PROPOSED AVIANTO MIXED USE DEVELOPMENT

Aquatic Specialist Assessment

SEF Reference No. 502171

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EXECUTIVE SUMMARY

Strategic Environmental Focus (Pty) Ltd, as independent environmental practitioners, was appointed by D'Oliveira Developments (Pty) Ltd to Facilitate the Environmental Impact Assessment for the proposed Avianto Driefontein Mixed-use development. This report represents an assessment of the aquatic ecosystem associated with the proposed development.

Based on results obtained during the present assessment, no apparent change in seasonality to the hydrology of the Muldersdrif se Loop associated with the proposed area of development was evident. However, this may not be representative of natural conditions, as monitoring of the hydrology only commenced in 1974 after development within the area was already established. Also, no significant increases in annual surface water runoff was observed, although there does appear to be a general trend for higher runoff within recent years. Nevertheless, it is recommended that development within the study area take cognisance of possible increases in surface water runoff likely to occur within the near future as continued development within the upper catchment of the Crocodile River continues. At a minimum, no development should therefore occur within the present 1:100 year floodlines as a result of possible future increases in flood lines, as has occurred within the Jukskei River catchment due to the highly developed nature of the catchment.

Water quality of the Muldersdrif se Loop was considered potentially limiting to the abundance and diversity of aquatic life within the study area, with relatively high concentrations (i.e. above sub-lethal threshold concentrations) of magnesium sulphate likely to be present based on aggregated salt determinations, as well as known high concentrations of aluminium present within upstream tributaries. Furthermore, the current nutrient status of the Muldersdrif se Loop associated with the area of proposed development indicates a potential for nuisance aquatic plant growth and blue-green algal blooms, particularly where weirs and slow-flow conditions are present.

Instream aquatic habitat within the study area was considered relatively good, with a variety of hydraulic habitats available for utilisation by aquatic biota, including habitats considered to be sensitive to changes in flow such as riffles and runs. Amongst the many ecologically important roles provided by these flow-sensitive habitats, they provide spawning areas for fish and increase the dissolved oxygen concentrations present within the Muldersdrif se Loop. However, the presence of weirs within the study area decreases the number of such flow-sensitive habitats by inundating such areas, and the settlement of sediment within the weirs creates "silt-hungry" water that increases the erosive power of water released, often undercutting and destabilising river banks. It is highly recommended that no further loss of flow-sensitive habitats should occur within the Muldersdrif se Loop. Furthermore, riparian vegetation within the study area was determined to generally be dominated by exotic and alien vegetation. It is therefore recommended that an alien eradication and riparian rehabilitation programme that follows a phased approach be established so that the natural attributes associated with riparian zones be maintained during the process.

In terms of aquatic biota, aquatic macroinvertebrate and fish diversity and abundance within the study area was considered seriously modified and impoverished. The lower than expected macroinvertebrate diversity was primarily attributed to poor water quality within the study area, particularly with regards to magnesium sulphate, whereas the poor condition of the fish population within the study area was attributed to the presence of weirs, preventing dispersal, reproduction and subsequent recruitment. Based on the present condition of the water quality and aquatic habitat present within the study area, no Red Data fish species were expected to be present. Similarly, the likelihood of significant populations of fish species of special concern being present was considered poor. It is highly recommended that the installation of fish ladders be considered in order to increase the state of the fish population within the study area.

Furthermore, should stocking of any water body within the study area be considered, it is recommended that only indigenous fish species naturally occurring within the study area be considered and should be in accordance with Section 70 of the National Environmental Management: Biodiversity Act, Act No. 10 of 2004. Indigenous fish species having angling potential and naturally occurring within the study area include *Clarias gariepinus* (Sharptooth Catfish), *Labeobarbus marequensis* (Lowveld Largescale Yellowfish), *Labeobarbus polylepis* (Bushveld Smallscale Yellowfish*),* and *Tilapia sparrmanii* (Banded Tilapia). It should be noted that there presently exists a moratorium on all translocations and releases of yellowfish within South Africa in order to protect the genetic diversity of the different species. Should the stocking of yellowfish within the study area be considered, the following guidelines should be adhered to:

- The land-owner must apply to the relevant provincial conservation agency for a permit to stock yellowfish species in farm dams.
- The dam or dams must be free of alien fish species.
- The conservation agency will determine which species of yellowfish are native to the catchment area in which the dam is situated. A permit will then be issued listing the species that may be stocked and where they may be obtained.
- Stocked fish should be caught by conservation agency staff from the nearest stream or river in the same catchment as the dam. If possible, approximately 100 juvenile fish of size 5-10cm or 20-30 larger fish of a size greater than 30cm should be stocked. It is imperative that fish are not moved from one river system to another for stocking purposes. The landowner should not catch fish for stocking unless authorized to do so by the conservation agency.
- Landowners should pay to have dams stocked. This will include travel costs, labour costs and the cost of individual fish, where applicable.
- Where feasible, spawning areas should be created in dams to allow stocks to expand. The dam and streams feeding the dam should be managed in such a way as to facilitate favorable spawning habitat. Such a management plan should

be drafted by a suitably qualified individual with specific expertise in yellowfish ecology.

- A record of each stocking must be kept by the provincial conservation agency and it is essential that the co-ordinates of the dam being stocked are taken and retained for future reference purposes.

The above requirements should be regarded as general until such time as the relevant provincial authority has been consulted. The stocking of other fish species (including those presently occurring within the study area) are prohibited

Additional recommendations relevant to the study area include the following:

- Development within the study area should occur within the winter months where possible so as to decrease the runoff of sediment into the Muldersdrif se Loop during times of heavy rainfall;

- Ensure that the proposed development makes use of a layout design that facilitates the management and attenuation of stormwater at the source;

- Water use licences will be required in accordance with Section 21 of the National Water Act for any proposed upgrading of bridges, development within the designated floodlines and discharge of stormwater into the Muldersdrif se Loop; and

- It is recommended that the conservancy proposed within the study area be relocated to a more suitable natural area.

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1. INTRODUCTION

South Africa's aquatic ecosystems are generally in a poorer state than its terrestrial ecosystems, reflecting the fact that South Africa is a water-scarce country. Quality, quantity and sustainability of the county's water resources are fully dependant on good land management practices within catchments. The fate of our natural water resources therefore lies on the integrated approach to managing water and land in order to achieve ecological and socio-economic sustainability.

1.1 Project Description

Strategic Environmental Focus (Pty) Ltd, as independent environmental practitioners, was appointed by D'Oliveira Developments (Pty) Ltd to Facilitate the Environmental Impact Assessment for the proposed Avianto Mixed-use development. This report represents an assessment of the aquatic ecosystem associated with the proposed development.

1.2 Terms of Reference

The terms of reference for the current study were as follows:

- Provide an assessment of the ecological state of the aquatic ecosystem associated with the site of proposed development;
- Determine possible impacts associated with the proposed development; and
- Identify mitigation measures to limit impacts on the aquatic resources.

This report presents the findings obtained following an assessment of the aquatic ecosystem associated with the site of the proposed development. The field survey was conducted on the 11th of March 2009.

1.3 Assumptions and Limitations

In order to obtain a comprehensive understanding of the dynamics of the ecological communities and the presence of fauna and flora within the area, ecological studies should ideally be conducted over a number of seasons during various times of the year. However, due to time constraints associated with Basic Assessments and Environmental Impact Assessments, such studies could not be conducted. Instead, the assessment of the aquatic resources associated with the proposed development was based on a single site visit.

2. Description of the Environment

2.1 Location

The study area is situated within the Muldersdrift area, which lies at an altitude between 1660m and 1360m above mean sea level within the province of Gauteng. The study area is located downstream of the town of Muldersdrif, and upstream of the Driefontein Waste Water Treatment Works.

2.2 Biophysical description

2.2.1 Climate

The highest maximum and lowest minimum temperatures recorded at the closest weather station approximately 50km east of the proposed site at OR Tambo International Airport, for the period 1961 to 1990 were 35°C and –8°C, respectively. The average maximum temperature for January, the hottest month, is 26°C while the average minimum temperatur e for June, the coldest month, is 4°C. Rainfall is strongly seasonal, with an average monthly rainfall of 125 mm in January and 4 mm in July (for the period 1961 to 1990). Most rain occurs as heavy, isolated thundershowers in the summer months between October and March. The average rainfall per annum is 735 mm.

2.2.2 Geology

According to Department of Development Planning and Local Government (2002), Halfway House Granite is found to be common to all areas of the proposed development, with the main geology being migmitite and ultramafic rocks.

2.2.3 Associated Water Courses

The main rivers of the Crocodile (West) and Marico water management area (namely the Crocodile River and the Marico River) give rise to the Limpopo River at their confluence. The Crocodile River catchment lies to the north-west of Johannesburg, with its origin near Krugersdorp.

One main water course is associated with the study site, namely the Muldersdrif se Loop (also referred to as the Crocodile River in Nel *et al*, 2004). For the purpose of the present assessment, the name for the river reach within the area of study will be retained as the Muldersdrif se Loop based on the nomenclature of CDSM (2004). The Muldersdrif se Loop associated with the study area was observed to be partially regulated at various locations, with weirs having been constructed along its length. Several wetland systems as well as several farm dams were also observed to be associated with the study area.

According to Nel *et al* (2004), the Present Ecological Status of the Crocodile River (i.e. Muldersdrif se Loop) associated with the proposed development is considered moderately modified (Present Ecological Status Class C) based on the desktop assessment developed by Kleynhans (2000; cited in Nel *et al*, 2004). However, limitations associated with this classification included the fact that the study was done primarily as a desktop study, with little ground-truthing done and that data received for the study was out-dated.

Additionally, Nel *et al* (2004) classified the Crocodile River's conservation status as endangered due to the fact that the river heterogeneity signature has an intact length greater that of the conservation target of 10% of total length but less than 40% of their total length.

A summary of the general site information is contained within Table 1 below.

Table 1: Summary of general site information

Map Reference	2627BB
Political Region	Gauteng
Freshwater Ecoregion	Southern Temperate Highveld
Level 1 Ecoregion	11. Highveld
Level 2 Ecoregion	11.01
Geomorphic Province	Northeastern Highveld
Geology	Halfway House Granite
Vegetation Type	Egoli Granite Grassland
Water Management Area	3. Crocodile (West) and Marico
Secondary Catchment	A2
Quaternary Catchment	A21E
Watercourse	Muldersdrif se Loop (Crocodile River)
Slope Class	Upper Foothills
Stream Order	1
Stream Type	Perennial

2.3 Selection of sampling sites

Sampling sites were selected within the Muldersdrif se Loop so as to identify trends regarding the occurrence of species within the study area as well as provide a comparative basis by which future impacts can be evaluated. Co-ordinates of the selected sampling sites were determined using a Garmin GPS global positioning device and are listed in Table 2 and presented graphically in Figure 1. Photographs

of the selected sampling sites are provided in Appendix 2.

Table 2: Description of sampling sites surveyed

Site name	Co-ordinates	Site description
Site A1	S: 26°01' 02.2'' E: 27°50' 05.1''	Site located below the Seringa Pit Bike bridge on the Muldersdrif se Loop after the confluence with the Wilgespruit River
Site A2	S: 26°01' 40.5'' E: 27°50' 21.1''	Site located on the Muldersdrif se Loop within the grounds of Avianto Estate below a weir

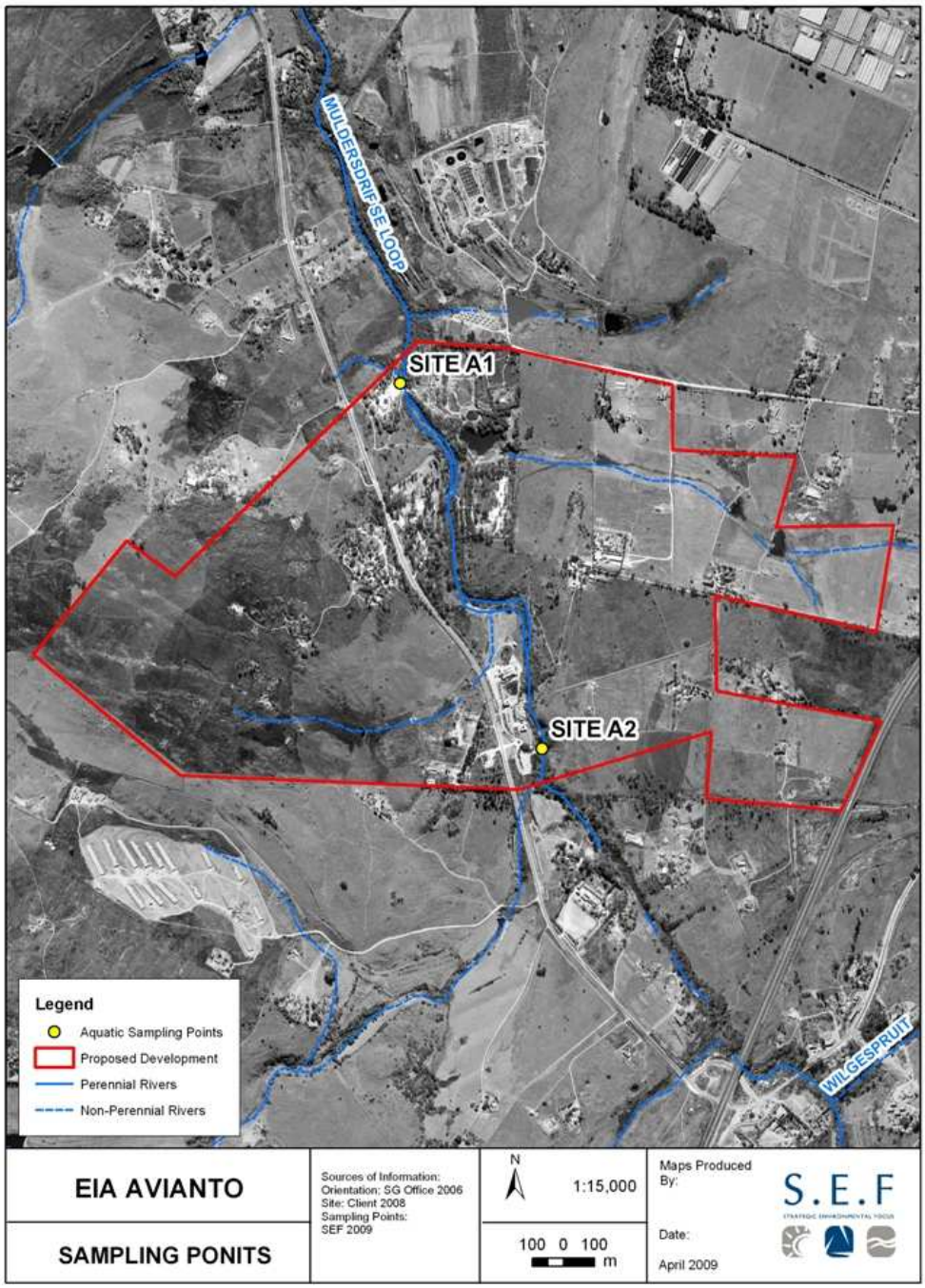

Figure 1: Location of aquatic sampling points

3. RESULTS

3.1 Hydrology

Analysis of the hydrology of the Muldersdrif se Loop was conducted so as to assist with characterising the aquatic environment and determining possible causal factors for results obtained during the assessment of the associated biological communities. For the purpose of the present assessment, flow data from the Department of Water Affairs and Forestry Flow Gauging Station A2H051 located approximately 1km upstream of the proposed development was used to assess the hydrology of the Muldersdrif se Loop associated with the proposed development (DWAF, 2008a). The catchment size associated with DWAF Gauging Station A2H051 is 109km^2.

Data obtained for the year 2000 to present was compared to average monthly flow volumes for previous years (averaged over 10 years) in order to determine possible changes in seasonality and catchment runoff rates. Results are presented in Figure 2. Similarly, the total annual flow was used to determine possible increased catchment runoff (Figure 3). Based on data obtained, it was determined that the seasonality of the Muldersdrif se Loop has not changed since monitoring of the flows began during the 1970's. Furthermore, the volume of catchment runoff has not been significantly affected by developments within the upstream catchment since the start of monitoring. However, an increased trend was observed with regards to increased catchment runoff, indicating the potential of future impacts on the hydrology of the Muldersdrif se Loop. In contrast, the adjacent catchment of the Jukskei River has shown an increase in average monthly and annual flows since monitoring began, with the result that the seasonality and hydrology of the Jukskei River can no longer be classified as natural. As a result, a high degree of erosion and biological impairment are associated with the Jukskei River, with a significant increase in the risk and magnitude of flooding.

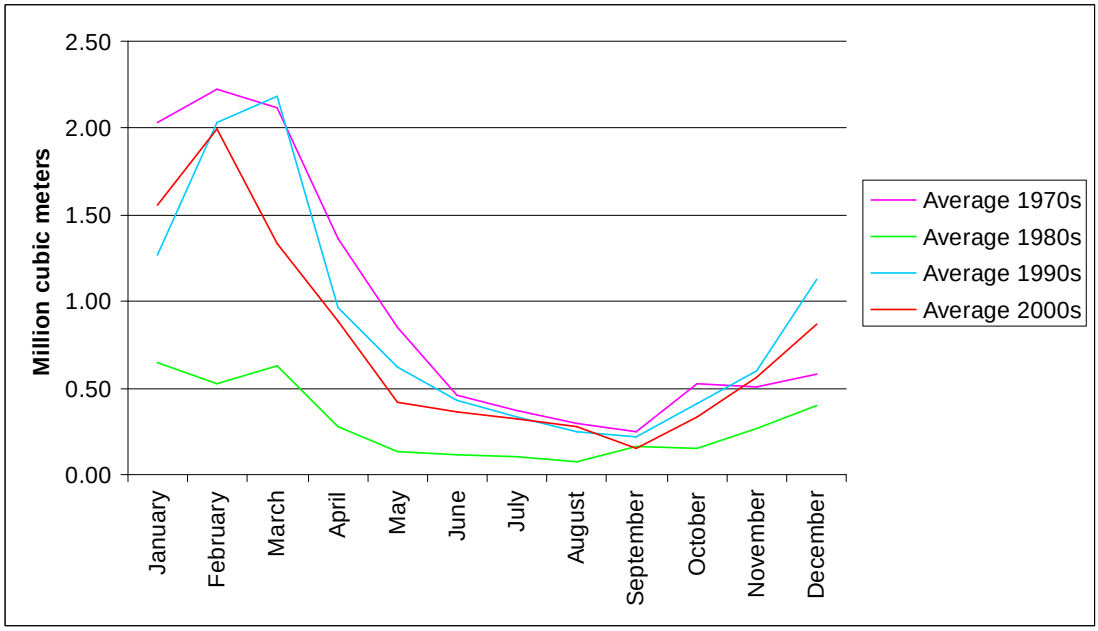

Figure 2: Average monthly flows of the Muldersdrif se Loop at DWAF Gauging Station A2H051

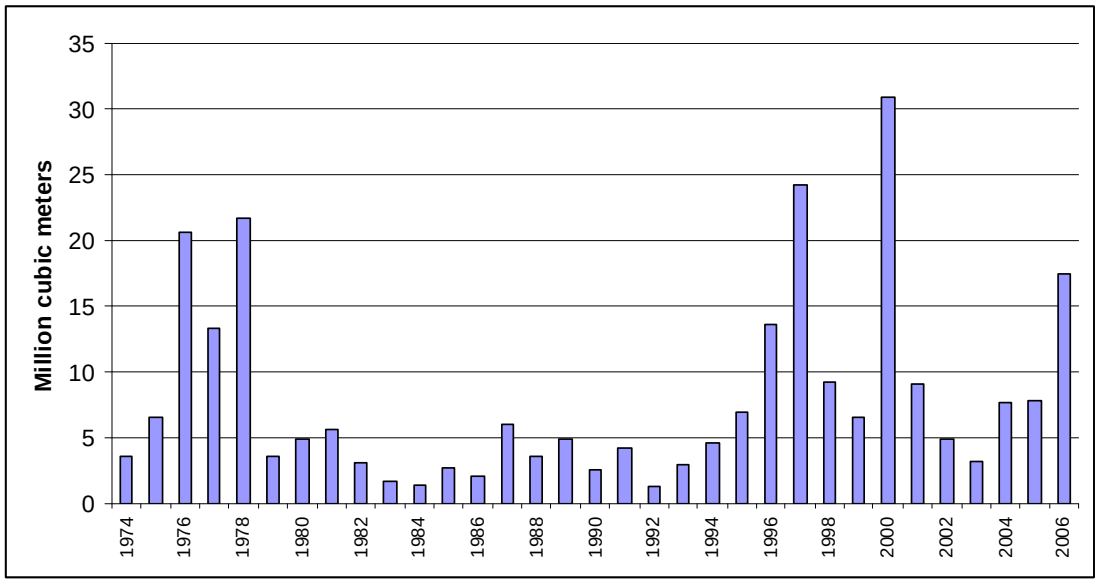

Figure 3: Total annual flow observed at DWAF Gauging Station A2H051 for the period 1974 to 2006

3.2 Water Chemistry

For the purpose of the present assessment, water quality for DWAF Gauging Station A2H051 was obtained and used to determine present water quality and nutrient status of the Muldersdrif se Loop within the study area. Additionally, the Tool for Ecological Aquatic Chemical Habitat Assessment (TEACHA 1.32) software programme was used to determine the relative concentrations of aggregated salts within the Muldersdrif se Loop for the time period July 2004 to July 2008. In assessing the concentrations of aggregated salts, the 95th percentile was used (in

accordance with DWAF, 2008b). Additionally, water quality results obtained during previous studies within the study area were used to supplement data obtained by the Department of Water Affairs and Forestry.

Based on the TEACHA model, the only aggregated salt determined to be of concern was magnesium sulphate ($MgSO_4$), with a 95th percentile concentration of 28.47mg/l, indicating the possibility of sub-lethal effects being present in aquatic organisms. According to Jooste and Russouw (2003), magnesium sulphate is considered to be the aggregated salt with the highest toxicity relative to other aggregated salts assessed, with a sub-lethal concentration of 16mg/l and a lethal concentration of 37mg/l.

Water samples previously collected within the Muldersdrif se Loop and the Wilgespruit rivers prior to its confluence and from the Muldersdrif se Loop below the confluence of the Mulderdrifseloop and Wilgespruit rivers indicated that the majority of variables analysed were present in concentrations below the detection limit. Of the remaining variables, only aluminium was observed to exceed the Target Water Quality Range for aquatic ecosytems as provided by DWAF (1996). Of particular importance was the fact that the aluminium concentrations present within the Wilgespruit River were observed to be several orders of magnitute greater than those observed in the adjacent Muldersdrif se Loop River. A likely explanation for the higher values observed may be the present mining operations occurring within the catchment of the Muldersdrif se Loop River.

Stormwater runoff is presumed to contribute significantly to non-point source water pollution originating from urban areas due to fertilizer and pesticide use. Furthermore, other chemicals (e.g. lead from road surfaces) and solid particles (i.e. sediment) are collected when passing over hard surfaces. This results in deterioration in the surface and ground water quality in catchments. Urban runoff water quality has been identified as a rapidly growing problem throughout South Africa (Schoeman *et al*, 2001).

In terms of nutrient enrichment, a 50th percentile value (average summer concentration for 2007) of 0.785mg/l for total inorganic nitrogen was observed to be associated with the Muldersdrif se Loop at DWAF Gauging Station A2H051, whereas a 50th percentile value of 0.027mg/l for phosphorous was observed. Therefore, the Muldersdrif se Loop associated with the proposed development is presently considered to be in a mesotrophic to eutrophic state, indicating that the system is considered to be a productive system with a potential for nuisance growths of aquatic plants and blue-green algal blooms, particularly where weirs are present to create slow-flowing conditions.

3.3 Aquatic Habitat

Habitat integrity refers to the maintenance of a balanced, integrated composition of physico-chemical and habitat characteristics on a temporal and spatial scale that are comparable to the characteristics of natural habitats of the region. The habitat integrity status of a river or stream will essentially provide the template for a certain level of biotic integrity to be realized. In this sense, the assessment of the habitat integrity of a river can be seen as a pre-cursor of the assessment of biotic integrity. It follows that in this context habitat integrity and biotic integrity together constitute ecological integrity (Kleynhans, 1996).

For the purpose of the present assessment, the Invertebrate Habitat Assessment System (IHAS) and the Intermediate Habitat Integrity Assessment index (IHIA) were used to assess the status of aquatic habitats within the study area.

3.3.1 Invertebrate Habitat Assessment System

The Invertebrate Habitat Assessment System (IHAS, Version 2.2), developed by McMillan (1998), has routinely been used in conjunction with the South African Scoring System (SASS) as a measure for the variability in the amount and quantity of aquatic macroinvertebrate biotopes available for sampling. During the course of study, the IHAS was applied to each site so as to compare the difference in the representative biotope sampling effort for aquatic macroinvertebrates and the condition of the habitat availability. Results obtained during March 2009 indicated the habitat availability for aquatic macroinvertebrate utilisation was considered good at all sites surveyed (Table 3). Therefore, according to MacMillan (1998), habitat availability presented a limited impact on the results obtained during aquatic macroinvertebrate investigations.

Table 3: Invertebrate Habitat Assessment System results obtained during March 2009

Site	IHAS Value (%)	Description
Site A1	68	Good
Site A2	69	Good

However, it should be noted that according to a recent study conducted within the Mpumalanga and Western Cape regions, the IHAS method does not produce reliable scores with regard to the suitability of habitat at sampling sites for aquatic macroinvertebrates (Ollis *et al*, 2006). Furthermore, the performance of the IHAS seems to vary between geomorphologic zones and between biotope groups (Ollis *et al*, 2006). However, more testing of the IHAS method is required before any final conclusion can be made regarding the accuracy of the index.

3.3.2 Intermediate Habitat Integrity Assessment

Information for use in the assessment of instream and riparian integrity by means of the Intermediate Habitat Integrity Assessment (IHIA) was obtained while conducting biological assessments, 1:50 000 topographical map (2627BB) and aerial photographs. It should be noted that the assignment of scores for the IHIA can be highly subjective. As a result, the use of a guideline document formulated by Brown *et al* (2001) was necessary in order to limit the subjective nature of the scoring system. Results obtained during the present study are presented in Table 4.

Results obtained following application of the Intermediate Habitat Integrity Index (IHIA) indicated the instream habitat to be moderately modified (PES Class C), with the most significant variable being that of the weirs constructed in the Muldersdrif se Loop. The presence of weirs within the stream channel has resulted in the loss of significant flow-sensitive aquatic habitats (e.g. riffles and runs), as well as decreasing the longitudinal connectivity of the Muldersdrif se Loop, providing a barrier to the migration of aquatic biota and preventing the repopulation of upstream reaches.

The riparian habitat within the study area was determined to present a largely modified state (PES Class D), with a significantly large amount of exotic plant species observed within and dominating the riparian zone. Exotic plants within the riparian zone included *Canna indica* (Garden Canna), *Populus* sp., *Morus alba* (White Mulberry), *Acacia* spp. (Wattle), *Eucalyptus* spp. (Bluegums), *Salix babylonica* (Weeping Willow) and *Rubus* sp. (Bramble).

Table 4: Intermediate habitat integrity scores obtained during the present assessment

Habitat Score	Present Ecological State Class
Instream Habitat	
67.98	C
Riparian Habitat	
47.06	D

3.4 Aquatic Macroinvertebrates

A total of 26 aquatic macroinvertebrate taxa (20 – 22 taxa per site) were sampled within the Muldersdrif se Loop associated with the proposed development during March 2009 (Table 5). In addition, several taxa regarded as being moderately sensitive were sampled, including Caenidae (Squaregill mayflies), Chlorocyphidae (Jewel damselflies), Gomphidae (Clubtail dragonflies), Elmidae (Riffle beetles), Hydraenidae (Minute moss beetles) and Ancylidae (Freshwater limpets). Also, two species of Baetidae (Mayflies) and Hydropsychidae (Caddisflies) were collected within the study area.

Table 5: SASS5 Scores, Number of Taxa and Average Score per Taxon (ASPT) for sites surveyed during March 2009

Site	SASS5 Score	No. of Taxa	ASPT*
Site A1	93	20	4.65
Site A2	106	22	4.82

* Average Score per Taxa

3.4.1 Present Ecological State

For the purpose of the Macroinvertebrate Response Assessment Index (MIRAI), a reference list of aquatic macroinvertebrates associated with River Health Programme sites within the same Level 2 Ecoregion and the same slope class (Thirion, in preparation) was used as a basis for comparison, and adapted where necessary (Appendix 3). Based on results obtained following the application of the MIRAI (Thirion, 2008), it was determined that the Present Ecological State of the Muldersdrif se Loop associated with the proposed development was seriously modified (PES Class E) (Table 6). Furthermore, water quality was observed to present the greatest impact on aquatic macroinvertebrates in terms of the drivers assessed.

Table 6: Results obtained during March 2009 following the application of the Macroinvertebrate Response Assessment Index

Site	MIRAI %	Present Ecological State Class	Description
Site A1	**30.28**	**E**	**Seriously modified**
Site A2	**30.64**	**E**	**Seriously modified**

3.5 Ichthyofauna

Table 7 presents the fish species that are likely to occur within the study area under reference conditions, based on Kleynhans *et al* (2008) and Koekemoer and Steyn (2008). Of the fish species likely to occur within the study area, several species were considered to be key migratory species (i.e. migration considered critical for the survival of the species). These included *Barbus motebensis* (Marico Barb), *Barbus paludinosis* (Straightfin Barb), *Labeobarbus marequensis* (Lowveld Largescale Yellowfish) and *Labeobarbus polylepis* (Bushveld Smallscale Yellowfish).

During the March 2009 field survey, a total of 10 fish were sampled within the Muldersdrif se Loop. Fish species sampled included *Clarias gariepinus* (Sharptooth Catfish) and *Labeobarbus polylepis* (Bushveld Smallscale Yellowfish). Furthermore,

while not collected during the present assessment, individual specimens of *Cypinus carpio* (Carp) were observed within standing water bodies adjacent to the Muldersdrif se Loop during the present survey, and the likelihood of this species occurring within the Muldersdrif se Loop associated with the study site was therefore regarded as high, particularly within the impounded sections of the river.

Table 7: Indigenous and Exotic fish species expected and observed within the study area

Scientific Name	Common Name	Expected	Observed
Indigenous fish species			
*Amphilius uranoscopus**	Stargazer (Mountain Catfish)	X	
Barbus anoplus	Chubbyhead Barb	X	
*Barbus motebensis**	Marico Barb	X	
Barbus paludinosus	Straightfin Barb	X	
*Chiloglanis pretoriae**	Shortspine Suckermouth	X	
Clarias gariepinus	Sharptooth Catfish	X	X
Labeobarbus marequensis	Lowveld Largescale Yellowfish	X	
Labeobarbus polylepis	Bushveld Smallscale Yellowfish	X	X
Pseudocrenilabrus philander	Southern Mouthbrooder	X	
Tilapia sparrmanii	Banded Tilapia	X	
Exotic fish species			
Cyprinus carpio	Carp	X	X
Gambusia affinis	Mosquitofish	X	
Micropterus salmoides	Largemouth Bass	X	

* Red Data species and/or species of Special Concern (Smith-Adao *et al*, 2006)

Clarias gariepinus (Sharptooth Catfish; Figure 4), possibly the most widely distributed fish species in Africa, occurs in almost any habitat but favours floodplains, waterbodies and slower-flowing sections in rivers. Completely omnivorous, this fish species will consume any form of organic food items, including fish, birds, frogs, small mammals, reptiles, snails, crabs and other invertebrates, and plant matter such as seeds and fruit. *Clarias gariepinus* is considered highly tolerant to a variety of environmental factors, including poor water conditions.

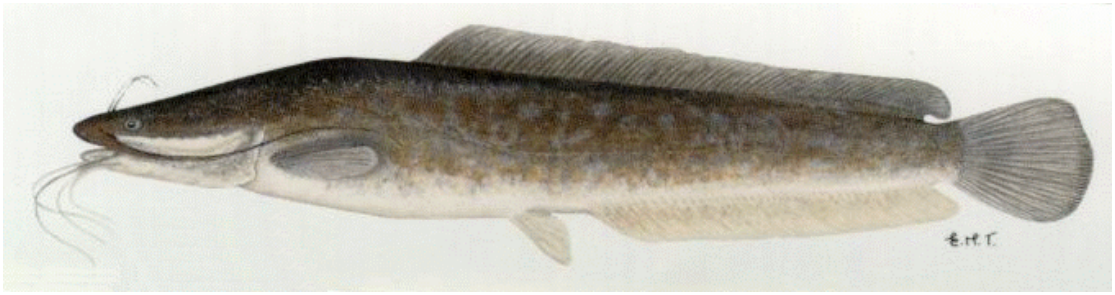

Figure 4: *Clarias gariepinus* (Sharptooth Catfish) (Skelton, 2001)

Labeobarbus polylepis (Bushveld Smallscale Yellowfish; Figure 5) is restricted to the higher altitude tributaries of the Limpopo, Inkomati and Phongolo River, not occuring below an altitude of 600m and are naturally restricted to perennial rivers with riffles, runs and deep pools. This fish species is an omnivore, feeding predominantly on filamentous algae during autumn and winter and benthic invertebrates in the summer months, but is also known to take mussels, snails, crabs and small fish. Migration is considered critical for the survival of *L. polylepis*. Spawning habitat for *L. polylepis* consists of runs/riffles with adjacent resting and nursery areas with a bed of pebbles and gravel at average depth of 16cm and an average velocity of 0.65m/sec. The current status of the population in the Crocodile River catchment indicates low genetic biodiversity with declining numbers.

Figure 5: Juvenile *Labeobarbus polylepis* (Bushveld Smallscale Yellowfish) collected within the Muldersdrif se Loop associated with the proposed development

It should be noted that, while not sampled during the present assessment, additional fish species may be present within the Muldersdrif se Loop associated with the proposed development. Koekemoer and Steyn (2008) collected several additional fish species within the Muldersdrif se Loop in close proximity to the present study area during December 2007. Fish species sampled during December 2007 included *Clarias gariepinus, Tilapia sparrmanii, Labeobarbus marequensis, Pseudocrenilabrus philander* and *Barbus paludinosus*, as well as the exotic Cyprinus carpio and *Gambusia affinis*.

3.5.1 Red Data Fish Species and Species of Special Concern

The recent discovery of an isolated population of *Barbus motebensis* (Marico Barb; currently listed as Vulnerable) within the Walter Sisulu Botanical Gardens warrants mention within this report. The section of river associated with the Walter Sisulu Botanical Gardens has been surveyed many times during previous routine biomonitoring surveys, with a significant lack of successful fish collection. While the likelihood of this fish species occurring within the current study area is considered minimal due to poor habitat conditions and anthropogenic influences, it should nevertheless be taken into consideration as cryptic, isolated populations may be present within certain areas of the upper Muldersdrif se Loop.

According to Kleynhans *et al* (2008), two additional fish species considered as being of special concern (Smith-Adao *et al*, 2006) may potentially occur within the area (Table 4). Based on the aquatic habitat present within the study area, it was concluded that the possibility of *Amphilius uranoscopus* (Stargazer/Mountain Catfish) being present is unlikely due to the specie's requirement for good water quality and a high abundance of rocky substrate. While a similar conclusion can be reached with regards to *Chiloglanis pretoriae* (Shortspine Suckermouth), recent sampling conducted within the Crocodile River downstream of the present study area has produced several specimens of this fish species.

3.5.2 Health Assessment

For the purpose of the present study, assessment of the health of individual fish was confined to external examination only. This approach ensured minimal stress imposed on the individual fish, allowing for them to be returned alive. External abnormalities noted during the present survey included assessment of eyes, fins, tumours, gills, external parasites, and skeletal deformities.

During the March 2009 field survey, fish collected appeared to be in good health, with the exception of the presence of external trematode cysts. Trematodes (flukes) occur either as adults within the internal organs or as larvae in the form of white and black cysts in the skin. Heavy infections can affect swimming ability of the fish itself, thereby increasing the susceptibility of the individual to predation (Skelton, 2001).

3.5.3 Present Ecological State

Based on results obtained during the application of the Fish Response Assessment Index (FRAI; Kleynhans, 2008) during March 2009, it was determined that the Present Ecological State of the fish assemblage within the Muldersdrif se Loop associated with the proposed development was considered to be seriously modified (Present Ecological State Class E) (Table 8).

Table 8: Results obtained during March 2009 following the application of the Fish Response Assessment Index

FRAI %	Present Ecological State Class	Description
33.90	**E**	**Seriously modified**

The poor structure of the fish assemblage observed within the study area was considered to be the result of the loss of connectivity within the Muldersdrif se Loop as well as poor water quality. Freshwater fish undergo migration within a catchment for a number of reasons, including the optimisation of feeding, enhancement of reproductive success, dispersal and the avoidance of environmentally unfavourable conditions, with many of the larger fish species undertaking large-scale migrations following rains in the summer months. Weirs prevent the upstream migration of aquatic fauna, resulting in prevention of spawning and colonisation of the upper reaches of river systems. The presence of weirs within rivers of South Africa is known to be a major factor responsible for the reduction in numbers and range of many of the migratory fish and invertebrate species throughout South Africa.

3.6 General Comments

In addition to the Muldersdrif se Loop, a number of farm dams were located within the study area. These were observed to be located within wetland systems, and were not expected to support diverse numbers of aquatic macroinvertebrates or fish species due to the lack of diverse aquatic habitats. While not considered natural water bodies, these farm dams were observed to support faunal taxa not generally associated with lotic (flowing) water bodies, including *Pelomedusa subrufa* (Helmeted Terrapin). Furthermore, an off-channel dam located adjacent to the Muldersdrif se Loop and the Seringa Pit Bike race course was determined to have been previously utilised by a local fishing club, with entertainment facilities also located on site. The deep water created by the dam has provided suitable habitat for populations of exotic fish species such as *Cyprinus carpio* (Carp) which have been utilised by the local fishing club. *Phragmites* sp. was observed to dominate the emergent vegetation associated with the dam.

Of particular concern was a burst water pipe observed at approximately S26°01’10.43” E27°50’36.30”. The water released fro m this pipe was observed to have created erosion gullies on the gravel road surface, resulting in the deposition of sediment into the valley-bottom wetland located downslope of the burst pipe. Furthermore, the large volume of water entering the wetlands system has resulted in channelization of the wetland, thereby decreasing the functionality of the wetland (Figure 6).

Figure 6: Burst pipe located within study area (A), resulting in channelization of downslope wetland and sediment deposition (B)

It should also be noted that as development within the upper catchments of the Crocodile River continues to increase, a corresponding increase in surface water runoff is expected to occur as a result of an increased in impermeable and hardened surfaces. As such, an increase in the intensity, periodicity and unpredictability of flood events will occur within the area of proposed development, resulting in potential losses to property, infrastructure and human life, as is currently being experienced in the Jukskei River catchment.

4. IMPACT ASSESSMENT AND MITIGATION

4.1 Assessment Criteria

In order to assess these impacts, the proposed development has been divided into two project phases, namely the construction and operation phase. The criteria against which these activities were assessed are discussed below.

The environmental impacts are assessed with mitigation measures (WMM) and without mitigation measures (WOMM) and the results presented in impact tables which summarise the assessment. Mitigation and management actions are also recommended with the aim of enhancing positive impacts and minimising negative impacts.

4.1.1 Nature of the Impact

This is an appraisal of the type of effect the project would have on the environment. This description includes what would be affected and how and whether the impact is expected to be positive or negative.

4.1.2 Extent of the Impact

A description of whether the impact will be local (extending only as far as the servitude), limited to the study area and its immediate surroundings, regional, or on a national scale.

4.1.3 Duration of the Impact

This provides an indication of whether the lifespan of the impact would be short term (0-5 years), medium term (6-10 years), long term (>10 years) or permanent.

4.1.4 Intensity

This indicates the degree to which the impact would change the conditions or quality of the environment. This was qualified as low, medium or high.

4.1.5 Probability of Occurrence

This describes the probability of the impact actually occurring. This is rated as improbable (low likelihood), probable (distinct possibility), highly probable (most likely) or definite (impact will occur regardless of any prevention measures).

4.1.6 Degree of Confidence

This describes the degree of confidence for the predicted impact based on the available information and level of knowledge and expertise. It has been divided into low, medium or high.

4.2 Impact Assessment

Any development in a natural system will impact on the surrounding environment, usually in a negative way. The purpose of this phase of the project was therefore to identify and assess the significance of the impacts likely to arise during the construction and the operational phases of the project, and provide a short description of the mitigation required so as to limit the impact of the proposed development on the natural environment. Possible impacts associated with the proposed development and their sources are provided in Table 9 (Construction phase) and Table 10 (Operational phase).

Table 9: Possible impacts arising during construction phase

Possible impact	Source of impact
Increased stormwater runoff volume and velocity	Increase of hard impermeable surfaces and reduction of ground cover
Erosion of drainage lines	Increased stormwater runoff volume and velocity
Increased sediment input into associated watercourses	Reduction of ground cover and stockpiling of excavated earth
Surface water pollution	Activities of workforce, e.g. washing of clothes in the river

Table 10: Possible impacts arising during operation phase

Possible impact	Source of impact
Increased runoff volume	Increase in impermeable surfaces
Nutrient enrichment	Gardens, sports fields and driving range
Water quality impairment	Runoff and loss of wetland functionality
Decrease in groundwater recharge	Increase in impermeable surfaces and lack of infiltration
Loss of terrestrial biodiversity	Bridges

4.2.1 Construction Phase

4.2.1.a Increased stormwater runoff volume and velocity

Extent	Duration	Intensity	Probability of occurrence	Significance		Confidence
				WOMM	WMM	
Local	Short	Low	Probable	Low to Medium	Low	Medium

Description of Impact

The presence of bare soils without vegetation and the development of less permeable surfaces, i.e. roads and parking areas, will result in an increase in stormwater runoff volume. This would, however, be of limited significance if the recommended mitigating measures are implemented.

Mitigation Measure

- Provide permeable surfaces and address increased runoff volumes at source; and
- Implement an ecologically-sensitive stormwater management plan during the construction phase.

4.2.1.b Erosion of drainage lines

Extent	Duration	Intensity	Probability of occurrence	Significance		Confidence
				WOMM	WMM	
Local	Short	Low	Probable	Low	Low	High

Description of Impact

The clearance of vegetation will reduce the capacity of the land surface to retard the flow of surface water, thus decreasing infiltration and increasing both the quantity and velocity of surface water runoff and erosion as well as decreasing the functionality of the associated wetland. Human activities, such as the compaction of soil along footpaths and vehicle tracks, and the disturbance of soil structure through soil movement, which disturb the soil structure can result in increased susceptibility to erosion. Roads and pathways created during the construction phase have the potential to become preferred drainage lines, resulting in gully erosion.

Mitigation Measures

- All proposed construction activities should be undertaken during the dry season as far as practicable;

- Appropriate flow diversion and erosion control structures, i.e. earth embankments, must be put in place where soil may be exposed to high levels of erosion due to steep slopes, soil structure, etc.;

- Should a freak storm displace the temporary earth embankments or other erosion control structures, a visual inspection of the site must be made and any damage be recorded. Any damage and loss of soil resulting from a storm is to be remedied immediately. Should the temporary walls collapse due to construction error, the contractor is to fund the remediation process;

- Stormwater at the construction crew camps must be managed so as to reduce the silt loads in the wetland and farm dam. Measures must be implemented to distribute stormwater as evenly as possible to avoid point sources of erosion;

- Construction on steep slopes and in soft or erodable material will require erosion control measures and correct grassing methods;

- All construction areas should be suitably top soiled and vegetated as soon as is possible after construction; and

- Disturbed surfaces to be rehabilitated must be ripped, and the area must be backfilled with topsoil or overburden.

4.2.1.c Increased sediment input into associated watercourses

Extent	Duration	Intensity	Probability of occurrence	Significance		Confidence
				WOMM	WMM	
Regional	Short	Moderate	Definite	Low to Medium	Low	High

Description of Impact

Clearance of existing vegetation will expose the upper layers of the soil horizon to soil erosion and sediment runoff. The transport of eroded soil into surrounding surface water resources will increase the Total Suspended Solids (TSS), which may adversely affect the aquatic fauna in a number of ways. These include the alteration of substrate composition and changing the suitability of the substrate for certain taxa, the effect on respiration due to the deposition of silt on the gills of biota, the effect on the feeding activities by impeding filter feeding, and reduction of the food value of the periphyton and reduction of density of the prey organisms.

The movement of construction vehicles and personnel can also result in the onset of erosion. The stockpiling of excavated earth and construction materials can result in contamination of runoff, as a result of erosion of stockpiles.

Mitigation Measures

- To prevent erosion of material that is stockpiled for long periods, the material must be retained in a bermed area;
- All topsoil must be removed and stockpiled on the site;
- The temporary storage of topsoil, inert spoil, fill etc. should be above the 1:100 year floodline or at least 100m from the top of the bank of any drainage lines or wetland zones, whichever is the maximum or as agreed with the Environmental Control Officer;
- Mulch, roughen or sterile grass seeding can be used on any batter or topsoil stockpile that is to be maintained for longer than 28 days;
- Construct an earth bank around the upslope portion of any stockpiles in order to redirect runoff and prevent scouring of stockpiles;
- Erect a silt fence around any stockpiles in order to trap sediment and prevent stockpile sediment loss;
- Stockpiles should not be higher than 2m to avoid compaction, and single handling is recommended; and
- Dust suppression is necessary for stockpiles older than a month – with either water or a biodegradable chemical binding agent.

4.2.1.d Surface water pollution

Extent	Duration	Intensity	Probability of occurrence	Significance		Confidence
				WOMM	WMM	
Local	Short	Medium	Probable	Medium	Low	Medium

Description of Impact

Hydrocarbon-based fuels or lubricants spilled from construction vehicles, construction materials that are not properly stockpiled, and litter deposited by construction workers may be washed into the surface water bodies. Should appropriate toilet facilities not be provided for construction workers at the construction crew camps, the potential exists for surface water resources and surrounds to be contaminated by raw sewage. The utilisation of the water body for washing of clothes or disposal of water used for washing will decrease the abundance and diversity of aquatic macroinvertebrates inhabiting the farm dam associated with the proposed development.

Mitigation Measures

- Construction vehicles are to be maintained in good working order, to reduce the probability of leakage of fuels and lubricants;
- A dedicated, walled concrete platform with adequate flooring or bermed area should be used to accommodate chemicals such as fuel, oil, paint, herbicide and insecticides, as appropriate, in well-ventilated areas;
- Storage of potentially hazardous materials should be above any 100-year flood line and outside of the designated wetland buffer zone, as stipulated by a wetland specialist. These materials include fuel, oil, cement, bitumen, etc.;
- Sufficient care must be taken when handling these materials to prevent pollution;
- Surface water draining off contaminated areas containing oil and petrol would need to be channelled towards a sump, which will separate these chemicals and oils;
- Oil residue shall be treated with oil absorbent, such as Drizit or similar and this material removed to an approved waste site;
- Concrete is to be mixed on mixing trays only, not on exposed soil;
- Concrete and tar shall be mixed only in areas, which have been specially demarcated for this purpose;
- All concrete and tar that is spilled outside these areas shall be promptly removed by the Contractor and taken to an approved dumpsite;
- After all the concrete / tar mixing is complete, all waste concrete / tar shall be removed from the batching area and disposed of at an approved dumpsite;
- Where “ready-mix” concrete trucks are used, no washing is to be allowed within the study area;
- Stormwater shall not be allowed to flow through the batching area or any washing area. Cement sediment shall be removed from time to time and disposed of in a manner as instructed by the Consulting Engineer;
- All construction materials prone to spillage are to be stored in appropriate structures with impermeable flooring;
- Portable septic toilets are to be provided and maintained for construction crews. Maintenance must include their removal without sewage spillage;
- Under no circumstances may ablutions occur outside of the provided facilities;

- Care should be taken not to contaminate surface water resources at all times;
- No uncontrolled discharges from the construction crew camps to any surface water resources shall be permitted. Any discharge points need to be approved by the relevant authority;
- In the case of pollution of any surface or groundwater, the Regional Representative of the Department of Water Affairs must be informed immediately;
- Where construction in close proximity to sewer lines is unavoidable, excavations must be done by hand, while at all times ensuring that the soil beneath the sewer lines is not destabilised;
- Store all litter carefully so that it cannot be washed or blown into any of the water courses within the study area;
- Provide bins for construction workers and staff at appropriate locations, particularly where food is consumed;
- The construction site should be cleaned daily and litter removed;
- Conduct ongoing staff awareness programs so as to reinforce the need to avoid littering; and
- Backfill must be compacted to form a stabilised and durable blanket.

4.2.2 Operational Phase

4.2.2.a Increased runoff volume

Extent	Duration	Intensity	Probability of occurrence	Significance		Confidence
				WOMM	WMM	
Regional	Permanent	Low	Definite	Low to Medium	Low	High

Description of Impact

Increased surface water runoff is expected to occur as a result of an increase in the hardened and impermeable surfaces associated with the proposed development. An increase in the surface water runoff will have a corresponding increase in the potential for erosion of preferred drainage lines and subsequent sediment input into the Muldersdrif se Loop and a loss in flow-sensitive habitat as a result of sediment deposition.

Mitigation Measure

- Make use of a stormwater-sensitive layout plan to facilitate the management of stormwater at source within the proposed development.

4.2.2.b Nutrient enrichment

Extent	Duration	Intensity	Probability of occurrence	Significance		Confidence
				WOMM	WMM	
Regional	Permanent	Low	Probable	Low to Medium	Low	Medium

Description of Impact

The application of fertilizers for the purposes of maintaining landscaped gardens, sports fields and the driving range may result in the increase of nitrates and phosphates within water bodies associated with the proposed development.

Mitigation Measure

- Ensure stormwater runoff is addressed at the source (see above);
- Use indigenous vegetation when conducting landscaping;
- Ensure a well-vegetated, indigenous riparian buffer zone of 32m from the edge of the delineated riparian zone. The riparian zone and its associated buffer should be maintained in a natural state and should not be subjected to landscaping;
- Incorporate detention ponds into the design of the proposed development to minimise the input of nutrient-rich water into water bodies;
- Detention ponds should be sized to maximise water holding during storm events and to minimise outputs during non-storm events;
- Where the use of fertilizers is warranted, slow-release natural organic fertilizers should be used sparingly, with application rates as low as possible;
- The application of fertilisers should be avoided when heavy rainfall is forecast and should be applied under calm wind conditions;
- A well-vegetated buffer zone with a narrow grass strip at the upland edge should be incorporated and maintained along identified wetlands. The buffer surface should be managed so as to avoid concentrated storm flows, and developed sand berms should be periodically removed;

- No chemicals should be applied to buffer zones, and grass should be allowed to lengthen and thicken naturally to facilitate reduction in runoff velocity and volume and increase infiltration;

- Wetland condition should be closely monitored for erosion and managed accordingly;

- Introduction of indigenous aquatic vegetation at the inlets, outlets and along the perimeter of water bodies will facilitate the uptake of nutrients and biodegradation of possible pesticides to less-toxic metabolites;

- Algal build-up in water bodies should be removed mechanically so as to prevent the release of future nutrients from the breakdown of organic matter; and

- The inclusion of appropriate indigenous vegetation along drainage paths will assist in the trapping of nitrates.

4.2.2.c Water quality impairment

Extent	Duration	Intensity	Probability of occurrence	Significance		Confidence
				WOMM	WMM	
Regional	Permanent	Low	Probable	Low to Medium	Low	Medium

Description of Impact

Stormwater runoff is known to contain a number of pollutants associated with surrounding land uses. An increase in the volume and velocity of stormwater runoff from the site will result in the transport of chemicals and pollutants into the water resources associated with the proposed development.

Mitigation Measure

- No mitigation measures required provided mitigation measures above are adhered to.

4.2.2.dDecrease in groundwater recharge

Extent	Duration	Intensity	Probability of occurrence	Significance		Confidence
				WOMM	WMM	
Local	Permanent	Low	Probable	Low	Low	Medium

Description of Impact

The increase in hardened surfaces and the decrease in the infiltration of surface water as a result of increased stormwater runoff will ultimately result in the loss of

vertical connectivity and a subsequent decease in groundwater recharge within the study area.

Mitigation Measure

- No mitigation measures required provided mitigation measures above are adhered to.

4.2.2.e Loss of terrestrial biodiversity

Extent	Duration	Intensity	Probability of occurrence	Significance		Confidence
				WOMM	WMM	
Regional	Permanent	Medium	Probable	Medium	Low	Medium

Description of Impact

The riparian zone of rivers facilitates the movement of terrestrial fauna by providing cover from possible predation. The construction of new bridges and/or the upgrading of existing bridges within the study area is likely to result in a loss of the riparian zone as a corridor for movement by impeding the movement of fauna.

Mitigation Measure

- The construction of new bridges should be minimised and only constructed at the shortest possible route perpendicular to the natural drainage line or water course;

- Where possible, bridge crossings should be span the entire stretch of the buffer zone;

- An underpass should facilitate the movement of terrestrial and aquatic fauna and should not impede their movement;

- All underpasses should be dressed with a layer of sand of approximately 10cm thick, should be a minimum of 1.5m high and 1m wide so as to facilitate maintenance access and should be provided with small grates in the road surface to allow light penetration into the underpass; and

- Underpasses should be accessible to maintenance staff and should be cleared of accumulated material at least at the start of every rainy season.

5. CONCLUSION AND RECOMMENDATIONS

Based on results obtained during the present assessment, no apparent change in seasonality to the hydrology of the Muldersdrif se Loop associated with the proposed area of development was evident. However, this may not be representative of natural conditions, as monitoring of the hydrology only commenced in 1974 after development within the area was already established. Also, no significant increases in annual surface water runoff was observed, although there does appear to be a general trend for higher runoff within recent years. Nevertheless, it is recommended that development within the study area take cognisance of possible increases surface water runoff likely to occur within the near future as continued development within the upper catchment of the Crocodile River continues. At a minimum, no development should therefore occur within the present 1:100 year floodlines as a result of possible future increases in flood lines, as has occurred within the Jukskei River catchment due to the highly developed nature of the catchment.

Water quality of the Muldersdrif se Loop was considered potentially limiting to the abundance and diversity of aquatic life within the study area, with relatively high concentrations (i.e. above sub-lethal threshold concentrations) of magnesium sulphate likely to be present based on aggregated salt determinations, as well as known high concentrations of aluminium present within upstream tributaries. Furthermore, the current nutrient status of the Muldersdrif se Loop associated with the area of proposed development indicates a potential for nuisance aquatic plant growth and blue-green algal blooms, particularly where weirs and slow-flow conditions are present.

Instream aquatic habitat within the study area was considered relatively good, with a variety of hydraulic habitats available for utilisation by aquatic biota, including habitats considered to be sensitive to changes in flow such as riffles and runs. Amongst the many ecologically important roles provided by these flow-sensitive habitats, they provide spawning areas for fish and increase the dissolved oxygen concentrations present within the Muldersdrif se Loop. However, the presence of weirs within the study area decreases the number of such flow-sensitive habitats by inundating such areas, and the settlement of sediment within the weirs creates “silt-hungry” water that increases the erosive power of water released, often undercutting and destabilising river banks. It is highly recommended that no further loss of flow-sensitive habitats should occur within the Muldersdrif se Loop. Furthermore, riparian vegetation within the study area was determined to generally be dominated by exotic and alien vegetation. It is therefore recommended that an alien eradication and riparian rehabilitation programme that follows a phased approach be established so that the natural attributes associated with riparian zones be maintained during the process.

In terms of aquatic biota, aquatic macroinvertebrate and fish diversity and abundance within the study area was considered seriously modified and impoverished. The

lower than expected macroinvertebrate diversity was primarily attributed to poor water quality within the study area, particularly with regards to magnesium sulphate, whereas the poor condition of the fish population within the study area was attributed to the presence of weirs, preventing dispersal, reproduction and subsequent recruitment. Based on the present condition of the water quality and aquatic habitat present within the study area, no Red Data fish species were expected to be present. Similarly, the likelihood of significant populations of fish species of special concern being present was considered poor. It is highly recommended that the installation of fish ladders be considered in order to increase the state of the fish population within the study area.

Furthermore, should stocking of any water body within the study area be considered, it is recommended that only indigenous fish species naturally occurring within the study area be considered and should be in accordance with Section 70 of the National Environmental Management: Biodiversity Act, Act No. 10 of 2004. Indigenous fish species having angling potential and naturally occurring within the study area include *Clarias gariepinus* (Sharptooth Catfish), *Labeobarbus marequensis* (Lowveld Largescale Yellowfish), *Labeobarbus polylepis* (Bushveld Smallscale Yellowfish*),* and *Tilapia sparrmanii* (Banded Tilapia). It should be noted that there presently exists a moratorium on all translocations and releases of yellowfish within the South Africa in order to protect the genetic diversity of the different species. Should the stocking of yellowfish within the study area be considered, the following guidelines should be adhered to:

- The land-owner must apply to the relevant provincial conservation agency for a permit to stock yellowfish species into a farm dam.

- The dam or dams must be free of alien fish species.

- The conservation agency will determine which species of yellowfish are native to the catchment area in which the dam is situated. A permit will then be issued listing the species that may be stocked and where they may be obtained.

- Stocked fish should be caught by conservation agency staff from the nearest stream or river in the same catchment as the dam. If possible, approximately 100 juvenile fish of size 5-10cm or 20-30 larger fish of a size greater than 30cm should be stocked. It is imperative that fish are not moved from one river system to another for stocking purposes. The landowner should not catch fish for stocking unless authorized to do so by the conservation agency.

- Landowners should pay to have dams stocked. This will include travel costs, labour costs and the cost of individual fish, where applicable.

- Where feasible, spawning areas should be created in dams to allow stocks to expand. The dam and streams feeding the dam should be managed in such a way as to facilitate favorable spawning habitat. Such a management plan

should be drafted by a suitably qualified individual with specific expertise in yellowfish ecology.

- A record of each stocking must be kept by the provincial conservation agency and it is essential that the co-ordinates of the dam being stocked are taken and retained for future reference purposes.

The above requirements should be regarded as general until such time as the relevant provincial authority has been consulted. The stocking of other fish species (including those presently occurring within the study area) are prohibited

Additional recommendations relevant to the study area include the following:

- Development within the study area should occur within the winter months where possible so as to decrease the runoff of sediment into the Muldersdrif se Loop during times of heavy rainfall;

- Ensure that the proposed development makes use of a layout design that facilitates the management and attenuation of stormwater at the source;

- Water use licences will be required in accordance with Section 21 of the National Water Act for any proposed upgrading of bridges, development within the designated floodlines and discharge of stormwater into the Muldersdrif se Loop; and

- It is recommended that the conservancy proposed within the study area be relocated to a more suitable natural area.

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Appendices

Appendix 1: Methodology

Appendix 2: Photographs of sampling sites

Appendix 3: Macroinvertebrate Data

APPENDIX 1: METHODOLOGY

Hydrology

For the purpose of the present assessment, hydrological data starting from 1974 was obtained from the Department of Water Affairs and Forestry for DWAF Gauging Station A2H051. Data obtained was assessed based on average flow volumes for 1974–1979, 1980-1989, 1990-1999 and 2000-present in order to assess changes in seasonality of river flow. Also, annual data from 1974 was assessed in order to determine differences in annual surface water catchment runoff volumes.

Water Quality

For the purpose of the present assessment, water quality data was obtained from the Water Management System of the Department of Water Affairs and Forestry for DWAF Gauging Station A2H051 (DWAF, 2008a). In order to determine the aggregated salt concentrations likely to be present within the Muldersdrif se Loop associated with the proposed development as well as the current nutrient status of the Muldersdrif se Loop, the Tool for Ecological Aquatic Chemical Habitat Assessment (TEACHA Version 1.32) was used, and guidelines according to DWAF (2008b) followed.

Invertebrate Habitat Assessment System (IHAS), Version 2.2

Assessment of the habitat available for aquatic macroinvertebrate colonization and the habitats sampled during rapid biomonitoring practices are vital in the correct interpretation of results obtained following biological assessments. Previous methods of determining habitat were not specific to rapid biomonitoring assessments, and were far too variable in their approach to achieve consistency amongst users.

The Invertebrate Habitat Assessment System (IHAS) was developed by McMillan (1998), and has routinely been used in conjunction with the South African Scoring System (SASS) as a measure of the variability in the amount and quantity of aquatic macroinvertebrate biotopes available for sampling. The habitat scoring system is based on 100 points (or percentage), and is split into two sections, namely the sampling habitat (comprising 55% of the total score) and the general stream characteristics (comprising 45% of the total score). Summation of the scores obtained for the two sections will provide an overall habitat percentage, which can be categorised according to the following values (McMillan, 2006):

IHAS Score (%)	Description
>75	Very good
65-74	Good
55-64	Adequate / Fair
<55	Poor

It has, however, become clear that the IHAS requires field validation and testing, and results obtained should be interpreted with care. Nevertheless, the IHAS does still provide a convenient and rapid method to record details about aquatic macroinvertebrate biotopes sampled during SASS application.

Intermediate Habitat Integrity Assessment

Habitat integrity in this sense then refers to the maintenance of a balanced, integrated composition of physico-chemical and habitat characteristics on a temporal and spatial scale that are comparable to the characteristics of natural habitats of the region. The habitat integrity status of a river or stream will essentially provide the template for a certain level of biotic integrity to be realized. In this sense the assessment of the habitat integrity of a river can be seen as a pre-cursor of the assessment of biotic integrity. It follows that in this context habitat integrity and biotic integrity together constitutes ecological integrity (Kleynhans, 1996). The purpose of this section of the study is therefore to assess both the instream habitat integrity and the riparian habitat integrity of the watercourses associated with the proposed development, based on certain key criteria.

The Intermediate Habitat Integrity Assessment (IHIA) protocol, as described by Kemper (1999) was used for the assessment of both instream and riparian habitat during this study. The IHIA protocol was developed for the assessment of riverine ecosystems in segments of approximately 5km in length. The procedure used to determine the habitat integrity was as follows (Kemper, 1999):

- The Habitat Integrity was scored according to 12 different criteria (Table 11), which represent some of the 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' (1996) 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 12.

- 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 Assessment of the rivers/streams in the study area are shown in Table 13.

- Based on the relative weights of the criteria, the impact of each criterion are estimated as follows:

  Rating for the criterion/maximum value (25) x weight (percent)

- The instream and riparian Habitat Integrity for each segment were then calculated by adding the weighted scores of the appropriate criteria separately for each of the two zones 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, 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, 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 14.

By calculating the mean of the instream and riparian Habitat Integrity scores, an overall Intermediate Habitat Integrity score was obtained for each segment.

Table 11: Criteria used in the assessment of habitat integrity (from 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. Indirect indications of sedimentation are stream bank and catchment erosion. Purposeful alteration of the stream bed, e.g. the removal of rapids for navigation 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.
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. 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 12: 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 13: 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 14: Intermediate Habitat Integrity Assessment Classes/Categories (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

Aquatic macroinvertebrates

Aquatic macroinvertebrates were sampled at all sites selected within the Muldersdrif se Loop associated with the area of proposed development. Aquatic macroinvertebrates were sampled utilising methodology based on the qualitative kick method called SASS5 (South African Scoring System, version 5). The SASS5 method takes into account the various habitats available to macroinvertebrates (Gravel/Sand/Mud, Stones and Vegetation) and attempts to record the diversity and abundances of the macroinvertebrates utilizing those habitats by means of representative sampling.

The collection of aquatic macroinvertebrates by means of the SASS5 method is done by churning up the sediment/gravel, kicking over stones and disturbing both aquatic and marginal vegetation, where available. Organisms are then collected by means of sweeping a 1000 micron net mounted on a 300mm square net over the disturbed area, and identified to family level (Thirion *et al*, 1995; Dickens & Graham, 2001; Gerber & Gabriel, 2002).

For the purpose of determining the Present Ecological State of aquatic macroinvertebrates present, the Macro Invertebrate Response Assessment Index (MIRAI; Thirion 2008) was used. This was done by integrating the ecological requirements of the aquatic macroinvertebrate taxa in a community or assemblage and their response to modified habitat change (Thirion, 2008). Also taken into account during the assessment of the Present Ecological State was the presence and abundance of the aquatic macroinvertebrates relative to a derived expected list likely to be present under natural, unimpacted conditions.

The four metric groups utilised during the application of the MIRAI were then combined within the model to derive the Present Ecological State Class (PES Class) of the river in terms of aquatic macroinvertebrates. The allocation protocol is presented in Table 15.

Chutter (1998) developed the SASS protocol as an indicator of water quality. It has since become clear that SASS gives an indication of more than mere water quality, but rather a general indication of the present state of the invertebrate community. Because SASS was developed for application in the broad synoptic assessment required for the River Health Programme (RHP), it does not have a particularly strong cause-effect basis. The aim of the MIRAI, on the other hand, is to provide a habitat-based cause-and-effect foundation to interpret the deviation of the aquatic invertebrate community (assemblage) from the reference condition. This does not preclude the calculation of SASS scores should they be required. However, the recent tendency is to use the MIRAI even for River Health Programme purposes, and it is now the preferred approach (Thirion, 2008).

The present ecological state was determined for each individual sampling site during March 2009.

Table 15: Allocation protocol for the determination of the Present Ecological State for aquatic macroinvertebrates following application of the MIRAI

MIRAI Percentage	Category	Description
>89	**A**	Excellent Unimpaired; community structures and functions comparable to the best situation to be expected. Optimum community structure for stream size and habitat quality.
80-89	**B**	Very Good – Minimally impaired; largely natural with few modifications. A small change in community structure may have taken place but ecosystem functions are essentially unchanged
60-79	**C**	Good – Moderately impaired; community structure and function less than the reference condition. Community composition lower than expected due to loss of some sensitive forms. Basic ecosystem functions are still predominantly unchanged.
40-59	**D**	Fair – Largely impaired; fewer families present then expected, due to loss of most intolerant forms. An extensive loss of basic ecosystem function has occurred.
20-39	**E**	Poor – Seriously impaired; few aquatic families present, due to loss of most intolerant forms. An extensive loss of basic ecosystem function has occurred.
<20	**F**	Very poor – Critically impaired; few aquatic families present. If high densities of organisms, then dominated by a few taxa. Only tolerant organisms present.

Ichthyofaunal Assessment

Fish were collected by means of electro-narcosis, whereby an anode and a cathode are immersed in the water to temporarily stun fish in the near vicinity. Thereafter, the fish are easily scooped out by means of a hand net. All fish were identified in the field and released back into the river where possible.

Assessment of the Present Ecological State of the fish assemblage of the Muldersdrif se Loop associated with the proposed area of development was conducted by means of the Fish Response Assessment Index (FRAI; Kleynhans, 2008). The procedure followed to determine the fish Present Ecological State, or Ecological Category, is an integration of ecological requirements of fish species in an assemblage and their derived or observed responses to modified habitat conditions. In the case of the present assessment, the observed response was determined by means of fish sampling as well as a consideration of species requirements and driver changes (Kleynhans, 2008).

It should be emphasised that although the FRAI uses essentially the same information as the Fish Assemblage Integrity Index (FAII), it does not follow the same procedure. The FAII was developed for application in the broad synoptic assessment required for the River Health Programme, and subsequently does not offer a particularly strong cause-and-effect basis. The purpose of the FRAI, on the other hand, is to provide a habitat-based cause-and-effect underpinning to interpret the deviation of the fish assemblage from the perceived reference condition (Kleynhans, 2008).

The FRAI is based on the assessment of metrics within metric groups. These metrics are assessed in terms of:

- Habitat changes that are observed or derived; and
- The impact of such habitat changes on species with particular preferences and tolerances.

The relationship between the drivers used in the FRAI and the various fish response metric groups are indicated in Figure 7. Table 16 provides the steps and procedures required for the calculation of the FRAI.

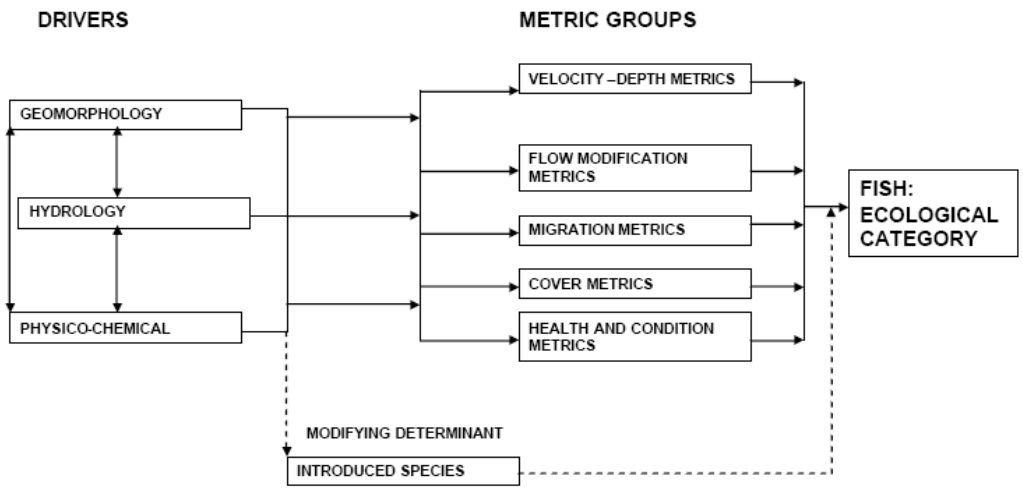

Figure 7: Relationship between drivers and fish metric groups

Table 16: Main steps and procedures in calculating the Fish Response Assessment Index

STEP	PROCEDURE
River section earmarked for assessment	As for study requirements and design
Determine reference fish assemblage: species and frequency of occurrence	• Use historical data & expert knowledge • Model: use ecoregional and other environmental information • Use expert fish reference frequency of occurrence database if available
Determine present state for drivers	• Hydrology • Physico-chemical • Geomorphology or • Index of habitat integrity
Select representative sampling sites	Field survey in combination with other survey activities
Determine fish habitat condition at site	• Assess fish habitat potential • Assess fish habitat condition
Representative fish sampling at site or in river section	• Sample all velocity depth classes per site if feasible • Sample at least three stream sections per site
Collate and analyze fish sampling data per site	Transform fish sampling data to frequency of occurrence ratings
Execute FRAI model	• Rate the FRAI metrics in each metric group • Enter species reference frequency of occurrence data • Enter species observed frequency of occurrence data • Determine weights for the metric groups • Obtain FRAI value and category • Present both modelled FRAI & adjusted FRAI.

Interpretation of the FRAI score follows a descriptive procedure in which the FRAI score is classified into a particular Present Ecological State Class or Ecological Category based on the integrity classes of Kleynhans (1999). Each class gives a description of generally expected conditions for a specific range of FRAI scores (Table 17).

Table 17: Allocation protocol for the determination of the Present Ecological State/Ecological Category for fish following application of the FRAI

FRAI Percentage	Category	Description
90-100	**A**	Unmodified and natural. Community structures and functions comparable to the best situation to be expected. Optimum community structure for stream size and habitat quality.
80-89	**B**	Largely natural with few modifications. A small change in community structure may have taken place but ecosystem functions are essentially unchanged
60-79	**C**	Moderately modified. Community structure and function less than the reference condition. Community composition lower than expected due to loss of some sensitive forms. Basic ecosystem functions are still predominantly unchanged.
40-59	**D**	Largely modified. Fewer species present then expected due to loss of most intolerant forms. An extensive loss of basic ecosystem function has occurred.
20-39	**E**	Seriously modified. Few species present due to loss of most intolerant forms. An extensive loss of basic ecosystem function has occurred.
0-19	**F**	Critically modified. Few species present. Only tolerant species present, if any.

APPENDIX 2: PHOTOGRAPHS OF SAMPLING SITES

Site A1

Site A2

APPENDIX 3: MACROINVERTEBRATE DATA

List of aquatic macroinvertebrate fauna samples in the study area
Abundances were estimated on the following scale:

1= single individual; A= 2-10; B= 11-100; C= 100-1000; and D > 1000

Taxon	Common Names	Reference	Site A1	Site A2
PORIFERA	Freshwater sponges	**A**		
TURBELLARIA		**B**	B	A
ANNELIDA				
Oligochaeta	Segmented Aquatic Worms	**B**	A	B
Hirudinae	Leeches	**A**		1
CRUSTACEA				
Amphipoda		**A**		
Atyidae	Freshwater shrimps	**B**		
Potamonautidae	Crabs	**A**	B	B
HYDRACARINA				
Hydrachnellae	Water Mites	**B**		
PLECOPTERA				
Perlidae		**A**		
EPHEMEROPTERA				
Baetidae 2spp	Small minnow flies		C	B
Baetidae >2spp	Small minnow flies	**B**		
Caenidae	Cainflies	**B**	B	B
Heptageniidae	Flat-headed mayflies	**A**		
Leptophlebiidae	Prongills	**B**		
Polymitacyidae	Pale burrowers	**A**		
Prosoptomatidae	Water specs	**A**		
Tricorythidae	Stout crawlers	**A**		
ODONATA				
Aeshnidae	Dragonflies	**A**		
Chlorocyphidae	Damselflies	**A**	1	1
Chlorolestidae	Damselflies	**A**		
Coenagrionidae	Damselflies	**B**	A	A
Gomphidae	Dragonflies	**B**	B	A
Lestidae	Damselflies	**A**		
Libellulidae	Dragonflies	**B**	A	
Platycnemidae	Damselflies	**A**		
LEPIDOPTERA	Aquatic caterpillars			
Pyralidae		**A**		
HEMIPTERA				
Belostomatidae	Giant Water Bugs	**B**	A	A
Corixidae	Water Boatman	**B**	A	A
Gerridae	Pond skater	**B**	1	
Hydrometridae	Marsh treaders	**1**		

Naucoridae	Creeping water bugs	**A**		
Nepidae	Water scorpions	**A**		
Notonectidae	Backswimmers	**A**		
Pleidae	Pigmy backswimmers	**A**		
Veliidae	Broad-shouldered water striders	**B**	A	A
TRICHOPTERA				
Ecnomidae	Caseless caddisflies	**A**		
Hydropsychidae 2spp	Caseless caddisflies		B	B
Hydropsychidae <2spp	Caseless caddisflies	**A**		
Philopotamidae	Caseless caddisflies	**A**		
Hydroptilidae	Micro caddisflies	**B**		
Leptoceridae	Cased caddisflies	**B**		
COLEOPTERA				
Dytiscidae	Predacious Diving Beetles	**B**		
Elmidae/ Dryopidae	Riffle beetles	**B**	B	A
Gyrinidae	Whirligig beetles	**B**		1
Haliplidae		**A**		
Helodidae	Marsh beetles	**A**		
Hydraenidae	Minute moss beetles	**A**	A	A
Hydrophilidae	Water scavenger beetles	**B**		
Psephenidae	Water penny beetles	**A**		
DIPTERA				
Athericidae	Snipe flies	**A**		
Ceratopogonidae	Biting midges	**B**	A	1
Chironomidae	Midges	**B**	B	B
Culicidae	Mosquitoes	**A**		
Dixidae	Meniscus midges	**A**		
Muscidae	House flies	**A**		
Simuliidae	Black flies	**B**	A	A
Tabanidae	Horseflies	**B**		
Tipulidae	Crane flies	**A**		
GASTROPODA				
Ancylidae	Limpets	**B**		1
Lymnaeidae	Pond snails	**A**		
Planorbinae	Orb snails	**B**		A
Thiaridae	Snails	**A**		
PELECYPODA				
Corbiculidae	Clams	**B**		
Sphaeridae	Pill clams	**B**	A	
SASS SCORE:		**240**	93	106
NUMBER OF TAXA:			20	22
AVERAGE SCORE PER TAXON:		**6.8**	4.65	4.82