river. Annually contact the Endangered Wildlife Trust to see if bird flappers more effective at river crossings have been designed, and, where available, implement these for line sections crossing the river.
	Roads	High	As above
	Transmission Route 1	High	As above
5	Layout (preferred)		
	Roads		
	Transmission Route 1	Low (in current position); High if moved outside of the riparian zone	Position Transmission route so as not to occur with the riparian zone (except where direct crossing are required) of the Orange River; Prevent clearing of vegetation where not necessary.
6	Layout (preferred)	Medium	Fence all access to open canal and maintain fences, to prevent drowning.
	Roads		
	Transmission Route 1		

Impact Reference	Project	Mitigation Potential	Mitigation Measures
7	Layout (preferred)	High	Monitor flows through the turbines at sub-daily resolution, and ensure adequate maintenance of turbines to promote consistency in operation as and when flows enter the intake.
	Roads		
	Transmission Route 1		
8	Layout (preferred)	High	Adhere to minimum flow requirements as determined by reserve (see Table 4.6 for final flows).
	Roads		
	Transmission Route 1		
9	Layout (preferred)	High	**Adhere to minimum flow requirements as determined by reserve (see Table 4.6 for final flows).**
	Roads		
	Transmission Route 1		
10	Layout (preferred)	High	**Adhere to minimum flow requirements as determined by reserve (see Table 4.6 for final flows).**
	Roads		
	Transmission Route 1		
11	Layout (preferred)	High	**Adhere to minimum flow requirements as determined by reserve (see Table 4.6 for final flows).**
	Roads		
	Transmission Route 1		
12	Layout (preferred)	High	Adhere to minimum flow requirements as determined by reserve (see Table 4.6 for final flows).
	Roads		
	Transmission Route 1		

6 CONCLUSIONS AND RECOMMENDATIONS

The zone of impact below the Boegoeberg Dam wall is a complicated anastomosing channel mostly dominated by bedrock and fast lowing habitats, but with some alluvial sections and slower deep water. These fast flowing bedrock habitats are important spawning habitats for especially yellowfish. The spawning habitats consist of fast flow over rocky substrate. Cobble beds are of major importance for fish spawning. These areas should be protected, and the minimum flow requirements as determined by the Reserve should be adhered to in order to ensure successful spawning of yellowfish in the area. Other fish such as the Orange River mudfish, and the rock catfish also utilise these habitats for spawning. The species mentioned above also have a preference for these habitats in terms of feeding and cover.

The impact of the proposed hydro power station will only be local, and the river should again attain its current integrity downstream of the tailrace of the plant. It is, however, important to protect rare spawning areas and ensure its functioning in order to ensure the survival of our already scarce and endangered fish species such as the largemouth yellowfish and the rock catfish.

Construction (laying) of cobble beds below the tailrace of the plant should be considered, as this will create additional spawning habitat, reduce scour and it may replace habitat lost due to the development and its activities.

It is also important to note that the marginally vegetated areas next to the cobble beds and river channels be inundated during spawning season to facilitate species with a spawning preference for these habitats.

The riparian zone is well vegetated with a threatened vegetation unit and is dominated by woody species, reeds and sedges. Other than clearing and removal of vegetation the proposed activity should not change the present ecological state as long as the environmental flows (as set out above) are not prevented, including small and moderate floods. The transmission line in its proposed position will result in significant removal of riparian vegetation and fragmentation of the riparian corridor. This loss in riparian zone integrity will result in loss of functionality and diversity, especially as a corridor connecting upstream and downstream environments. It is strongly suggested that the transmission line and associated roads be moved outside of any riparian zone, except where direct crossing is necessary.

7 REFERENCES

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Impact of no flow on fish at the proposed hydro-power station site directly below Boegoeberg Dam

The project would consist of an off-take structure at the weir and a canal/ tunnel of up to 400m long (AURECON, 2013). The hydro scheme requires a flow of up to 120m^3/s when sufficient river flow is available after environmental releases. The off-take structure would consist of a predominantly concrete structure built into the riverbank 120m to 250m upstream of the existing weir wall. The tailrace canal would be approximately 100m long.

The impact of water abstraction for the proposed hydro-power station at Boegoeberg is, therefore, going to be 400m long, reaching from above the weir to below, with the tailrace and impacted area downstream of the weir expected to be 100m to 150m long.

The hydro scheme will require a flow, for operation, in excess of the current flows experienced during low flow season, implicating that the river channel directly below the weir will be dry during low flow seasons for a distance of 100-150m.

Unnatural zero flow conditions are generally undesirable for rivers as it will negatively affect the biotic integrity of the system. The biotic integrity of the area or site at Boegoeberg Weir is, however, already compromised due to the presence of the weir. The main impacts of large weirs such as at Boegoeberg are mainly flow regulation, upstream inundation, in-stream habitat loss, and the loss of migration of fish further upstream. The most important habitat which will be impacted below the weir is the rapid and riffle habitat with rocky substrate.

The rapids below the dam wall are, however, not unique to the reach and rapids and cobble beds also occur further downstream, but the loss of spawning habitat below the dam will have a negative impact on the spawning success of the fish in this reach, and these types of habitats need to be protected as they become less and less due to the impact of dams (inundation) and water abstraction from our rivers.

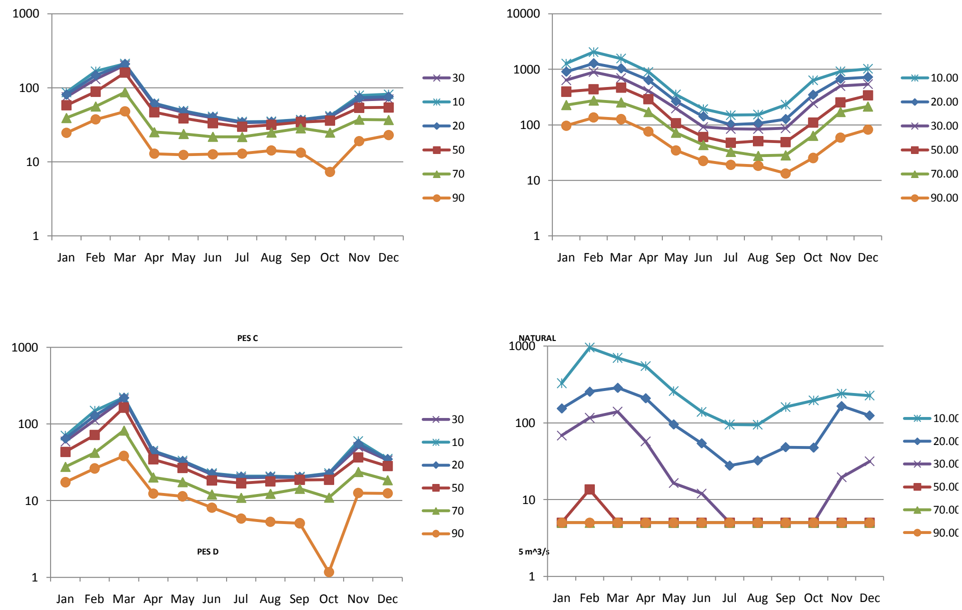
The area directly below the weir is, therefore, mainly of importance in terms of spawning for fish and habitat for stream loving aquatic species including fish species such as yellowfish.

The loss of flow in the rapids directly below the dam wall will, however, only be of high significance for the immediate site (i.e. at the dam wall), but of lower significance to the reach.

Other habitats that occur below the dam wall such as the slow deep channels with marginal vegetation in the mid- and right-hand sections of the river will also be affected, but is of lesser importance as it is utilised to a lesser extent by fish. These habitats are also more abundant throughout the system (Kotze and Koekemoer, 2010)

The impact of no flow at the site is considered to be low as a relatively short length of river (100-150m) will be affected, during low flow seasons/periods.

The main criterion for fish at the site is that there should be enough flow during high flow season over the weir to facilitate spawning in the rapid and rocky habitat below the weir (see box below for comparison of flow scenarios).



Box 1. Comparison of flow scenarios: top left – PES C; top right – Natural; bottom left – PES D; bottom right – 5m^3/s.

The river below the dam wall was divided into three channels during the survey: A right-hand channel which consisted mostly of slow deep and shallow habitat with sandy bottom substrate; and a middle and left-hand channel with rocky rapid and riffle habitat. The right-hand and middle channels are of less importance in terms of fish as the habitat diversity is low with minimal cover. The left-hand channel is of higher importance due to various flow depth classes being present as well as ample cover in terms of rocks and water column.

Figure 1 indicates the habitat in the left-hand channel downstream from the dam wall which will be affected by the proposed development. This habitat will be dry during low flow season.

Figure 1: **Downstream view of dominant habitat of left-hand channel at and below the site.**

Figure 2 shows the right-hand channel of the river below the dam wall consisting of slow shallow and slow deep sandy habitat. Very little cover is present at these habitats.

Figure 2: **Dominant habitat of right-hand channel at site.**

Figures 3 and 4 show the habitat directly below the dam wall on left of the main river channel that will be affected and laid dry during low flows.

Figure 3: **Main habitat section below dam expected to be dry or lost during low flow periods.**

Figure 4: **Main section of habitat on left-hand of river below dam expected to be dry or lost.**

The flow was measured to be 42m^3/s further downstream from the site at the time of the survey. There are, however, two channels within the reach between the Boegoeberg Weir and the gauging station, which supplement the flow in the Orange River from an irrigation channel that flows parallel to the river on the left bank. One of these channels (upper channel) delivers approximately 5m^3/s to the river. The outlet of this channel falls within the lower reaches of the affected area, which means that this additional inflow will help mitigate the effects of the proposed water abstraction. This channel should maintain fish and fish habitats in this area within the deeper sections of the main river and its deeper pools during low flow periods.

Both the channels from the irrigation channel have adequate and even fast flow with ample habitat and cover in terms of water column and rocky substrate. Overhanging vegetation is also abundant. These two channels are, therefore, of importance as they provide additional habitat for fish and flow to the main river.

When the above is taken into account it can be reasoned that the flow over the Boegoeberg Dam wall was approximately 30m^3/s at the time of the survey. If this flow is spread between the three channels identified within the main channel below the weir, it can be estimated that there was a flow of approximately 10m^3/s per channel. It was observed during the survey that half of the observed flow should be adequate to maintain the river during low flows. This calculates to 5m^3/s per channel (i.e. 15m^3/s for the three channels combined within the main stream). The flow of the upper supplementing channel from the irrigation channel falling within the affected reach will, therefore, be of high importance to the site as it will provide flow to the left-hand channel which was identified as the most important section of the river within the development area.

Figure 5 indicates the upper channel falling within the development area. The channel has a fast deep flowing stream with ample cover for fish (water column, rocks, and vegetation overhang). These channels are important as they provide additional habitat for fish.

Figure 5: Fast flow from the upper irrigation canal to the main river in impacted area of site.

Figure 6: General habitat characteristics of the stream channels fed from the irrigation channel feeding into the Orange River.

Figure 6 shows the general habitat of the lower channel flowing from the irrigation canal into the Orange River. Rocky substrate (rocks, cobbles, and gravel) seems to be dominant (Figure 7), and is also the preferred habitat of the more sensitive species.

The additional habitat created by these side channels from the irrigation canal are important and will help with the mitigation of the upstream impacts from the proposed development.

Figure 7: Substrate in the side channels in area and downstream of site.

General Discussion:
The area below the Boegoeberg Weir is mainly important in terms of spawning for fish. It is, however, expected that there would be enough flow over the weir during floods (high flow season) to facilitate spawning.

The supplementing flows (two channels observed) from the irrigation canal will help mitigate effects (no flow) from the proposed development. These channels also provide the preferred habitat for the more sensitive species.

It will be preferable (and recommended) if the flows from the side channels from the irrigation canal can be maintained.

The affected reach (100m) is relatively short if the extent of the development and the size of the Orange River are taken into account. The impact can, therefore, be seen as low for the reach.

The advantages of the development seem to outweigh the disadvantages to the system, but it is important to note that from a conservation point of view the development and the effect of total loss of flow still remain undesirable to the natural area and ecosystem.

It is still recommended that some flow, if possible, is released to help maintain the area below the weir especially the left-hand channel in the mainstream.

The tailrace from the hydro power scheme may also provide new habitat for fish as it will most probably flush sand and sediment from the right-hand channel creating new rocky substrate for fish. In addition constructed cobble beds will provide additional fish habitat and serve to mitigate other losses.

It is highly likely the there will be reed encroachment is the impacted section.

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Simon Clark

From: James MacKenzie <bioriver@vodamail.co.za>
Sent: Friday, February 07, 2014 8:47 AM
To: Simon Clark
Subject: RE: Sedimentation Boegoeberg - Aquatic assessment

Hi Simon
Please refer to our comment about the sediment management statement below
Thanks
James

RE The sediment removal from Boegoeberg Dam:

Negative impacts of sedimentation include:
Habitat loss – embedding of interstitial spaces between gravel and cobbles
Oxygen loss for aquatic biota
Loss of visibility / sunlight penetration
Loss of plant growth
Clogging of fish gills and gilled invertebrates
Increased turbidity will impact the whole food web
Increased toxicity due to metals bound to sediments

Statement:
If the operators of the hydro-electrical scheme adhere to the proposed sediment removal or dredging plan for Boegoeberg Dam there will be no foreseen negative impacts on the river system. The sediment removal plan, as proposed, states that the sediment or sediment rich water will be pumped downstream from the dam to 2 or 3 silt storage basins and the water allowed to drain. The dry sediment will then be removed by a third party. According to this plan sediment will be removed from the system which will result in positive effects and outcomes for all parties involved and the ecosystem in general.

If the operators do not adhere to the sediment dredging plan the above mentioned negative impacts will take effect on the river system below the weir and further downstream. From a fish point of view sedimentation will cause the general loss of oxygen from the water, a loss of habitat, and the clogging of gills. Loss of habitat in terms of cover and feeding substrate will affect algae feeders such as the Labeo's and the rock catfish in terms of cover.

The rock catfish utilises rocky habitat in flowing water, favouring rapids, and it feeds on invertebrates taken from rock surfaces (Skelton, 1993). Skelton (1993) further states that the rock catfish is rare, uncommon, and threatened by gross habitat changes caused by construction of weirs and dams, extraction of water, pollution, alluvial mining operations and sedimentation from soil erosion.

Both yellowfishes that occur in the Orange River, along with the rock catfish, prefer clear flowing water (Skelton, 1993), and sedimentation will, therefore, have a negative impact on these species. Increased sedimentation and siltation will also have a negative impact on the development of fish eggs and larvae as sedimentation will smother the eggs. The above mentioned fish also need oxygen rich water for their survival, and increased turbidity will reduce the oxygen in the water which may lead to fish kills.

Skelton, P.H. 1993. A complete guide to the freshwater fishes of Southern Africa. Southern Book Publishers, Halfway House, South Africa.

From: Simon Clark [mailto:Simon.Clark@aurecongroup.com]
Sent: 06 February 2014 08:50 AM
To: bioriver@vodamail.co.za

Cc: Diane Erasmus
Subject: Sedimentation Boegoeberg - Aquatic assessment

Hi James

Please see the attached sediment management statement as discussed with Diane. Please give this your urgent attention and get back to us as soon as possible.

Kind regards

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