PROPOSED NCWABENI OFF-CHANNEL STORAGE DAM, KWAZULU-NATAL.

AQUATIC & RIVERINE ASSESSMENT; AND ICHTHYOLOGICAL IMPACT SURVEY, MAY 2012.

Prepared for:

Nemai Consulting
PO Box 1673, Sunninghill, 2157.
Tel: +27 (0) 11 781 1730

EnviRoss *CC*
PO Box 369, Wendywood, 2144.
Tel/fax: 011 706 9753
Cell: 082 293 5752
Email: admin@enviross.co.za

Report authors: **Mathew Ross (*Pr Sci Nat, MSc*), Dr Tahla Ross**

EnviRoss CC Report Ref: **ENV_Ncwabeni OCS Fishway_06/12**
Date: **June 2012**

Declaration

This report has been prepared according to the requirements of Section 33 (2) of the Environmental Impact Assessments Regulations, 2006 (GNR 385). We (the undersigned) declare the findings of this report free from influence or prejudice.

Report Authors:

Mathew Ross *Pr Sci Nat* (Ecological Sciences) 400061/09

MSc (Aquatic Health) (RAU);
Currently completing PhD (Aquatic Health), University of Johannesburg).

Field of expertise:

Fish ecology, fishway evaluations, biomonitoring and wetland evaluations, aquatic ecology, aquatic & terrestrial fauna and flora.

____________________ Date: 30 June 2012

Mathew Ross

Dr Tahla Ross

PhD (Zoology) (UJ);

Field of expertise:

Biomonitoring and wetland evaluations, aquatic ecology, aquatic & terrestrial fauna and flora.

____________________ Date: 30 June 2012

Dr Tahla Ross

EXECUTIVE SUMMARY

Introduction and Background.

In order to secure a more reliable source of water to meet the increase water demand of downstream users of the Mzimkhulu River, an off-channel storage dam has been proposed that will be able to store water during the high-flow season to be utilised during the low-flow season. Two site alternatives have been proposed, namely one on the Ncwabeni River and one on the Gugamela River – two river systems that are closely associated with one another and are both tributaries of the Mzimkhulu River. An abstraction/flow gauging weir will need to be constructed on the Mzimkhulu River in order to provide a pumping point for the off-channel storage dam. This weir would represent the only migratory barrier along the otherwise open Mzimkhulu River. This river, due to the retention if a high degree of ecological integrity and functionality has been identified as one of the priority rivers in the National Freshwater Ecosystems Priority Areas (Nel, *et al.,* 2011) and therefore mitigation measures are required in order to ensure that the proposed weir does not pose as a migratory barrier to aquatic biota requiring upstream and downstream access.

The aim of the survey was to assess the overall ecological integrity of the Ncwabeni, Gugamela and Mzimkhulu Rivers in order to evaluate the potential impacts of the various development activities on the systems. This would allow for the implementation of appropriate mitigation measures and allow for the delivery of biological information and requirements to the engineers and design teams to be incorporated into the overall planning and implementation of the various structural features.

Materials and Methods.

The following methodologies were applied during the survey:

- General riparian and habitat assessments:
    - Walk-about surveys both upstream and downstream of the survey sites;
- Aquatic habitat assessments:
    - *In situ* water quality (pH, oxygen content, dissolved oxygen, electro-conductivity (EC), total dissolved solids (Tds) and temperature);
    - IHAS (Integrated Habitat Assessment System) for habitat particular to aquatic macro-invertebrates;
    - IHI (Index of Habitat Integrity). A general impact assessment tool for each river reach.

- Aquatic macro-invertebrates:
    - SASS5 collection protocol.
- Ichthyofauna:
    - Electro-narcosis and cast netting at the various sites.

Results and Discussions.

General habitat descriptions:

The catchment areas of all three watercourses within the vicinity of the survey sites were found to have retained a high degree of functionality and overall integrity. Some commercial agriculture does occur, but limited impacts were noted to emanate from this.

Aquatic habitat descriptions:

Rivers and streams within the area were noted to be dominated by bedrock, boulders and gravel substrates. A diversity of biotopes was present within all the watercourses, which provided good habitat cover and flow-depth classes for fish and aquatic macro-invertebrate inhabitation.

Water quality.

The results from the *in situ* water quality parameter testing indicated that there were no limiting factors in terms of water quality that could potentially limit the aquatic biota. It was noted that the water temperature recorded at the Gugamela River was considerably colder than that taken at the Ncwabeni and Mzimkhulu Rivers, which could feature as a limiting factor to recruitment of fish from downstream.

Macro-invertebrate sampling:

The macro-invertebrate community structures from the SASS5 sampling scored overall high values, showing the habitat integrity and water quality features to have been retained. All the survey sites scored Present Ecological State (PES) ratings, according to the macro-invertebrate populations structures, of A to B/C. A relatively good ASPT (average score per taxon) was noted, reiterating the high degree of overall functionality of the riverine habitat.

Fish sampling:

The fish survey showed that the implementation of a fishway to mitigate the migratory barrier formation of the proposed weir is a necessity. The river at the survey area forms an important conduit for obligatory migratory species that would not be able to complete their life cycle within the system if migratory freedom was inhibited. A fishway has therefore been proposed.

Fish species populations were noted to be better represented in the Ncwabeni River than in the Gugamela River. Possible reasons are that the relatively cooler water temperatures of the Gugamela River creates a temperature barrier, making fish reluctant to recruit upstream or the presence of a poorly-designed bridge crossing that poses a migratory barrier under low to moderate flows inhibits upstream migrations. It is recommended that this be rectified accordingly.

Fishway evaluation:

A vertical slot fishway channel has been proposed for the weir. Further recommendations include the terracing of the weir with sloping sides to allow for splash zones to allow for migrational movements of juvenile eels and migrating invertebrates.

Impact significance and evaluation of alternatives:

An impact evaluation was undertaken for the various construction features and alternatives associated with the proposed development activities. After an evaluation of the two alternative locality proposals for the off-channel storage dam and the overall impacts imposed on the aquatic systems and catchments, it has been established the *Ncwabeni option be the preferred alternative*. This is largely due to the establishment of the quarry areas that are associated with the Ncwabeni site. After the dam construction, this quarry area will be inundated. This will therefore have a lesser overall impact footprint than if the dam was constructed on the Gugamela River as the quarry activities would still be undertaken at the Ncwabeni River.

The impact significance of the perceived impacts has been incorporated into an Environmental Management Plan (EMP), featured in Appendix D.

Conclusions & Recommendations:

After the impact survey it was found that there are impacts that are unavoidable pertaining to a development of this nature. The main impacting feature is the abstraction weir creating a migratory barrier to aquatic biota. Mitigation of this impact is possible with the implementation of a fishway. It is recommended that a monitoring programme be undertaken after the completion of the construction phase in order to evaluate the functionality of the fishway.

TABLE OF CONTENTS

LIST OF TABLES.

LIST OF FIGURES.

1. INTRODUCTION & TERMS OF REFERENCE.

The Ncwabeni Off-Channel Storage Scheme has been proposed where an abstraction weir will be constructed on the Mzimkhulu (=Umzimkhulu, = Mzimkulu) River and water pumped to a nearby storage dam that has been proposed on either the Ncwabeni or the Gugamela Rivers. The stored water is to serve the surrounding community with a reliable source of water.

The proposed project will consist of the following components:
1. An OCS dam on either the Ncwabeni River (site D2) or Gugamela River (site D3A);
2. An abstraction / gauging weir on the Mzimkhulu River;
3. An abstraction works with a mechanism to remove silt;
4. A pumps station and pipeline to deliver water to the dam; and
5. An outlet infrastructure to make measured releases back to the Mzimkhulu River.

The proposed construction site is located approximately 25 km northwest of Port Shepstone in KwaZulu-Natal Province (Figure 1). It falls within the Quaternary Catchment of T52M and the Mzimvubu Primary Catchment (Figure 2). It incorporates an area of approximately 312 km^2, with a catchment area dominated by sporadic rural settlement, with an increasing dominance of forestry and sugarcane farming toward the mid to upper catchment. The upper catchment areas originate within the UKhahlamba Drakensberg Range, with associated protected areas. The catchment and main watercourses therefore have retained a good Present Ecological State (PES), with the Mzimkhulu being classified as an overall A/B PES (DWA, 2011), meaning that it has retained near-natural functionality and ecological integrity. SANBI (2010) classified the Mzimkhulu River as a Class B PES, translating to *largely natural*. River ecosystems with a Class B PES are regarded as an Endangered habitat unit. The Mzimkhulu River catchment area is also regarded as one of the National Freshwater Ecosystem Priority Area (NFEPA), making it a strategically important river from an ecological perspective (Nel, *et al*., 2011).

Barriers along river courses have been around since ancient times, where ancient Chinese and Egyptians utilised weirs to develop intricate irrigation schemes (Northcote, 1998). The need for maintaining longitudinal connectivity has been recognised as early as the Middle Ages, when the decline of fish populations and harvesting was realised after the establishment of barrier structures within European rivers, especially the Danube. The harvesting of freshwater fish was a major source of food and therefore the decline of fish populations posed a threat to food security for surrounding communities (Jungwirth, *et al.,* 1998), but it has only been throughout the 300 years or so that the idea of fishways has been implemented as a means to conserve freshwater fish populations (Waidbacher & Haidvogl, 1998, Mallen-Cooper, 2007). The socio-economical importance of the Salmon industry throughout rivers if North America has meant that maintaining longitudinal connectivity of the river systems has been emphasised to ensure that breeding adults had access to upstream spawning grounds. These anadromous salmonid species are regarded as species as they reach adulthood within the marine environment and then these adults migrate upstream to spawn. Therefore upstream migrations are undertaken by individuals that have strong swimming capabilities, which can overcome some quite substantial barriers. Regardless of the reason for the migrations of the various species, the maintenance of longitudinal connectivity, and therefore allowing for migratory freedom, is imperative to the conservation for all fish species in the long term.

Fishways to cater for these species have therefore traditionally been designed for relatively strong swimming species and species with substantial jumping abilities (Mallen-Cooper, 2007). Australian fishway designs have mostly been designed for conservational purposes and to maintain the biodiversity with freshwater systems. South African fishway designs initially were based on the North American basis pool and weir concepts that served the salmon migrations, but more recent studies have shown that the different requirements of South African migratory biota required a refinement of fishway designs to better cater for local species. Due to similarities of our rivers to those found in Australia, recent fishway designs and concepts have largely been based upon those utilised throughout Australia. The vertical slot design also gained popularity throughout European rivers and has been implemented with a high success rate (Bok *et al*., 2007).

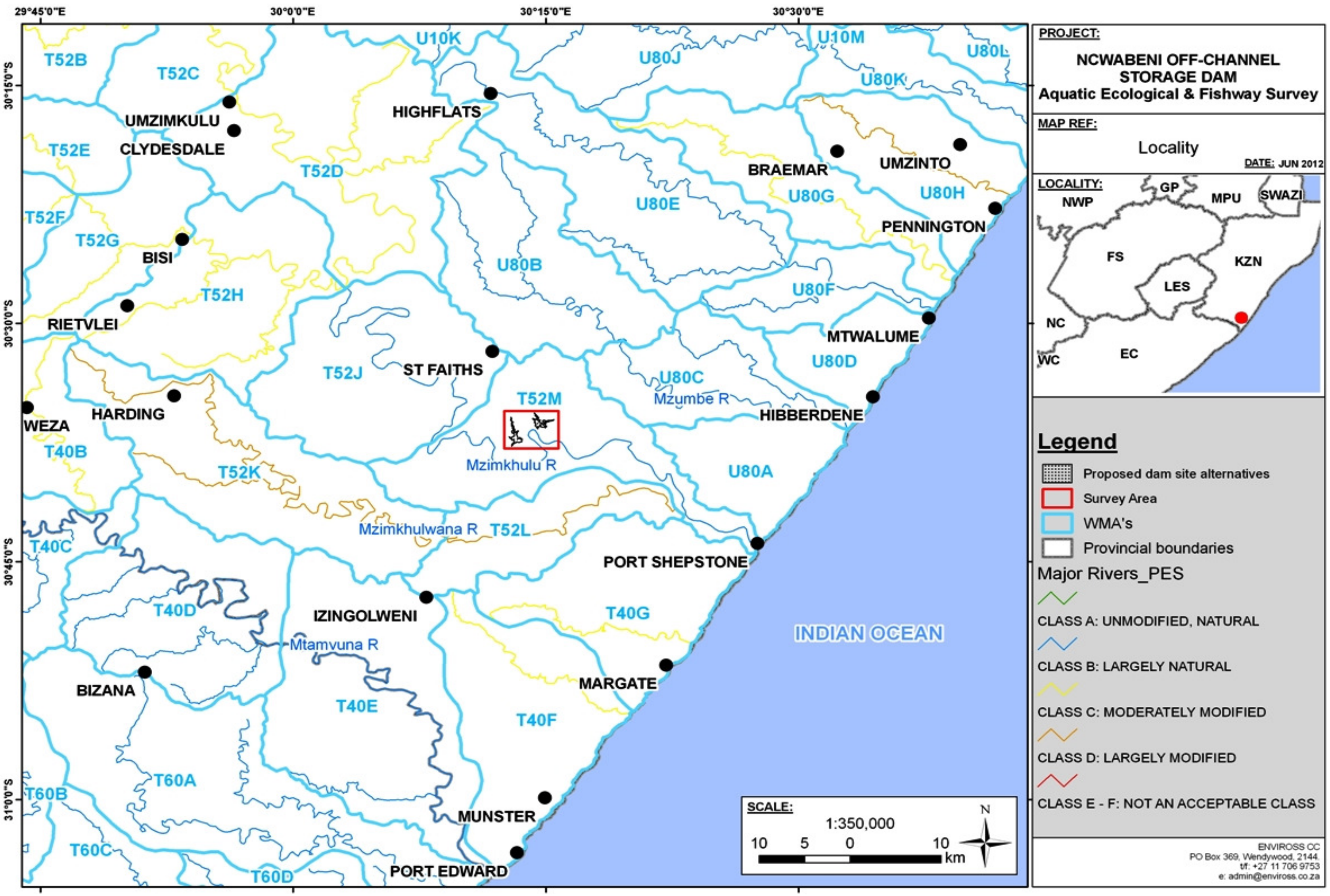

Figure 1: Locality of the survey area.

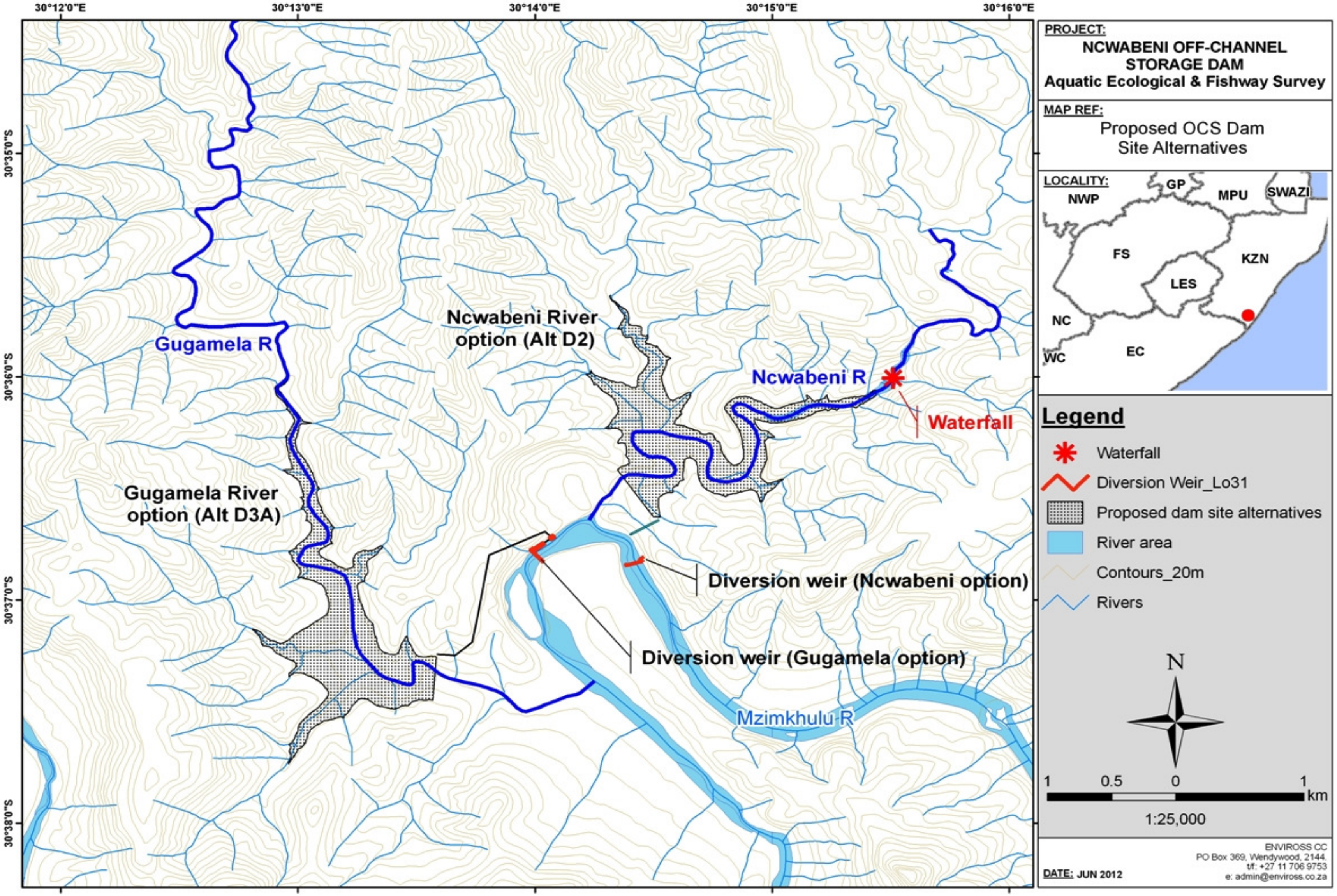

Figure 2: Site alternatives for the off-channel storage dam.

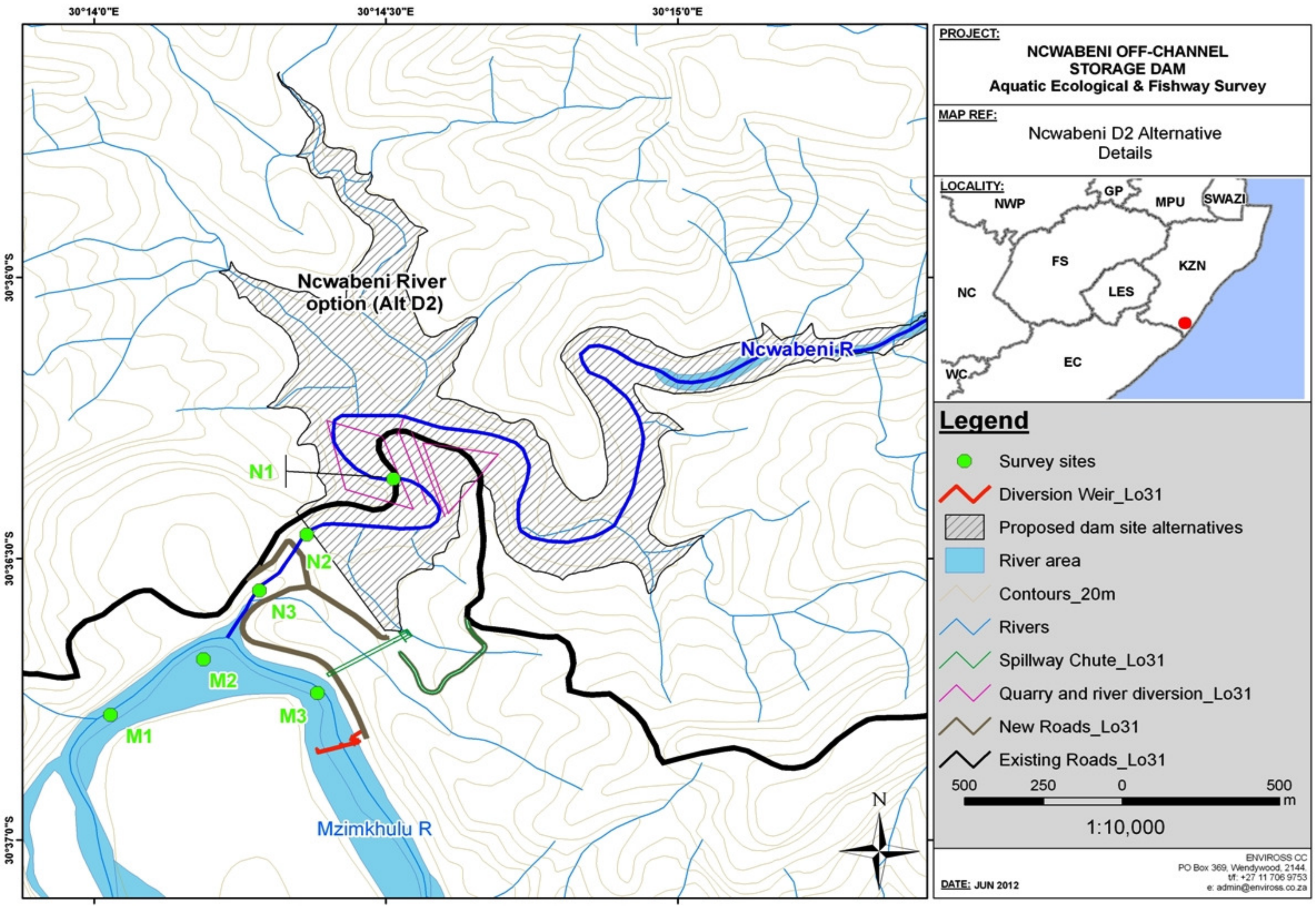

Figure 3: Site details of the Ncwabeni River alternative.

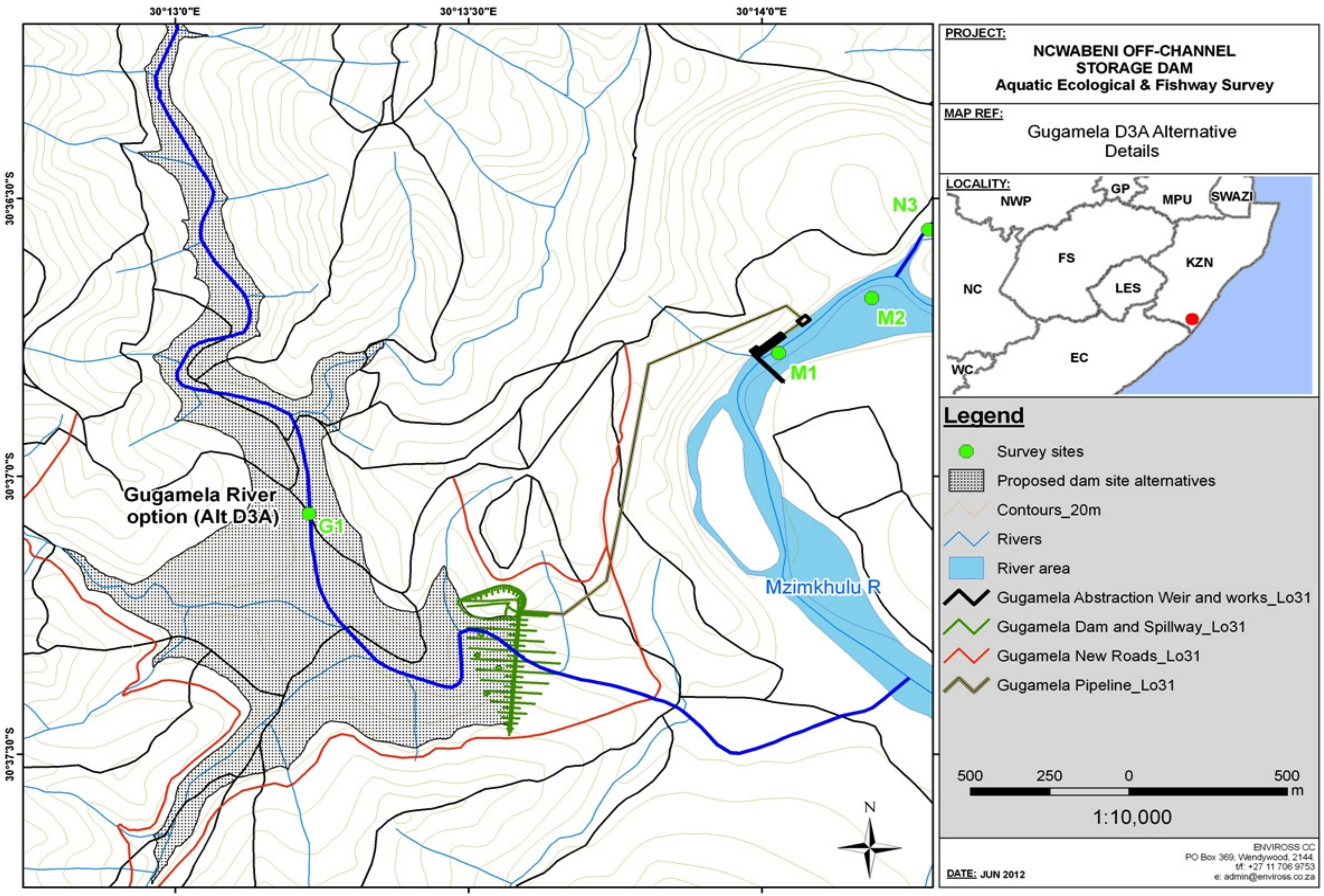

Figure 4: Site details of the Gugamela River alternative.

Nemai Consulting requested an aquatic and riverine ecological survey for the watercourses that would be potentially impacted by the proposed Ncwabeni off-channel storage dam and the associated infrastructure. Part of this was an ichthyological impact survey due to the construction of the abstraction weir across the Mzimkhulu River. The aim of the survey was to ascertain the present ecological state and to identify potential negative impacts on the aquatic environment in order to recommend mitigation measures to potentially negate the impacts of the proposed construction on the aquatic habitat. Mitigation measures are to include the potential implementation of a fishway to be incorporated into the weir design.

2. AIMS & OBJECTIVES.

The objective of this report is to provide the biological information to the engineers, planners and construction teams that will allow for mitigation of the negative ecological impacts on the aquatic environment emanating from the construction of the weir. This document presents the findings of the field survey that was undertaken in May 2012.

3. STUDY AREA.

The study area comprised of various aquatic sites along the Ncwabeni, Gugamela and Mzimkhulu Rivers. The surrounding area was also surveyed using aerial photographs, topographical maps and GIS datasets to evaluate the aquatic habitats both upstream and downstream of the proposed construction sites. This was done in order to evaluate the necessity of a fishway in terms of availability and suitability of habitat located upstream of the site.

Figure 5: Various views of the study sites associated with the Mzimkhulu River.

Figure 6: Various views of the study sites associated with the Ncwabeni River.

Figure 7: Various views of the study sites associated with the Gugamela River.

4. MATERIALS & METHODS.

Standard, DWA-endorsed biomonitoring protocols and methodologies were followed for the aquatic survey for all of the sites that are based on the nationally-implemented River Health Programme. The outline of the ecological indicators that were utilised in order to ascertain the ecological integrity of the various study sites are outlined in Table 1.

Table 1: The various components of the ecological indicators selected for characterisation of the aquatic and associated riparian sites.

Ecological indicators	Measurable ecological components.
Stressor indicators	*In situ* water quality
Habitat indicators	General habitat assessment; Index of Habitat Integrity (IHI); Integrated Habitat Assessment System (IHAS)
Response indicators	Aquatic macro-invertebrates (SASS v.5); Ichthyofauna

4.1. Habitat characterisation.

The assessment of the physical habitat characteristics of an aquatic system that are available for inhabitation by aquatic fauna plays an important role in determining whether a particular site is inhabitable or not. This is an important aspect to consider when interpreting the biological data that are gathered at each study site. An example of this aspect is that a system with good water quality and poor habitat availability will show poor aquatic faunal inhabitation, whereas a system with good water quality and good habitat availability will show a diverse aquatic faunal species community structure. Therefore, habitat evaluations are as important in interpreting aquatic ecological integrity of a site as the determination of the water quality.

In river systems with variable-use catchment areas, the use of the Integrated Habitat Assessment System (IHAS) is regarded as being an important habitat evaluating tool. The IHAS is aimed at determining the instream habitat integrity for suitability for aquatic macro-invertebrate inhabitation (coupled to SASS5 data). A reason why the IHAS tool (together with the SASS5 protocols) are regarded a being reliable aquatic ecological integrity indicators is that aquatic macro-invertebrates are highly mobile within a system as the majority of the taxa have adult terrestrial life-stages capable of flight. Therefore, periodically impacted stretches of river systems are rapidly recolonised when the negative impact disappears.

The IHAS methodology recognises three major biotopes within aquatic systems. These include:

- *Stones* (including stones in current, stones out of current and bedrock);
- *Gravel, sand & mud* (both in current and out of current); and
- *Vegetation* (including aquatic, emergent and marginal, both in current and out of current).

The IHAS evaluates the quality and quantity of these three major biotopes and this is expressed as a percentage score per site. It is further split into Sampling habitat (constituting 55% of the total IHAS score rating) and Stream condition (constituting 45% of the total IHAS rating). See Appendix C for methodologies and calculations specific to the IHAS.

The use of the IHI (Index of Habitat Integrity) is a generalised habitat evaluation tool that is modified slightly to make it more applicable to the various study sites as many aspects of the IHI are undeterminable due to unknown factors that fall outside of the scope of the survey. Only applicable aspects of the IHI will therefore be reported on. See Appendix C for methodologies, calculations and explanations specific to the IHI.

4.1.1. Vegetation and general riparian area.

The various aquatic sites were inspected on foot for a distance both upstream and downstream of the actual study site. General readily-observable indicators of ecological integrity were noted. Site photographs were also taken for both upstream and downstream habitat for these sites.

4.1.2. Water quality.

The *in situ* water quality of all of the aquatic biomonitoring sites were taken using a *Hanna model 9828* multiparameter water quality meter. These data are important to the interpretation of the biological data that are gathered during the sampling at the various sites. The parameters that were recorded were: Dissolved oxygen (%), Oxygen content (mg/ℓ), pH, Total dissolved solids (Tds) (ppm), Electro-conductivity (EC) (µS/cm) and Temperature (°C).

4.1.3. Site categorisation and classification.

The ecological state of a stretch of a river is compared to a *reference state,* which is regarded as the ideal ecological state of a river within a similar river reach as the study site. The ecological state model allows for the classification of the system according to various combinations of index scores. To ensure applicability, a *reference state model* was created that takes into account the natural variations that river reaches within similar geographical area are subjected to. The reference state model most applicable to the rivers of the South Eastern Uplands (Lower) Ecoregion is presented in Table 2.

Table 2: Eco-classification model for determining the Present Ecological State for South Eastern Uplands (Lower) rivers, based on SASS5 and ASPT* scores.

SASS5 Score	ASPT	Description	Class
>170	>7.5	**Excellent/Unimpaired.** Community structures and functionality comparable to the best situation that can be expected. This is the optimum community structure for stream size and habitat quality.	A
141-170	6.8-7.5	**Very Good/Minimally impaired.** Largely natural with few modifications. A small change in community structure may have taken place, but ecosystem functionality remains essentially unchanged.	B
111-140	6.1-6.7	**Good/Moderately impaired.** Community structure and function less than the reference condition. Community composition lower than expected due to loss of some sensitive taxa. Basic ecosystem functionality remains predominantly unchanged.	C
91-110	5.3-6.0	**Fair/Largely impaired.** Fewer taxa presented than expected due to loss of sensitive species. This is indicative of a loss of basic ecosystem functionality.	D
61-90	4.1-5.2	**Poor/Seriously impaired.** Few aquatic taxa are present due to loss of most of the sensitive species. This is indicative of an extensive loss of basic ecosystem functionality.	E
<60	<4.0	**Very poor/Critically impaired.** Few aquatic taxa present. Aquatic community (if present) often dominated by high densities of tolerant taxa. This is indicative of critical loss of ecosystem functionality.	F

***ASPT = Average Score per Taxon.**

4.2. Biological Sampling.

4.2.1. Aquatic macro-invertebrate sampling.

Benthic macro-invertebrate communities of the selected sites were investigated according to the South African Scoring System, version 5 (SASS5) approach (Dickens & Graham, 2001). This method is based on the British Biological Monitoring Working Party (BMWP) method and has been adapted for South African conditions by Dr. F. M. Chutter (Thirion *et al.*, 1995). The SASS method is a rapid, simple and cost effective method, which has progressed through four different upgrades/versions. The current upgrade is Version 5, which is specifically designed to comply with international accreditation protocols. Accredited SASS5 practitioners applied this protocol. Refer to Appendix A for the sampling method details.

4.2.2. Ichthyofauna.

The assessment of fish community structures is often a useful tool in ascertaining the ecological integrity of a river system as fish represent a different trophic level to aquatic macro-invertebrates and, whereas aquatic macro-invertebrates are indicators of short term stressors, fish are indicators of more long term impacts on a system. The fish community structure is, however, very often governed by factors other than local habitat integrity and water quality. The presence or absence of fish in a river reach is largely determined by the lack of accessibility to the specific reaches due to instream migratory barriers. Whereas aquatic macro-invertebrates are capable of overcoming many of these barriers due to morphological adaptations, fish often cannot and are consequently excluded from colonising a river reach upstream of a migratory barrier. These barriers are often in the form of low-level bridges, gauging and other weir structures, dam walls, culverts, etc. Rivers and streams that have highly urbanised catchment areas (especially) are well-known to suffer greatly from this impact. Therefore, the absence of fish species within certain study sites is not necessarily an indication of poor localised habitat or water quality, but may be due to migratory barriers that are often located relatively far downstream of the study site. A desktop survey of both upstream and downstream habitat through review of topographical maps, aerial photographs and available GIS data was undertaken prior to undertaking the field survey in order to pinpoint the closest major migratory barriers relevant to the project.

Fish were sampled throughout the study area to determine the fish community structures within the river reach associated with the proposed construction sites. Fish were surveyed with the use of electro-narcosis and cast-netting as sampling techniques. Electronarcosis makes use of an electric current that is passed through the water that induces a temporary narcotic and paralysed state in the fish. The fish can then be netted using hand-held nets and placed into a bucket away from the electrical current. The different species are then identified and measured, to later be released back into the system. This collection method is regarded as the most effective collection technique for riverine habitat where the physical habitat and hydrology allows for it where the water does not exceed wading depth. Deeper and faster-flowing waters were sampled using cast-netting.

4.3. Fishway Assessment.

Prior to the construction of a fishway, there are certain procedures and protocols for the planning, design, provision and operation that are worked through in order to ascertain the need for a fishway at a particular barrier site. These procedures can be summarised into the following categories (Bok *et al,* 2007):

- *Necessity Protocol*

Where the ecological need for a fishway and the feasibility of providing a successful and cost effective fishway is determined;

- *Priority Protocol*

Where the ecological impact of a barrier on migratory species present is quantified;

- *Design Protocol*

Where the appropriate information on migratory species is gathered for the site, which includes swimming ability and behaviour (e.g. seasonal spawning migrations, etc);

- *Construction Protocol*

Where the ECO (Environmental Conservation Officer) oversees and audits the construction at the critical stages during the project to ensure that design criteria are adhered to;

- *Monitoring Protocol*

Where a monitoring protocol is devised and implemented in order to assess the effectiveness of the fishway in passing target species and to reveal any problem areas (e.g. “bottlenecks”).

5. RESULTS & DISCUSSIONS.

5.1. General site descriptions and riparian vegetation.

5.1.1. Vegetation type.

The area falls within the vegetation unit of Eastern Valley Bushveld, of the Sub-escarpment Valley bioregion of the Savanna biome. This is a semi-deciduous savanna woodland in a mosaic with thickets, often succulent and dominated by species of *Euphorbia* and *Aloe.* Most of the river valleys run along a northwest-northeast axis, which results in unequal distribution of rainfall on respective north-facing and south-facing slopes since the rain-bearing winds blow from the south. The steep north-facing slopes are sheltered from the rain and also receive greater amounts of insulation adding to xerophilous conditions on the slopes (Mucina & Rutherford, 2006).

The area has largely remained rural in nature, with the north-western banks of the Mzimkhulu River having retained the natural vegetation features. There is a gravel roadway that follows the contours of the terrain within the proposed development area, which has had an impact on riparian vegetation within some isolated areas where the roadway runs into the riparian areas (low-level bridges crossing the Ncwabeni and Gugamela Rivers) and one small area along the edge of the Mzimkhulu River. Further to this, the riparian areas are subject to a small degree of livestock grazing, but have largely retained ecological integrity and functionality.

The riparian areas along the south-eastern banks have been impacted by commercial agriculture. This land use has encroached to within the riparian zones in many areas and therefore the natural floral communities have been transformed. Land disturbance features coupled to the land use mean that sediments and agro-chemicals routinely enter the aquatic system via runoff from this side of the river.

5.2. Water quality.

The South African Water Quality Guidelines for Freshwater Aquatic Ecosystems (Volume 7) (SAWQG, DWA, 1996) notes that different systems have naturally different water chemistries. The aquatic organisms that inhabit the systems are adapted through evolutionary processes to survive within these systems. This means that chemical parameters for one system may differ significantly from another to the point that organisms from one system very often cannot survive within another system (in extreme cases). The same system also undergoes cyclic changes that occur hourly, daily or seasonally. For this reason, guideline values for water quality parameters are given as a range bracket that anthropogenic influence should no transform beyond before an impact is imposed. In order to accurately ascertain the potential impact of anthropogenic influence, routine monitoring is required to enable trend identification.

In situ water quality parameters were taken at various points along the stretches of the Mzimkhulu, Ncwabeni and Gugamela Rivers within the survey area. The average values are reported on in Table 3. These readings were taken at each site at the time of the biological sampling. Water quality determination forms an integral part of enabling accurate interpretations of the biological data as the final ecological class allocation is a combination between the habitat quality, water quality and biological integrity.

Various water quality parameters were tested for using a hand-held *Hanna Multiparameter water quality meter: Model 9828*. The parameters tested for and the results from each site sample are presented in Table 3.

Table 3: *In situ* water quality results for each site. Recorded values all fall within the SAWQG's (1996) guideline values for aquatic ecosystems.

Site	Temp. (°C)	pH	DO (%)	DO (mg/ℓ)	EC (µS/cm)	TDS (ppm)	Salinity
Mzimkhulu	19.57	8.41	95.74	8.65	101.00	50.40	0.05
Ncwabeni	21.02	8.62	77.06	6.74	261.60	130.40	0.12
Gugamela	12.06	8.00	79.80	8.42	220.00	110.00	0.11

5.2.1. Water temperature.

Water temperature plays an integral role in biochemical processes and therefore governs the rate of associated metabolic processes of poikilothermic ("cold-blooded") aquatic organisms. The metabolic rate of aquatic organisms is governed by temperature and therefore the rate of development and growth as well as repair of damaged tissue and the functionality of associated stress-coping mechanisms of aquatic organisms is also all governed by the water temperature. The South African Water Quality Guidelines (SAWQG's) (1996) stipulate that water temperature should not fluctuate by more than 2°C or 10% of the normal daily temperature cycle of a system for the season associated with the sampling. Different river systems and even different reaches of the same river system have differing temperature regimes due to the origin of the water source or the habitat through which the watercourse passes. Underground water fed streams display typically colder water temperatures than that of the midwaters of a wide river that has been exposed to radiant temperature for a longer period of time. Aquatic organisms have evolved to survive within an optimal range of water temperatures for a given reach of a river and therefore any sudden fluctuations that are artificially induced adversely affect their survival rates.

The water temperatures recorded at the time of sampling are presented in Table 3, where it can be seen that the water within the Gugamela River is considerably colder 12.06 °C) that the temperatures recorded at the Mzimkhulu (19.57 °C) and Ncwabeni (21.02 °C) Rivers. This is a natural function of the river and is probably derived from the river being fed from nearby underground sources. The riparian zones (being a typically closed-canopy) also largely blocks sunlight from reaching the water and therefore does not have sufficient chance to influence the temperature. The water temperatures recorded for the Mzimkhulu and Ncwabeni Rivers were largely similar. It was noted that a significantly higher population of fish populate the Ncwabeni River than does the Gugamela River. This could partly be due to a temperature barrier that limits recruitment of the system from the Mzimkhulu River. This point is further discussed in subsequent chapters (fish community structures). The water temperature recorded within all the sites is not expected to be a limiting factor on the survival of the aquatic organisms as it is a reflection of the natural temperature regimes of the habitat units.

5.2.2. pH.

The pH of the natural waters of a river system is influenced by both geological and atmospheric factors as well as biological processes that take place within the water. Most natural waters are relatively well buffered to pH fluctuations due to the presence of bicarbonates and other buffering chemicals (SAWQG's, 1996) and therefore aquatic organisms have evolved to function optimally within a generally very narrow pH range. An undue fluctuation in pH of a system therefore has adverse effects on the survival of aquatic organisms.

According to the SAWQG's (1996), pH of a river system should not fall outside of the range of 6 to 8 pH units. The fluctuation of pH during one 24-hr cycle should also not exceed 0.5 pH units or 5% of the natural pH range for a given system at any given time.

The pH of the sites ranged between 8.00 and 8.62 (Table 3). These values reflect the upper limits of the pH stipulated as the guideline values, but are viewed as being a reflection of the natural pH of the river systems and therefore are not thought to be problematic. Long-term monitoring would be necessary to determine the "normal" pH fluctuations within the system. The pH values are not viewed as being a limiting factor to supporting aquatic life.

5.2.3. Dissolved oxygen and oxygen content.

The maintenance of adequate dissolved oxygen (DO) concentrations is critical for the survival and functioning of the aquatic biota because it is required for the respiration of all aerobic organisms. Therefore, the DO concentration provides a useful measure of the health of an aquatic ecosystem (SAWQG's, 1996). This can be measured as oxygen saturation expressed as a percentage, or as dissolved oxygen concentration, expressed in mg/ℓ. The general guideline value of oxygen content for supporting aquatic life is >5mg/ℓ. Oxygen saturation of the water varies and is dependent on the temperature of the water. In general, the cooler the water, the higher the saturation (100%) point. As the water approaches freezing temperature, its saturation point for oxygen content is at its greatest, explaining the reason why ice floats on the surface of water.

Many factors influence the oxygen content of water. The most influential oxygen depleting mechanism applicable to urban systems is nutrient and hydrocarbon contamination. High nutrient contamination has a consequential high biological oxygen demand (BOD), which, in turn, depletes the water of oxygen to be utilised in biochemical processes to metabolise the nutrients. These nutrients are typically in the form of sewerage (both raw as well as processed) and fertilisers from lawns (golf courses, gardens, etc.) and therefore are not limited to urban systems. Hydrocarbon contamination from spilled fuels and motor oils on roadways that enter the water course through runoff storm waters have a high chemical oxygen demand (COD). The chemical interactions of hydrocarbons with water on entering the watercourse also then deplete the system of oxygen available for sustenance of aquatic life. Many aquatic organisms are specifically adapted to life under low oxygen conditions, and an abundance of these organisms is often an indication of low oxygen content within the system. Oxygen content can be increased in a system first and foremost by photosynthesis of aquatic plants as well as by mechanical means as a result of turbulence that exposes more of the water surface for oxygen exchange with the atmosphere, such as flowing over weirs, etc.

The oxygen content at all the survey sites was found to be within guideline values and therefore are not considered a limiting factor to supporting aquatic biota.

5.2.4. Total dissolved solids.

The measure of total dissolved solids (Tds) is coupled to the measure of the salinity of the water. This is, in turn, coupled to the electro-conductivity (EC) of the water. Aquatic organisms are dependent on salts within the system for normal metabolic functionality as well as to maintain osmoregulation (salt balance) within their bodies. Too high salinity values (>1,000ppm) are considered, however, to be a limiting factor especially to many aquatic macro-invertebrates (SAWQG's, 1996). The Tds of a system should not range by more than 15% for the "normal range" for any given system. This, however, requires more extensive surveys to gain cyclic data in order to interpret accurately. The Tds values recorded at the Mzimkhulu River was noted to be considerably lower (50.4 ppm) than the Ncwabeni (130.4 ppm) and Gugamela (110.0 ppm) Rivers (Table 3). Normally, the main watercourse (Mzimkhulu River) would reflect the cumulative impacts of the catchment area, which is often reflected in elevated tds values. As this is not the case, the relatively higher tds values at both of the tributary sites is thought to be a reflection of the natural catchment characteristics and are therefore not considered to be a limiting factor to supporting aquatic biota.

5.3. Habitat characterisation.

5.3.1. Integrated Habitat Assessment System (IHAS), version 2.

Habitat integrity and water quality forms the basis for aquatic faunal inhabitation. Assessing the habitat integrity therefore forms the basis for accurate data interpretation following the biological sampling of a system. The Instream Habitat Assessment System (Version 2) (IHAS) (McMillan, 1998) is a habitat evaluation tool used in conjunction with the SASS5 methodology. Table 4 presents the results from the IHAS application at all of the biomonitoring sites.

The IHAS score is presented as a percentage – with 100% representing ideal habitat quality. It is therefore thought that a score of above 65% indicates good habitat quality (green); 55-64% indicates adequate habitat quality (blue). A score of less than 55% indicates poor habitat quality (red) and is regarded as being a limiting factor to aquatic macro-invertebrate inhabitation. A score of above 65% represents a biomonitoring site that has adequate representation of all the major biotopes, whereas a score of between 55 and 65% is indicative of a sampling site that lacks adequate representation of certain biotopes or biotopes of poor quality. A score of less than 55%

is indicative of the complete lack of certain biotopes or biotopes of critically modified or transformed biotopes.

Table 4: Results from the IHAS survey conducted at each site.

Site	IHAS			Description
	Sampling habitat (55)	Stream condition (45)	Total (%)	
Mzimkhulu	53	31	84	Good
Gugamela	50	36	86	Good
Ncwabeni	53	43	96	Good

The IHAS scores for all the river sections that were surveyed indicated that good instream habitat quality to support a wide diversity of aquatic macro-invertebrates existed. These scores indicate rivers that have a wide diversity of biotopes and therefore a comparatively good SASS5 score was to be expected at all the survey sites. The Mzimkhulu Rivers showed comparatively lower scores as the river was characterised by deeper waters and the substrate was dominated by large boulders. Instream vegetation was also dominated by reeds, which is known to support a comparatively lower diversity of macro-invertebrates than leafy vegetation. These factors are considered to be natural features of the river system.

5.3.2. Index of Habitat Integrity (IHI).

Another procedure for assessing habitat integrity is the Index of Habitat Integrity (IHI). This tool was developed as a rapid habitat assessment tool that evaluates the general and readily-observable perceived impacts on a specific river segment in the field. This index takes riparian habitat as well as instream aquatic habitat into consideration. Table 5 presents the results from the application of the IHI to all of the sites surveyed.

Table 5: Results of the IHI after application at each survey site.

Sites		Mzimkhulu	Gugamela	Ncwabeni
Instream habitat quality (Impact score out of 25)				
Primary:				
Criteria	**weight**			
Water abstraction	14%	5	2	1
Flow modification	13%	0	2	0
Bed modification	13%	0	2	0
Channel modification	13%	0	2	1
Water quality	14%	0	0	0
Inundation	10%	0	1	0
Sub Total:	**77%**	**2.8**	**4.64**	**1.08**
Secondary:				
Exotic macrophytes	9%	0	0	0
Exotic fauna	8%	0	0	0

Sites		Mzimkhulu	Gugamela	Ncwabeni
Instream habitat quality (Impact score out of 25)				
Solid waste disposal	6%	1	1	1
Total (75):	**23%**	**0.24**	**0.24**	**0.24**
Instream habitat integrity (%):	**100%**	**97**	**95**	**99**
Instream habitat integrity class:		**A**	**A**	**A**
Riparian zone habitat integrity (Impact score out of 25)				
Indigenous vegetation removal	13%	5	5	5
Exotic vegetation encroachment	12%	5	5	5
Bank erosion	14%	2	4	1
Channel modification	12%	2	2	2
Water abstraction	13%	0	0	0
Vegetation inundation	11%	0	2	0
Flow modification	12%	0	2	0
Water quality	13%	0	0	0
Total:	**100%**	**7.08**	**10.04**	**6.52**
Riparian habitat integrity score (%):		**92.92**	**89.96**	**93.48**
Riparian habitat integrity class:		**A**	**B**	**A**
Total integrity score (%):		**95**	**93**	**96**
Total integrity class:		**A**	**A**	**A**

From Table 5, the results of the IHI indicate that both the three rivers at the survey sites presently do not suffer from habitat modification and have largely retained ecological integrity and functionality, placing all three river segments within an “A” integrity class. This translates to a comparably natural system. The slight variations on score along for the Gugamela River are due to the presence of a poorly-designed bridge that has created some channel inundation upstream and some erosion of the channel downstream. It has therefore had a small impact in that it modifies the hydrology of the river. The trapping of silt upstream of the bridge also enhances the encroachment of aquatic vegetation to within the channel.

The IHI results do not concur entirely with the results of the other habitat index (IHAS) due to the measurable impacts that each index represents – the IHAS focuses on aquatic sampling habitat, whereas the IHI incorporates terrestrial riparian habitat as well. Various priority weights are also designated in different impact areas that differ between the various indices and therefore the average values after application of all of the indices are ultimately regarded as the most accurate reflection of habitat integrity.

Table 5 shows the IHI results indicate that the habitat of the three river sections that were surveyed represent an “A” PES category and are therefore regarded as largely natural systems that have not suffered transformation of degradation.

5.4. Aquatic macro-invertebrate sampling.

Reference data was sources from available literature (DWA, 2011), wherein a reference state model was created. This reference state was also developed from literature-based results, and then supplemented from data emanating from surveys in the Mkomazi and Mzimkhulwana Rivers. This reference state model is therefore not entirely representative of the status of the Mzimkhulu River and should be utilised as a guideline, but does represent findings taken from similar river systems that are located within the same local catchment area and subjected to the same catchment drivers and pressures as the Mzimkhulu River.

The results of the SASS5 survey were based on a cumulative sample over a few sites along each river segment. These results are presented, together with the reference data (DWA, 2011), in Table 6.

Table 6: Results from the SASS5 survey of the three river sites presented as a comparison to perceived reference state conditions (*from* DWA, 2011).

Taxon	Sensitivity /15	Reference Abundance	Mzimkhulu	Gugamela	Ncwabeni
PORIFERA (SPONGE)	5				A
TURBELLARIA (FLATWORMS)	3	A		1	A
Oligochaeta (Earthworms)	1	A	A	A	A
Leeches	3	A	A	A	1
Potamonautidae* (Crabs)	3		1		1
Atyidae (Shrimps)	8	B	D	D	D
HYDRACARINA (MITES)	8	C	A	1	A
Perlidae	12	B	A	1	B
Baetidae > 2 sp	12	B	C	A	C
Caenidae (Squaregills/Cainfles)	6	A	A	A	A
Heptageniidae (Flatheaded mayflies)	13	B	A	A	B
Leptophlebiidae (Prongills)	9	A	B	A	B
Oligoneuridae (Brushlegged mayflies)	15	B			
Prosopistomatidae (Water specs)	15	A			
Tricorythidae (Stout Crawlers)	9	A	A	A	A
Calopterygidae ST,T	10	A			
Chlorocyphidae	10	A			
Coenagrionidae (Sprites and blues)	4	A		B	A
Aeshnidae (Hawkers & Emperors)	8		1		1
Gomphidae (Clubtails)	6	A	A	1	A
Libellulidae (Darters)	4	A	1		1
Belostomatidae* (Giant water bugs)	3	A	1	B	
Corixidae* (Water boatmen)	3	A	A	A	A
Naucoridae* (Creeping water bugs)	7	A			
Notonectidae* (Backswimmers)	3	A	A		
Pleidae* (Pygmy backswimmers)	4		1	A	A
Veliidae/M...veliidae* (Ripple bugs)	5	B	A	A	
Hydropsychidae 1 sp	4			A	
Hydropsychidae 2 sp	6	A			A
Hydropsychidae > 2 sp	12		B		
Leptoceridae	6	A		1	
Dytiscidae/Noteridae* (Diving beetles)	5	A			
Elmidae/Dryopidae* (Riffle beetles)	8	A		1	1

Taxon	Sensitivity /15	Reference Abundance	Mzimkhulu	Gugamela	Ncwabeni
Gyrinidae* (Whirligig beetles)	5	A	B	B	B
Hydraenidae* (Minute moss beetles)	8			1	
Hydrophilidae* (Water scavenger beetles)	5		1	A	A
Psephenidae (Water Pennies)	10	A	A	A	A
Athericidae	10	A			
Ceratopogonidae (Biting midges)	5	A		A	1
Chironomidae (Midges)	2	A	A	A	A
Culicidae* (Mosquitoes)	1			A	
Simuliidae (Blackflies)	5	A	A	A	B
Tabanidae (Horse flies)	5	A			
Ancylidae (Limpets)	6	A	A	A	A
Physidae* (Pouch snails)	3	A	A	A	A
SASS Score		171	168	177	176
No. of Taxa		23	27	30	28
ASPT		7.5	6.2	5.9	6.3
	PES Category	**A/B**	**B/C**	**A/B**	**A/B**

***Abundances: 1=1; A=1-10; B=11-100; C=101-1000; D=>1000.**

The results from the SASS5 survey at each site resulted in overall good ecological (biological) integrity of the sites (Classes A/B to B/C). The taxa (families or groups) of aquatic macro-invertebrates that were sampled were dominated by those taxa known to be intolerant of pollution. The SASS5 scores from the various sites are therefore indicative of both good habitat ecological integrity and comparatively good water quality.

5.5. Ichthyofauna.

Standard electro-narcosis (electro-shocking) was utilised as a collection method at all of the sites, which was supplemented by exhaustive cast-netting sampling. The combination of these methods was deemed adequate for the nature of the river at the sampling sites. It was found that sampling was hampered within the Mzimkhulu River due to high flows that inhibited access to certain areas with electro-fishing equipment. This is a feature that would influence the results of the survey.

Table 7: Results from the ichthyofaunal survey shown in relation to the relative abundances of the species on record as having been collected at the particular site (Kleynhans, 2007).

Species	Reference: RELATIVE ABUNDANCE	Sampled:		
		Mzimkhulu	Ncwabeni	Gugamela
Awaous aeneofuscus	2	0	0	0
Anguilla marmorata	1	0	0	0
Anguilla mossambica	2	0	0	0
Barbus anoplus	2	0	0	0
Barbus gurneyi	1	0	5	0
Labeobarbus natalensis	2	5	23	0
Barbus viviparus	2	14	94	0
Clarias gariepinus	1	4	0	1
Oreochromis mossambicus	3	0	3	2
	Totals:	**23**	**125**	**3**

Figure 8: Some fish collected during the survey.

Table 7 presents the results from the fish survey. The reference list of expected fish species at the site was taken from Kleynhans (2007) and Scott, *et al*. (2006). The survey site on the Mzimkhulu River is an actual River Health Programme reference site (T4MZIM-HORSE = Gibraltar) and therefore the expected fish species, together with their relative expected abundances could be sourced for the site. Other fish species lists have been provided as reference source material (BKS Scoping Report, 2011), but reflect all species known for the river along all reaches (including the estuarine species), and therefore is not necessarily a reflection of the fish diversity present at the proposed weir site. The survey site is located relatively close to the coast and therefore the occurrence of various eel species was expected. None of these eels (Anguillid species) were sampled at the time of the survey, but this group of species is expected to utilise the Mzimkhulu River at this site as a conduit to inland waters to complete part of their lifecycle. The majority of the expected fish species were not sampled within the Mzimkhulu River, but this is due to river conditions that did not allow for comprehensive sampling and is not a reflection of the fish community species.

A species that requires migratory freedom for breeding purposes that was sampled was *Labeobarbus natalensis* (Kwazulu-Natal yellowfish). Two breeding-sized adults and three juveniles were sampled in the Mzimkhulu River, whereas numerous (23) juveniles and two adults were sampled within the Ncwabeni River. Juvenile individuals of this species are known to occur in schools within marginal habitat (Skelton, 2001) and therefore this local species distribution could be expected. No individuals of this species were surveyed within the Gugamela River – presumably due to the relatively colder water temperature of this system that has formed a thermal barrier. This was true for all but the most opportunistic of species (*Oreochromis mossambicus* and *Clarias gariepinus*) that were sampled in small numbers (two and one, respectively). The bridge that is located at the survey site would inhibit upstream migrations under low to moderate flow conditions and would only flood out under relatively high-flow conditions. Therefore upstream recruitment within this system from the main watercourse would be limited. The Ncwabeni River is more readily accessible to recruitment from the main channel and this system showed the most abundance and diversity. The water quality parameters of the Ncwabeni River were also more similar to those of the main watercourse (Mzimkhulu River) and therefore fish would colonise this system more readily than the Gugamela River.

The proposed development activities – the weir on the Mzimkhulu River and the impoundment of either the Gugamela or the Ncwabeni River will inhibit migratory freedom of the fish within the river reach. Many species (such as the Anguillid eels) require long-distance migrations and are therefore severely impacted by migratory barriers within a system. This is especially pertinent at a locality relatively close to the coastal areas. Inhibiting upstream migrations at this site would cut off an entire river system for exploitation by this species and would therefore profoundly impact on the survival of these species. Also see section 6: *Fishway Assessment* for more detail.

6. FISHWAY ASSESSMENT.

6.1. Environmental Legislation.

South African environmental legislation that has recently been promulgated ensures adequate protection of riverine ecosystems from man-induced impacts if applied correctly and strictly. This legislation ensures that appropriate mitigation (e.g. fishways) is taken when in-stream barriers to fish migration are constructed (Bok, *et al,* 2007). This legislation includes:

- The Environment Conservation Act, 1989 (No 73 of 1989) – In terms of Regulations (Section 21, Schedule 1, No 1 (j) published in Government Gazette No 18261, 5 Sept 1997) and in terms of the Environmental Conservation Act, 1989 (ECA);

- The National Environmental Management Act (Act 107 of 1998) – in terms of Regulation 386, Activity 1 (m) gazetted in terms of Section 24;
- National Water Act, 1998 (Act No 36 of 1998) in terms of Section 21 (a), (c) and (i).
- National Environmental Management: Biodiversity Act, 2004.

6.2. Standard Fishway Procedures and Protocols.

6.2.1. Necessity Protocol.

Application of the Necessity Protocol indicated that a fishway ***is required*** as the instream structure will have the following characteristics:

- The structure will be a barrier at both high and low flows and will only drown out when the river is undergoing flood conditions. This will not occur frequently enough to adequately cater for the migratory movement needs of the fish (and invertebrate) species within the system;
- Fish will survive downstream migration over the barrier;
- There are no other feasible or more cost-effective mitigation measures for reducing the environmental impact on the aquatic ecosystem;
- There is accessible and biologically significant habitat upstream of the barrier the exploitation by migratory species. The Mzimkhulu River is regarded as an “open system” (DWA, 2011), meaning that no barriers presently occur within the system; and
- There will be no negative impacts from implementing a fishway that may outweigh the benefits (e.g. allowing for invasion of previously-excluded exotic fish species, or large-scale poaching of fish from the fishway itself).

6.2.2. Priority Protocol.

The Priority Protocol is based on scoring criteria that quantify the importance of providing a fishway. A completed protocol form is presented in Table 8. The rating scores calculated to 98%, which translates to the implementation and construction of a fishway being of ***High Priority*** to the overall conservation of the fish community structures within the system.

Table 8: Proposed scoring scheme to determine the importance of providing a fishway (Bok, *et al* (2007).

Criteria	Max. Score	Site Score	Explanation
Socio-economic value of migratory species present	12	12	Value for food, angling, eco-tourism Low (4); moderate (8) and high (12)
Conservation status of migrants present (number of RDL or Threatened species)	12	10	Taken on a provincial level (4); national level (8); global (12)

Criteria	Max. Score	Site Score	Explanation
Ecological value of migrants (importance of role in eco-system functioning)	12	12	Value in natural food web, eg high in reserves Low (4); moderate (8) and high (12)
Importance of upstream habitat to migrants	12	12	Low (4); moderate (8) and high (12)
Proportion of catchment/upstream habitat obstructed	9	9	<25% (3); 25-50% (6) and >50% (9)
Fish habitat integrity of river for migrants (i.e. PES/Management Class)	9	9	Poor, or Class E/F (3); moderate or Class C/D (6), good, Class A/B (9)
Percentage of stream flows that structure blocks fish passage due to drown-out characteristics of site	8	8	20-40% (3); 40-60% (5), >60% (8)
Feasibility of constructing a successful fishway (i.e. confidence of success)	8	8	Low (3), moderate (5), excellent (8)
Expense of fishway in relation to ecological benefits	6	6	High (2), moderate (4), low (6)
Financial and other support from NGO's, government, special interest groups, etc)	6	6	Low (2), moderate (4), high (6)
Presence of permanent/natural barriers downstream	6	6	None (6), rare (4), many (2)
TOTAL SCORE*	**100**	**98**	***High Priority***

*A score of >85 = Very High Priority; 75-85 = High Priority; 50-75 = Moderate Priority; <50 = Low Priority.

6.2.3. Design Protocol and considerations.

6.2.3.1. Target aquatic biota.

A number of fish and invertebrate (crustacean) species have been recorded from the Mzimkhulu River (as given in Table 20, BKS, 2011). Not all of these species are relevant to the study as not all are found within the vicinity of the proposed weir. Many species remain localised within the estuary, or very close to it, and do not migrate further. Other species remain within the upper reaches of the catchment. There are therefore only key species (or groups of species) that need to be catered for. It should be noted that the key species are those that are virtually the weakest swimmers of the system and therefore catering for these species will adequately cater for the requirements of the remaining species.

6.2.3.2. Fish species.

The construction of the abstraction weir that spans across the Mzimkhulu River will pose a migratory barrier to any aquatic biota requiring up and downstream migratory freedom along the watercourse. Aquatic biota require migratory freedom for various reasons, including seasonally-cyclic spawning migrations, genetic dispersal, habitat exploitation, feeding migrations and avoidance of unfavourable conditions (over-wintering, physical habitat or water quality). Some fish species undertake seasonal migrations over vast distances in search of favourable spawning habitat (e.g. Yellowfishes [*Labeobarbus* spp.]), whereas other species undertake relatively shorter migrations (e.g. member of the Cichlidae family, more commonly known as "kurper" (Afr) as well as

Barbus spp (ghieliemientjies) (Afr) or barbs (Eng). The relatively close proximity to the coast means that the Mzimkhulu River forms an important conduit to inland waters for catadromous Anguillid species (eels). These species include *Anguilla bicolor bicolor, Anguilla benghalensis, Anguilla mossambica* and *Anguilla marmorata* (threatened) – all of which have been recorded from the system. These species breed in the marine environment (at sea) and the planktonic larvae drift with the coastal currents and then migrate into estuaries, where they undergo a stage of maturity and migrate up the rivers along the east coast into freshwater systems as glass eels, where they develop into elvers. These elvers measure 40-60mm. At this stage these elvers are not capable of strong swimming movement and are therefore particularly vulnerable to the impacts of artificial instream barriers. These eels are capable, however, of leaving the main water column and crawling up wetted edges (splash zones) of channels, provided a roughened surface is available to aid in grip. A further catadromous species that has been recorded from within 5km of the site is *Mugil cephalus* (Freshwater mullet), which breeds at sea and recruits into freshwater environments as juveniles (typically 20-50mm in length) during late winter. Research has indicated that these juvenile individuals can only attain maximum burst speeds of approximately 1.0 to 1.3m/s (Bok *et al.,* 2004; Bok *et al*., 2007). It is therefore recommended that the mean maximum velocities through a fishway structure not exceed these values. In fact many amphidromous species utilise estuaries for breeding purposes and then the juveniles migrate upstream into freshwater systems to complete (either fully or partially) their lifecycles. Therefore the individuals of these species are looking to migrate upstream as juveniles and are also then particularly vulnerable to the impacts of artificial migratory barriers (Bok *et al*., 2007).

6.2.3.3. Macro-invertebrates.

Limited data is available on the macro-invertebrate species community structures specific to the lower Mzimkhulu River. The given list of recorded aquatic fish, crustaceans and molluscs provided by BKS (2011) includes a variety of macro-invertebrate species that would require free passage across the barrier to complete a stage in their respective lifecycles (successful larval development), habitat exploitation and genetic dispersal. Adults and juveniles would then migrate downstream toward the estuaries again (Bok, *et al.,* 2007). The main genera of crustaceans that would require migratory freedom include *Macrobrachium, Varuna* and *Brachipodopsis*. Another species of freshwater shrimp identified through the Scoping Report from Ezemvelo KZN Wildlife's Strategic Environmental Assessment Plan is *Atyoida serrata*. Provision should therefore be made to mitigate the effects of migratory inhibition on macro-invertebrates emanating from the construction of the weir in the Mzimkhulu River.

In terms of migratory behaviour, during natural migrations, both prawns and crabs tend to migrate upstream on the edge of the main river flow in shallow water against the river banks to avoid strong currents and to seek shelter from predators (birds and fish). The species mentioned above have the ability to pass over waterfalls and low weirs by leaving the water and crawling up the sloping rock or concrete surfaces in the splash zone at the edge of the river flow, providing the surface is rough and wet (Bok *et al.*, 2007).

6.2.3.4. Migrational timing requirements.

As mentioned elsewhere, aquatic organisms migrate for different purposes. Regular cyclic migrations may occur daily between feeding and refuge areas. Irregular migrations occur for genetic dispersal, habitat exploitation, predator evasion or avoidance of unsuitable conditions. These migratory movements are not regarded as being essential to survival of the individual, or species community, but rather add to the overall functionality of the ecosystem. Genetic dispersal, however, is regarded as being imperative to long-term species survival. A delay in gaining access to alternative reaches of a river (be it upstream of downstream) for whatever reason (floods, smaller natural barriers that drown out only when higher flows are encountered, etc) will not have a detrimental impact on the survival of the populations. Seasonal migrations may occur to locate favourable habitat (warmer water in winter), but also occur *en masse* with some species that require upstream or downstream passage for breeding purposes. Seasonal spawning migrations are governed by environmental factors and cues that induce simultaneous migrational urges in individuals of a population. A delay created by a barrier or event in gaining access to suitable areas for these individuals will have a detrimental impact on the survival of these populations. Energy wastage of individuals attempting to overcome barriers also negatively impacts the breeding potential of the individuals, ultimately impacting on the population. Having a fishway that can cater for flow conditions of a river when these obligatory migrational events occur is therefore vital to overall functionality. This is determined by the migratory needs of the species composition associated with the river reach.

The known fish and macro-invertebrate species that occur within the river system (Scoping report, BKS, 2011) include species and groups of species that are known to migrate seasonally during spring/summer as well as sporadically during autumn/winter. Some species migrate during receding flood conditions; whereas others migrate during pending flood conditions. Others migrate sporadically during average baseflow conditions. It is therefore clear that the fishway facility should be able to cater for a wide variance in flow conditions.

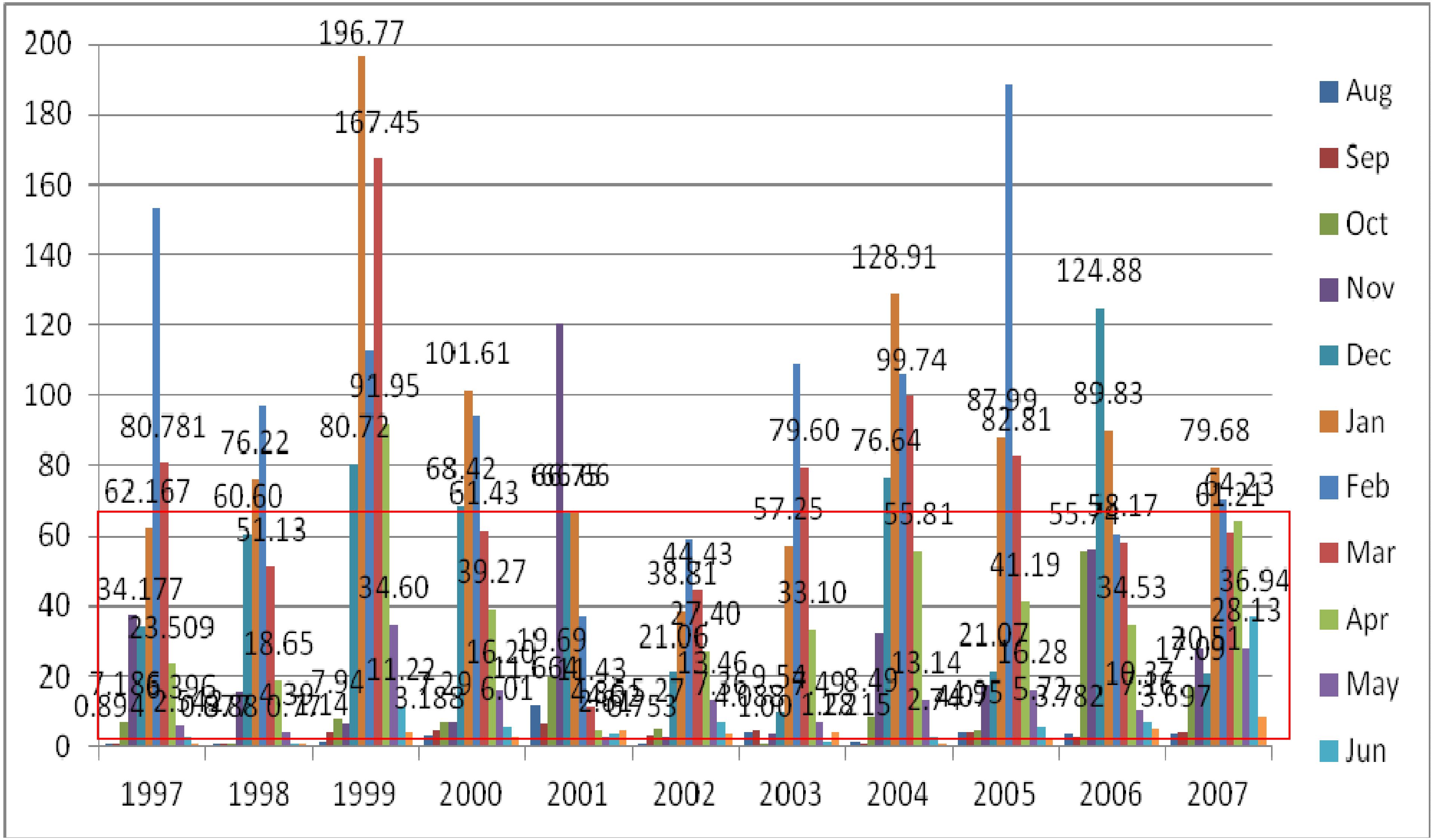

Figure 9: The flow diagram of the Mzimkhulu River from 1997 to 2007, showing the high variance in flow volume, being strongly influenced by summer rainfall cycles. The enclosed red area is the recommended discharges when the fishway should be operational.

Looking at the monthly natural hydrological regime of the Mzimkhulu River from the period 1997 to 2007, a great variance of flow volume can be seen (Figure 9), which is in accordance to a summer rainfall cycle. It is unpractical to design a fishway that can cater for all flow conditions, including exceptionally high flows to exceptionally low flows, and therefore a set of parameters must be designed for a fishway that can cater for the majority of the average base flows. Separate recommendations are therefore made to accommodate aquatic species needing to migrate under low flow conditions. The fishway functionality and optimal flow conditions does, however, need to coincide with the times of the year when the aquatic biota need to migrate, being especially pertinent to groups that undertake migrations *en masse*. The point when the obstruction will drown out and no longer poses as a barrier to migration also needs to be determined as the functionality of the fishway under these flow conditions is not required.

Lower base flows also need to be considered as it is known that many crustaceans undertake migrations during the winter to early spring periods. Recruitment of estuarine species upstream into freshwaters has also been known to be undertaken during the winter (low-flow) season (Bok, *et al.,* 2007). The vast majority of the aquatic biota will migrate during the spring-summer cycle during higher base flows or times of receding floods or freshets.

6.2.4. Fishway design options.

The successful design of a fishway depends largely on providing the hydraulic and physical characteristics that cater for all the migratory species expected to use it (Bok, *et al*, 2007). There are a variety of fishway designs and options that are available, all of which have overall advantages and disadvantages. Important factors to consider are:

- The target biota and the basic hydrological conditions that can be tolerated by these species;
- The hydrological regimes of the river and variations in flows that have to be catered for;
- The topographical aspects of the watercourse and underlying stratum (technical constraints);
- The proposed infrastructure design and requirements.

With these aspects in mind, there are basically three different fishway design options that could be considered.

6.2.4.1. Bypass channel (natural rock ramp).

A bypass channel is the establishment of a side channel with an entrance far downstream of the obstruction and the exit being located upstream of the obstruction – the distances of which are determined by the height difference that has to be catered for, whish, in turn, influences the length of the bypass channel in order to maintain a gradient of between 1:10 and 1:20. This channel is designed with embedded rocks, etc to simulate a natural channel or rapid section of the river itself. If this option can be catered for in terms of topographical features and the required position of the barrier, then it is regarded as the ideal mitigation measure. This option was explored, but it was found to be impossible. Where the weir would have to be constructed to accommodate a bypass channel, largescale excavations would be required to locate suitable foundation material and the weir itself would have to be considerably longer. Besides the obvious cost implications, the structural integrity of the infrastructure would also be a factor to consider. It was therefore found that this option was impossible to implement.

6.2.4.2 Pool and weir designs.

The pool a weir design of fishway includes the traditional pool and weir, which is a series of stepped pools, each at a regular distance below the preceding one. Migrating biota are compelled to jump from pool to pool. The height difference between pools is governed by the height of the obstruction that has to be traversed, the length of the fishway, the design constraints imposed by the local species community, etc. A variations of this design is the sloping baffle fishway, where the horizontal baffles between each pool are sloped to allow for varying water velocities across the width of the baffle (due to the different water depths) and the concentration of flow over the baffle during low flow conditions. This fishway type is has the advantage that it is successful in passing fish and macro-invertebrates within the same fishway channel. The disadvantage of this fishway design is that it is functional over a relatively narrow variation in flow and is therefore only implemented on highly-regulated system such as below dam walls with constant discharge rates or within regulates watercourses. The Mzimkhulu River is subject to regular extremes in flow and therefore this fishway design would only cater for a small period, making it largely unsuitable for the site.

6.2.4.3 Vertical slot design.

The vertical slot design is basically an open channel with no horizontal baffles. Vertical baffles are strategically placed to create turbulent flow and effectively "back" the water up. A series of successive pools is therefore created, but with no actual solid barrier to be encountered or negotiated. Therefore, no jumping ability is required by the species looking to negotiate upstream passage. The vertical slot design remains functional over a wide variance of flow conditions. The disadvantage of the vertical slot is that it is not optimally functional at very low flows. This, however, can be readily overcome by prioritising flow through the fishway. The vertical slot fishway design is therefore the preferred fishway design that will be functional over the widest variance in flow conditions. Provision has also already been made for a vertical slot channel within the weir design.

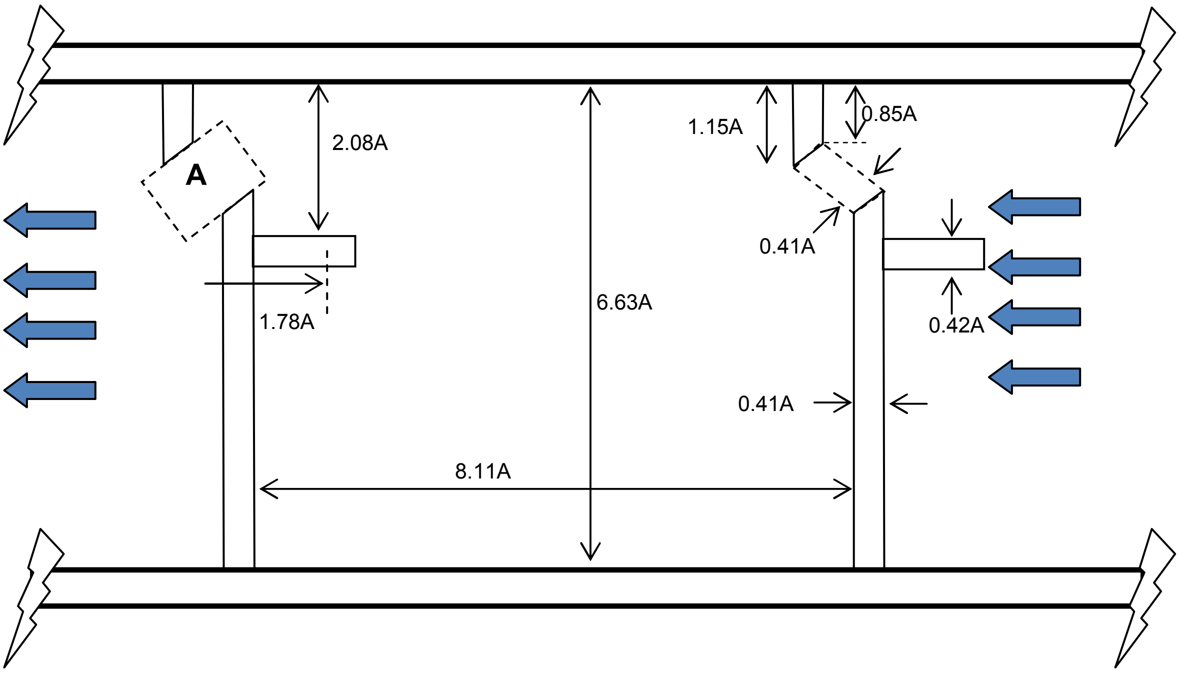

Figure 10: The dimensions of a single bucket of the experimental vertical-slot fishway channel used in this study (*adapted from* Larinier, *et al.*, 2002).

The vertical slot fishway is a design that relies on accurate dimensions as the flows and turbulences encountered within each successive pool (or bucket) is a function of the preceding pool. The repeatability of the hydrological parameters also aids in helping migrating biota find a pattern, which makes it easier to pass through. Figure 10 shows the technical design parameters that should be followed during the design and construction process. It can be seen that all dimensions are a function of the slot opening width (shown as "A" in Figure 10). This will ensure that the lowest possible turbulence levels are encountered within each pool.

At a given slope and discharge rate, the width of the slot dictates the volume of water entering the bucket, which in turn governs the amount of turbulence within the bucket. The change in heights of the water level between successive buckets is a function of the slope of the channel. The steeper the slope of the channel, the higher the discharge rate would be as there would be a higher drop in water levels between successive buckets. As the discharge into a bucket can be measured at a given slope, the turbulence levels within the bucket can also be determined as the exact bucket dimensions (and therefore water volume) are a known factor within the fishway. Therefore, the gradient of the fishway channel at a given discharge rate controls the height difference between each pool, the water velocity within the slot opening and the turbulence levels within the bucket.

The slot width is selected in accordance to the largest individual that is expected to utilise the fishway. In this case a slot with of 150 mm will adequately cater for all individuals that are expected to utilise the fishway as well as be large enough to not be unduly influenced by the accumulation of sediments. This slot width will also be adequate in limiting crowding at the entrance of each pool. As the fishway dimensions are a function of this slot width, further design parameters are 0.995 m (W) x 1.217 m (L). It is further recommended that a slope of 1:10 not be exceeded. At this slope, the height difference between the water levels between successive pools will be 0.123 m, which is another dimension that should not be exceeded. A vertical slot fishway channel with these given dimensions will be functional from discharge ranges of approximately 0.0108 m^3/s, but will function optimally from discharge values of 0.012 m^3/s, where the turbulence within each pool would not exceed 150 Watts/m^3 (optimal). Increased discharge rates see the turbulence levels decreasing. From discharge rates of 0.012 m^3/s, the velocity of the water between successive pools is approximately 0.957 m/s and increases by small increments as the discharge increases. *This velocity should not be allowed to exceed 1.2 m/s and is thought to be the most important limiting factor that will affect the functionality of the fishway.* This water velocity will be exceeded at discharge rates of 0.024 m^3/s. The typical hydrology of a vertical slot fishway channel of the given dimensions at a slope of 1:10 is presented in Figure 11.

It can be seen that the Mzimkhulu River has been known to be reduced to flows as low as 0.7 m^3/s and therefore provision should be made to prioritise flow through the fishway before overtopping the weir.

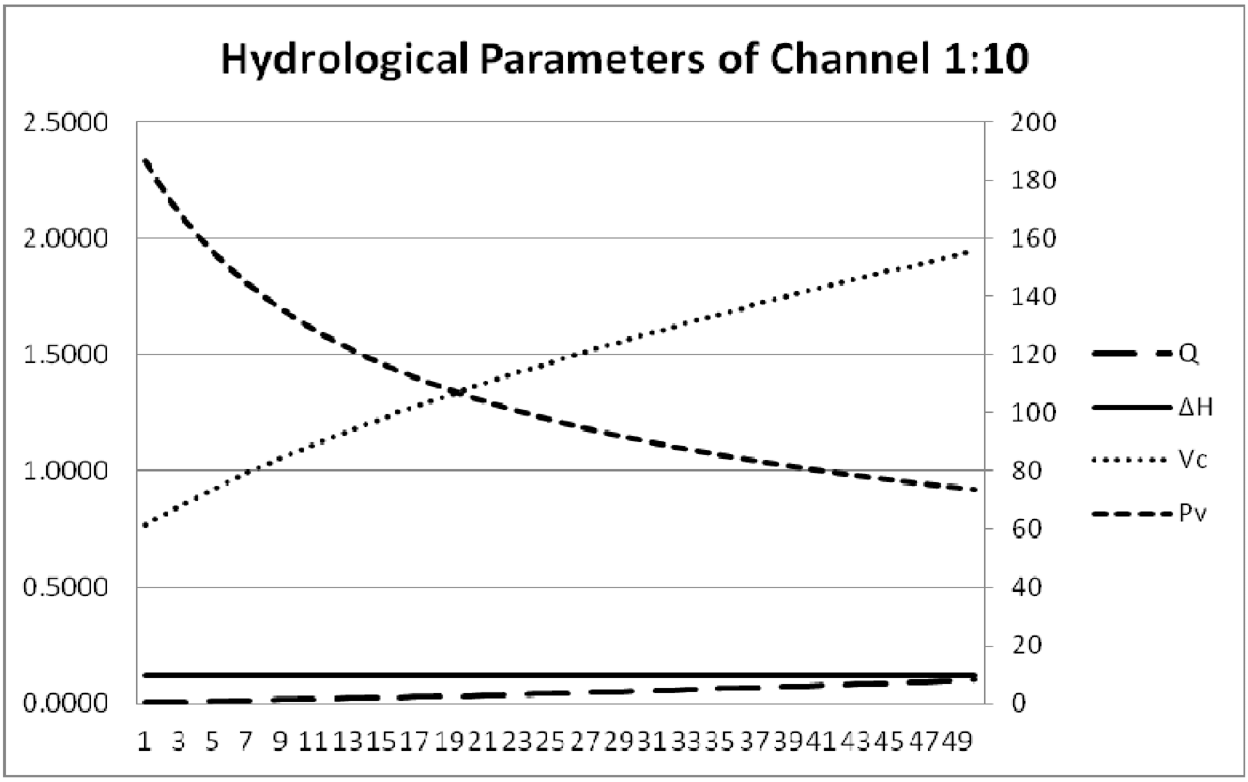

Figure 11: Typical hydrological features of a vertical slot fishway with the dimensions given above. All parameters are presented on the primary axis, with only the turbulence (Pv) levels being presented on the secondary axis.

The functionality of the fishway channel can be further enhanced by the placement (embedding) of rounded stones (of approximately 100-150 mm in diameter) on the bottom of the channel. This will create refuge from turbulence encountered within the channel and provide resting areas for weaker-swimming species. Placing sills of approximately 120mm in the opening of each slot will also enhance functionality at low flows as this will ensure that water will always be retained within the channel.

Other aspects to consider in designing an ecologically functional fishway include attraction flows. Fish and migratory invertebrates tend to utilise the water velocity of the main channel for navigational purposes whilst swimming upstream. The stronger-swimming species tend to favour faster water velocities, whilst weaker swimmers tend to navigate along the periphery of the main flowing areas. The directional movement of all migrating biota is governed by the flow direction. Many a correctly-designed fishway has suffered poor functionality due to the entrance of the fishway channel (the exit of the water, or “bottom outlet”) being poorly located. As fish and many invertebrates tend to favour the flowing waters of the main channel or the periphery of that channel, the entrance of the fishway needs to coincide with this flow. Upon reaching a barrier, fish tend to move laterally in order to locate a passage over the barrier. It is in this lateral movement that they should be able to find the entrance to the fishway. If fish cannot find the entrance to the fishway, many will perish out of exhaustion, be targeted by predators as they gather in large numbers, or will spawn in unfavourable conditions at the base of the barrier. By locating the fishway entrance within a quiet area of the river below a barrier, away from all turbulence and flows, the fish attempting upstream passage will struggle to locate it and the fishway will not be utilised. An advantage of the vertical slot fishway is that the channel can be double-backed in order to locate the entrance within the vicinity of the flowing water. The bucket that incorporates the turning point should be larger than the preceding and proceeding buckets in order to dissipate the turbulence and provide for a resting area.

The vertical slot fishway will provide migratory freedom to the fish species and some migratory invertebrates within the system, but will not adequately cater for juvenile eels and the vast majority of migratory invertebrates that migrate as juveniles as well. Studies have shown that individuals of these species migrate along the periphery of the channel, often where the water velocity is tending toward zero. They also have the ability to leave the main water column and move along the wetted roughened surfaces of the splash zones (Bok, *et al.,* 2007). This splash zone does not occur within a vertical slot fishway due to the vertical surfaces. Provision therefore needs to be made elsewhere to accommodate these groups of species. To mitigate this, it is proposed that the weir that spans the width of the river be constructed in a series of terraces and the transition from a lower terrace to a higher one be done with a sloped surface of approximately 30%. This will ensure that a splash zone always exists. The amount of terraces should coincide with the flow variations experienced by the channel, but it is assumed that not more than three different levels would be required to ensure that there is a splash zone featured at most low to moderate flows. Freshet and particularly high flow conditions do not need to be catered for as weaker-swimming species seek refuge from flood conditions and are not inclined to migrate under these conditions. Further to this, it is recommended that the lowest terrace be fitted with a sloping surface toward the downstream side that extends to the substrate of the watercourse in a spreading, cone-like structure. Under very low-flow conditions, this will ensure that a wetted surface always occurs.

7. IMPACT SIGNIFICANCE SURVEY.

The significance of the potential impacts of the various development activities both before mitigation and after the implementation of mitigation measures has been summarised and is presented in Appendix D, Table 15., as part of the Environmental management Plan (EMP).

7.1. Off-Channel Storage Dam.

7.1.1. Establishment of the storage dam.

The establishment of a dam wall on a river will completely alter the characteristics of the system and profoundly impact the organisms that inhabit it. Rivers such as the Ncwabeni and Gugamela Rivers are non-perennial in nature, meaning that they flow seasonally in accordance to the rainfall received within their respective catchment areas. They also receive water sources through groundwater discharge, which is also rainfall-dependent. Even during the low-flow periods, the systems provide habitat by the retention of surface waters within isolated pools. During high-flow periods, flow within these tributaries is restores, opening up access recruitment of species from the main channel, and many fish and invertebrate species utilise these tributary channels for a variety of reasons. These include refuge from the main channel during flood conditions, exploitation of the habitat for inhabitation or feeding, increased breeding habitat and provision of nursery areas. Damming a river will remove this. The dam could provide permanent habitat for invertebrates and fish (if stocked), but the genetic dispersal of these populations would largely be lost to the system. Only a few of the riverine species would flourish within a dam environment as well, which will drastically alter the species community structures on a local catchment scale. In looking at the local catchments associated with the Mzimkhulu River within the region, it was found that the Gugamela and the Ncwabeni River local catchments were not unique and that numerous catchment areas of similar size and state of ecological integrity are associated with the system that could provide alternative habitat opportunities. Figure 12 presents other local catchment areas within the region that could be alternatively utilised for habitat exploitation.

It should be noted that the significance of this impact is dependent on the cumulative impact of developments of this nature. This development is regarded as an isolated development within a catchment area that does not suffer significantly from this impact. Cumulative impacts of a greater number of impoundments within the future within this catchment area will have to be carefully evaluated.

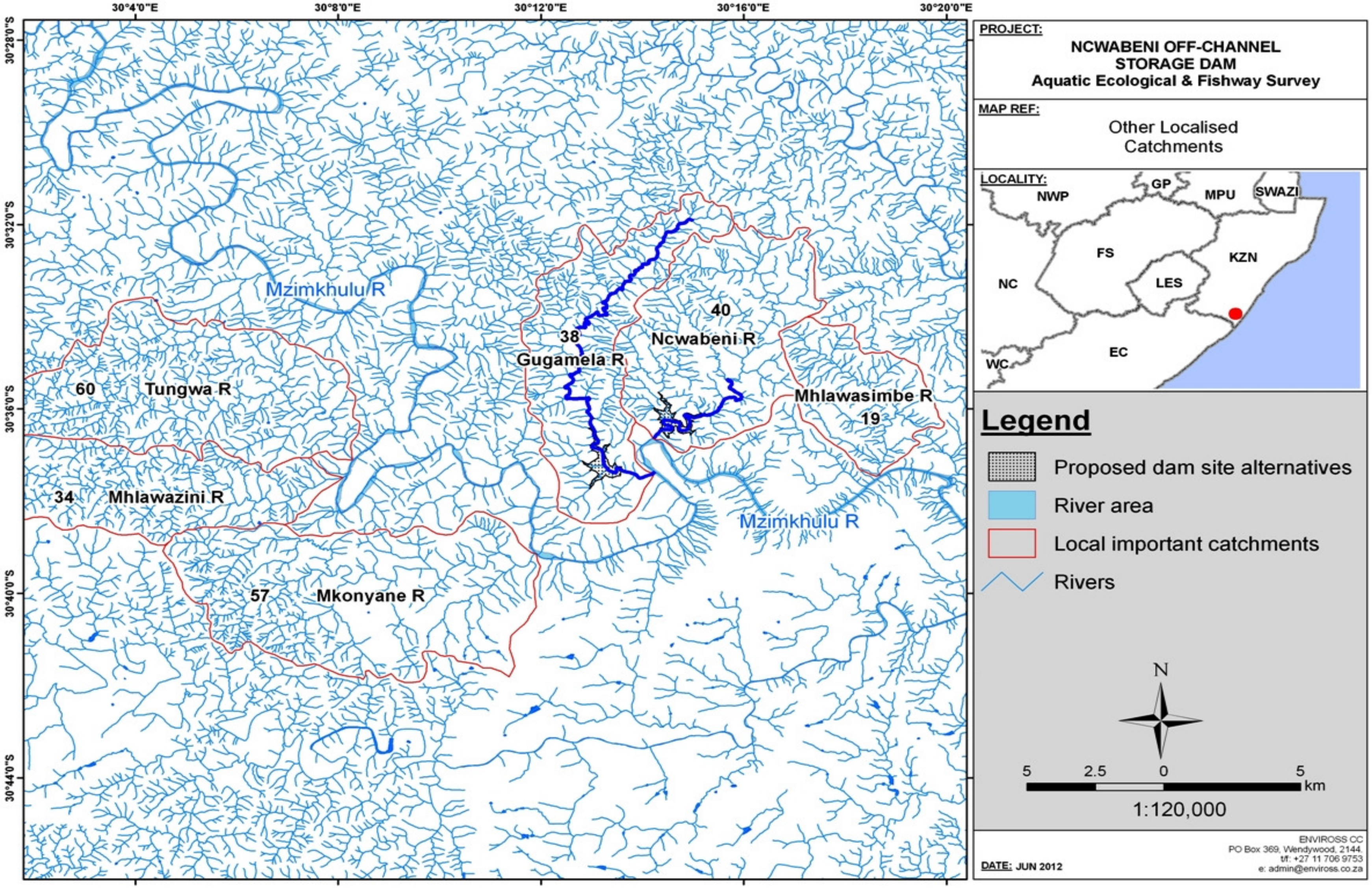

Figure 12: Other local catchment areas of similar PES and habitat features available for inhabitation within the region.

7.1.2. Site alternatives.

There have been two site alternatives proposed for the off-channel storage dams, namely on the Gugamela River or the Ncwabeni River. Both of these river catchments are located on the northern side of the Mzimkhulu River. The Gugamela River has a localised catchment area slightly smaller to that of the Ncwabeni River, being 38 km^2 and 40 km^2, respectively. Both of these local catchments incorporate catchment areas of similar land use, drivers and impacts.

From the ecological surveys of each river, it was found that the Ncwabeni River supported a far greater diversity and density of aquatic biota than what was supported by the Gugamela River. The most significant difference in habitat characteristics noted during the survey was the water temperature. The Gugamela River showed a water temperature between 8 and 10°C colder than that of the receiving Mzimkhulu River. The Ncwabeni River showed a similar temperature to the Mzimkhulu River. This means that aquatic biota would naturally seek refuge or naturally inhabit the Ncwabeni River, freely migrating between the two channels. This would not be true for the Gugamela River as the relatively large temperature difference would form a temperature barrier which would not readily be crossed through, making this channel less important to aquatic biota as a refuge or for habitat exploitation. This temperature difference is presumed to be purely as a function of the localised catchment characteristics. The Gugamela River passes through ravine habitat, where steep banks and the generally closed canopy of the riparian vegetation means that the water does not have chance to be heated by the sun. It is also a system that could be heavily supplemented by underground water, which is naturally colder than surface waters within the given landscape. A poorly-constructed bridge crossing on the Gugamela River also poses as a migratory barrier under all but considerable high flow conditions, further inhibiting upstream recruitment of aquatic biota within this system. This is an impact that can be readily mitigated though by relatively simple and cost-effective means.

The Ncwabeni River has a waterfall that poses a natural migratory barrier approximately 4 km upstream of its confluence with the Mzimkhulu River. This waterfall would be located within the area that would be inundated by the establishment of a dam. Therefore, even though a highly-productive section of river, the entire catchment area is not open to upstream recruitment by fish and many invertebrate species. This greatly decreases the significance of the impact of establishment of the impoundment on this river. This feature is not present on the Gugamela River, potentially making the Gugamela River catchment a far bigger catchment area open to exploitation by migrating aquatic biota. Therefore, placing the off-channel storage dam on the Ncwabeni River will not impact on the extent of the catchment area open to fish and many invertebrates in relation to if it was to be placed on the Gugamela River.

7.1.3. Impacts of stored water and releases.

It is proposed that the, as part of the operational procedures of the dam, that water will be pumped from the Mzimkhulu River and stored within the OCS dam during the high-flow periods. During the low-flow periods, water will be pumped or released back into the channel to supplement the volume to meet the pumping demand for abstraction at St Helen's Rock Abstraction Works near Port Shepstone. The storage of the water will effectively change the system from a flowing (lotic) system to a still (lentic) system. This means that the water will not be subject to mixing that would otherwise occur within a shallow, flowing system. Temperature stratification (layering) will occur within the stored water, with the cooler water being located at the deepest points of the dam. The water located within the deeper areas of the dam can be considerably cooler than the upper layers of the dam. A thermocline will develop, with the consequence that only the upper layers (epilimnion) will mix. This will be largely driven by wind and cyclic (daily) heating and cooling of the water and is the layer that retains gaseous exchange with the atmosphere. The lower layer (hypolimnion) will not mix across the thermocline and therefore never comes into contact with the atmosphere for gaseous exchange, with the result that it will become depleted of oxygen (anoxic). The hypolimnion also tends to have a higher pH and higher Tds than the epilimnion. Release of this water into the receiving aquatic ecosystem would be detrimental to the aquatic biodiversity.

The significance of the impact emanating from releasing water that has been stored for a relatively long time (during the summer, high-flow period) will be determined by the depth of the intake for the release. Releasing water from the hypolimnion will mean that the colder, oxygen-poor water will impact on the characteristics of the receiving water. Having the intake within the hypolimnion would be an effective way of releasing sediments from the storage dam, but the altering of the characteristics of the receiving waters will have a significant impact on the species community structures of the receiving waters. It is proposed that only water from the epilimnion (the layer above the thermocline that has a temperature governed largely by ambient temperature, wind and radiant energy) should be released or pumped into the watercourse. This will ensure that the characteristics of the water within the Mzimkhulu River are not significantly altered and will therefore not impact the species community structures of the system.

As both dam walls are similar in height, this impact feature does not influence the choice of the preferred alternative.

7.2. Quarry pits and river diversion (Ncwabeni River).

A quarrying area has been identified in association with the Ncwabeni River. In order to accommodate the quarrying processes, a localised diversion of the Ncwabeni River will also be required. Quarrying activities will disturb and destabilise the soils, making them vulnerable to erosion, which will, in turn add to siltation and smothering of the aquatic habitat. This quarrying activity (excavations) is proposed within an area that would be inundated should the Ncwabeni option for the off-channel storage dam be favoured. If this is the case, then the excavated area will merely add in creating a larger storage capacity for the dam. No disturbed soils will also not be subjected to scouring impacts of flowing water as there will be minimal to zero water velocity encountered within the impoundment. If the Ncwabeni option is found to be the preferred option, then the diversion of the river will also be reduced to a short-term impact that will only be imposed on the system during the construction phase and during the initial phases whilst the impoundment fills.

If the Gugamela River option is found to be the preferred alternative, the quarrying activities along the Ncwabeni River and the permanent diversion of the watercourse will have a long-term impact on the system. Diverting a river will lead to disturbances of the soils and the aggravation of soil erosion. The diversion of the watercourse will also alter the natural hydrology of the localised area, which could further aggravate erosion. If allowed to remain unabated, this has the potential to completely transform the system over the long term. If this aspect is looked at in isolation, then the Ncwabeni alternative site would be the option with the least overall ecological impacts, which could also be more readily managed.

If this aspect is looked at in isolation, then the construction of the dam at the Ncwabeni River site, together with the quarrying activities would be the preferred option as this would localise the impact footprint and have the least overall long-term impacts. The present ecological state of the rivers has been retained in near-natural condition through the catchment areas being unimpacted. Localising the impact footprint is therefore important to conserving the catchment area, which will, in turn, conserve the watercourses within the catchment. This is only true if the quarry activities occur within the proposed areas (adjacent to the Ncwabeni River).

7.3. Impacts of associated infrastructure on watercourses.

The relatively steep topography of the surrounding area means that runoff water potential is high during rainfall events. This means that numerous drainage lines occur within the area and were noted within the map development. Upon exploration these drainage lines were found to not support aquatic habitats as the retention of surface water for any significant period was impossible due to the steep topographies. Construction processes within these areas are therefore not thought to have any significant impacts on the aquatic habitat units. It should be noted, however, that these areas would be particularly vulnerable to the scouring effects of running water creating erosion and subsequent siltation of the receiving aquatic habitat. If construction within these drainage lines is to take place, measures to mitigate and permanently manage the impacts of soil erosion must be put in place. These could include the provision of silt traps and silt fences on all disturbed sloped areas until vegetation has had a change to become established and stabilise the disturbed soils.

8. PREFERRED ALTERNATIVE.

In looking at the impacting features above and the various factors that will drive the pressures on the watercourses and catchment areas, the preferred alternative is to construct the off-channel storage dam on the Ncwabeni River. The overall impacting features associated with the proposed construction activities can be localised and the impact footprint minimised in this way. The overall ecological condition of the catchment area is considered a major driver for the good PES ratings of the associated watercourses. The ecological integrity of the watercourses can be retained if the catchment impacts can be contained and localised, which will be the case if the off-channel storage dam together with the quarrying activities are located within the same foot print area.

Table 9: Comparison between the key findings and overall ecological implications of constructing a dam on the Gugamela or Ncwabeni Rivers.

River	PES Rating	Level of support to aquatic biota		Quarry activities & river diversion	Impacts of infrastructure on other watercourses
		Fish	Macro-invertebrates		
Ncwabeni	A	Medium to High – an impassable waterfall occurs 4km upstream of the confluence with the main channel	High	Preferred Ncwabeni option: Short term impacts, but eventual inundation will negate long-term impacts. It will reduce the overall footprint of the impact within the catchment area – important for long-term conservation significance.	Minimal
Gugamela	A/B	Low	Medium-High	Preferred Gugamela option: Quarrying activities at the Ncwabeni River will necessitate river diversion over the long term. Open quarries will have high, long-term impacts on the system, which are not readily managed.	Minimal, but will require more than three times the length of infrastructure, which will increase the impact footprint.

9. CONCLUSIONS & RECOMMENDATIONS.

An aquatic and riverine habitat survey was undertaken, together with a fish community and impact survey, to evaluate the impacts of the proposed Ncwabeni off-channel storage dam and its associated infrastructure. A field survey was undertaken during May 2012.

The following salient conclusions could be drawn upon completion of the survey:

- The Mzimkhulu River was found to be listed as a priority catchment as part of the National Freshwater Ecosystems Priority Areas and has retained an overall A/B Present Ecological State. The field survey reiterated the high ecological value of the river system;
- The Mzimkhulu River also acts as a conduit for priority migratory species that require access to inland waters to complete their lifecycles;
- A vertical slot fishway channel has been recommended to be incorporated into the weir design on the Mzimkhulu River;
- Further modifications have also been recommended to the weir design to cater for migrating invertebrates and juvenile Anguillid eels;
- A follow-up monitoring programme is recommended to determine the overall functionality of the fishway;
- The establishment of the off-channel storage dam on the Ncwabeni River is considered to have the least overall impact in both aquatic habitat as well as catchment impacting footprint;
- It is recommended that the bridge crossing at the Gugamela River be improved so that it does not inhibit upstream migrations.
- The associated infrastructure will have an insignificant impact on the remaining drainage lines within the area;
- An Environmental Management Plan (EMP) (Appendix D) has been developed to aid in lessening the overall ecological impacts of the proposed development activities, which shows that most of the perceived impacts can be appropriately mitigated.

10. REFERENCES

BOK, A., KOTZE, P., HEATH, R. and ROSSOUW, J. (2007). **Guidelines for the planning, design and operation of fishways in South Africa.** WRC Report no. TT287/07. Water Research Commission, Pretoria, South Africa.

BKS (2012) **Ncwabeni off-channel storage dam – Scoping Report.** Report to Department of Water Affairs. NEAS Ref No: DEA/EIA/0000586/2011; DEA Ref. No: 12/12/20/2468.

CHUTTER, F. M. (1998) **Research on the Rapid Biological Assessment of Water Quality Impacts in Streams and Rivers.** *Water Research Commission.* WRC Report No. 422/1/98, Water Research Commission, Pretoria, South Africa.

DALLAS, H.F. and DAY, J.A. (2004). **The Effect of Water Quality Variables on Aquatic Ecosystems: A Review.** WRC Report No. TT 224/04.

DICKENS C and GRAHAM M (2002). **The South African Scoring System (SASS) Version 5 Rapid Bioassessment Method for Rivers**. *African Journal of Aquatic Science*. 27; 1-10.

D.W.A.F. (1996) **South African Water Quality Guidelines. Volume 7: Aquatic Ecosystems.** Department of Water Affairs and Forestry, Pretoria, South Africa.

D.W.A.F. (2002) **Proposal to establish the Mvoti to Mzimkulu Catchment Management Agency.** Prepared by AJ Wilson and Associates International CC and Catchment Consultant CC (T/a IWR Consultants) for the Depart of Water Affairs and Forestry, KwaZulu Natal Regional Office.

D.W.A.F. (2005) **A practical field procedure for identification and delineation of wetlands and riparian areas (edition 1).** Department of Water Affairs and Forestry, Pretoria.

D.W.A.F. (2005) **River eco-classification: Manual for EcoStatus determination (version 1).** Document no. KV 168/05, Department of Water Affairs and Forestry, Pretoria.

D.W.A.F. (2011) **Mzimkhulu River Catchment water resource study (WP990) – Riverine ecology water requirements. Report no WMA 11/T50/00/3009 Volume 5.** Prepared by Aurecon South Africa (Pty) Ltd *in association with* Isikhungusethu (Pty) Ltd), Institute of Natural Resources, and Geomeasure Group (Pty) Ltd *for* the Depart of Water Affairs, Pretoria.

IWR Source-to-Sea (eds). (2004) **A comprehensive EcoClassification and habitat Flow Stressor Response Manual.** Prepared for IWQS: DWAF, Project no: 2002-148.

GERBER, A. and GABRIEL, MJM. (2002). **Aquatic Invertebrates of South Africa: A Field Guide.** Institute of Water Quality Studies (IWQS), DWAF, Pretoria, South Africa.150pp.

KEMPSTER, PL., HATTINGH, WHJ., and VAN VLIET, HR. (1982). **Summarised water quality criteria. Technical report NR. Tr 108.** Department of Environmental Affairs and Forestry, Pretoria.

KLEYNHANS, CJ. (1996). **A qualitative procedure for the assessment of the habitat integrity status of the Luvuvhu River (Limpopo System, South Africa).** *Journal of Aquatic Ecosystem Health 5:41-54*.

KLEYNHANS, CJ. (1997). **An exploratory investigation of the Instream Biological Integrity of the Crocodile River, Mpumalanga, as based on the Assessment of Fish Communities.** Draft Report, Department of Water Affairs and Forestry, Institute for Water Quality Studies, Pretoria. 61 pp.

KLEYNHANS, CJ. LOUW, MD. (2007). **Module A: EcoClassification and EcoStatus determination in River EcoClassification: Manual for EcoStatus Determination (version 2).** Joint Water Research Commission and Department of Water Affairs and Forestry report. WRC Report No. TT329/08

McMILLAN, PH. (1998). **An Integrated Habitat Assessment System (IHAS v2), for the Rapid Biological Assessment of Rivers and Streams.** A CSIR research project. Number ENV-P-I 98132 for the Water Resources Management Programme. CSIR. ii + 44 pp.

NEL, JL., DRIVER, A., STRYDOM, WF., MAHERRY, A., PETERSON, C., HILL, ROUX, DJ., NIENABER, S., VAN DEVENTER, H., SWARTZ, E and SMITH-ADAO, LB (2011). **Atlas of freshwater ecosystem priority areas in South Africa: Maps to support sustainable development of water resources.** Report to the Water Research Commission. WRC Report No. TT 500/11.

SCOTT, LEP., SKELTON, PH., BOOTH, AJ., VERHEUST, L., HARRIS, R AND DOOLEY, J. (2006). **Atlas of southern African freshwater fishes.** Smithian monograph 2. Published by The South African Institute for Aquatic Biodiversity (SAIAB), Grahamstown.

SKELTON PH. (2001). **A complete guide to freshwater fishes of southern Africa.** Struik Publishers (Pty) Ltd., Cape Town, South Africa. 395pp.

THIRION, CA.; MOCKE, A. and WOEST, R. (1995). **Biological Monitoring of Streams and Rivers using SASS4: A User Manual. Final Report, No. N 000/00/REQ/1195.** Institute of Water Quality Studies, Department of Water Affairs and Forestry, Pretoria.

THIRION, C. (2007). **Module E: Macroinvertebrate Response Assessment Index in River EcoClassification: Manual for Eco Status Determination (version 2).** Joint Water Research Commission and Department of Water Affairs and Forestry report, Pretoria, South Africa.

APPENDIX A - METHODOLOGIES APPLIED DURING THIS BIOMONITORING ASSESSMENT – AQUATIC MACRO-INVERTEBRATE COLLECTION – SASS5 METHODOLOGY.

Sample Collection.

A standard SASS invertebrate net (300 x 300 mm square with 1mm gauge mesh netting) was used for the collection of the organisms. The available biotopes at each site were identified and each of the biotopes was sampled by different methods explained under the relevant sections.

The biotopes were combined into three different groups, which were sampled and assessed separately:

a) Stone (S) Biotopes:

Stones in current (SIC) or any solid object: Movable stones of at least cobble size (3 cm diameter) to approximately 20 cm in diameter, within the fast and slow flowing sections of the river. Kick-sampling is used to collect organisms in this biotope. This is done by putting the net on the bottom of the river, just downstream of the stones to be kicked, in a position where the current will carry the dislodged organisms into the net. The stones are then kicked over and against each other to dislodge the invertebrates (kick-sampling) for ± 2 minutes.

Stones out of current (SOOC): Where the river is still, such as behind a sandbank or ridge of stones or in backwaters. Collection is again done by the method of kick-sampling, but in this case the net is swept across the area sampled to catch the dislodged biota. Approximately 1 m^2 is sampled in this way.

Bedrock or other solid substrate: Bedrock includes stones greater than 30cm, which are generally immovable, including large sheets of rock, waterfalls and chutes. The surfaces are scraped with a boot or hand and the dislodged organisms collected. Sampling effort is included under SIC and SOOC above.

b) Vegetation (Veg) Biotopes:

Marginal vegetation (MV): This is the overhanging grasses, bushes, twigs and reeds growing on the edge of the stream, often emergent, both in current (MvegIC) and out of current (MvegOOC). Sampling is done by holding the net perpendicular to the vegetation (half in and half out of the water) and sweeping back and forth in the vegetation (± 2m of vegetation).

Submerged vegetation (AQV): This vegetation is totally submerged and includes Filamentous algae and the roots of floating aquatics such as water hyacinth. It is sampled by pushing the net (under the water) against and amongst the vegetation in an area of approximately one square meter.

c) Gravel, Sand and Mud (GSM) biotopes:

Sand: This includes sandbanks within the river, small patches of sand in hollows at the side of the river or sand between the stones at the side of the river. This biotope is sampled by stirring the substrate by shuffling or scraping of the feet, which is done for half a minute, whilst the net is continuously swept over the disturbed area.

Gravel: Gravel typically consists of smaller stones (2-3 mm up to 3 cm). It is sample in a similar fashion to that of sand.

Mud: It consists of very fine particles, usually as dark-collared sediment. Mud usually settles to the bottom in still or slow flowing areas of the river. It is sample in a similar fashion to that of sand.

d) Hand picking and visual observation:

Before and after disturbing the site, approximately 1 minute of "hand-picking" for specimens that may have been missed by the sampling procedures was carried out.

APPENDIX B - METHODOLOGIES APPLIED DURING THIS BIOMONITORING ASSESSMENT – INTEGRATED HABITAT ASSESSMENT (IHAS) METHODOLOGY AND CALCULATIONS.

Sampling Habitat Score	Mzimkhulu		Gugamela		Ncwabeni	
Stones In Current (SIC)	**Descr**	**Score**	**Descr**	**Score**	**Descr**	**Score**
Total length of white water rapids (ie: bubbling water) (in m)	>5	5	>1-2	2	>5	5
Total length of submerged stones in current (run) (in m)	>10	4	>2-5	2	>10	4
Number of separate SIC area's kicked	>5	4	2-3	2	>5	4
Average stone sizes kicked (in cm's)	<2>20	1	2-10	2	<2>20	1
Amount of stone surface clear (in %)	>75	4	26-50	2	>75	4
Protocol: time spent actually kicking SIC's (in mins)	>3	5	>3	5	>2-3	4
SIC score (max 20)		**23**		**15**		**22**
Vegetation (VEG)						
Length of marginal vegetation sampled (banks) (in m)	>2	5	>2	5	>2	5
Amount of aquatic vegetation/algae sampled (underwater in m^2)	None	0	>1	3	0-0.5	1
Fringing vegetation sampled in or out of current	mix	5	mix	5	mix	5
Type of veg. (percent leafy as apposed to stems/shoots)	0	1	>75	5	51-75	4
Veg score (max 15)		**11**		**18**		**15**
Other Habitat / General (O.H.)						
Stones Out Of Current (SOOC) sampled (in square m^2)	1	3	1	3	0-0.5	1
Sand sampled (in minutes)	0-0.5	2	0-0.5	2	0-0.5	2
Mud sampled (in minutes)	0-0.5	2	0-0.5	2	0-0.5	2
Gravel sampled (in minutes)	>0.5**	3	0-0.5	1	>0.5**	3
Bedrock sampled (all = no SIC, sand, gravel)	some	1	some	1	some	1
Algal presence (m^2)	none	5	none	5	isol.	4
Tray identification	corr.	3	corr.	3	corr.	3
O.H. score (max 20)		**19**		**17**		**16**
Sampling habitat totals (max 55)		**53**		**50**		**53**
Stream Condition						
Physical	**Descr**	**Score**	**Descr**	**Score**	**Descr**	**Score**
River make up	3 mix	5	2 mix	4	3 mix	5
Average width of stream (in meters)	>10	1	1-2	4	1-2	4
Average depth of stream (in meters)	>1-2	1	0.5	4	0.5	4
Approximate velocity of stream	mix	5	slow	1	mix	5
Water colour	discol	3	clear	5	clear	5
Recent disturbances	none	5	none	5	none	5
Bank/Riparian vegetation	mix	4	mix	4	mix	4
Surrounding impacts	farm	1	open	5	open	5
Left bank cover (rocks and vegetation) (in %)	>95	3	81-95	2	>95	3
Right bank cover (rocks and vegetation) (in %)	>95	3	81-95	2	>95	3
Stream condition total (max 45)		**31**		**36**		**43**
Total IHAS score (%)		**84**		**86**		**96**

APPENDIX C - METHODOLOGIES APPLIED DURING THIS BIOMONITORING ASSESSMENT – INDEX OF HABITAT INTEGRITY (IHI) METHODOLOGY AND CALCULATIONS.

- The Habitat Integrity of the stream segment was scored according to 12 different criteria (Table 10), which represent the most important, and easily quantifiable, anthropogenically-induced impacts on the system. The instream and riparian zones were analyzed separately, and the final assessment was made separately for each, in accordance with Kleynhans' (1999) approach to Habitat Integrity Assessment. Data for the riparian zone are however primarily interpreted in terms of the potential impact on the instream component;
- The assessment of the severity of impact of modifications is based on six descriptive categories with ratings ranging from 0 (no impact), 1 to 5 (small impact), 6 to 10 (moderate impact), 11 to 15 (large impact), 16 to 20 (serious impact) and 21 to 25 (critical impact), in accordance with the level of the impact created by the criterion (Table 11).
- Analysis of the data was carried out by weighting each of the criteria. The weights given to the different instream and riparian factors used in the Intermediate Habitat Integrity are listed in Table 12.
- Based on the relative weights of the criteria, the impact of each criterion is estimated as follows: Rating for the criterion/maximum value (25) x weight (percent);
- The instream and riparian habitat integrity for each segment was calculated by adding the weighted scores of the appropriate criteria separately and subtracting the resulting values from one hundred, thus obtaining provisional Habitat Integrity scores (expressed as percentages) for instream and riparian habitats;
- In cases where riparian zone criteria and the water abstraction, flow, bed and channel modification, water quality and inundation criteria of the instream component exceeded ratings of large, serious or critical, an additional negative weight was applied. The aim of this is to accommodate the possible cumulative effect (and integrated) negative effects of such impacts (Kemper *et al*. 1999).

The following rules were applied in this respect:

- Impact = Large, lower the integrity status by 33% of the weight for each criterion with such a rating.
- Impact = Serious, lower the integrity status by 67% of the weight for each criterion with such a rating.

- Impact = Critical, lower the integrity status by 100% of the weight for each criterion with such a rating.
- The negative weights were added for the instream and riparian facets respectively and the total additional negative weight subtracted from the provisionally determined intermediate integrity to arrive at a final intermediate habitat integrity estimate (Kemper *et al*., 1999).
- The eventual total scores for the instream and riparian zone components are then used to place the habitat integrity of both in a specific intermediate habitat integrity class/category. These classes are indicated in Table 13;
- By calculating the mean of the instream and riparian Habitat Integrity scores, an overall Habitat Integrity score is obtained.

Table 10: Criteria used in the assessment of habitat integrity (Kleynhans, 1996).

Criterion	Relevance
Water abstraction	Direct impact on habitat type, abundance and size. Also impacted in flow, bed, channel and water quality characteristics. Riparian vegetation may be influenced by a decrease in the supply of water.
Flow modification	Consequence of abstraction or regulation by impoundments. Changes in the temporal and spatial characteristics of flow can have an impact on habitat attributes such as an increase in duration of low flow season, resulting in low availability of certain habitat types or water at the start of the breeding, flowering or growing season.
Bed modification	Regarded as the result of increased input of sediment from the catchment or a decrease in the ability of the river to transport sediment (Gordon *et al.,* 1993). Indirect indications of sedimentation are stream bank and catchment erosion. Purposeful alteration of the stream bed, e.g. the removal of rapids for navigation (Hilden & Rapport, 1993) is also included.
Channel modification	May be the result of a change in flow, which may alter channel characteristics causing a change in marginal instream and riparian habitat. Purposeful channel modification to improve drainage is also included.
Water quality modification	Originates from point and diffuse point sources. Measured directly or agricultural activities, human settlements and industrial activities may indicate the likelihood of modification. Aggravated by a decrease in the volume of water during low or no flow conditions.
Inundation	Destruction of riffle, rapid and riparian zone habitat. Obstruction to the movement of aquatic fauna and influences water quality and the movement of sediments (Gordon *et al*., 1992).
Exotic macrophytes	Alteration of habitat by obstruction of flow and may influence water quality. Dependant upon the species involved and scale of infestation.
Exotic aquatic fauna	The disturbance of the stream bottom during feeding may influence the water quality and increase turbidity. Dependent upon the species involved and their abundance.
Solid waste disposal	A direct anthropogenic impact which may alter habitat structurally. Also a general indication of the misuse and mismanagement of the river.
Indigenous vegetation removal	Impairment of the buffer the vegetation forms to the movement of sediment and other catchment runoff products into the river (Gordon et al., 1992). Refers to physical removal for farming, firewood and overgrazing.
Exotic vegetation encroachment	Excludes natural vegetation due to vigorous growth, causing bank instability and decreasing the buffering function of the riparian zone. Allochtonous organic matter input will also be changed. Riparian zone habitat diversity is also reduced.
Bank erosion	Decrease in bank stability will cause sedimentation and possible collapse of the river bank resulting in a loss or modification of both instream and riparian habitats. Increased erosion can be the result of natural vegetation removal, overgrazing or exotic vegetation encroachment.

Table 11: Descriptive classes for the assessment of modifications to habitat integrity (from Kleynhans, 1996).

Impact category	Description	Score
None	No discernible impact or the factor is located in such a way that it has no impact on habitat quality diversity, size and variability.	0
Small	The modification is limited to a very few localities and the impact on habitat quality, diversity, size and variability is also very small.	1 – 5
Moderate	The modification is present at a small number of localities and the impact on habitat quality, diversity, size and variability is also limited.	6 – 10
Large	The modification is generally present with a clearly detrimental impact on quality habitat quality, diversity, size and variability. Large areas are, however, not influenced.	11 – 15
Serious	The modification is frequently present and the habitat quality, diversity, size and variability almost the whole of the defined section are affected. Only small areas are not influenced.	16 – 20
Critical	The modification is present overall with a high intensity; the habitat quality, diversity, size and variability in almost the whole of the defined section are detrimentally influenced.	21 – 25

Table 12: Criteria and weights used for the assessment of intermediate habitat integrity (from Kleynhans, 1996).

Instream Criteria	Weight	Riparian Zone Criteria	Weight
Water abstraction	14	Indigenous vegetation removal	13
Flow modification	13	Exotic vegetation encroachment	12
Bed modification	13	Bank erosion	14
Channel modification	13	Channel modification	12
Water quality	14	Water abstraction	13
Inundation	10	Inundation	11
Exotic macrophytes	9	Flow modification	12
Exotic fauna	8	Water quality	13
Solid Waste Disposal	6		
TOTAL	**100**	**TOTAL**	**100**

Table 13: Intermediate Habitat Integrity Assessment Classes (from Kleynhans, 1996).

Class	Description	Score (% of total)
A	Unmodified, natural.	90-100
B	Largely natural with few modifications. A small change in natural habitats and biota may have taken place but the basic ecosystem functions are essentially unchanged.	80-90
C	Moderately modified. A loss and change of natural habitat and biota have occurred, but the basic ecosystem functions are still predominantly unchanged.	60-79
D	Largely modified. A large loss of natural habitat, biota and basic ecosystem functions has occurred.	40-59
E	The loss of natural habitat, biota and basic ecosystem functions is extensive.	20-39
F	Modifications have reached a critical level and the lotic system has been modified completely with an almost complete loss of natural habitat and biota. In the worst instances, basic ecosystem functions have been destroyed and the changes are irreversible.	0-19

APPENDIX D - ENVIRONMENTAL MANAGEMENT PLAN (EMP) PERTAINING TO THE MITIGATION OF THE ECOLOGICAL IMPACTS AFFECTING THE OVERALL ECOLOGICAL INTEGRITY FOR THE PROPOSED NCWABENI OFF-CHANNEL STORAGE DAM.

All quoted literature references are listed under section 10. References.

D1. INTRODUCTION.

Umgeni Water has proposed the construction and development of the Ncwabeni Off-Channel Storage Dam, which is a scheme to enable a more reliable source of water for downstream users of the Mzimkhulu River. As part of the proposed development, an abstraction/flow gauging weir is to be constructed on the Mzimkhulu River, which will represent the only major barrier on an otherwise open system. There are two alternatives offered for the off-channel storage dam, being either on the Ncwabeni River or the Gugamela River, both tributaries of the Mzimkhulu River. The establishment of a quarry to supply construction material is proposed within an area along the Ncwabeni River, which will necessitate the diversion of the watercourse. An ecological survey had to be undertaken in order to ascertain what the impacts of the various alternatives would be on the riverine and aquatic habitat, as well as what impacts would be suffered by the fish communities associated with the ricer reach. As part of the ecological assessment, an impact evaluation had to be provided and mitigation measures provided for to abate these ecological impacts as part of an Environmental Management Plan (EMP).

The purpose of an EMP is to facilitate the management of a development in a sustainable manner, in keeping with legislation, company policies and sound business practices, to ensure the safe, sustainable and optimal operation of the services provided for (Vosloo, 2004).

This proposed EMP provides general mitigation measures aimed at abating the expected impacts imposed on the overall ecological functionality of the various development activities and, in doing so, to preserve the ecological integrity, whilst retaining the functionality of the infrastructure. This will be applicable for both the *Construction* and *Operation* phases of the proposed development activity.

The impacts on the environment can only be minimised by the dedicated and sincere implementation of the EMP by the *Contractor*. The *Client* will be responsible for ensuring compliance by the *Contractor*, during the construction phase, with the findings of the EMP. Compliance with the EMP must be audited monthly during the construction phase and following completion of the project.

D1.1. Project activities.

The proposed project involves the construction of an abstraction/flow gauging weir within the Mzimkhulu River. Besides the immediate physical impacts of the construction phase, this weir will present as an impassable migratory barrier within an otherwise open system. This will require mitigation. This will necessitate the establishment of coffer dams to provide dry areas for construction. It is presumed that localised river diversions will also be necessary to provide the necessary work areas. Construction of a dam on either the Ncwabeni or Gugamela River will presumably be undertaken during the dry season. These are both non-perennial systems. It is presumed that construction will take longer that the period that can be considered the dry season (approximately 6 months) and therefore river diversions will also have to be implemented. This is of minor significance on a system where an impoundment is to be established. A quarry area is proposed along the Ncwabeni River to provide construction materials. This will necessitate major localised excavations. In order to accommodate this, it is also proposed that the watercourse be diverted for a small area. Associated infrastructure (pipelines, pump houses, etc.) will also be established. Vegetation stripping, riparian habitat destruction, aggravation of soil erosion will be major factors that will require mitigation.

These construction activities will be done with the aid of earth-moving equipment and other heavy machinery that will impinge on the ecological integrity of the various habitat units and overall ecological integrity at the localised catchment area. Once established, the infrastructure will be largely self-managing and only a relatively minor access roadway will be regularly utilised to aid in maintenance and monitoring purposes. The infrastructure will be constructed and run in perpetuity, with the dam footprint being considered permanently inundated.

D1.2. Construction phase.

The main construction activities will include the following main activities:

- Site preparation (vegetation stripping in certain areas, excavations within the quarry areas, excavations within the watercourses to located suitable foundation material, etc);
- Establishment of contractors' and construction camps;
- Earthworks (excavations for foundations, etc);
- Construction of the infrastructure;

It is assumed that the entire construction process will have a life-cycle of approximately 12 months.

D1.3. Operations (Management) phase.

The operations phase for a development of this nature has an indefinite timeframe and incorporates the following main activities:

- Ongoing monitoring and measuring of flows (assumed to be an automatic relay system requiring very limited maintenance);
- Pumping management, together with regular maintenance of pumping infrastructure;
- The maintenance (debris clearing, etc) of the fishway channel and other components associated with the abstraction works.

D2. ENFORCEMENT

The responsibility for enforcing the implementation of the EMP lies with *The Client*. It is the responsibility of the Environmental Control Officer (ECO) to monitor the Principal Contactor.

The ECO is responsible for the following:

- To monitor the execution of the mitigation measures, and to ensure the safeguarding of the environment;
- To facilitate communication between I&AP's (Interested and Affected Parties), Consultants and the Contractor;
- To inspect the construction site on a weekly basis, and to prepare a monitoring report which will be forwarded to the project team, the applicable municipal representatives and representatives from the I&APs (i.e. community members).
- To train the Contractor, Site Agent, Construction Supervisor and Safety Officer on the mitigation measures, and to verify that the Contractor's employees have undergone induction on these measures.

The abovementioned monitoring report will include a **checklist** and an **issues list**. The checklist will be completed by awarding the following scores, based on the level of compliance

COMPLIANCE SCORES	DESCRIPTION
1	Task not achieved
2	Task 20% completed
3	Task 50% completed
4	Task 80 % completed
5	Task 100% completed

Where non-compliance is encountered (i.e. COMPLIANCE SCORE < 5), the significance of the associated impact will be recorded, based on the following guidelines:

IMPACT SCORES	IMPACT
1	**Low** – mitigation not needed
2	**Medium** – mitigation should be considered
3	**High** – mitigation compulsory

The issues list will highlight the most pertinent issues that require mitigation, and provide the deadline for compliance. The following EMP has been compiled to mitigate against any general negative impacts identified during the initial reconnaissance survey.

D3. MITIGATION MEASURES.

In the EMP tables below, general mitigation measures are provided for the planning phase, while specific measures are listed to address the identified environmental impacts during the construction and operation stages of the project. This EMP should be made binding to the contract.

• PROJECT PHASE: PLANNING

Environmental Consideration	Mitigation Measures	Responsible Party
EMP Induction	Introduce the ECO* to the Project Team.	Project Manager
	Training of the Contractor's employees on the EMP and RoD.	ECO
	Explanation of environmental monitoring protocol to the Project Team by the ECO.	ECO
	All correspondence from ECO must be filed and kept onsite.	Project Manager
Construction Camp	Make provision for enough chemical toilets for all employees.	Project Manager; Contractor
	In consultation with the ECO, establish a suitable site for a construction camp.	
Waste	Identify suitable landfill, which will accept the type of waste material to be generated.	Project Manager; Contractor
Soil	Identify suitable site/burrow pit (if applicable) to obtain soil. All new borrow pits, or extensions to existing pits, require an Environmental Management Programme Report (EMPR) in terms of the Minerals Act (Act no. 50 of 1991).	Project Manager
Social	Labour intensive methods must be used where feasible, cost effective and not time constraining.	Contractor
	Local labour should be employed were possible.	Contractor
	Local suppliers must be used, as far as possible.	Contractor

* ECO – Environmental Control Officer

D4. SIGNIFICANCE RATINGS OF PERCEIVED ENVIRONMENTAL IMPACTS.

The significance rating (SP) is calculated by the following formula:

SP = Consequence X Probability

Where: Consequence = (S + D + I + E) – R

S= Spatial extent
D=Duration
I=Intensity
E=Effects on important ecosystems
R=Reversibility

Rating scores for the various aspects are presented in Table 14. Table 15 presents the outcomes of the perceived ecological impacts on the conservation of important habitat units and therefore the retention of the ecological features, functionality and biodiversity conservation for the duration of the construction and management phases of the proposed development both before and after the implementation of mitigation measures.

The perceived potential impacts vary in their significance. Some aspects such as the loss of riverine habitat through inundation following the construction of a dam are not readily mitigated and therefore the “before mitigation” and “after mitigation” significance remains the same. Other impacting features, such as the weir posing as a barrier to migrations is shown to be a high impact without the implementation of any mitigation measures, but, with mitigation, this impact is negated., The majority of the impacts identified can be effectively reduced or negated through implementation of appropriate mitigation measures.

The general mitigation measures proposed for the purpose of limiting the general ecological impacts and to maintain biodiversity within the area applicable to the construction and operations phases of the proposed Ncwabeni Off-Channel Storage Dam development activities are presented in Table 16 and Table 17, respectively.

Table 14: Rating scores for the various factors used for calculating the significance rating of a particular impact.

Spatial extent		Duration		Intensity		Effects on important ecosystems		Reversibility		Probability	
Rating	Score	Rating	Score	Rating	Score	Rating	Score	Rating	Score	Rating	Score
Site specific	1	Short (0-15yrs)	1	Low	1	None	1	Irreversible	0	Improbable	1
Local	2	Medium (2-15yrs)	2	Medium	3	Negligible	2	Largely irreversible	1	Possible	2
Regional	3	Long (16-30yrs)	3	High	5	Insignificant	3	Somewhat reversible	2	More than likely	3
National	4	Discontinuous	4			Significant	4	Largely reversible	3	Highly probable	4
International	5	Permanent	5			Vast	5	Totally reversible	4	Definite	5

Table 15: Significance assessment of the perceived major environmental impacts pertaining to a development of this nature and general ecological and habitat conservation both before and after mitigation measures that are applicable to the proposed development activities.

Potential environmental impact	Project activity or issue	Environmental significance *before* mitigation								Environmental significance *after* mitigation as per EMP							
		S	D	I	E	R	P	Conf	SP	S	D	I	E	R	P	Conf	SP
PRECONSTRUCTION & CONSTRUCTION PHASES																	
Habitat destruction within watercourses	Instream habitat destruction through construction processes.	2	2	3	4	2	5		**45**	1	1	2	3	3	5		**20**
	Altering hydrological aspects of the watercourse (inundation of previously shallow riffle areas, decrease of water velocities through deepening of the water and impounding.	2	5	1	3	0	5		**55**	2	5	1	3	1	5		**50**
	Complete inundation of riverine habitat from impoundment construction.	2	5	3	4	0	5		**70**	2	5	3	4	0	5		**70**
Inhibition of migratory movements of aquatic fauna.	Direct impacts through isolation of populations and inhibition of access to habitat of species necessary to complete their lifecycle. Due to the location of this weir, this has international significance.	5	5	5	5	2	5		**90**	1	1	1	1	4	1		**0**
Impacts on faunal communities	Habitat destruction leading to loss of faunal diversity.	2	4	1	3	2	3		**21**	2	1	1	2	2	2		**8**
	Impacts on faunal communities by indiscriminent collecting and hunting by construction teams.	1	4	1	1	4	4		**12**	1	1	1	1	4	2		**0**
	Increased disturbance factors that will displace sensitive faunal species.	2	4	1	3	2	3		**21**	2	1	1	2	2	2		**8**
Riparian zone habitat impacts	Construction activities and movement of heavy machinery and personnel within riparian zones leading to loss of functionality.	2	4	3	4	2	4		**44**	1	1	1	2	3	2		**4**
Contamination of soils and water resources	Pollution of soils and water resources due to oil/fuel leaks & wastes and poor on-site sewerage management.	2	4	3	4	1	3		**36**	1	1	1	1	3	2		**2**

Potential environmental impact	Project activity or issue	Environmental significance ***before*** mitigation								Environmental significance ***after*** mitigation as per EMP							
		S	D	I	E	R	P	Conf	SP	S	D	I	E	R	P	Conf	SP
PRECONSTRUCTION & CONSTRUCTION PHASES																	
Soil erosion	Erosion of stockpiled topsoil & disturbance of soils due to vegetation stripping leading to habitat inundation and potential smothering of aquatic habitat.	2	4	3	3	2	4		**40**	1	1	1	1	3	2		**2**

Potential environmental impact	Project activity or issue	Environmental significance ***before*** mitigation								Environmental significance ***after*** mitigation as per EMP							
		S	D	I	E	R	P	Conf	SP	S	D	I	E	R	P	Conf	SP
MANAGEMENT PHASE																	
General biodiversity impacts	Exotic vegetation encroachment following soil disturbances.	2	4	3	3	2	4		**40**	1	1	1	1	3	2		**2**
	Inundated watercourses will trap sediments that could lead to vegetation encroachment within the channel.	2	4	1	2	3	2		**12**	1	1	1	1	3	2		**2**
Riverine biodiversity impacts	Establishment of a migratory barrier will dramatically alter the community structure of obligatory migratory species (Anguillid eels); Long-term isolation of populations will lead to speciation.	5	5	5	5	2	5		**90**	1	1	1	1	4	1		**0**
	Loss of riverine habitat leading to displacement of specialist species.	2	5	3	3	0	5		**35**	2	5	3	3	0	5		**35**

[Significance of Environmental Impact (SP) = Consequence x Probability (P),
where Consequence = Spatial extent (S) + Duration (D) + Intensity (I) + Effects on important ecosystems (E)) - Reversibility (R).
SP ratings: 0-33 (Low), 34-74 (Medium), 75-100 (High)

- **PROJECT PHASE:** CONSTRUCTION

Table 16: Mitigation measures proposed for the *Construction phase* of the proposed development activities.

Environmental Impacts	Mitigation Measures	Time Frames	Responsible Party
RIPARIAN FLORAL IMPACTS			
• Destruction of RDL and sensitive floral species; • Soil disturbances that allow for the establishment of exotic vegetation; • Damage to plant life.	• Existing servitudes and roadways should be utilised as far as possible, thereby limiting the impact of establishing new service roads; • Movement of personnel and machinery to be limited to the areas designated for the established access roadways; • No movement of personnel or machinery to take place within any riparian areas in order for this ecologically sensitive habitat unit to retain its features; • Any recruitment of exotic vegetation to be managed on an ongoing basis until indigenous pioneering vegetation has dominated the disturbed areas. These species should be limited to naturally-occurring species representative of the vegetation type for the locality. Ongoing monitoring of exotic vegetation recruitment should be undertaken and any recruitment controlled; • Dumping or storage of topsoil must not be done on established vegetation, but should remain within designated areas; • Workers and machinery to remain inside construction footprint. All labourers to be informed of disciplinary actions for the wilful or indiscriminent damage to plants.	Continuous throughout the construction phase.	Contractor
AQUATIC FAUNAL IMPACTS			
• Establishment of a migratory barrier	• Provision is to be made for a fishway which will allow migratory freedom over seasons and periods when required by the various species groups inhabiting the system (see Section 6).		
• Inundation of riverine habitat through establishment of a dam.	• This is an unavoidable impact, which cannot be mitigated for.		

Environmental Impacts	Mitigation Measures	Time Frames	Responsible Party
• Habitat destruction.	• Movement of personnel and machinery to be limited to the areas designated for the established servitude and construction footprint. • No indiscriminent movement of personnel or machinery to take place within the riparian zones or channel areas in order for this ecologically sensitive habitat unit to retain its features; • Dumping or storage of topsoil must not be done on established vegetation, but should remain within the construction footprint. • Workers and machinery to remain inside construction footprint. All labourers to be informed of disciplinary actions for the indiscriminent or wilful damage to habitat.	Continuous throughout the construction phase.	Contractor
• Transformation of riverine habitat through inundation upstream of the weir.	• This is an aspect that cannot be mitigated for.		
GENERAL IMPACTS POTENTIALLY AFFECTING AQUATIC BIODIVERSITY			
• Pollution through vehicle fluid leaks or poor onsite sewerage or waste management leading to contamination of surface waters.	• The source of the pollution must immediately be identified and rectified; • Polluted soils should be immediately cleaned and transferred to an appropriate registered landfill site; • Subsequentially removed soils should be replaced with unpolluted soils of similar geological, chemical and pedological characteristics; • Vehicles must be routinely serviced to avoid fluid leaks; • Adequate toilet facilities must be provided for all construction personnel; • Adequate on-site waste management and disposal must be implemented to avoid contamination of watercourses.	Following the construction phase.	Contractor
• Disturbances of soils leading to aggravation of soil erosion.	• Stockpiled soils should be protected from erosion; • Adequate stabilisation of river banks must be undertaken to abate erosion formation.	Following any construction activities that would affect soil profiling	Contractor

- **PROJECT PHASE:** OPERATION

Where applicable, the mitigation measures for the construction phase will be carried forward to the operations phase. In addition, the following specific measures will also apply:

Table 17: Mitigation measures proposed for the *Operations phase* of the proposed development activities.

Environmental Consideration	Environmental Impacts & Mitigation measures	Responsible Party
Flora	• Damage to plant life outside of the footprint area should be prohibited; • Encroachment of alien vegetation should be monitored for and controlled.	Client
Aquatic Fauna	• Routine monitoring to assess the functionality of the fishway should be undertaken; • Routine maintenance of the fishway should be undertaken to ensure functionality (debris removal, sediment flushing, etc).	Client
General	• The relevant mitigation measures proposed for the construction phase should be carried forward to operations, where potential environmental impacts may still occur. • Special conditions relating to operations, as stipulated in the RoD, need to be adhered to. • The contractor must perform appropriate maintenance functions, as required. Responsible parties must be competent in the necessary maintenance tasks. • Feedback must be provided to the ECO and project proponent on a frequent basis.	Client

D5. CONCLUSION.

The Contractor can use **Appendix D** as a standalone document, as the mitigation measures contained therein address the potential negative impacts associated with the project. Following the recruitment of the aforesaid mitigation measures, no impacts with a significance rating of 1 or higher are perceived to remain.