# PROPOSED PIPE LINE PROJECT IN THE HEX RIVER CATCHMENT, RUSTENBURG, NORTH-WEST.



DR ANDREW DEACON

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## THE PRESENT ECOLOGICAL STATE OF THE RIVER REACHES AT THE PROPOSED PIPELINE CROSSINGS.

**DR ANDREW DEACON**

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Executive summary

The pipeline crossings which are relevant for the study are tributaries to the Hex River. There are two tributaries with surface flows, the Dorps River at Crossing 1, and the Boschfontein Spruit at Crossing 2, and two tributaries that are drainage lines with ephemeral surface flows only during high rainfall events, Crossing 3, Kanana Drainage line and Crossing 4, Tierkop Spruit. The latter two systems were not evaluated in the same detail as the systems with surface water. Since the Hex River is the main stem and the only river with adequate data available, the information of this river was utilized as background information for the associated tributaries.

**Task 1.2.3.1. Flow and sediment regimes:** The flow situation in the Hex River is reflected in the two river crossing sites with surface water flows: un-seasonally high pulses of flow; large numbers of dams and weirs; severely fragmented; distinctly seasonal; weirs and deep pools are the only refuge.

**Task 1.2.3.2. Water quality:** At the two river crossing sites with surface water flows, certain water quality parameters are regularly not meeting the Target Water Quality Range. Due to this, the overall EcoStatus for these tributaries equates to "Poor".

**Task 1.2.3.3. Riparian and In-stream Habitat.**

**Task 1.2.3.3.1 Morphology (Physical structure):** The outcome of the in-stream and riparian IHI evaluated for the rivers with surface flows in the study area (Dorp's and Boschfontein rivers), resulted in an in-stream IHI of 74.2 (C), and a riparian IHI of 79.0 (C), resulting in both being classified as "Moderately modified" according to the Habitat Integrity Categories.

**Task 1.2.3.3.2 Vegetation:** The combined Level 3 VEGRAI (Riparian Vegetation Response Assessment Index) scores per site present a score of 56.2% at the Dorp's Spruit river crossing, and 44.6% at the Boschfontein Spruit river crossing. The final riparian vegetation integrity described by the Ecological Class of both these two sites, are grouped in a Class D (40-59%) which reflects a "Largely modified" vegetation integrity.

**Task 1.2.3.4. Biota – Aquatic invertebrates and Fish**

**Aquatic habitat assessment:** The IHAS (Integrated Habitat Assessment System) and HQI (Habitat Quality Index) were relatively low due to poor water quality, limited habitats and human related impacts on the aquatic environment (erosion, siltation, vegetation removal, litter, eutrophication, etc.). Due to these impacts on the rivers, habitat scores are quite low at the river crossing sites with surface flows, and are all categorized as "Poor" according to SASS5 (South African Scoring System version 5) values.

**Task 1.2.3.4.1 - Aquatic invertebrate assessment:** The relative MIRAI (Macro-invertebrate Response Assessment Index) score of the Dorp's River reach was placed within the limits of an ecological state category Class E (34%), which means this reach is "Seriously modified". The relative MIRAI score of the Boschfontein Spruit reach was placed within the limits of an ecological state category Class D (56%), which means this reach is "Largely modified".

**Task 1.2.3.4.2 - Fish Response Assessment Index (FRAI):** The relative FRAI score of this stretch of the Dorp's River falls within the limits of an ecological state category Class E (33.3%). The relative FRAI score of the Boschfontein Spruit also falls within the limits of an ecological state category Class E (35.7%), which means that both the river crossings with surface water are

affected by an environment that is “Seriously modified”.

**Task 1.2.5. Existing land and water use impacts:** According to the River Health Programme the overall EcoStatus for the Lower Hex River during 2005 was “Poor”. With a current category description of “Serious Modification”, it is clear that the Hex River catchment is under pressure due to development and utilization. These PES ratings will also reflect in most of the tributaries of the Hex River, especially the lower sections that flows into the main stem.

**Task 1.2.6. List and map sensitive environments:** According to the Land-Use Decision Support Tool (LUDS) Report areas directly around the river crossings are in a built-up area along a national highway where very little natural habitat remains intact. This area is known as a production landscape and should be managed to optimise sustainable utilization of natural resources. The only protected area in the project vicinity is in the form of a conservancy around the Bospoort Dam.

**Present Ecological State or PES**

Listed below, are the attributes that give rise to the overall Present Ecological State of the crossing sites:

- River flows: EC: Serious (impacted)
- Water quality: Poor / EC: Serious (impacted)
- Morphology: Poor
- Riparian: D: Largely modified
- Aquatic invertebrates: E: Seriously - Largely modified
- Fish: E: Seriously modified
- Ecological Importance and Sensitivity: Very low

The Dorp’s River and the Boschfontein Spruit crossing sites have very similar Ecostatus values (D; 44.9% and D; 45.2%), but for different reasons: the Dorp’s River has a Category D due to the poor water quality that influences the in-stream biota, while the Boschfontein Spruit has a Category D due to the lack of a riparian zone (removed by humans) which influences the integrity score.

Final PES: D: Largely modified

- EcoStatus: D: Largely modified
- In-stream Habitat Integrity: Poor
- In-stream ecological category: E: Seriously modified
- Riparian vegetation ecological category: D: Largely modified

# Table of Contents

## Abbreviations

| | |
|---|---|
| AQV | Aquatic vegetation |
| As | Arsenic |
| ASPT | Average Score per Taxon |
| BA | Basic assessment |
| CBA | Critical Biodiversity Areas |
| Cd | Cadmium |
| Cl | Chloride |
| CSIR | Council for Scientific and Industrial Research |
| Diss | Dissolved |
| DMS | Dimethyl Sulphide |
| DREAD | North West Department of Rural, Environment and Agricultural Development |
| DWA | Department of Water Affairs (post-2010) |
| DWAF | Department of Water Affairs (pre-2010) |
| DWA&S | Department of Water Affairs and Sanitation |
| EC | Ecological Category |
| EcoStatus | Ecological Status |
| EIA | Environmental Impact Assessment |
| EIS | Ecological Importance and Sensitivity |
| ESA | Ecological Support Area |
| FRAI | Fish Response Assessment Index |
| FROC | Frequency of Occurrence |
| HCR | Habitat Cover Ratings |
| HQ | Habitat Quality Index |
| IHAS | Integrated Habitat Assessment System |
| IHI | Index of Habitat Integrity |
| K | Potassium |
| km | Kilometre |
| LUDS | Land-Use Decision Support Tool |
| l | Litre |
| m | Meter |
| mg/l | Milligrams per litre |
| mm | Millimetre |
| Mℓ/d | Million litres per day |
| MCDA | Multi Criteria Decision Analysis |
| MIRAI | Macro-invertebrate Response Assessment Index |
| MV | Marginal vegetation |
| N | Nitrogen |
| Na | Sodium |
| NFEPA | National Freshwater Ecosystem Priority Areas |
| $NH_3$ | Ammonium |
| $NO_3$ | Nitrate |
| P | Phosphorus |
| Pb | Lead |
| PES | Present Ecological State |
| $PO_4$ | Phosphate |
| RHP | River Health Programme |
| Si | Silicon |
| SASS5 | South African Scoring System version 5 |
| SI | Socio-cultural Importance |
| SIC | Stones in current |
| SHI | Site Fish Habitat Integrity Index |
| $SO_4$ | Sulfate |
| SOOC | Stones out of current |
| SQ | Sub-quaternary |
| SQR | Sub-quaternary reach |
| TAL | Total alkalinity |
| TDS | Total dissolved solids |
| Veg | Vegetation |
| VEGRAI | Riparian Vegetation Response Assessment Index |
| WTW | Water Treatment Works |
| WUL | Water Use License |

# 1. Introduction

## 1.1 Project description

The following was taken from the Background Information Document (BID, Ecoleges 2014).

**Project:** The proposed upgrading and expansion of the Boitekong WWTW (Ref. No. NWP/EIA/41/2014), Bospoort WTW (Ref. No. NWP/EIA/42/2014), and Monakato WWTW (Ref. No. NWP/EIA/44/2014). construction of a new Dissolved Air Flotation (DAF) plant at the Rustenburg WWTW (Ref. No. EIA241/2003NW) and a new pipeline from the Bospoort WTW to the Bospoort reservoirs (NWP/EIA/43/2014) currently under the jurisdiction of the Rustenburg Local Municipality, North West Province.

Ecoleges, as the independent Environmental Consultant, has been appointed by Bigen Africa on behalf of the proponent/applicant, to compile the Basic Assessment (BA) Reports, Water Use License (WUL) applications, and amendments which will be reviewed by the relevant competent authorities (the North West Department of Rural, Environment and Agricultural Development (DREAD), and the Department of Water & Sanitation (DWS), respectively).

The aim of the reports is to ensure that the environmental impacts are taken into consideration, to ensure stakeholder engagement, and to provide decision makers with sufficient information to make an informed decision on the proposed activities.

**Applicable legislation for:** New pipeline from the Bospoort WTW to the Rustenburg Reservoirs via the Bospoort reservoirs:

| Listed activity as described in GN R.983, 984 and 985 (EIA Regulations, 2014) | Description of project activity |
|---|---|
| *GN R.983 Activity 12*: *The construction of facilities or infrastructure exceeding 1 000m in length for the bulk transportation of water, sewage or storm water –*<br>*(i) with an internal diameter of 0,36 metres; or*<br>*(ii) with a peak throughput of 120 litres per second or more,*<br>*Excluding where:*<br>*a) Such facilities or infrastructure are for bulk transportation of water, sewage or storm water or storm water drainage inside a road reserve; or*<br>*b) Where such construction will occur within urban areas but further than 32 metres from a watercourse, measured from the edge of the watercourse.* | A 600mm diameter pipe will be constructed between the Bospoort WTW and the nearby Bospoort Reservoirs (approximately 20km's). The pipe will be a steel pipe and it will convey 12Mℓ/d (approximately 150ℓ per second) from the plant to the reservoirs where it will be incorporated in the existing Vaalkop pipeline between the Bospoort Reservoirs and Rustenburg Municipality, thereby augmenting the availability of potable water to the town. |
| *GN R.983 Activity 12(x)(a): The development of- (x) buildings exceeding 100 square metres in size; where such development occurs-* | The scour valve chambers and sacrificial anode beds (and/or other forms of cathodic protection) installed within 32m of a |

| | |
|---|---|
| *(a) within a watercourse;* | watercourse. |
| *GN R.983 Activity 19(i): The infilling or depositing of any material of more than 5 cubic metres into, or the dredging, excavation, removal or moving of soil, sand, shells, shell grit, pebbles or rock of more than 5cubic metres from-(i) a watercourse;* | When trenching through the Paardekraalspruit & Hex River, unless Pipe-jacking is selected as an alternative and the jacking pits are further than 32m from the edge of the watercourse. |
| *GN R.985 Activity 1(e)(v): The development of billboards exceeding 18 square metres in size outside urban areas, mining areas or industrial complexes. (e) In North West: v. Critical biodiversity areas as identified in systematic biodiversity plans adopted by the competent authority or in bioregional plans;* | If the intention is to erect several "notice" boards along the pipeline route, within a Critical Biodiversity Area (CBA), the collective area may exceed 18m$^2$. |
| *GN R.985 Activity 12(a)(ii): The clearance of an area of 300square metres or more of indigenous vegetation except where such clearance of indigenous vegetation is required for maintenance purposes undertaken in accordance with a maintenance management plan. (a) In Eastern Cape, Free State, Gauteng, Limpopo, North West and Western Cape provinces: ii. Within critical biodiversity areas identified in bioregional plans;* | A section of the pipeline closest to the waste treatment works is within a CBA and more than 300m$^2$ will be cleared for the new installation. |
| *GN R.985Activity 14(x)(e)(i)(ff): The development of-(x) buildings exceeding 10square metres in size; (e) In North West (i)Outside urban areas, in: (ff) Critical biodiversity areas or ecosystem service areas as identified in systematic biodiversity plans adopted by the competent authority or in bioregional plans;* | The scour valve chambers and sacrificial anode beds (and/or other forms of cathodic protection) installed within 32m of a watercourse within a CBA. |

**Purpose of Project:** The overall objective is to undertake and complete a robust and defendable BA & WUL process that will serve to inform the North West Department of Rural, Environment and Agricultural Development's (DREAD) & DWS decision on the environmental acceptability of the proposed developments.

**Project Description:** New pipeline from Bospoort water Treatment works to Rustenburg Reservoirs via Bospoort Reservoir.

As an interim measure in order to augment the supply of water to Rustenburg, it was decided that 600mm diameter pipe will be constructed between the WTW and the nearby

Bospoort Reservoirs. The reservoirs are approximately 2 kilometres from the plant (situated some 15km north east of Rustenburg) along the proposed pipe route, which follows existing access roads. In future this pipe will also be connected to the bulk water pipeline (whether the parallel system or a new 600mm pipe) between Rustenburg and Bospoort Water Treatment Works. The pipe will be a steel pipe and it will convey 12Mℓ/d (approximately 150ℓ per second) from the plant to the reservoirs where it will be incorporated in the existing Vaalkop pipeline between the Bospoort Reservoirs and Rustenburg Municipality, thereby augmenting the availability of potable water to the town.

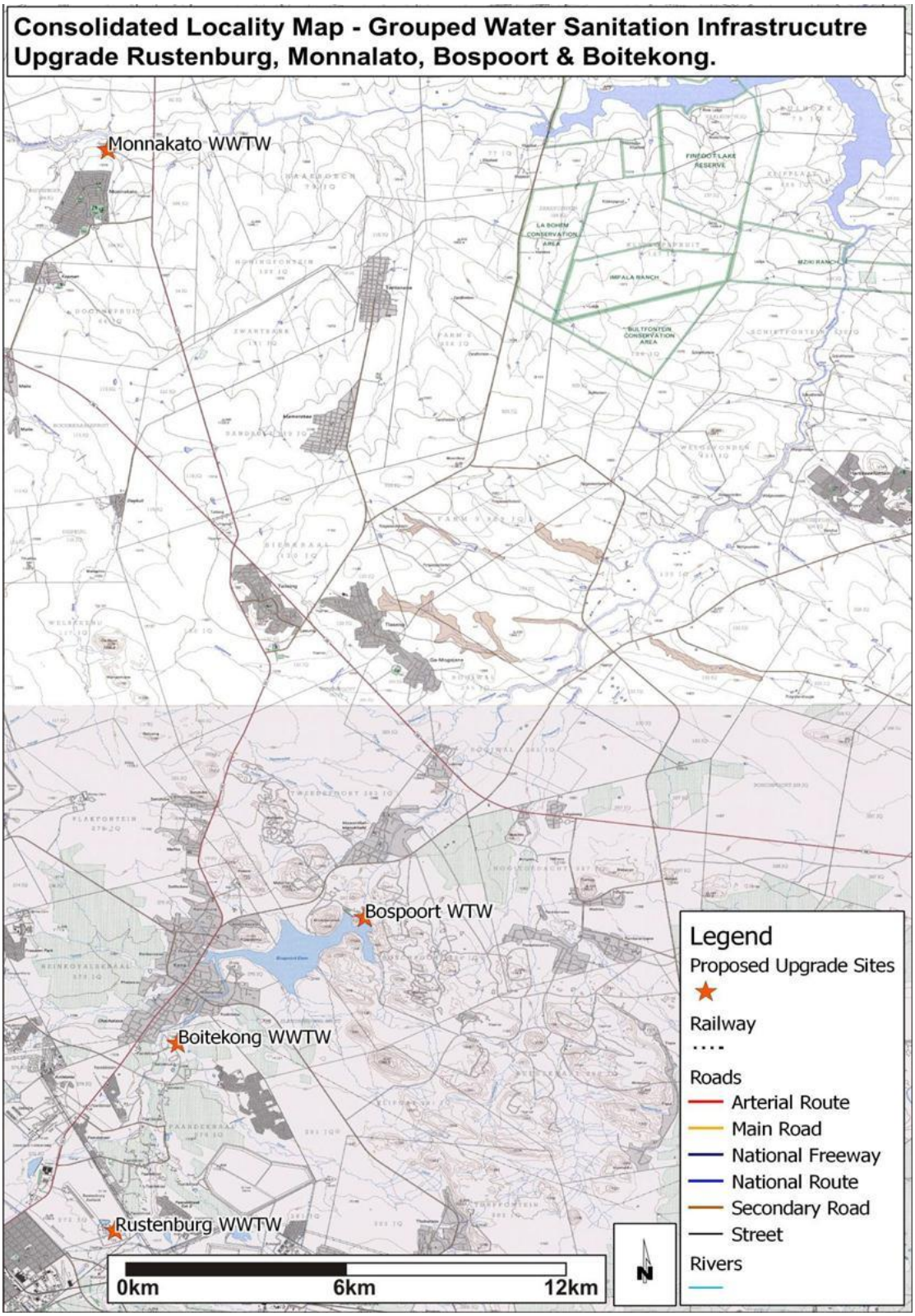


**Figure 1:** Location of the Grouped Sanitation Projects, Rustenburg Local Municipality.

## 1.2 Project brief

This specialist study forms part the process to compile the Basic Assessment (BA) Reports, Water Use License (WUL) applications, and amendments which will be reviewed by the relevant competent authorities (the North West Department of Rural, Environment and Agricultural Development (DREAD), and the Department of Water & Sanitation (DWS)), respectively, relating to the proposed pipeline in the Hex River catchment. Since the activities in the project area will impact on the riverine system (construction of pipeline) at river crossings in the Hex River catchment, this report will determine the Present Ecological State (PES) for these rivers.

The following tasks list certain activities required to determine the Present Ecological State (PES) and are based on the Department of Water Affairs document:

"Supplementary Water Use Information (Section 21 (c) and (i) Water Uses; Section 21(c) - impeding of diverting the flow of water in a watercourse; Section 21 (i) - altering the bed, banks, course or characteristics of a watercourse)."

1.2.3 Describe within context of the immediate catchment and segment, the historic as well as current state (Present Ecological State or PES) of the affected reach/es of the watercourse with regards to the following characteristics (attributes):

1.2.3.1. **Flow** and **sediment regimes** at appropriate flows

1.2.3.2. **Water quality** (including the **physical, chemical and biological characteristics** of the water) in relation to the flow regime

1.2.3.3 Riparian and In-stream **Habitat**.

1.2.3.3.1 **Morphology** (physical structure)

1.2.3.3.2 **Vegetation**

1.2.3.4 **Biota**

1.2.4 Describe the ecological importance and sensitivity (**EIS**) as well as the **Socio-cultural Importance (SI)** of the affected reach/es of the watercourse including the functions.

1.2.5 Discuss existing **land and water use impacts** (and threats) on the characteristics of the watercourse.

1.2.6 **List and map sensitive environments** in proximity of the project locality-sensitive environments include wetlands, nature reserves, protected areas, etc.

**Background studies and Fieldwork:**

1.2.3.1. Flow and sediment regimes at appropriate flows: To be obtained from existing DWS data base and other relevant studies.

1.2.3.2. Water quality (including the physical, chemical and biological characteristics of the water) in relation to the flow regime: To be obtained from existing DWS data base (PES of the river crossings in the Hex River catchment) and other relevant studies.

1.2.3.3 Riparian and In-stream Habitat.

1.2.3.3.1 Morphology (physical structure):

1.2.3.3.2 Vegetation: Identification and **delineation of wetlands and riparian areas**. The delineation process requires that the following be taken into account:

- **Topography** associated with the watercourse;
- Vegetation;
- **Alluvial soils** and deposited material.

Riparian habitat surveys will incorporate the Riparian Vegetation Index (**VEGRAI**).

1.2.3.4 Biota

**Aquatic biota and associated habitats**

Fish and macro-invertebrates are good indicators of river health. By making use of established and accepted survey methods and incorporate the habitat aspects, a proper basis for biological diversity could be obtained. The following recognized bio-parameters and methods will be used:

- General **habitat assessment** to assess the general physical habitat condition of the rivers and identify potential sources and impacts responsible for deterioration of the aquatic ecosystem. The general habitat assessment and biota specific habitat assessments also evaluated the condition and availability of habitats for specific biotic groups.

- **Fish communities**: All applicable non-destructive fish sampling methods will be applied at sites along the relevant rivers in an attempt to gain a representation of the fish assemblage per river. All fish were identified to species level and returned unharmed back into the aquatic ecosystem. The fish results will be interpreted using existing fish indices such as the Fish Response Assessment Index (FRAI).

- **Aquatic macro-invertebrates** by the application of the **SASS5** (South African Scoring System) protocol. The Integrated Habitat Assessment System (IHAS) method will be used to assess the invertebrate specific habitats.

## 2. Methods

As partial requirement for the DWS licensing requirements protocol, specific biodiversity surveys were recommended by the environmental consultant. The terms included for this investigation are as follow:

- Assess the ecological status, importance and sensitivity of the site as required for section 21 (c) and (i) water use license applications by the Department of Water & Sanitation (DWS),

- Aquatic and riparian surveys are proposed in the riverine habitats in the vicinity of the proposed development. The objective of this survey is to provide information on the aquatic environment of the proposed development regarding the fish and macro-invertebrate integrity, integrity of the aquatic habitat and possible impacts and mitigation.

For the purposes of this report, the site was assessed during 23 - 25 December 2015.

**Task 1.2.3.1. Flow and sediment regimes at appropriate flows.**

Flow and sediment regimes at appropriate flows will be obtained from existing DWS data base and other relevant studies.

**Task 1.2.3.2. Water quality (including the physical, chemical and biological characteristics of the water) in relation to the flow regime.**

Water quality (including the physical, chemical and biological characteristics of the water) in relation to the flow regime will be obtained from existing DWS data base (PES of the river crossings in the Hex River catchment) and other relevant studies.

**Task 1.2.3.3 Riparian and In-stream Habitat.**

**Aquatic habitat assessments**

Habitat assessments have been carried out to identify situations in which changes in habitat are responsible for changes in faunal populations. The nature and diversity of habitats available at the sampling point are factors of overwhelming influences on the biota present. The diversity of available biotopes itself is often incorporated in information on the conservation status of the river.

The habitat indices used in this survey are the Invertebrate Habitat Assessment System (IHAS) and the Habitat Quality Index (HQI).

a) IHAS (Integrated Habitat Assessment System)

b) HQI (Habitat Quality Index)

- **IHAS** (Integrated Habitat Assessment System, version 2) habitat assessments were performed in conjunction with the SASS5 assessment to determine the role of habitat on the observed biotic integrity based on the macro-invertebrates.
- General **habitat assessment** (including photographic assessment) to assess the general physical habitat condition of the sites and identify potential sources and impacts responsible for deterioration of the aquatic ecosystem.

**Task 1.2.3.3.1 Morphology (physical structure).**

Four survey sites at the proposed pipeline crossings on the tributaries to the Hex River were earmarked for assessment. At each of these survey sites, 3 transects per site were surveyed, from the terrestrial area through the riparian area to the edge of the river.

Both the sites with surface water were evaluated according to the Index of Habitat Integrity (IHI) model (Tables 6 and 7). For the fish section the Habitat Cover Ratings (HCR) and Site Fish Habitat Integrity Index (SHI) were also applied (Tables 34 and 35).

**Task 1.2.3.3.2 Vegetation.**

**a) Riparian delineation**

It is important to differentiate between wetlands and riparian habitats. Riparian zones are not wetlands, however, depending on the ecosystem structure, wetlands can be also be classified as riparian zones if they are located in this zone (e.g. valley bottom wetlands). Although these distinct ecosystems will be interactive where they occur in close proximity it is important not to confuse their hydrology and eco-functions.

Riparian delineations are performed according to *"A practical field procedure for identification and delineation of wetlands and riparian areas"* as amended and published by the Department of Water Affairs and Forestry (2005); (Henceforth referred to as DWAF Guidelines (2005)).

Aerial photographs (Figure 10a and b) and land surveys were used to determine the different features and riparian areas of the study area. Vegetation diversity and assemblages were determined by completing survey transects along all the different vegetation communities identified in the riparian areas.

Riparian areas are protected by the National Water Act (Act 36 of 1998), which defines a riparian habitat as follows:

> *"Riparian habitat includes the physical structure and associated vegetation of the areas associated with a watercourse which are commonly characterized by alluvial soils, and which are inundated or flooded to an extent and with a frequency sufficient to support vegetation of species with a composition and physical structure distinct from those of adjacent land areas."*

Riparian areas include plant communities adjacent to and affected by surface and subsurface hydrologic features, such as rivers, streams, lakes, or drainage ways. Due to water availability and rich alluvial soils, riparian areas are usually very productive.
Tree growth rate is high and the vegetation is lush and includes a diverse assemblage of species. The delineation process requires that the following be taken into account:

- Topography associated with the watercourse;
- Vegetation;
- Alluvial soils and deposited material.

A typical riparian area according to the DWAF Guidelines (2005) is projected in Figure 2.

In addition to the DWAF Guidelines (2005), the unpublished notes: *Draft riparian delineation methods prepared for the Department of Water Affairs and Forestry, Version 1* (Mackenzie &

Rountree, 2007) were used for classifying riparian zones encountered on the property according to the occurrence of nominated riparian vegetation species.

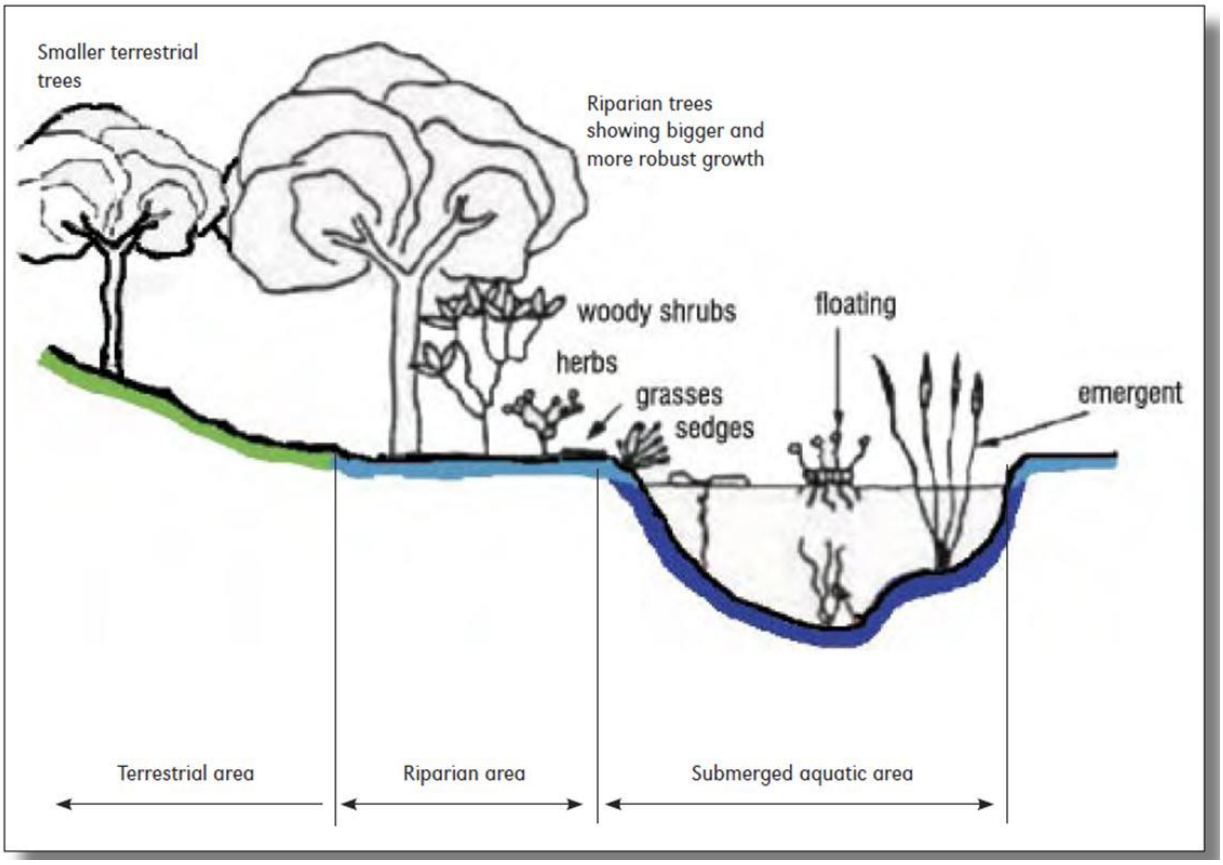


**Figure 2:** A cross section through a typical riparian area (DWAF Guidelines, 2005).

### b) Riparian habitat surveys (Riparian Vegetation Index — VEGRAI)

The general components of the VEGRAI are specified as following:

It is a practical and rapid approach to assess changes in riparian vegetation condition.

It considers the condition of the different vegetation zones separately but allows the integration of zone scores to provide an overall index value for the riparian vegetation zone as a unit.

The vegetation is assessed based on woody and non-woody components in the respective zones and according to the different vegetation characteristics which include, inter alia:

- Cover
- Abundance
- Recruitment
- Population structure
- Species composition

It provides an indication of the causes for riparian vegetation degradation.

It is impact based. This means that the reference condition will only be broadly defined and based on the natural situation in the absence of impacts. Where possible, however, reference conditions should be derived based on reference sites or sections.

The index is based on the interpretation of the influence of riparian vegetation structure and function on in-stream habitat.

Although biodiversity characteristics are used in assessing the riparian vegetation condition, it is not a biodiversity assessment index *per se.*

For this study the Level 3 VEGRAI will be used as Level 3 is applied by the River Health Programme (RHP) and for rapid Ecological Reserve purposes. This level will be aimed at general aquatic ecologists.

### Task 1.2.3.4 Biota – Aquatic invertebrates and Fish

**Aquatic surveys**

An aquatic specialist assessed the condition of the proposed development and its impact on the aquatic environment. The following recognized bio-parameters and methods were used.

- Aquatic invertebrates (South African Scoring System version 5 — SASS5). In addition to using this method the operators must be accredited SASS 5 practitioners.
- Fish communities (FRAI Fish Response Assessment Index). Applicable fish habitat assessments such as the Habitat Cover Ratings (HCR) and Site Fish Habitat Integrity Index (SHI) were used to assess the habitat potential and condition for fish assemblages.
- Riparian vegetation (Riparian Vegetation Index — VEGRAII)

**Aquatic biota**

Macro-invertebrates and fish are good indicators of river health. By making use of established and accepted survey methods (SASS5 for invertebrates and FRAI-based surveys for fish) and incorporate the habitat aspects, a proper basis for biological diversity could be obtained.

The Aquatic specialist assessed the condition of the proposed development and its impact on the aquatic environment. The following recognized bio-parameters and methods were used:

- Aquatic invertebrates (South African Scoring System version 5 — SASS5).
- Fish communities (Fish Response Assessment Index - FRAI)
- Riparian habitat surveys (Riparian Vegetation Index — VEGRAI)

#### 1.2.3.4.1 Aquatic invertebrate assessment

Benthic macro-invertebrate communities of the selected sites were investigated according to the South African Scoring System, version 5 (SASS5) approach. An invertebrate net (30 x 30cm square with 0.5mm mesh netting) was used for the collection of the organisms. The

available biotopes at each site will be identified on arrival. Each of the biotopes was then sampled separately and by different methods. Sampling of the biotopes was done as follow:

**Stones in current (SIC):** 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 placing 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 calm, such as behind a sandbank or ridge of stones or in backwaters.* Collection is again done by 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.

**Sand:** These include 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 where flow was slow or no flow was recorded. This biotope is sampled by stirring the substrate, shuffling or scraping of the feet 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). Sampling similar to that of sand.

**Mud:** *It consists of very fine particles, usually as dark-coloured sediment.* Mud usually settles to the bottom in still or slow flowing areas of the river. Sampling similar to that of sand.

**Marginal vegetation (MV):** *This is the overhanging grasses, bushes, twigs and reeds from the riverbank.* 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).

**Aquatic vegetation (AQV):** *Rooted, submerged or floating waterweeds such as Potamogeton, Aponogeton and Nymphaea.* Sampled by pushing the net (under the water) against and amongst the vegetation in an area of approximately one square meter.

The organisms sampled in each biotope were identified and their relative abundance is also noted on the SASS5 datasheet. Habitat assessments, according to the habitats sampled, were performed due to the fact that changes in habitat can be responsible for changes in SASS5 scores. This was done by the application of SASS orientated habitat assessment indices. The indices used are the Integrated Habitat Assessment System (IHAS) score sheet and the Habitat Quality Index (HQI).

The SASS5 method was used to establish the macro-invertebrate integrity and it was attempted to sample all three of the main habitat assemblages: stones, vegetation and sand/mud/gravel. The associated habitats were determined with the Invertebrate Habitat Assessment System (IHAS) and the Habitat Quality Index (HQI).

Although the SASS5 method was used as prescribed by DWA&S, it must be kept in mind that this method was designed for water quality purposes. Therefore the macro-invertebrate integrity scores may vary throughout the year as water quality changes, due to flow variation, as should be the case in the pre- and post-construction phases of the monitoring project.

### 1.2.3.4.2 Fish communities - Fish Response Assessment Index (FRAI)

The biotic assessment method uses a series of fish community attributes related to species composition and ecological structure to evaluate the quality of an aquatic biota. Data on distribution, richness, length frequency and abundance will be collected. The sampling methods will be fish traps, seine nets, mosquito nets and electro-fishing.

Fish segment identification, species tolerance ratings, abundance ratings, frequency of occurrence and health status techniques are applied during this survey to determine the integrity of the fish communities.

On arrival at the site a basic on site visual appraisal is made of the habitats available on that particular day at that particular flow. A site diagram is sketched indicating the different habitats and the various components thereof. Sampling takes place in each of the different habitats. These different habitats are sampled separately using different methods.

**a) Electro-shocking**

Electro-shocking commences in the downstream component of the habitat. One person uses a backpack electro-shocker for shocking, using a scoop net to catch the stunned fish. The researcher progresses upstream, keeping the fish caught in a bucket until that particular habitat is finished. Each habitat shocked is timed. It is necessary to take care (as far as possible) when shocking so as not to disturb the rest of the habitat still to be worked. As each habitat is completed the fish species caught, are identified, recorded and released back into their respective habitats.

Any fish species that cannot be identified at the time is preserved in 10% formalin (in a sample bottle with label inside) for later identification by experts. The data sheet is completed for that particular habitat – recording every fish, its age class (adult, sub-adult, juvenile) and whether any fish is diseased (e.g. visible ecto-parasites). Each habitat type is recorded (e.g. shoot, riffle or pool etc), as well as the width, depth, substrate, the extent sampled, the percentage of algae on substrate, whether there was any vegetation, and the turbidity. The flow of that particular habitat is classified into one of five flow classes (no flow, slow flow, medium flow, fast and very fast flow).

The electro shocking device is used to sample certain habitats: shoots, riffles, rapids, shallow- medium depth pools in stream and off stream, runs and back waters.

**b) Cast net**

A cast net (a weighted circular net that is thrown into the water) is used in pool type or slower flow and deeper habitats. As with method (a) all aspects of the habitat type are recorded as well as the fish species, numbers, age class and health. The number of throws / efforts per a habitat is also recorded.

**Task 1.2.4 Describe the ecological importance and sensitivity (EIS) as well as the Socio-cultural Importance (SI) of the affected reach/es of the watercourse including the functions.**

**Ecological Importance and Sensitivity (EIS)**

The ecological importance of a river is an expression of its importance to the maintenance of biological diversity and ecological functioning on local and wider scales. Ecological sensitivity (or fragility) refers to the system's ability to resist disturbance and its capability to recover from disturbance once it has occurred (resilience). Both abiotic and biotic

components of the system are taken into consideration in the assessment of ecological importance and sensitivity.

**Ecological Category (EC)**

The basis of the assessment of the importance of the metrics of biophysical components in determining the EC and EcoStatus is a Multi Criteria Decision Analysis approach (MCDA). The MCDA process allows the development of consistent rating systems or indices for the categorisation of ecosystem components and aggregates these mathematically in a theoretically justifiable way.

A six-point rating system is followed, where metrics of the drivers and biological responses are scored in terms of the degree to which they have changed compared to the natural or close-to-natural reference (if necessary, half points such as 1.5 and so on can also be used):

0 = No discernable change from reference/close to reference
1 = Small modification from reference
2 = Moderate modification from reference
3 = Large modification from reference
4 = Serious modification from reference
5 = Extreme modification from reference

These qualitative ratings are expert knowledge-based, and are assessed by the relevant expert in a particular speciality. It is preferable that the relative difference between for example, 0 – 1 be the same as between 3 – 4. However, this is difficult to control and is currently exclusively based on expert knowledge.

The calculation of the Ecological Categories of drivers and biological responses is done by totalling the weighted scores and expressing this as a percentage of the maximum. This value indicates the percentage change away from the expected reference and must be subtracted from 100 to arrive at the percentage value that represents the EC. This value is used to place the EC of the component in a particular category that ranges from A to F (Table 1).

**Table 1:** Generic ecological categories for EcoStatus components (Kleynhans et al, 2009).

| ECOLOGICAL CATEGORY | 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 ecosystem functions are essentially unchanged. | 80-89 |
| 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 have occurred. | 40-59 |
| E | Seriously modified. The loss of natural habitat, biota and basic ecosystem functions are extensive. | 20-39 |
| F | Critical/Extremely modified. Modifications have reached a critical level and the system has been modified completely with an almost complete loss of natural habitat and biota. In the worst instances the basic ecosystem functions have been destroyed and the changes are irreversible. | 0-19 |

After the Ecological Categories of the driver and ecological response components are determined, there remains the issue of how to integrate these to provide an indication as to the EcoStatus. Deriving the EcoStatus from the Ecological Categories of components is based on the following principles (Kleynhans *et al*, 2005):

- The Ecological Categories of the physical drivers (hydrology, geomorphology and physico-chemical integrity) are not integrated to provide an indication of the EcoStatus purely based on the drivers.
- Information on the driver metrics, i.e. how different they are from the reference is considered when assessing the biological responses. This is an expert knowledge approach and the attributes and environmental requirements of the biota should be considered when doing this.
- The biological responses are considered to provide the best indication of the EcoStatus of the river because it integrates the effect of the driver components.

The steps in deriving the EcoStatus are:

- Criteria are considered that provide an indication of the relative indicator value of the two instream biological groups, fish and invertebrates. These criteria are used to weigh the relative importance of these two groups as indicators of in-stream health. The Ecological Categories of the two biological groups are proportioned according to these weights and combined to provide the in-stream Ecological Category.
- A suitable index to get an indication of riparian vegetation Ecological Category within the EcoStatus context is not yet available. Consequently the riparian vegetation zone can only be considered conceptually and in terms of its influence on the in-stream EC. In this regard the influence, importance and integrity of the riparian vegetation zones, i.e. marginal, lower and upper vegetation, are considered in terms of its significance for the instream biota. Some indication of the health of the riparian vegetation can also be gleaned from the geomorphological driver where certain metrics of this driver do serve as indicators.
- The riparian vegetation Ecological Category and the instream Ecological Category are integrated based on a proportioning of weights according to the availability of high confidence information. This provides the EcoStatus of the river.
- Where riparian vegetation information is insufficient, the instream EC is used as the best indicator of the EcoStatus of the river.

The *modus operandi* followed by DWAF's Directorate: Resource Directed Measures (RDM) is that, if the EIS is high or very high, the ecological aim should be to improve the condition of the river. However, the causes related to a particular PES should also be considered to determine if improvement is realistic and attainable. This relates to whether the problems in the catchment can be addressed and mitigated. If the EIS evaluated as moderate or low, the ecological aim should be to maintain the river in its PES. Within the Ecological Reserve context, Ecological Categories A to D can be recommended as future states (REC - the Recommended Ecological Category) depending on the EIS and PES. Ecological Categories E and F PES are regarded as ecologically unacceptable, and remediation is needed.

**Task 1.2.5 Discuss existing land and water use impacts (and threats) on the characteristics of the watercourse.**

## EcoClassification

During recent years DWS has published the *River Ecoclassification* series of methods used to determine the health of rivers and streams in South Africa. As part of this series the methods for ecological status determinitation and the classification of riparian and aquatic systems, is published in Module A: *EcoClassification and EcoStatus Determination* (Kleynhans & Louw, 2009). The following sections are extracted and modified (where appropriate) from the last mentioned authors.

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

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

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

## Present Ecological State (PES)

The PES of the river is expressed in terms of various components. That is, **drivers** (physico-chemical, geomorphology, hydrology) and **biological responses** (fish, riparian vegetation and aquatic invertebrates), as well as an integrated state, the EcoStatus. A rule-based procedure is followed to assign each component an Ecological Category for the PES (on a scale of A to F) using the following information:

- Biophysical surveys conducted during the project.
- Information and data from historical surveys, databases and reports.
- Aerial photographs and videos.
- Land-cover data.
- Internal Strategic Perspective (ISP) reports of DWAF.
- Expert knowledge is regularly used to estimate the degree of change to a particular component.

It must be emphasised that the A to F scale represents a continuum (Figure 3), and that the boundaries between categories are notional, artificially-defined points along the continuum. There may therefore be cases where there is uncertainty as to which category a particular entity belongs. This situation falls within the concept of a fuzzy boundary, where a particular entity may potentially have membership of both classes. For practical purposes these situations are referred to as boundary categories and are denoted as B/C, C/D, and so on. The B/C boundary category, for example, is indicated as the light green to dark-blue area in Figure 3.


**Figure 3:** The continuum on an A to F scale for rating Ecological Category

The models for each component all use a swing ranking system in which key ecological components are ranked and weighted to provide consistent results.

**Trend**

Trend is viewed as a directional change in the attributes of the drivers and biota (as a response to drivers) at the time of the PES assessment. A trend can be absent (close to natural or in a hanged state but stable), negative (moving away from reference conditions) or positive (moving back towards natural - when alien vegetation is cleared, for instance). The ultimate objective is to determine if the biota have adapted to the current habitat template or are still in a state of flux. Generally such an assessment can be approached from a driver perspective. This means that there can be a positive or negative trend response from the biota if the drivers (specifically geomorphology and water quality) are still in a directional state of change (+ or -).

**Task 1.2.6 List and map sensitive environments in proximity of the project locality- sensitive environments include wetlands, nature reserves, protected areas, etc.**

**Land-Use Decision Support Tool (LUDS)**

To establish how important the site is for meeting biodiversity targets, it is necessary to answer the following three simple but fundamentally important questions:

- How important is the site for meeting biodiversity objectives (e.g. is it in a Critical Biodiversity Areas (CBA) or Ecological Support Area (ESA)?
- Is the proposed land-use consistent with these objectives or not (to be checked against the land-use guidelines)?
- Does the sensitivity of this area trigger the North West Province requirements for assessing and mitigating environmental impacts of developments, or in terms of the listed activities in the EIA regulations?

## 3. Results and discussion: Present Ecological State (PES)

**Task 1.2.3 Present Ecological State or PES**

**Describe within context of the immediate catchment and segment, the historic as well as current state (Present Ecological State or PES) of the affected reach/es of the watercourse with regards to the following characteristics (attributes):**

The Crocodile (West) Marico Water Management Area (WMA) lies primarily within the North West Province with parts of it in the northern region of Gauteng and the south- western corner of the Limpopo Province (Mager & Jayiya, 2010). The Elands sub-management area consists of the Elands River catchment which includes the tributaries of the Koster, Selons and Hex rivers.

The Hex River is situated near the town of Rustenburg, North West Province and is the main regional arterial drainage for the area. It is a source of water supply for many in the region. It flows in a northerly direction and conveys water to the Bospoort Dam east of Rustenburg. The various tributaries that drain into the Hex River are the Dorp Spruit, Klipfontein Spruit, Klipgat Spruit, and Paardekraal Spruit. Tributaries that drain into Bospoort Dam are from the Boschfontein- and Tierkop Spruit catchments (Du Plessis, 2006).

The study area is situated in the Marikana Thornveld (SVcb6). The distribution of this vegetation type occurs on the plains from Rustenburg area in the west, through Marikana and Brits to the Pretoria area in the east. The vegetation comprises open *Acacia karroo* woodland, occurring in valleys and slightly undulating plains, and some lowland hills. Shrubs are denser along drainage lines, on termitaria and rocky outcrops or in other habitat protected from fire (Mucina & Rutherford, 2006).

North of the Magaliesberg the geology is largely dominated by the Bushveld Igneous Complex. Formations in this complex are extremely rich in minerals and a number of mines have been developed in the area as a result. Platinum, chrome and vanadium mining in particular, are taking place at a large scale.

The pipeline crossings which are relevant for the study are on tributaries to the Hex River. There are two tributaries with surface lows, the Dorps River at Crossing 1, and the Boschfontein Spruit at Crossing 2, and two tributaries that are drainage lines with ephemeral surface flows only during high rainfall events: Crossing 3, Kanana Drainage line and Crossing 4, Tierkop Spruit. Since the Hex River is the main stem and the only river with adequate data available, the information of this river was utilized as background material for the associated tributaries.

**Task 1.2.3.1. Flow and sediment regimes at appropriate flows.**

The Hex River falls within the Summer Rainfall Climatic Zone. The area is characteristically warm to hot; maximum and minimum temperatures are experienced during January and July respectively. Rainfall is strongly seasonal, erratic, and extremely variable, ranging from 450 to 750 mm per year with most rainfall occurring as thunderstorms during the summer period of October to April. The rainfall is also somewhat unreliable and in about 12% of all years rather severe drought conditions occur. Temperatures vary between extremes of –6.0°C and 40°C with an average of 19°C.

**Table 2:** The natural hydrology of the Hex River. (What are these measurements – mega litres/hour?

| Quat | Array Parameter | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A22J | Mean Total | 21.86 | 27.017 | 23.056 | 11.468 | 4.34 | 2.569 | 1.922 | 1.447 | 1.348 | 1.815 | 5.07 | 11.051 |
| A22J | SD Total | 46.06 | 69.689 | 53.296 | 25.438 | 7.279 | 2.678 | 1.798 | 1.154 | 1.593 | 2.415 | 6.275 | 13.154 |
| A22J | CV Total | 2.107 | 2.579 | 2.312 | 2.218 | 1.677 | 1.043 | 0.935 | 0.797 | 1.181 | 1.331 | 1.238 | 1.19 |
| A22J | Mean Baseflow | 1.062 | 1.276 | 1.502 | 1.654 | 1.681 | 1.611 | 1.45 | 1.25 | 0.997 | 0.915 | 0.906 | 0.939 |
| A22J | SD Baseflow | 0.576 | 0.903 | 1.328 | 1.591 | 1.629 | 1.577 | 1.302 | 0.898 | 0.62 | 0.747 | 0.704 | 0.589 |
| A22J | CV Baseflow | 0.543 | 0.708 | 0.884 | 0.962 | 0.969 | 0.979 | 0.898 | 0.719 | 0.621 | 0.816 | 0.777 | 0.627 |

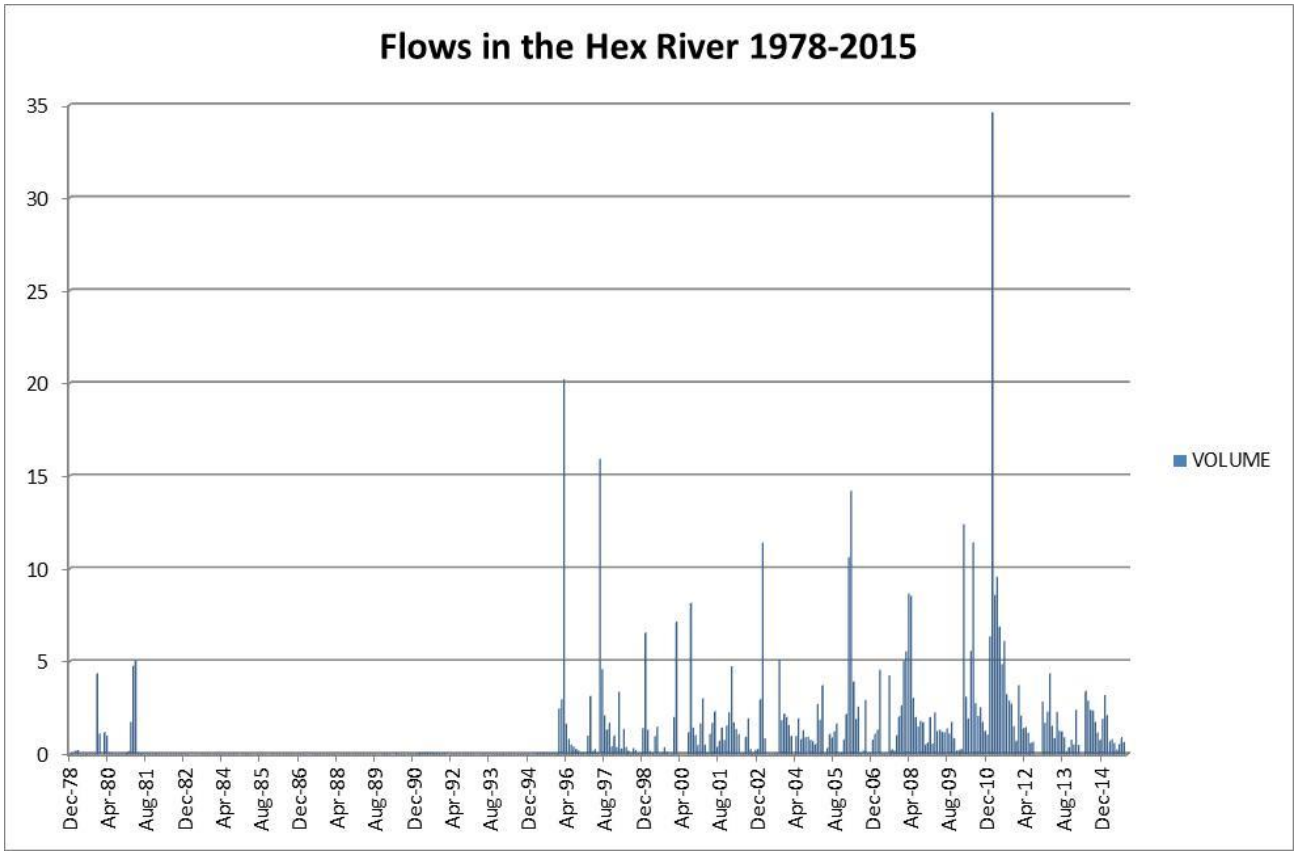


**Figure 4:** The surface flows in the Hex River for the period 1978-2015. No y-axis value

In the Hex River, flows are largely managed on demand for anthropological purposes. This results in un-seasonally high pulses of flow in the river and extended periods of low flow. The managed flow regime, when combined with the large numbers of dams and weirs, has resulted in river habitats becoming severely fragmented with what were largely perennial rivers now being distinctly seasonal in nature. For extended periods, weirs and deep pools are the only refuge for any aquatic life (Du Plessis, 2006).

Rustenburg is the only major city in this sub-catchment and the major dams are Bospoort Dam on the Hex River and Vaalkop Dam on the Elands River. The Bospoort Dam is a small state-owned impoundment situated on the Hex River upstream of the Vaalkop Dam, northeast of Rustenburg in the Crocodile West/Marico WMA in the North West Province. The

Bospoort dam is used for irrigation and domestic water supply (Mogakabe & Van Ginkel, 2008).

The following natural mean annual runoff (MAR) for the rivers in the catchment is relevant to this report (Table 3):

**Table 3:** The natural mean annual runoff (MAR) for the rivers in the Hex River catchment.

| River name | Area ($km^2$) | MAR (mil $m^3$) |
|---|---|---|
| Hex River at Bospoort Dam | 1078 | 18.4 |
| Paardekraal Spruit | 28 | 0.7 |
| Dorp Spruit | 74 | 1.7 |

**Task 1.2.3.2. Water quality (including the physical, chemical and biological characteristics of the water) in relation to the flow regime.**

Due to the location and the associated industrial development, mining activities and urbanization (formal and informal) taking place in the catchment, the water quality of the Hex River and its tributaries has progressively deteriorated. The physical and chemical constituent concentrations recorded in the Hex River and its associated tributaries decreased during peak rainfall in the summer months. Higher constituent concentrations were recorded during the dry winter months (Du Plessis, 2006). The overall EcoStatus for the Lower Hex River is POOR (RHP, 2005).

Major impacts on the water quality of the lower Hex River catchment are agriculture and livestock production, industrial effluent, mining activities, processing as well as residential impacts including treated and untreated sewage from the town of Rustenburg as well as informal settlements surrounding the Hex River. Large rural developments of high density housing are furthermore evident in the catchment. The area is densely populated due to the proximity of the town Rustenburg and various informal settlements (Du Plessis, 2006).

***Water Quality*** is FAIR - flows have between low and intermediate levels of nutrients but are largely free of significant organic pollution. High conductivity readings were recorded – high salinity levels are possibly due to mines.

The long-term water quality trends showed a significant mine water, industrial effluent and sewage impact on the Hex River after the confluence with the tributaries. Inferior water quality conditions including contributions to the salt (TDS, Cl, $SO_4$) as well as nutrient and metal concentrations is evident from the Dorp's Spruit draining the Rustenburg Northern Industrial Zone Province (Mager & Jayiya, 2010).

The high contribution of nutrient ($NO_3$, $PO_4$ and $NH_3$) concentrations to the Hex River catchment can be ascribed to the various waste water treatment works situated in the area. High metal concentrations of which primarily Aluminium and Manganese occur in selected areas of high mining activities (Mogakabe & Van Ginkel, 2008).

Untreated and partially treated sewage water is considered to be a major problem in the catchment. TDS, Hardness, Sulphate and Chloride concentrations increase progressively towards the Bospoort Dam. Although the reduction of high constituent concentrations by high volumes of water is evident in the dam, various nutrients including TDS, Cl, nutrients, Fluoride and hardness are problematic as it decreases the assimilative capacity of the receiving water body (Mogakabe & Van Ginkel, 2008).

In 2005, the National River Health Programme (RHP) of the CSIR concluded that the Hex River and its tributaries were (in terms of water quality) in an unsustainable state owing to various water discharges into the river. Further, the programme called on DWAF to institute rehabilitative and mitigatory measures that could help reverse the situation.

**Table 4:** Water quality in the Hex River and Target Water Quality Range used as guidelines for water quality parameters.

| | Target Water Quality Range | Hex River | |
|---|---|---|---|
| | | DWA average | Case |
| EC | 0-70 | 71.1 | 90.0 |
| Major ions chemical composition | | | |
| PH | 6.0-9.0 | 8.4 | 8.9 |
| TDS | 0-450 mg/l | 486 mg/l | 535 mg/l |
| NA | 0-100 mg/l | 43.7 mg/l | 82.1 mg/l |
| MG | 0-30 mg/l | 28.0 mg/l | 43.2 mg/l |
| CA | 0-32 mg/l | 54.6 mg/l | 62.4 mg/l |
| F | 0-1.0 mg/l | 0.17 mg/l | 0.320 mg/l |
| CL | 0-100 mg/l | 83.8 mg/l | 132 mg/l |
| NO3+NO2 | 0-6 mg/l | 0.186 mg/l | 1.74 mg/l |
| SO4 | 0-200 mg/l | 80.2 mg/l | 78.0 mg/l |
| K | 0-50 mg/l | 6.09 mg/l | 13.2 mg/l |
| NH4 | 0-1.0 mg/l | 0.020 mg/l | 0.028 mg/l |

Nutrient loading in the Bospoort Dam seem to be a cause of concern as the system does not show any sign of recovery from the previous trophic state classifications. The continuous hypertrophic nature of the impoundment suggests possible contamination arising from the sewage treatment works upstream, agricultural run-offs, urban run-offs and re-circulation of nutrients from bottom sediments (Marx *et al*, 2008).

The presence of heavy metals such as Cadmium (Cd), Arsenic (As) and Lead (Pb) in the water albeit in minimal concentration is also of concern considering that these metals might have elevated concentration in the sediment part of the impoundment. The system also shows a high salt content, commonly indicated by conductivity values. Urban surface runoff and mining activities are possible sources of ions that contributed to the high salinity levels in the Bospoort dam (Du Plessis, 2006).

The construction phase of the project will impact the Dorps River at Crossing 1. Various upstream factors impacting on water quality in close proximity of the survey site, which comprise the Rustenburg Northern Industrial zone, include storm water runoff from industrial premises, chicken farms, informal settlements and informal sewage works, seepage from a landfill and sludge settling dams. According to Table 5, the Dorp's River water quality is regularly not meeting the Target Water Quality Range for the following parameters: EC, Mg, Ca, F, Cl, NO3, NO2, and NH4.

The construction phase of the project will impact the Boschfontein Spruit at Crossing 2. Upstream factors impacting on water quality include effluent from the township and turbidity due to trampling and erosion.

Due to the absence of surface water in the ephemeral drainage lines of two of the crossing sites, Crossing 3 Kanana Drainage line and Crossing 4 Tierkop Spruit, very little water quality impacts are expecting to originate from these sources.

**Table 5:** Water sample data from DWA–RQS at monitoring point 184812 in the Dorps River from 1999 to 2004.

| Monitoring feature ID | date_time | Ca_Diss_Water | Cl_Diss_Water | DMS_Tot_Water | EC_Phys_Water | F_Diss_Water | K_Diss_Water | KJEL_N_Tot_ Water | Mg_Diss_Water | Na_Diss_Water |
|---|---|---|---|---|---|---|---|---|---|---|
| 184812 | 1999/11/09 13:35 | 131.388 | 132.775 | 985.548 | 140 | 0.1 | 7.398 | 1.747 | 45.624 | 74.826 |
| 184812 | 2000/03/14 15:15 | 39.672 | 44.224 | 340.389 | 53.1 | 0.1 | 2.624 | 1.477 | 20.528 | 19.647 |
| 184812 | 2001/10/31 10:24 | 96.648 | 108.404 | 639.772 | 98.7 | 0.148 | 5.511 | 3.911 | 33.041 | 30.279 |
| 184812 | 2002/02/12 15:00 | 194.765 | 227.734 | 1245.78 | 186 | 0.156 | 7.427 | 7.432 | 60.536 | 73.231 |
| 184812 | 2002/04/29 15:00 | 146.344 | 179.072 | 968.12 | 150 | 0.146 | 6.611 | 2.099 | 54.426 | 58.071 |
| 184812 | 2002/08/05 11:11 | 83.28 | 98.208 | 646.972 | 87.3 | 0.172 | 6.052 | 2.414 | 38.362 | 43.309 |
| 184812 | 2002/10/29 11:30 | 235.917 | 274.877 | 1413.036 | 219 | 0.164 | 11.059 | 11.905 | 54.341 | 86.587 |
| 184812 | 2003/01/28 10:00 | 37.535 | 37.233 | 260.001 | 43.3 | 0.174 | 3.659 | 1.743 | 15.67 | 12.807 |
| 184812 | 2003/05/20 12:45 | 123.06 | 145.037 | 756.266 | 109.4 | 0.195 | 5.997 | 5.225 | 34.531 | 44.984 |
| 184812 | 2003/11/17 11:45 | 73.811 | 102.678 | 514.143 | 79.3 | 0.1 | 4.904 | #N/A | 26.342 | 34.516 |
| 184812 | 2004/06/08 12:15 | 54.796 | 85.481 | 434.73 | 69.5 | 0.1 | 4.75 | 2.327 | 26.34 | 33.217 |

| Monitoring feature ID | NH4_N_Diss_Water | NO3_NO2_N_Diss_Water | P_Tot_Water | pH_Diss_Water | PO4_P_Diss_Water | Si_Diss_Water | SO4_Diss_Water | TAL_Diss_Water | Qat |
|---|---|---|---|---|---|---|---|---|---|
| 184812 | 0.797 | 4.766 | 1.039 | 8.137 | 0.398 | 12.262 | 199.803 | 303.701 | A22H |
| 184812 | 0.59 | 5.956 | 0.141 | 8.117 | 0.071 | 8.907 | 60.405 | 103.215 | A22H |
| 184812 | 1.991 | 28.755 | 0.588 | 7.557 | 0.313 | 8.547 | 115.641 | 97.833 | A22H |
| 184812 | 1.996 | 61.202 | 1.271 | 7.931 | 1.27 | 13.347 | 242.994 | 132.493 | A22H |
| 184812 | 1.721 | 39.274 | 1.546 | 8.167 | 0.487 | 12.86 | 196.889 | 122.2 | A22H |
| 184812 | 1.46 | 20.844 | 1.895 | 8.151 | 1.623 | 6.44 | 116.931 | 132.482 | A22H |
| 184812 | 11.19 | 87.049 | 2.532 | 7.841 | 2.32 | 13.557 | 229.21 | 93.506 | A22H |
| 184812 | 0.643 | 3.959 | 0.295 | 7.868 | 0.214 | 4.918 | 41.74 | 75.598 | A22H |
| 184812 | 1.995 | 29.512 | 0.895 | 7.891 | 0.118 | 5.916 | 125.225 | 117.828 | A22H |
| 184812 | 1.489 | 11.249 | #N/A | 8.053 | 0.142 | 6.132 | 74.221 | 119.27 | A22H |
| 184812 | 0.838 | 12.737 | 0.322 | 8.07 | 0.166 | 5.869 | 49.271 | 100.719 | A22H |

### Task 1.2.3.3 Riparian and In-stream Habitat.

#### Task 1.2.3.3.1 Morphology (physical structure)

**Project sites**

Four survey sites at the proposed pipeline crossings on the tributaries to the Hex River, were earmarked for assessment (Figure 5):

**Crossing 1** Dorps River ($25^0$ 37.876'S $27^0$ 15.915'E): this site is situated 500m downstream of the Prison Dam at the R510 bridge (Figure 6).

**Crossing 2** Boschfontein Spruit ($25^0$ 34.472'S $27^0$ 18.223'E): this site is situated downstream of the Chachalaza township at the newly constructed R510 bridge over the south-western inflow to the Bospoort Dam (Figure 7).

**Crossing 3** Kanana Drainage line ($25^0$ 34.194'S $27^0$ 18.377'E): this site is situated downstream of the Kanana township near the newly constructed R510 bridge over the south-western inflow to the Bospoort Dam (Figure 8).

**Crossing 4** Tierkop Spruit ($25^0$ 33.628'S $27^0$ 19.210'E): this site is situated east of Hermansburg along the road that passes north of the Bospoort Dam (Figure 9).


**Figure 5:** The study area depicting the Hex River and tributaries and the proposed pipeline crossings.


**Figure 6:** Crossing 1 Dorps River site at the R510 bridge (Figures 6.1 – 6.3).

6.1 An aerial photo of the study site.

6.2 The fringing riparian woodland and the bridge over the Dorps River.

6.3 View downstream of the site.


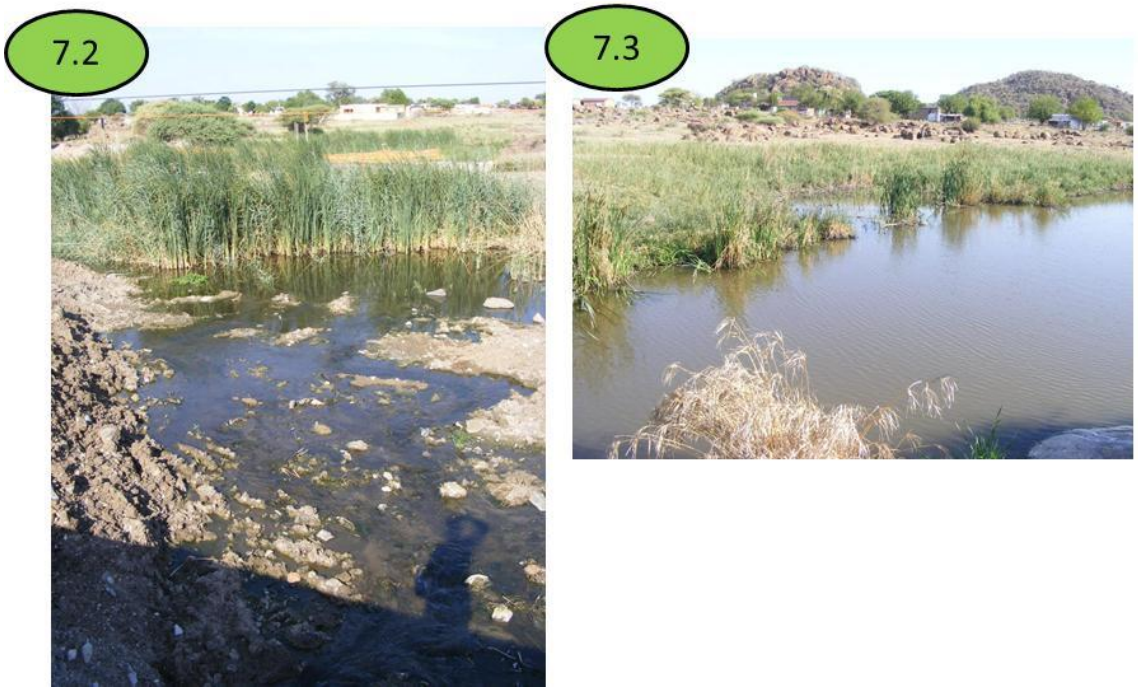


**Figure 7:** Crossing 2 Boschfontein Spruit at the newly constructed R510 bridge over the south-western inflow to the Bospoort Dam (Figures 7.1 – 7.3).

7.1 An aerial photo of the study site.

7.2 The fringing bulrush upstream of the bridge over the Boschfontein Spruit.

7.3 The Boschfontein Spruit with associated floodplain.

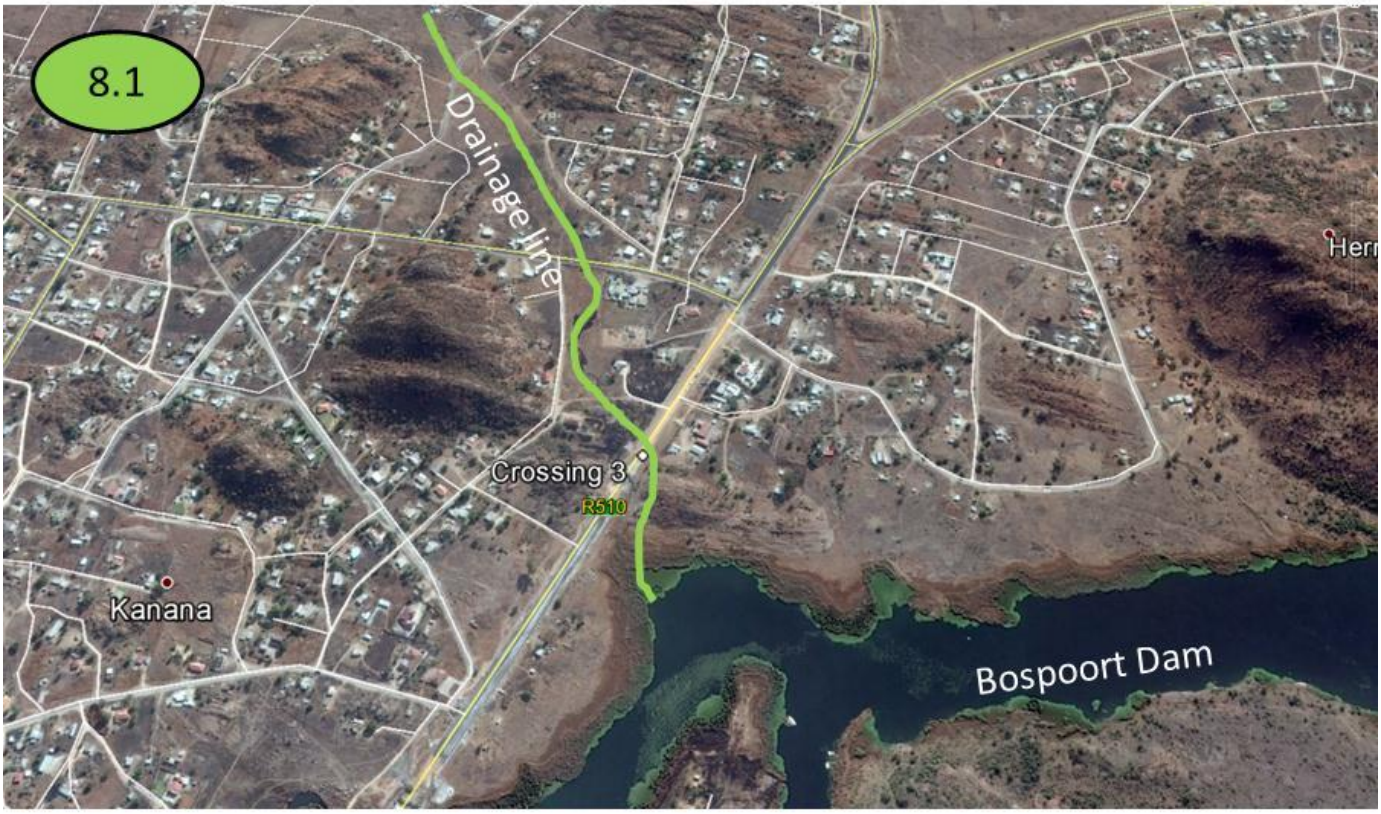




**Figure 8:** Crossing 3 Kanana Drainage line near the newly constructed R510 bridge leading to the south-western inflow to the Bospoort Dam (Figures 8.1 – 8.3).

8.1 An aerial photo of the study site.

8.2 The bare drainage line leading to the dam.

8.3 The culvert constructed for the drainage line underneath the R510.

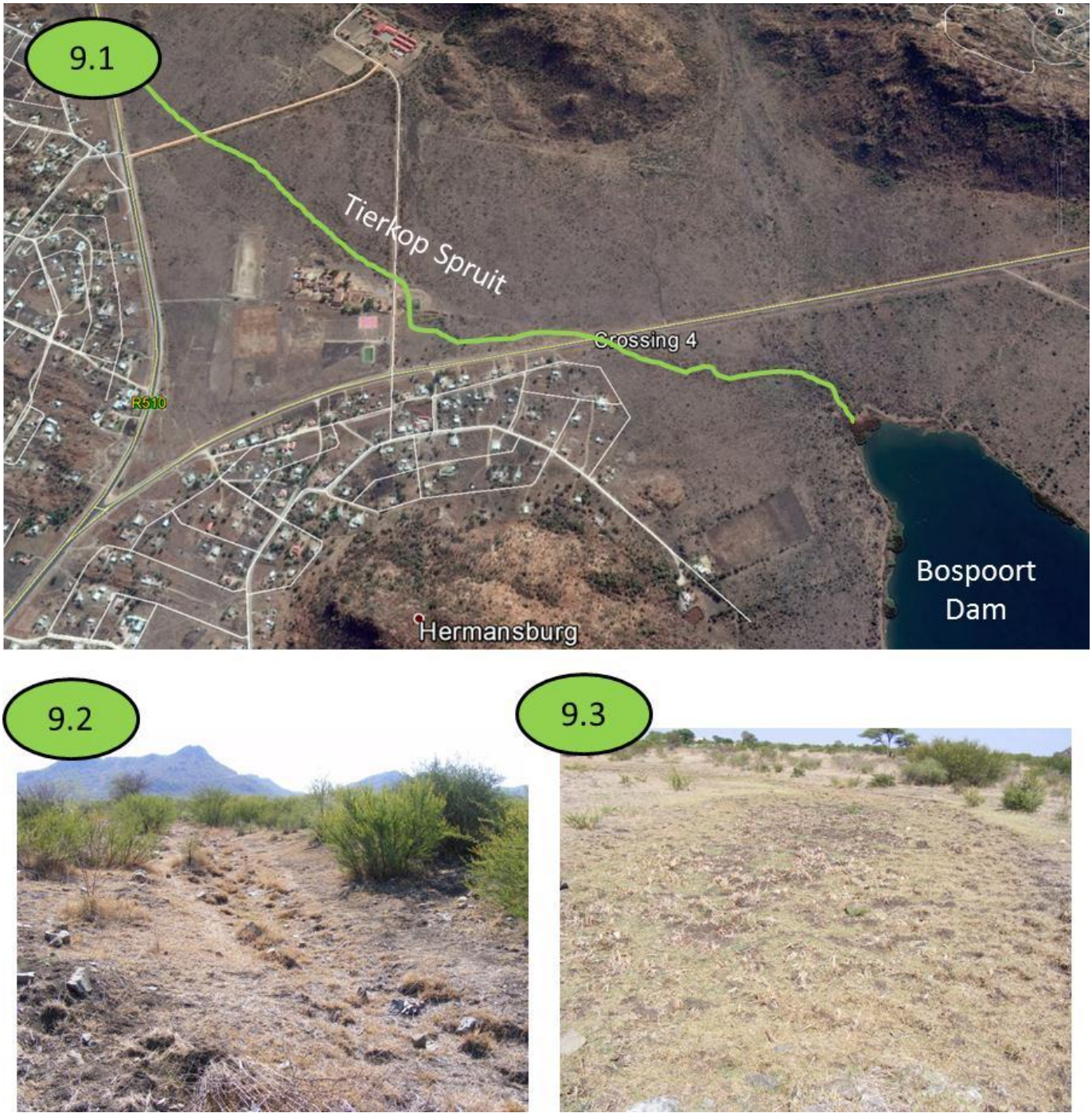


**Figure 9:** Crossing 4 Tierkop Spruit along the road that passes north of the Bospoort Dam (Figures 9.1 –9.3).

9.1 An aerial photo of the study site.

9.2 The drainage line, flanked by terrestrial plants, leading to the dam.

9.3 The dry drainage line with signs of a dried-out seepage wetland.

**Index of Habitat Integrity (IHI)**

The habitat integrity of a river refers to the maintenance of a balanced 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 (Kleynhans 1996).

Habitat integrity assessment is approached from an in-stream and riparian zone perspective. Both of these are formulated according to metric groups, each with a number of metrics that enable the assessment of habitat integrity. The model functions in an integrated way, using the results from the assessment of metric groups, or metrics within a metric group, for the assessment of other metric groups where appropriate.

**Table 6:** The in-stream IHI: evaluated for the rivers with surface flow in the study area (Dorp's and Boschfontein rivers). What does MRU stand for?

| | MRU |
|---|---|
| **INSTREAM IHI** | |
| Base Flows | -3.0 |
| Zero Flows | -1.0 |
| Floods | -1.5 |
| **HYDROLOGY RATING** | **1.7** |
| pH | -0.5 |
| Salts | -2.5 |
| Nutrients | -3.0 |
| Water Temperature | -2.0 |
| Water clarity | -2.5 |
| Oxygen | -1.0 |
| Toxics | -1.0 |
| **PC RATING** | |
| Sediment | -1.5 |
| Benthic Growth | -1.5 |
| **BED RATING** | **1.5** |
| Marginal | -1.5 |
| Non-marginal | -1.0 |
| **BANK RATING** | **1.3** |
| Longitudinal Connectivity | -2.5 |
| Lateral Connectivity | -0.5 |
| **CONNECTIVITY RATING** | **2.1** |
| | |
| **INSTREAM IHI %** | **74.2** |
| **INSTREAM IHI EC** | **C** |
| **INSTREAM CONFIDENCE** | **1.4** |

**Table 7:** The riparian IHI: evaluated for the rivers with surface flow in the study area (Dorp's and Boschfontein rivers).

| | MRU |
|---|---|
| **RIPARIAN IHI** | |
| Base Flows | -3.0 |
| Zero Flows | -0.5 |
| Moderate Floods | -1.0 |
| Large Floods | -0.5 |
| **HYDROLOGY RATING** | **1.1** |
| Substrate Exposure (marginal) | 1.0 |
| Substrate Exposure (non-marginal) | 1.0 |
| Invasive Alien Vegetation (marginal) | 1.0 |
| Invasive Alien Vegetation (non-marginal) | 1.0 |
| Erosion (marginal) | 1.0 |
| Erosion (non-marginal) | 1.0 |
| Physico-Chemical (marginal) | 0.5 |
| Physico-Chemical (non-marginal) | 0.0 |
| **Marginal** | 1.0 |
| **Non-marginal** | 1.0 |
| **BANK STRUCTURE RATING** | **1.0** |
| Longitudinal Connectivity | 1.0 |
| Lateral Connectivity | 0.5 |
| **CONNECTIVITY RATING** | **0.8** |
| | |
| **RIPARIAN IHI %** | **79.0** |
| **RIPARIAN IHI EC** | **C** |
| **RIPARIAN CONFIDENCE** | **2.0** |

The outcome of the in-stream and riparian IHI evaluated for the rivers with surface flows in the study area (Dorp's and Boschfontein rivers), resulted in an in-stream IHI of 74.2 (C), and a riparian IHI of 79.0 (C) (Tables 6 and 7), resulting in both being classified as "Moderately modified" according to the Habitat Integrity Categories in Table 8.

**Table 8:** The ratings for the Habitat Integrity Categories prescribed to the IHI model (Kleynhans et al, 2008).

| HABITAT INTEGRITY CATEGORY | DESCRIPTION | RATING (% OF TOTAL) |
|---|---|---|
| A | Unmodified, natural. | 90-100 |
| B | Largely natural with few modifications. The flow regime has been only slightly modified and pollution is limited to sediment. A small change in natural habitats may have taken place. However, the ecosystem functions are essentially unchanged. | 80-89 |
| C | Moderately modified. 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 | Seriously modified. The loss of natural habitat, biota and basic ecosystem functions is extensive. | 20-39 |

| | | |
|---|---|---|
| F | Critically / Extremely modified. Modifications have reached a critical level and the system has been modified completely with an almost complete loss of natural habitat and biota. In the worst instances the basic ecosystem functions have been destroyed and the changes are irreversible. | 0-19 |

### Task 1.2.3.3.2 Vegetation

According to the River Health Program assessment (RHP, 2005), the following integrity scores were obtained for the Hex River riparian zone:

The ***Riparian Zone Habitat Integrity*** is "Fair" - channel modifications caused by diversions for mining have impacted on riparian zone habitats. The ***Riparian Vegetation Integrity*** is "Fair" - there is some vegetation clearing for sand winning activities and some pockets of *Sesbania* and blue gums, both of which are very localised (RHP, 2005).

**Riparian surveys**

**Riparian delineation**

During the process of riparian delineation, 3 transects were surveyed at each crossing, from the terrestrial area through the riparian area to the edge of the river (Figure 10a and b). The results of the surveys are listed in Tables 9 and 10.

**Table 9:** The riparian transects surveyed along the Dorp's River.

| | **Riparian transect 1** | **Riparian transect 2** | **Riparian transect 3** |
|---|---|---|---|
| | | | |
| Riparian | River bushwillow (*Combretum erythrophyllum*) | River bushwillow (*Combretum erythrophyllum*) | River bushwillow (*Combretum erythrophyllum*) |
| | Buffalo-thorn *(Ziziphus mucronata)* | Buffalo-thorn *(Ziziphus mucronata)* | Buffalo-thorn *(Ziziphus mucronata)* |
| | Syringa (*Melia azedarach*)* | Syringa (*Melia azedarach*) | Syringa (*Melia azedarach*) |
| | Thatching reed (*Phragmites mauritianum*) | Thatching reed (*Phragmites mauritianum*) | Thatching reed (*Phragmites mauritianum*) |
| | Bluegum *(Eucalyptes)** | Hyacinth (*Eichornia crassipes*) | Hyacinth (*Eichornia crassipes*) |
| | Hyacinth (*Eichornia crassipes*)* | Creeping ludwigia (*Ludwigia stolonifera*) | Creeping ludwigia (*Ludwigia stolonifera*) |
| | Creeping ludwigia (*Ludwigia stolonifera*) | Sedge *(Cyperus sexangularis)* | Sedge *(Cyperus sexangularis)* |
| | Sedge *(Cyperus sexangularis)* | Sweet thorn *(Acacia karoo)* | |
| | 12.0m | 29.3m | 27.4m |
| Terrestrial | Sweet thorn *(Acacia karoo)* | Sweet thorn *(Acacia karoo)* | Sweet thorn *(Acacia karoo)* |
| | Karree (*Searsia lancea*) | Karree (*Searsia lancea*) | Bluebush (*Diospyros lycioides*) |
| | Common spike thorn (*Gymnosporia buxifolia*) | Bluebush (*Diospyros lycioides*) | Common spike thorn (*Gymnosporia buxifolia*) |
| | White mulberry (*Morus alba*) | Bluegum *(Eucalyptes)* | |
| | 20m<br>E25 37.853<br>S27 15.972 | 20m<br>E25 37.894<br>S27 15. 870 | 20m<br>E25 37.948<br>S27 15.801 |

*Alien plants

**Table 10:** The riparian transects surveyed along the Boschfontein Spruit.

| | Riparian transect 1 | Riparian transect 2 | Riparian transect 3 |
|---|---|---|---|
| | | | |
| Riparian | | | |
| | Sedge | Sedge | Sedge |
| | Bulrush (*Typha capensis*) | Bulrush (*Typha capensis*) | Bulrush (*Typha capensis*) |
| | Thatching reed | Thatching reed | Thatching reed |
| | | | |
| | 10.0m | 12m | 15m |
| | **Terrestrial** | | |
| | Umbrella thorn (*Acacia tortilis*) | Umbrella thorn (*Acacia tortilis*) | Umbrella thorn (*Acacia tortilis*) |
| | | | |
| | 20m<br>E25 34.471<br>S27 18.151 | 20m<br>E25 34.505<br>S27 18.105 | 20m<br>E25 34.544<br>S27 18.066 |

The riparian zone of the Dorp's Spruit (Figure 11) consists of reeds and sedges on the banks of an incised channel (Figure 14), floating invader water hyacinth (Figure 13), and moderate dense riparian woodland (Figure 12) with some alien trees. The Boschfontein Spruit (Figure 18) has very little riparian vegetation on the bank (Figure 22) where large bedrock boulders are prominent (Figure 21), but the marginal vegetation consists of dense stands of reeds (Figure 22) and bulrush (Figure 21). At the last two crossing sites, Crossing 3 Kanana Drainage line and Crossing 4 Tierkop Spruit (Figure 25), there were no riparian zone or aquatic vegetation present due to the ephemeral nature of the two drainage lines (Figure 28 and 29).


**Figure 10:** The riparian delineation of the Dorp's River (a) and the Boschfontein Spruit (b), showing the transects through the riparian zone.

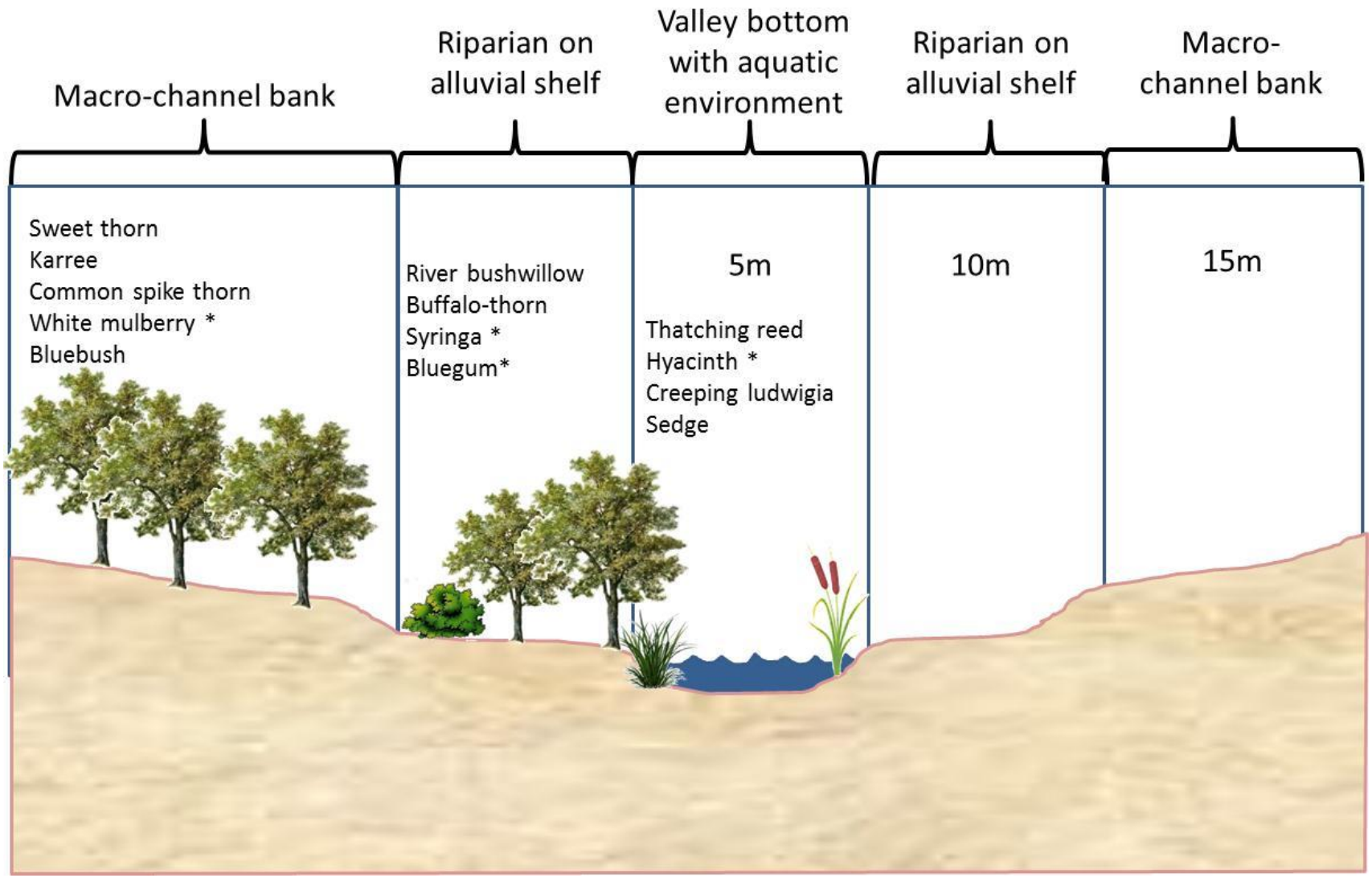


**Figure 11:** A diagram of the transect through the Dorp's River Crossing Site to illustrate the riparian and in-stream habitats. (*Alien plants).

**Figure 12:** Dorp's River - A large indigenous river bushwillow is part of the riparian zone woody vegetation.

**Figure 13:** Dorp's River - Alien, floating water hiasinth covers areas in slower flowing backwater.

**Figure 14:** Dorp's River - the sharply incised river channel of the Dorp's River.

**Figure 15:** Dorp's River - Shrubs and larger forbs form part of the lower layer of woody vegetation.

**Figure 16:** Dorp's River - Development on the outskirts of the riparian woodland - storm water.

**Figure 17:** Dorp's River - Development on the outskirts of the riparian woodland - road building.

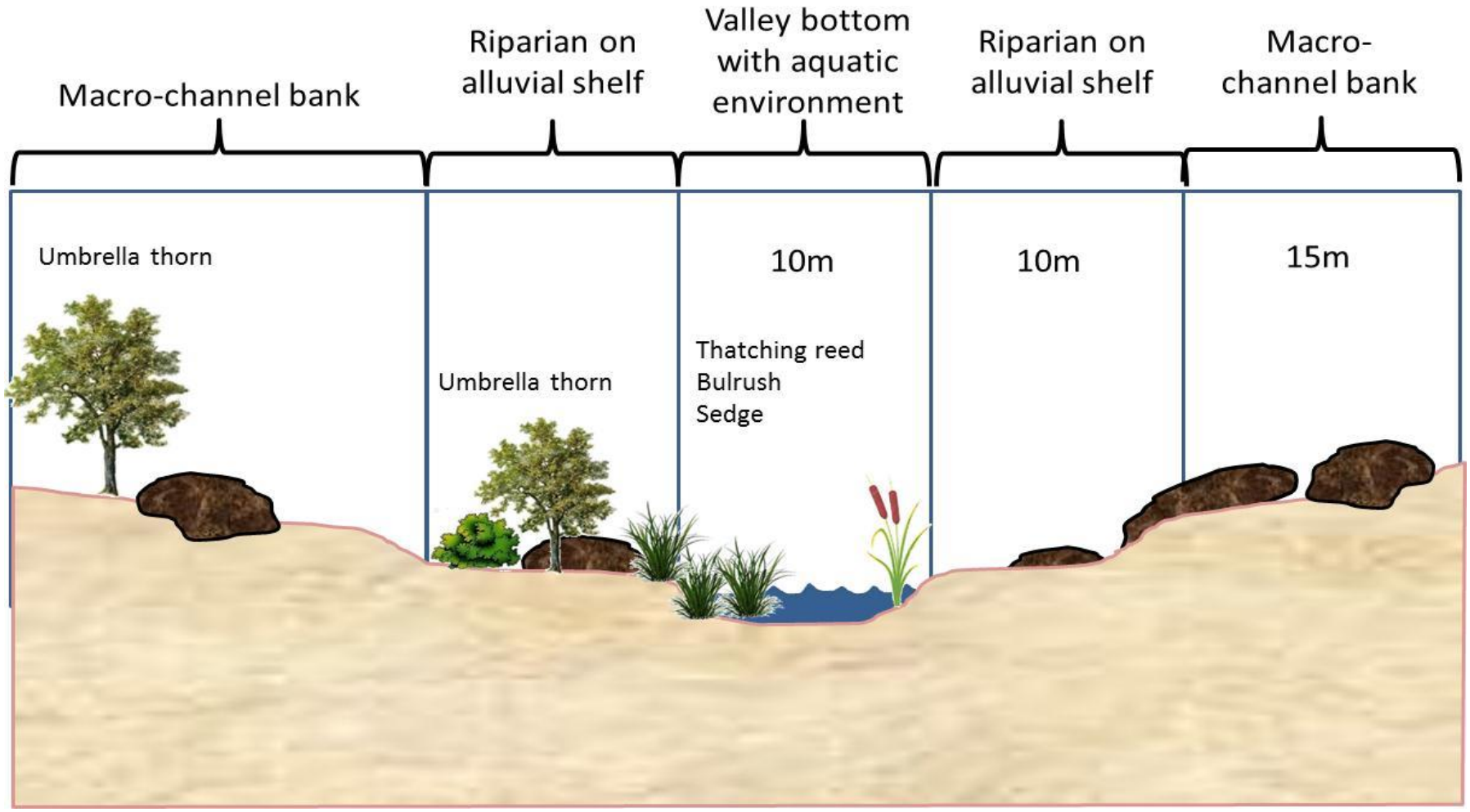


**Figure 18:** A diagram of the transect through the Boschfontein Spruit Crossing Site to illustrate the riparian and in-stream habitats. (*Alien plants).

**Figure 19:** Boschfontein Spruit - Low flow from the Boschfontein Spruit into the Bospoort Dam.

**Figure 20:** Boschfontein Spruit – **deeper** backwater in the stream surrounded by bulrush.

**Figure 21:** Boschfontein Spruit – The treeless surrounding of the stream and prominent bedrock boulders.

**Figure 22:** Boschfontein Spruit – Homesteads on the macro channel bank, boulders and grass on the floodplain, and reeds on the edge of the river.

**Figure 23:** Boschfontein Spruit – Flotsam in the reeds at the dam inflow.

**Figure 24:** Boschfontein Spruit – Signs of the road and bridge construction activities.

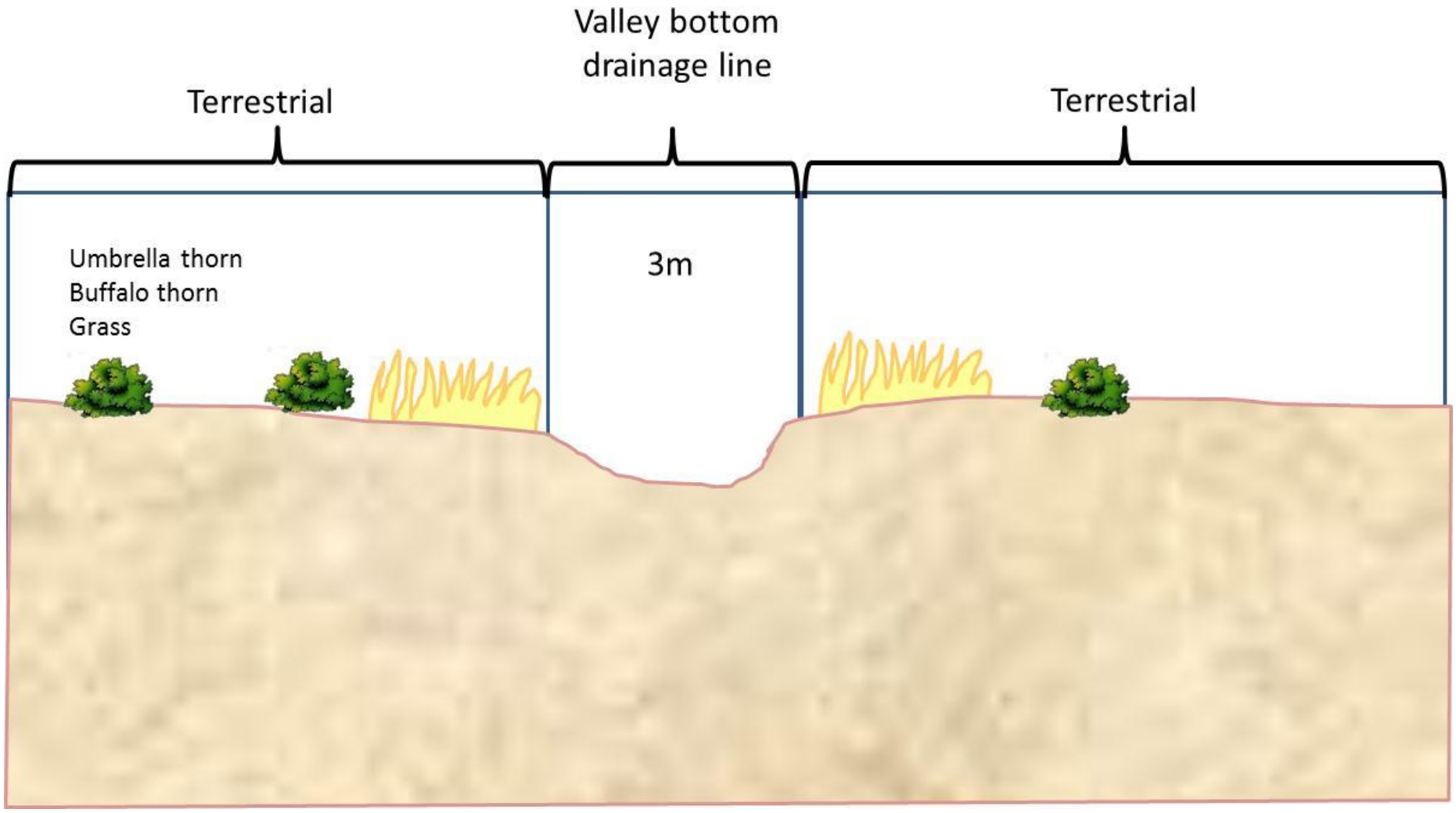


**Figure 25:** A diagram of the transect through the Kanana Drainage line and Tierkop Spruit Crossing Sites to illustrate the riparian and in-stream habitats. (*Alien plants).

**Figure 26:** Kanana drainage – The drainage line towards the Bospoort Dam.

**Figure 27:** Kanana drainage - The culvert constructed to allow storm water from the drainage line to pass through.

**Figure 28:** Kanana drainage – The dry drainage line coming from the Kanana settlement.

**Figure 29:** Tierkop Spruit – The drainage line towards the Bospoort Dam.

**Figure 30:** Tierkop Spruit - The culvert constructed to allow storm water from the drainage line to pass through.

**Figure 31:** Tierkop Spruit - Signs of a wetland or mudflat s during the rainy season.

True riparian plant species noted in the project area, are listed in Table 11 (Abstracted from Appendix 2).

**Table 11:** Riparian indicator plant species observed in the riverine zone at the river crossings during the survey.

| FAMILY | *TAXON* | HABITAT |
|---|---|---|
| COMBRETACEAE | *Combretum erythrophyllum* | Along river banks where it can form thick stands, with trunks reclining in and overhanging the water. |
| RHAMNACEAE | *Ziziphus mucronata* | In a wide variety of habitats, in open woodland, often in alluvial soils along rivers, and frequently on termite mounts; it is said to indicate the presence of underground water. |

**Riparian habitat surveys (Riparian Vegetation Index — VEGRAI)**

Riparian vegetation is described in the Water Act (Act No 36 of 1998**)** as follows: ”Riparian habitat" includes the physical structure and associated vegetation of the areas associated with a watercourse which are commonly characterised by alluvial soils, and which are inundated or flooded to an extent and with a frequency sufficient to support vegetation of species with a composition and physical structure distinct from those of adjacent land areas.

**VEGRAI model**

VEGRAI has a spread sheet model component that is composed of a series of metrics and metric groups each of which is rated in the field with the guidance of data collection sheets (referred to as field forms).

The metrics in VEGRAI first describe the status of riparian vegetation in both its current and reference states and second, compare differences between the two states as a measure of vegetation response to an impact regime.

The riparian vegetation zones (Marginal, Lower and Upper) are used as the metric groups. For the simplified Level 3 version, the Lower and Upper zones were combined to form the Non-Marginal metric group (zone).

A range of metrics for each metric group is selected of which some are essential for both Levels 3 and 4 (Abundance and Cover) and the others are optional (Species Composition, Population Structure and Recruitment). The metrics are then rated and weighted and an Ecological Category (A-F) determined which represents the Ecological Category for the riparian vegetation state.

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**Impact evaluation on riparian zone and interpretation**

The purpose is to evaluate and interpret the observed impacts at a site in terms of its relative influence on the riparian vegetation according to vegetation removal, alien vegetation invasion, water quantity and quality. The approach followed is that each of these four broad causes of modification relates to and is associated with particular human-related activities that would change the riparian vegetation characteristics directly or indirectly. Some of these changes may occur rapidly while others will occur gradually and only become evident through time.

This approach relates to the National Water Act which aims to protect aquatic ecosystems in order to secure ecologically sustainable development and use of the

relevant water resource. The protection of water resource quality is essential to achieve this:

``Resource quality'' means the quality of all the aspects of a water resource including,

- the quantity, pattern, timing, water level and assurance of in-stream flow;
- the water quality, including the physical, chemical and biological characteristics of the water;
- the character and condition of the in-stream and riparian habitat; and
- the characteristics, condition and distribution of the aquatic biota
- considering the functions of the riparian vegetation, these have been summarized as:

    - Sediment trapping,
    - Nutrient trapping
    - Bank stabilization and bank maintenance,
    - Contributes to water storage,
    - Aquifer recharge,
    - Flow energy dissipation,
    - Maintenance of biotic diversity,
    - Primary production.

Most of these functions relate to in-stream habitat conditions and it follows the basic consideration when assessing the condition of the riparian vegetation, and thus impacts should be interpreted in terms of the influence on the in-stream habitat.

The riparian marginal zone consists of shrubs and forbs, sometimes very dense; some reeds in level areas and abundant root wads of riparian trees. Some of these riparian trees are in the marginal zone and overhang the river. The riparian non-marginal zone consists of larger trees and marginal shrubs and forbs in the under-storey.

**Table 12:** A comparative description related to reference and present state of the proposed Dorp's River pipeline crossing site.

| Zones | Impacts | Response Metrics | Description of PRESENT STATE | Description of REFERENCE STATE |
|---|---|---|---|---|
| Marginal | Vegetation Removal<br>Exotic Vegetation<br>Water Quantity<br>Water Quality | Cover<br>Abundance<br>Species Composition | This reach consists of an incised channel and the marginal zone has woody species which form medium dense woodland mixed with abundant alien species, including *Eucalyptus*. Alluvial sandy areas are covered with shrubs, forbs and reeds, especially in the marginal areas, including some alien invading forbs. Selective removal of species for local use influences the abundance and species composition of this assemblage. | This reach consists of a U-shaped channel and the marginal zone has dense woody species and it forms closed canopy woodland. Alluvial sandy areas are covered with shrubs, forbs and reeds, especially in the marginal areas. |
| Non-marginal | Vegetation Removal<br>Exotic Vegetation<br>Water Quantity | Cover<br>Abundance<br>Species Composition | This reach consists of moderate dense woody species which has been reduced to more open woodland due to removals and development. Dry land areas are covered with shrubs and forbs, including some alien | This reach consists of moderate dense woody species which form closed woodland. The strip of non-marginal riparian woody vegetation is gradually |

| | | |
|---|---|---|
| Water Quality | invading forbs. | replaced by terrestrial components further away from the river. |

**Table 13: Evaluation of the marginal zone integrity (VEGRAI model) at the proposed Dorp's River pipeline crossing site.**

| | modification ratings | | | |
|---|---|---|---|---|
| **CAUSES OF MODIFICATION** | **INTENSITY** | **EXTENT** | **CONFIDENCE** | **NOTES: (give reasons for each assessment)** |
| REMOVAL | 2.0 | 3.0 | 4.0 | Areas been opened for development, local people utilize the wood of certain species. |
| EXOTIC INVASION | 3.0 | | 4.0 | A number of alien woody plants and alien forbs present. |
| WATER QUANTITY | 3.5 | 4.0 | 4.0 | An upstream dam impacts on the flow, as well as abstraction for certain users. |
| WATER QUALITY | 4.0 | 5.0 | 4.0 | The river runs through an industrial area with numerous effluent points. |
| AVERAGE | | | 4.0 | |

| | | RESPONSE METRIC RATINGS | | | |
|---|---|---|---|---|---|
| **VEGETATION COMPONENTS** | **RESPONSE METRIC** | **CONSIDER? (Y/N)** | **RATING** | **CONFIDENCE** | **NOTES: (give reasons for each assessment)** |
| WOODY | COVER | Y | 2.0 | 3.0 | Removal and alien competition impact on cover of indigenous riparian species. |
| | ABUNDANCE | Y | 2.5 | 3.0 | Removal and alien competition impact on abundance of indigenous riparian species. |
| | SPECIES COMPOSITION | Y | 2.0 | 3.0 | Hardy species remain. |
| | | | 2.2 | 3.0 | |
| NON-WOODY | COVER | Y | 1.5 | 3.0 | People presence: removal, development and paths through under-growth. |
| | ABUNDANCE | Y | 1.5 | 3.0 | People presence: removal, development and paths through under-growth. |
| | SPECIES COMPOSITION | Y | 2.0 | 3.0 | Hardy species remain. |
| | | | 1.7 | 2.0 | |

| **VEGETATION COMPONENTS** | **CONSIDER? (Y/N)** | **RANK** | **WEIGHT** | **RATING** | **WEIGHTED RATING** | **MEAN CONFIDENCE** | **NOTES: (give reasons for each assessment)** |
|---|---|---|---|---|---|---|---|
| WOODY | Y | 1.0 | 100.0 | 2.2 | 2.17 | 3.0 | Still some large trees present. |
| NON-WOODY | Y | 2.0 | 80.0 | 1.7 | 1.33 | 2.0 | React quicker to changes. |
| | | | | | 3.50 | 2.5 | |

| **CHANGE (%) IN MARGINAL ZONE CONDITION** | **38.9** |
|---|---|

**Table 14: Evaluation of the non-marginal zone integrity (VEGRAI model) at the proposed Dorp's River pipeline crossing site.**

| | MODIFICATION RATINGS | | | |
|---|---|---|---|---|
| **CAUSES OF MODIFICATION** | **INTENSITY** | **EXTENT** | **CONFIDENCE** | **NOTES: (give reasons for each assessment)** |
| REMOVAL | 3.0 | 0.5 | 4.0 | Areas been opened for development, local people utilize the wood of certain species. |
| EXOTIC INVASION | 2.5 | | 4.0 | A number of alien woody plants and alien forbs present. |
| WATER QUANTITY | 3.5 | 0.5 | 4.0 | An upstream dam impacts on the flow, especially small floods, as well as abstraction for certain users. |
| WATER QUALITY | 3.0 | 0.0 | 4.0 | The river runs through an industrial area with numerous effluent points, impact less on non-marginal due to distance from river. |
| AVERAGE | | | 4.0 | |

| | | RESPONSE METRIC RATINGS | | | |
|---|---|---|---|---|---|
| **VEGETATION COMPONENTS** | **RESPONSE METRIC** | **CONSIDER? (Y/N)** | **RATING** | **CONFIDENCE** | **NOTES: (give reasons for each assessment)** |
| WOODY | COVER | Y | 3.5 | 3.0 | Removal and alien competition impact on cover of indigenous riparian species. |
| | ABUNDANCE | Y | 3.0 | 3.0 | Removal and alien competition impact on abundance of indigenous riparian species. |
| | SPECIES COMPOSITION | Y | 2.0 | 3.0 | Hardy species remain. |
| | | | 2.8 | 3.0 | |
| NON-WOODY | COVER | Y | 1.5 | 3.0 | People presence: removal, development and paths through under-growth. |
| | ABUNDANCE | Y | 2.0 | 3.0 | People presence: removal, development and paths through under-growth. |
| | SPECIES COMPOSITION | Y | 2.5 | 3.0 | Hardy species remain. |
| | | | 2.0 | 2.0 | |

| **VEGETATION COMPONENTS** | **CONSIDER? (Y/N)** | **RANK** | **WEIGHT** | **RATING** | **WEIGHTED RATING** | **MEAN CONFIDENCE** | **NOTES: (give reasons for each assessment)** |
|---|---|---|---|---|---|---|---|
| WOODY | Y | 1.0 | 100.0 | 2.8 | 2.83 | 3.0 | Still some large trees present. |
| NON-WOODY | Y | 2.0 | 80.0 | 2.0 | 1.60 | 2.0 | React quicker to changes. |
| | | | | | 4.43 | 2.5 | |

| **CHANGE (%) IN MARGINAL ZONE CONDITION** | **49.3** |
|---|---|

**Table 15: The vegetation integrity evaluation of the proposed pipeline crossing site (VEGRAI model) at the proposed Dorp's River pipeline crossing site.**

| LEVEL 3 ASSESSMENT | | | | | | |
|---|---|---|---|---|---|---|
| **METRIC GROUP** | **CALCULATED RATING** | **WEIGHTED RATING** | **CONFIDENCE** | **RANK** | **% WEIGHT** | **NOTES: (give reasons for each assessment)** |
| MARGINAL | 61.1 | 32.2 | 2.5 | 1.0 | 100.0 | Although impacted, still some large indigenous species left. |
| NON MARGINAL | 50.7 | 24.0 | 2.5 | 2.0 | 90.0 | React quicker to changes. |
| 2.0 | | | | | 190.0 | |
| LEVEL 3 VEGRAI (%) | | | | 56.2 | | |
| **VEGRAI EC** | | | | **D** | | |
| AVERAGE CONFIDENCE | | | | 2.5 | | |

**Table 16:** A comparative description related to reference and present state of the proposed **Boschfontein Spruit** pipeline crossing site.

| Zones | Impacts | Response Metrics | Description of PRESENT STATE | Description of REFERENCE STATE |
|---|---|---|---|---|
| Marginal | Vegetation Removal<br>Exotic Vegetation<br>Water Quantity<br>Water Quality | Cover<br>Abundance<br>Species Composition | Removal of almost all woody vegetation as the area been inhabited for a long time and local people utilize the wood of most woody species. Reeds, bulrush and sedges survive in the marginal habitats of the river. Removed for making mats and roofs. | Seasonal drainage line with some emergent vegetation in more permanent pools, riparian corridor weakly developed due to the seasonal nature of the drainage line. Bedrock on the embankment also naturally discourages the forming of dense vegetation growths. |
| Non-marginal | Vegetation Removal<br>Exotic Vegetation<br>Water Quantity<br>Water Quality | Cover<br>Abundance<br>Species Composition | Removal of almost all woody vegetation as the area been inhabited for a long time and local people utilize the wood of most woody species. Few hardy species remain. Grazing and browsing livestock removed most of the herbaceous cover. | Open woodland with hardy species. |

**Table 17: Evaluation of the marginal zone integrity (VEGRAI model) at the proposed Boschfontein Spruit pipeline crossing site.**

| | MODIFICATION RATINGS | | | |
|---|---|---|---|---|
| **CAUSES OF MODIFICATION** | **INTENSITY** | **EXTENT** | **CONFIDENCE** | **NOTES: (give reasons for each assessment)** |
| REMOVAL | 4.5 | 4.5 | 3.0 | Areas been inhabited and local people utilize the wood of most woody species. |
| EXOTIC INVASION | 1.5 | | 3.0 | Some alien woody plants and alien forbs present. |
| WATER QUANTITY | 1.5 | 4.0 | 3.0 | Upstream impacts on the flow and abstraction for certain users. |
| WATER QUALITY | 3.5 | 3.5 | 3.0 | The river runs through an rural developed area with associated impacts. |
| AVERAGE | | | 3.0 | |

| | | RESPONSE METRIC RATINGS | | | |
|---|---|---|---|---|---|
| **VEGETATION COMPONENTS** | **RESPONSE METRIC** | **CONSIDER? (Y/N)** | **RATING** | **CONFIDENCE** | **NOTES: (give reasons for each assessment)** |
| WOODY | COVER | Y | 4.0 | 3.0 | Removal of almost all woody vegetation impacts on cover of indigenous riparian species. |
| | ABUNDANCE | Y | 4.0 | 3.0 | Removal of almost all woody vegetation impacts on abundance of indigenous riparian species. |
| | SPECIES COMPOSITION | Y | 4.0 | 3.0 | Few hardy species remain. |
| | | | 4.0 | 3.0 | |
| NON-WOODY | COVER | Y | 1.5 | 3.0 | Reeds, bulrush and sedges survive in the marginal habitats of the river. Removed for making mats and roofs. |
| | ABUNDANCE | Y | 2.0 | 3.0 | Reeds, bulrush and sedges survive in the marginal habitats of the river. Removed for making mats and roofs. |
| | SPECIES COMPOSITION | Y | 2.0 | 3.0 | Dominant species remain. |
| | | | 1.8 | 2.0 | |

| VEGETATION COMPONENTS | CONSIDER? (Y/N) | RANK | WEIGHT | RATING | WEIGHTED RATING | MEAN CONFIDENCE | NOTES: (give reasons for each assessment) |
|---|---|---|---|---|---|---|---|
| WOODY | Y | 1.0 | 100.0 | 4.0 | 4.00 | 3.0 | Almost no trees left. |
| NON-WOODY | Y | 2.0 | 75.0 | 1.8 | 1.38 | 2.0 | React quicker to changes - protected in water. |
| | | | | | 5.38 | 2.5 | |

| CHANGE (%) IN MARGINAL ZONE CONDITION | 61.4 |
|---|---|

**Table 18: The vegetation integrity evaluation of the proposed pipeline crossing site (VEGRAI model) at the proposed Boschfontein Spruit pipeline crossing site.**

| | MODIFICATION RATINGS | | | |
|---|---|---|---|---|
| CAUSES OF MODIFICATION | INTENSITY | EXTENT | CONFIDENCE | NOTES: (give reasons for each assessment) |
| REMOVAL | 4.5 | 4.5 | 3.0 | Areas been inhabited and local people utilize the wood of most woody species. |
| EXOTIC INVASION | 1.5 | | 3.0 | Some alien woody plants and alien forbs present. |
| WATER QUANTITY | 1.5 | 4.0 | 3.0 | Upstream impacts on the flow and abstraction for certain users. |
| WATER QUALITY | 3.5 | 3.0 | 3.0 | The river runs through a rural developed area with associated impacts. |
| AVERAGE | | | 3.0 | |

| | | RESPONSE METRIC RATINGS | | | |
|---|---|---|---|---|---|
| VEGETATION COMPONENTS | RESPONSE METRIC | CONSIDER? (Y/N) | RATING | CONFIDENCE | NOTES: (give reasons for each assessment) |
| WOODY | COVER | Y | 3.5 | 3.0 | Removal of almost all woody vegetation impacts on cover of indigenous riparian species. |
| | ABUNDANCE | Y | 3.0 | 3.0 | Removal of almost all woody vegetation impacts on abundance of |

| | | | | | |
|---|---|---|---|---|---|
| | | | | | indigenous riparian species. |
| | SPECIES COMPOSITION | Y | 2.0 | 3.0 | Few hardy species remain. |
| | | | 2.8 | 3.0 | |
| NON-WOODY | COVER | Y | 1.5 | 3.0 | Grazing and browsing livestock removed most of the herbaceous cover. |
| | ABUNDANCE | Y | 2.0 | 3.0 | Grazing and browsing livestock removed most of the herbaceous cover. |
| | SPECIES COMPOSITION | Y | 2.5 | 3.0 | Hardy species remain. |
| | | | 2.0 | 2.0 | |

| VEGETATION COMPONENTS | CONSIDER? (Y/N) | RANK | WEIGHT | RATING | WEIGHTED RATING | MEAN CONFIDENCE | NOTES: (give reasons for each assessment) |
|---|---|---|---|---|---|---|---|
| WOODY | Y | 1.0 | 100.0 | 2.8 | 2.83 | 3.0 | Still some large trees present. |
| NON-WOODY | Y | 2.0 | 90.0 | 2.0 | 1.80 | 2.0 | React quicker to changes. |
| | | | | | 4.63 | 2.5 | |

| CHANGE (%) IN MARGINAL ZONE CONDITION | 48.8% |
|---|---|

**Table 19: The vegetation integrity evaluation of the proposed pipeline crossing site (VEGRAI model) at the proposed Boschfontein Spruit pipeline crossing site.**

| LEVEL 3 ASSESSMENT | | | | | | |
|---|---|---|---|---|---|---|
| METRIC GROUP | CALCULATED RATING | WEIGHTED RATING | CONFIDENCE | RANK | % WEIGHT | NOTES: (give reasons for each assessment) |
| MARGINAL | 38.6 | 20.3 | 2.5 | 1.0 | 100.0 | Very little indigenous species left. |
| NON MARGINAL | 51.2 | 24.3 | 2.5 | 2.0 | 90.0 | React quicker to changes marginal emergent species important. |
| | 2.0 | | | | 190.0 | |
| LEVEL 3 VEGRAI (%) | | | | 44.6 | | |

| **VEGRAI EC** | **D** |
|---|---|
| AVERAGE CONFIDENCE | 2.5 |

Due to the absence of riparian and marginal habitats on the ephemeral drainage lines of the two crossing sites, Crossing 3 Kanana Drainage line and Crossing 4 Tierkop Spruit, the VEGRAI model could not be applied to these reaches. According to the VEGRAI model results, the two sites evaluated responded as follow:

Dorp's Spruit: This reach consists of an incised channel and the marginal zone has woody species which form medium dense woodland mixed with abundant alien species, including *Eucalyptus*. Alluvial sandy areas are covered with shrubs, forbs and reeds, especially in the marginal areas, including some alien invading forbs. Selective removal of species for local use influences the abundance and species composition of this assemblage.

Boschfontein Spruit: Removal of almost all woody vegetation is evident as the area has been inhabited for a long time and local people utilize the wood of most woody species. Reeds, bulrush and sedges survive in the marginal habitats of the river, although it is removed for making mats and to covers roofs. Grazing and browsing livestock removed most of the herbaceous cover.

Due to above-mentioned influences, the change in the riparian and marginal zone integrity of the two rivers is represented in Table 20.

**Table 20:** A summary of the VEGRAI scores at the two sites with surface flows.

| River crossing | Non-marginal zone condition | Marginal zone condition | Level 3 VEGRAI | VEGRAI EC |
|---|---|---|---|---|
| Dorp's Spruit | 38.9% | 49.3% | 56.2% | D |
| Boschfontein Spruit | 61.4% | 48.8% | 44.6% | D |

The non-marginal zone condition of the Boschfontein Spruit (61.4% change) seems to be more impacted on than that of the Dorp's Spruit non-marginal zone condition (38.9% change), but the change in the marginal zone condition is very similar at the two sites (48.8% and 49.3% respectively). The combined Level 3 VEGRAI scores per site present a score of 56.2% at the Dorp's Spruit river crossing, and 44.6% at the Boschfontein Spruit river crossing (Tables 17 and 19). The final riparian vegetation integrity described by the Ecological Class of both these two sites, are grouped in a Class D (40-59%) which reflects a "Largely modified" vegetation integrity (Table 21).

**Table 21:** Generic ecological categories for EcoStatus components (modified from Kleynhans 1996 & Kleynhans 1999).

| **ECOLOGICAL CATEGORY** | **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 ecosystem functions are essentially unchanged. | 80-89 |
| C | Moderately modified. 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 | Seriously modified. The loss of natural habitat, biota and basic ecosystem functions is extensive. | 20-39 |
| F | Critically modified. Modifications have reached a critical level and the | 0-19 |

| ECOLOGICAL CATEGORY | DESCRIPTION | SCORE (% OF TOTAL) |
|---|---|---|
| | lotic system has been modified completely with an almost complete loss of natural habitat and biota. In the worst instances the basic ecosystem functions have been destroyed and the changes are irreversible | |

### Task 1.2.3.4 Biota – Aquatic invertebrates and Fish

**Aquatic habitat assessment**

During the monitoring survey the following parameters were measured - IHAS (Integrated Habitat Assessment System) and HQI (Habitat Quality Index) with the results summarized in Table 22. Due to the absence of surface water in the ephemeral drainage lines of two of the crossing sites, Crossing 3 Kanana Drainage line and Crossing 4 Tierkop Spruit, the habitat integrity could not be assessed in these reaches.

**Table 22:** The habitat parameters as measured at the crossing sites with surface flows.

| | IHAS | HQI |
|---|---|---|
| Dorp's Spruit | 51% | 41% |
| Boschfontein Spruit | 42% | 39% |

During the December 2015 survey, the IHAS and HQI were relatively low due to poor water quality, limited habitats and human related impacts on the aquatic environment (erosion, siltation, vegetation removal, litter, eutrophication, etc.). At the Dorp's Spruit site the smell of sewage was evident and at the Boschfontein Spruit site the stagnant water could be seen pushing in from the Bospoort Dam.

According to the RHP assessment in 2005, the overall EcoStatus for the Lower Hex River was "Poor" (RHP, 2005):

The ***Fish Assemblage Integrity*** was also "Poor"- sensitive species are lost due to flow modifications and obstructions. Water quality problems originating from the mines and from agriculture have created stress conditions for fish species.

The ***Macro-invertebrate Integrity*** was also "Poor", the cumulative impacts of reduced water quality and, flow and habitat modifications have had a large effect on invertebrate diversity and abundance.

### Task 1.2.3.4.1 Aquatic invertebrate assessment

The macro-invertebrates were sampled according to the SASS5 method at the Dorp's Spruit and the Boschfontein Spruit crossing sites. Due to the absence of surface flows in the ephemeral drainage lines of the two crossing sites, Crossing 3 Kanana Drainage line and Crossing 4 Tierkop Spruit, the SASS5 method could not be implemented. Table 23 compares the macro-invertebrates sampled at the different river crossing sites with surface water and their SASS5 scores.

**Table 23:** SASS5 scores of the different habitat types at the Dorp's River crossing (a complete table of this summarized version in Appendix 3).

| TAXON | Stones | Vegetation | GSM | Total |
|---|---|---|---|---|
| Oligochaeta 1 | | | B | |
| Potamonautidae 3 | A | | | |
| Belostomatidae 3 | | A | | |
| Corixidae 3 | | A | | |
| Dytiscidae 5 | | A | | |
| Culicidae 1 | | | 1 | |
| SASS Score | 3 | 11 | 2 | 16 |
| No of families | 1 | 3 | 2 | 6 |
| ASPT | 3.0 | 3.6 | 1.0 | 2.6 |

Estimated abundance: 1=1; A=2-10; B=11-100; C=101-1000; D=>1000

**Table 24:** SASS5 scores of the different habitat types at the Boschfontein Spruit crossing (a complete table of this summarized version in Appendix 3).

| TAXON | Stones | Vegetation | GSM | Total |
|---|---|---|---|---|
| Leeches 3 | | A | | |
| Hydracarinae 8 | | 1 | | |
| Belostomatidae 3 | | A | | |
| Corixidae 3 | | B | | |
| Naucoridae 7 | | B | A | |
| Veliidae 5 | | | A | |
| Dytiscidae 5 | | A | | |
| Chironomidae 2 | | | B | |
| SASS Score | 0 | 29 | 14 | 36 |
| No of families | 0 | 6 | 3 | 8 |
| ASPT | 0 | 4.8 | 4.6 | 4.5 |

Estimated abundance: 1=1; A=2-10; B=11-100; C=101-1000; D=>1000

**Table 25:** Comparing IHAS, HQI and SASS scores at the relevant monitoring sites during the survey.

| SURVEY SITE | Habitat scores | | SASS5 Scores | | |
|---|---|---|---|---|---|
| | IHAS % | HQI % | SASS score | Number of families | ASPT |
| Dorp's River crossing | 51% | 41% | 16 | 6 | 2.6 |
| Boschfontein Spruit crossing | 42% | 39% | 36 | 8 | 4.5 |

Judging from Table 25, the habitat scores are quite low at both the river crossing sites, and are all categorized as "Poor" according to Table 26. The macro-invertebrate scores reacted accordingly to the poor habitat conditions at the sites, resulting in low SASS scores and low number of families. The very low ASPT score at the Dorp's River crossing, an ASPT of 2.6 which relates to a "Poor" according to Table 26, reflects on the poor water quality at the site. The Boschfontein Spruit crossing SASS scores react a bit better, resulting in an ASPT of 4.5 which is a "Fair" category according to Table 26.

**Table 26**: Categories used to classify Habitat, SASS and ASPT values:

| HABITAT | SASS4 | ASPT | CONDITION |
|---|---|---|---|
| >100 | >140 | >7 | Excellent |
| 80-100 | 100-140 | 5-7 | Good |
| 60-80 | 60-100 | 3-5 | Fair |
| 40-60 | 30-60 | 2-3 | Poor |
| <40 | <30 | <2 | Very poor |

**Macro-invertebrate Response Assessment Index: MIRAI**

The rating approach for the MIRAI involves four different metric groups that measure the deviation of the invertebrate assemblage from the reference (expected) assemblage in terms of flow modification, habitat modification and water quality modification, as well as system connectivity and seasonality.

The first step in determining the Present Ecological State (PES) of the invertebrates is to complete the data sheets. This includes the abundance and frequency of occurrence of the different invertebrate taxa under natural (reference) conditions, as well as the abundance and frequency of occurrence of the invertebrate taxa present. For this index an increase in abundance and/or frequency of occurrence, as well as a decrease in abundance and/or frequency of occurrence, is seen as an impact or change compared to natural. The six point rating system works as follows:

0 = No change from reference
1 = Small change from reference
2 = Moderate change from reference
3 = Large change from reference
4 = Serious change from reference
5 = Extreme change from reference

The data for the 2015 survey was used to run the MIRAI model and Table 27 summarises the results. Due to the fact that no data was generated by the River Health Programme for these river crossing sites, the macro-invertebrate data for the closest River Health Programme in the Hex River (A22J-00878; A2HEXR-PAARD) was used as background information.

**Table 27:** The final MIRAI score sheet for the Dorp's River (December 2015).

| INVERTEBRATE EC: BASED ON WEIGHTS OF METRIC GROUPS | | | | | | |
|---|---|---|---|---|---|---|
| **INVERTEBRATE EC METRIC GROUP** | | **METRIC GROUP CALCULATED SCORE** | **CALCULATED WEIGHT** | **WEIGHTED SCORE OF GROUP** | **RANK OF METRIC GROUP** | **%WEIGHT FOR METRIC GROUP** |
| **FLOW MODIFICATION** | **FM** | 35.5 | *0.204* | 7.24004 | 3 | 50 |
| **HABITAT** | **H** | 35.8 | *0.367* | 13.1504 | 2 | 90 |
| **WATER QUALITY** | **WQ** | 31.0 | *0.408* | 12.6464 | 1 | 100 |
| **CONNECTIVITY & SEASONALITY** | **CS** | 51.3 | *0.020* | 1.04762 | 4 | 5 |
| **INVERTEBRATE EC** | | | | | | 245 |
| | | | | 34.0844 | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| **INVERTEBRATE EC CATEGORY** | | | | **E** | | |

>89=A; 80-89=B; 60-79=C; 40-59=D; 20-39=E; <20=F

**Table 28:** The final MIRAI score sheet for the Boschfontein Spruit (December 2015).

| **INVERTEBRATE EC: BASED ON WEIGHTS OF METRIC GROUPS** | | | | | | |
|---|---|---|---|---|---|---|
| **INVERTEBRATE EC METRIC GROUP** | | **METRIC GROUP CALCULATED SCORE** | **CALCULATED WEIGHT** | **WEIGHTED SCORE OF GROUP** | **RANK OF METRIC GROUP** | **%WEIGHT FOR METRIC GROUP** |
| **FLOW MODIFICATION** | **FM** | 47.5 | *0.204* | 9.7035 | 3 | 50 |
| **HABITAT** | **H** | 57.3 | *0.367* | 21.0612 | 2 | 90 |
| **WATER QUALITY** | **WQ** | 58.3 | *0.408* | 23.7834 | 1 | 100 |
| **CONNECTIVITY & SEASONALITY** | **CS** | 80.0 | *0.020* | 1.63265 | 4 | 5 |
| **INVERTEBRATE EC** | | | | | | 245 |
| **INVERTEBRATE EC CATEGORY** | | | | 56.1807 **D** | | |

>89=A; 80-89=B; 60-79=C; 40-59=D; 20-39=E; <20=F

During the 2015 assessment the relative MIRAI score of the Dorp's River reach was placed within the limits of an ecological state category Class E (34%), which means this reach is "Seriously modified" (Table 29). The relative MIRAI score of the Boschfontein Spruit reach was placed within the limits of an ecological state category Class D (56%), which means this reach is "Largely modified". The Class ratings are explained in Table 29.

These results indicate the effect of the poorer water quality on the macro-invertebrate condition in the Dorp's River. The Boschfontein Spruit rather has a water quantity problem than water quality problem.

Due to the lack of surface water in the ephemeral drainage lines of two of the crossing sites, Crossing 3 Kanana Drainage line and Crossing 4 Tierkop Spruit, no freshwater aquatic macro-invertebrates were expected to occur here for most of the year. During heavy downpours in the rainy season, these ephemeral drainage lines might start to flow, however the presence of surface water is of such a temporary nature that aquatic macro-invertebrates do not get the opportunity to colonize the short-lived streams.

**Table 29:** Ratings for the macro-invertebrate integrity classes.

| | MIRAI ASSESSMENT CLASSES | |
|---|---|---|
| Class rating | Description of generally expected conditions for integrity classes | Relative FRAI score (% of expected) |
| A | Unmodified, or approximate natural conditions closely | 90 to 100 |
| B | Largely natural with few modifications. | 80 to 89 |
| C | Moderately modified. | 60 to 79 |
| D | Largely modified. | 40 to 59 |
| E | Seriously modified. | 20 to 39 |
| F | Critically modified. | 0 to 19 |

### Task 1.2.3.4.2 Fish Response Assessment Index (FRAI)

The purpose of the Fish Response Assessment Index (FRAI) is to provide a habitat-based cause-and-effect interpretation underpinning the deviation of the fish assemblage from the reference condition.

The application of the FRAI is based on the following:

- The FRAI is an assessment index based on the environmental intolerances and preferences of the reference fish assemblage and the response of the constituent species of the assemblage to particular groups of environmental determinants or rivers.

- These intolerance and preference attributes are categorized into metric groups with constituent metrics that relates to the environmental requirements and preferences of individual species.

- Assessment of the response of the species metrics to changing environmental conditions occur either through direct measurement (surveys) or are inferred from changing environmental conditions (habitat). Evaluation of the derived response of species metrics to habitat changes are based on knowledge of species ecological requirements. Usually the FRAI is based on a combination of fish sample data and fish habitat data.

- Changes in environmental conditions are related to fish stress and form the basis of ecological response interpretation.

Table 30 explains the 8 steps followed in the calculation of the FRAI.

**Table 30:** Main steps and procedures in the calculation of the FRAI

| **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<br>Model: use eco-regional and other environmental information<br>Use expert fish reference frequency of occurrence database if available |
| Determine present state for drivers | Hydrology<br>Physico-chemical<br>Geomorphology or<br>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<br>Assess fish habitat condition |
| Representative fish sampling at site or in river section | Sample all velocity depth classes per site if feasible<br>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<br>Enter species reference frequency of occurrence data<br>Enter species observed frequency of occurrence data<br>Determine weights for the metric groups<br>Obtain FRAI value and category<br>Present both modelled FRAI & adjusted FRAI. |

**Study of the river section earmarked for assessment**

The river portion of the Dorp's River in the area of the crossing consists mainly of a run in a U-shaped channel with some overhanging and emerging vegetation, and very few areas with faster flowing water and stones in current.

The river portion of the Boschfontein Spruit in the area of the crossing consists mainly of a series of pools with some floating and emerging vegetation before it flows into the Bospoort Dam; very few areas with faster flowing water and stones in current. (also see Task 1.2.3.3.2 of this report).

**Determine reference fish assemblage: species and frequency of occurrence**

Frequency of Occurrence (FROC)

The fish reference Frequency of Occurrence (FROC) database (Kleynhans, Louw, & Moolman, 2007), which provides consistent reference frequency of occurrence for more than 700 fish sites in South Africa, was used to establish the baseline data for this report. The FROC was developed to be used in the following programmes:

- the FRAI
- procedures that requires a reference fish assemblage (e.g. extrapolation from known sites to unknown sites)

Fish is considered to be one of the important indicators of river health and their responses to modified environmental conditions are measured in terms of the Fish Response Assessment Index (FRAI) (Kleynhans 1999; Kleynhans *et al*. 2005). This index is based on a combination of fish species habitat preferences as well as intolerance to habitat changes, and the present frequency of occurrence of species compared to the reference frequency of occurrence (Kleynhans, Louw, & Moolman, 2007).

The list of species is based on species that are known to be present or to have been present under close to reference habitat conditions. Species that are derived to have been present under relatively recent reference habitat conditions are also identified. The resulting species reference list is a combination of both of the above approaches.

The rating of the FROC refers to the reference fish frequency of occurrence (FROC) in a particular ecologically defined reach of a river. Ratings are scored from 1 to 5.

Rating of the reference fish FROC refers to the reference fish frequency of occurrence in a particular ecologically defined reach of a river. This means that FROC ratings are derived based on conditions at the particular site as well as the available habitat in the reach for species expected under reference conditions.

Basic habitat conditions that were considered in terms of the FROC of species are based on intolerance and preference rating as contained in the FRAI (Kleynhans *et al.* 2005). The presence and abundance of habitat features such as velocity-depth classes, cover types (including substrate) and the characteristics of the natural flow regime (especially the degree of perenniality) in a river reach under reference conditions formed the basis for the expert judgment of the FROC (Kleynhans, Louw, & Moolman, 2007).

**Table 31:** The FROC list (and the description of the column headings) for the Crocodile River west in the area of the river crossings of the proposed pipe line development (Figures 5 - 7). The freshwater fish species scientific name, abbreviation and common name are summarized in Appendix 4:

| | | | |
|---|---|---|---|
| **FROC SITE CODE** | 3CWF27 A22J-00878 | | |
| **LATITUDE** | -25.3031 | | |
| **LONGITUDE** | 27.4786 | | |
| **WMA** | Crocodile (West) Marico | | |
| **QUAT** | A22J | | |
| **MAJOR RIVERS** | Crocodile west | | |
| **ECOREGION** | 8.05 | | |
| **GEOMORPH ZONE** | D - Upper Foothills | | |
| **ALTITUDE** | 1058 | | |
| **FISH SPP** | **FROC** | **CONFIDENCE** | **RELATIVE ABUNDANCE** |
| AMOS | 3 | 3 | 0 |
| BMAR | 5 | 3 | 3 |
| BMAT | 3 | 3 | 1 |
| BTRI | 1 | 3 | 2 |
| BPAU | 5 | 3 | 3 |
| BUNI | 5 | 3 | 2 |
| CCAR | 3 | 3 | 2 |
| CFLA | 3 | 3 | 4 |
| CGAR | 3 | 3 | 1 |
| LCYL | 3 | 3 | 1 |
| LMOL | 3 | 3 | 1 |
| MBRE | 3 | 3 | 3 |
| MSAL | 3 | 3 | 1 |
| OMOS | 5 | 3 | 4 |
| PPHI | 5 | 3 | 3 |
| TSPA | 5 | 3 | 2 |

**Table 32:** Description for column headings in Table 31 above:

| FIELD NAME (COLUMN TITLE IN SPREADSHEET) | DESCRIPTION |
|---|---|
| XSPP | Species suspected to be present under reference conditions. |
| FROC | Fish frequency of occurrence rating:<br>1=Present at very few sites (<10% of sites)<br>2=Present at few sites (>10-25%)<br>3=Present at about >25-50 % of sites<br>4=Present at most sites (>50- 75%)<br>5=Present at almost all sites (>75%) |
| CONFIDENCE | The confidence in the frequency of occurrence rating:<br>1=Low confidence<br>2=Low to moderate<br>3=Moderate<br>4=Moderate to high<br>5=High |

| FIELD NAME (COLUMN TITLE IN SPREADSHEET) | DESCRIPTION |
|---|---|
| RELATIVE ABUNDANCE | It is assumed that assessment is done during a year when a suitable base flow is present. Rating:<br>1=1-5 individuals<br>2=6-50 individuals<br>3 >50 individuals<br>Or<br>1=Rare<br>2=Moderate<br>3=Abundant<br>Due to the high variability in natural abundance of fish, his rating was only applied where an assessor had high confidence in the rating. The rating is not used in the FRAI and is considered as supplementary information. |
| COMMENT | Any comment that the assessor felt was relevant and important. |

The list of species is based on species that are known to be present or to have been present under close to reference habitat conditions. This would include information from historical sites within a particular river reach.

**Determine present state for drivers**

The purpose is to provide information on the fish response and associated habitat condition and *vice versa* (i.e. fish responses that are possible, given certain habitat conditions). This assessment considers the whole river section to be studied. If information on the drivers is available, these should be used.

In the Hex River, flows are largely managed on demand for anthropological purposes. This results in un-seasonally high pulses of flow in the river and extended periods of low flow. The managed flow regime, when combined with the large numbers of dams and weirs, has resulted in river habitats becoming severely fragmented with what were largely perennial rivers now being distinctly seasonal in nature. For extended periods, weirs and deep pools are the only refuge for any aquatic life (Du Plessis, 2006).

Due to the location and the associated industrial development, mining activities and urbanization (formal and informal) taking place in the catchment, the water quality of the Hex River and its tributaries has progressively deteriorated. The physical and chemical constituent concentrations recorded in the Hex River and its associated tributaries decreased during peak rainfall in the summer months. Higher constituent concentrations were recorded during the dry winter months (Du Plessis, 2006).

**Sampling site selection**

Four survey sites at the proposed pipeline crossings on the tributaries to the Hex River, were earmarked for assessment (Figure 5):

Crossing 1 Dorps River ($25^0$ 37.876'S $27^0$ 15.915'E): this site is situated 500m downstream of the Prison Dam at the R510 bridge (Figures 6.1 – 6.3).

Crossing 2 Boschfontein Spruit ($25^0$ 34.472'S $27^0$ 18.223'E): this site is situated downstream of the Chachalaza township at the newly constructed R510 bridge over the south-western inflow to the Bospoort Dam (Figures 7.1 – 7.3).

Crossing 3 Kanana Drainage line ($25^0$ 34.194'S $27^0$ 18.377'E): this site is situated downstream of the Kanana township near the newly constructed R510 bridge over the south-western inflow to the Bospoort Dam (Figures 8.1 – 8.3).

Crossing 4 Tierkop Spruit ($25^0$ 33.628'S $27^0$ 19.210'E): this site is situated east of Hermansburg along the road that passes north of the Bospoort Dam (Figures 9.1 –9.3).

**Fish habitat assessment at site**

**Habitat potential assessment**

Habitat assessment refers to an evaluation of fish habitat potential (i.e., the potential that the habitat provides suitable conditions for a fish species to live there) at a site in terms of the diversity of velocity-depth classes present and the presence of various cover types at each of these velocity-depth classes. This provides a framework within which the presence, absence and frequency of occurrence of species can be interpreted. Habitat assessment includes a general consideration of impacts that may influence the condition or integrity of fish habitat at a site (Kleynhans, Louw, & Moolman, 2007).

The Dorps River and Boschfontein Spruit sites were surveyed for fish. These rivers were flowing but quite low during the time of sampling. The different sampling sites supplied a good indication of the fish present. Due to the absence of surface flows in the ephemeral drainage lines of the two crossing sites, Crossing 3 Kanana Drainage line and Crossing 4 Tierkop Spruit, the FRAI method could not be implemented.

The aquatic and in-stream environments of the two sites with surface flows consisted mainly of the following:

Dorp's River: The river flows as a slow run in a U-shaped channel (4-8m wide; 1m deep) with emerging marginal and floating vegetation on the edges. Very little faster flows or stones-in current habitats are present.

Boschfontein Spruit: The river flows as a slow open channel (4-6m wide; 1m deep), inter-linked with larger and deeper pools with emerging marginal and floating vegetation on the edges. Very little faster flows or stones-in current habitats are present.

**Table 33:** Fish velocity-depth classes and cover present in the project sites (project area).

| FISH VELOCITY-DEPTH CLASSES AND COVER PRESENT AT SITE<br>(Abundance: 0=absent; 1=rare; 2=sparse; 3=moderate; 4=abundant; 5=very abundant) | | | |
|---|---|---|---|
| SLOW DEEP:<br>3 | SLOW SHALLOW:<br>1 | FAST DEEP:<br>0 | FAST SHALLOW:<br>1 |
| Overhanging vegetation:<br>3 | Overhanging vegetation:<br>2 | Overhanging vegetation:<br>0 | Overhanging vegetation:<br>0 |
| Undercut banks & root wads:<br>2 | Undercut banks & root wads:<br>0 | Undercut banks & root wads:<br>0 | Undercut banks & root wads:<br>0 |
| Substrate:<br>2 | Substrate:<br>1 | Substrate:<br>0 | Substrate:<br>2 |
| Aquatic macrophytes: | Aquatic macrophytes: | Aquatic macrophytes: | Aquatic macrophytes: |

| | | | |
|---|---|---|---|
| 4 | 3 | 0 | 0 |
| Water Column:<br>3 | Water Column:<br>1 | Water Column:<br>0 | Water Column:<br>0 |
| Remarks:<br>No slow deep habitats due pools and deeper channel areas. | Remarks:<br>Little slow shallow habitats due to slope of reach | Remarks:<br>No fast deep biotopes present. | Remarks:<br>Shallow inter-linking faster flowing areas. |

**Habitat Condition**

The purpose is to provide an indication of the deviation of the habitat from the reference condition. In contrast to the assessment of driver conditions or the Index of Habitat Integrity (IHI) in a river section (Tables 6 and 7), fish habitat condition assessment is done for the site and modifications that have a direct influence on fish habitat at the site are considered.

**Table 34:** HRC's and SHI of the Dorp's River.

| **HCR's:** | Slow - Deep | Slow - Shallow | Fast - Deep | Fast - Shallow | Classification: |
|---|---|---|---|---|---|
| | | | | | Pools/Backwaters: Slow-<0.3m/s Shallow-<**0.5**m |
| Overhanging vegetation | 3 | 2 | 0 | 0 | Riffles/Runs/Rapids:Slow-<0.3m/s Shallow-<**0.3**m |
| Bank undercut root wads | 2 | 1 | 0 | 0 | Rating: |
| Substrate | 1 | 1 | 0 | 2 | **0**=Absent; **1**=Rare(<5%); **2**=Sparse(5-25%) |
| Macrophyte | 1 | 1 | 0 | 0 | **3**=Moderate(25-75%); **4**=Extensive(>75) |

| **SHI:** | **Score** | **Comments** | |
|---|---|---|---|
| Water abstraction: | 3 | Dam and irrigation | |
| Flow modification: | 3 | Dammed | RATINGS |
| Bed modification: | 2 | Erosion | 0 :None |
| Channel modification: | 2 | Erosion and scouring | 1: Small |
| Inundation: | 1 | Bridge | 2:Moderate |
| Exotic macrophytes: | 3 | Water hyacinth | 3:Large |
| Solid waste disposal: | 1 | Rubbish | 4:Serious |
| Indigenous vegetation removal: | 2 | Local wood collecting and construction disturbance | 5:Critical |
| Exotic vegetation encroachment | 3 | Riparian and aquatic | |
| Bank erosion: | 3 | Scouring | |

**Table 35:** HRC's and SHI of the Boschfontein Spruit.

| **HCR's:** | Slow - Deep | Slow - Shallow | Fast - Deep | Fast - Shallow | Classification: |
|---|---|---|---|---|---|
| | | | | | Pools/Backwaters: Slow-<0.3m/s Shallow-<**0.5**m |
| Overhanging vegetation | 3 | 1 | 0 | 0 | Riffles/Runs/Rapids: Slow-<0.3m/s Shallow-<**0.3**m |
| Bank undercut root wads | 2 | 1 | 0 | 0 | Rating: |
| Substrate | 1 | 1 | 0 | 1 | **0**=Absent; **1**=Rare(<5%); **2**=Sparse(5-25%) |
| Macrophyte | 2 | 2 | 0 | 0 | **3**=Moderate(25-75%); **4**=Extensive(>75) |

| **SHI:** | **Score** | **Comments** | |
|---|---|---|---|

| | | | |
|---|---|---|---|
| Water abstraction: | 2 | Irrigation | |
| Flow modification: | 3 | Dammed | RATINGS |
| Bed modification: | 2 | Erosion | 0 :None |
| Channel modification: | 2 | Erosion and scouring | 1: Small |
| Inundation: | 3 | Dam | 2:Moderate |
| Exotic macrophytes: | 1 | Water hyacinth | 3:Large |
| Solid waste disposal: | 1 | Rubbish | 4:Serious |
| Indigenous vegetation removal: | 4 | Local wood collecting and construction disturbance | 5:Critical |
| Exotic vegetation encroachment | 2 | Riparian and aquatic | |
| Bank erosion: | 3 | Scouring | |

According to Tables 34 and 35 the habitat integrity of the Dorp's River is mostly impacted by damming, exotic macrophytes and erosion, while the habitat integrity of the Boschfontein Spruit is impacted by damming, inundation, erosion and riparian vegetation removal.

**Fish sampling**

Sampling effort and results are reported per velocity-depth class sampled.

- **Fast-deep:** An electrical shocking apparatus, one operator and two dip net handlers are used in such habitat types. Capture results are recorded as number of fish caught per time unit (minutes).

- **Fast-shallow:** Capture results are recorded as number of fish caught per time unit (minutes) with an electrical shocker.

- **Slow-deep:** A large seine net can be used. A cast net, (diameter = 1.85 m, mesh size = 2.5 cm) can be used in pools. In this case, the river was flowing too fast for the use of the large seine method; however the cast net was used.

- **Slow-shallow:** A small seine net (5 m long, 1.5 m deep, mesh size = 1 mm) can be used to sample fish. An electrical shocking apparatus should preferably be used. Capture results are recorded as number of fish caught during each effort with a net, or the number of fish caught per time unit (minutes) with an electro-shocker. Both the electrical shocking apparatus and small seine net were used in this case.

**Table 36:** Habitats sampled and the sampling effort made per survey site.

HABITATS SAMPLED AND EFFORT

| SAMPLING EFFORT | SLOW DEEP | SLOW SHALLOW | FAST DEEP | FAST SHALLOW |
|---|---|---|---|---|
| Electro shocker (min) | 20 minutes | 15 minutes | | 10 minutes |
| Small seine (mesh size, length, depth, efforts) | 2 efforts | 2 efforts | | |
| Large seine (mesh size, length, depth, efforts) | | | | |
| Cast net (dimensions, efforts) | 10 casts | | | |
| Gill nets (mesh size, length, | | | | |

| | | | | |
|---|---|---|---|---|
| time) | | | | |

**Table 37:** Fish sampled during the survey (Dorp's River). The freshwater fish species scientific name, abbreviation and common name are summarized in Appendix 4.

| SPECIES SAMPLED | SLOW DEEP | SLOW SHALLOW | FAST DEEP | FAST SHALLOW |
|---|---|---|---|---|
| AMOS | | | | |
| BMAR | 1 | | | |
| BMAT | | | | |
| BPAU | | 1 | | |
| BUNI | | 1 | | 1 |
| CCAR | | | | |
| CFLA | | | | |
| CGAR | 1 | | | |
| LCYL | | | | |
| LMOL | | | | |
| MBRE | | | | |
| MSAL | | | | |
| OMOS | 1 | 2 | | |
| PPHI | 1 | 1 | | |
| | | | | |
| | | | | |
| | | | | |
| TSPA | 1 | | | |

**Table 38:** Fish sampled during the survey (Boschfontein Spruit). The freshwater fish species scientific name, abbreviation and common name are summarized in Appendix 4.

| SPECIES SAMPLED | SLOW DEEP | SLOW SHALLOW | FAST DEEP | FAST SHALLOW |
|---|---|---|---|---|
| AMOS | | | | |
| BMAR | | | | 1 |
| BMAT | | | | |
| BPAU | 1 | 1 | | |
| BUNI | | | | |
| CCAR | | | | |
| CFLA | | 1 | | |
| CGAR | 4 | 2 | | |
| LCYL | | | | |
| LMOL | | | | |
| MBRE | | | | |
| MSAL | | | | |
| OMOS | 3 | 1 | | |
| PPHI | | 1 | | |
| TSPA | 1 | | | |

**Table 39:** A comparison between the reference frequency of occurrence and the present frequency of occurrence in the Hex River.

| SCIENTIFIC NAMES: REFERENCE SPECIES (INTRODUCED SPECIES EXCLUDED) | REFERENCE FREQUENCY OF OCCURRENCE CATEGORY A | FREQUENCY OF OCCURRENCE: EC D 47.5% |
|---|---|---|
| **ANGUILLA MOSSAMBICA PETERS 1852** | 2 | 0 |
| **LABEOBARBUS MAREQUENSIS SMITH, 1841** | 5 | 3 |
| **BARBUS MATTOZI GUIMARAES, 1884** | 3 | 1 |
| **BARBUS TRIMACULATUS PETERS, 1852** | 4 | 2 |
| **BARBUS UNITAENIATUS GÜNTHER, 1866** | 4 | 3 |
| **CHETIA FLAVIVENTRIS TREWAVAS, 1961** | 5 | 2 |
| **CLARIAS GARIEPINUS (BURCHELL, 1822)** | 5 | 4 |
| **LABEO CYLINDRICUS PETERS, 1852** | 3 | 1 |
| **LABEO MOLYBDINUS DU PLESSIS, 1963** | 4 | 1 |
| **MESOBOLA BREVIANALIS (BOULENGER, 1908)** | 3 | 1 |
| **OREOCHROMIS MOSSAMBICUS (PETERS, 1852)** | 4 | 3 |
| **PSEUDOCRENILABRUS PHILANDER (WEBER, 1897)** | 5 | 4 |
| **TILAPIA SPARRMANII SMITH, 1840** | 5 | 3 |
| **BARBUS PALUDINOSUS PETERS, 1852** | 4 | 2 |

Table 39 lists the frequency fish expected to occur in the system historically, as well as present day. The EC for fish in the Hex River is equivalent to a D (47.5%), which is regarded as “Largely modified”.

### Collate and analyse fish sampling data per site

All the information collected during the survey are then collated in the tables of the FRAI model and analyzed throughout the database spreadsheets. The FRAI model calculates the ranks, weights and ratings to eventually provide an Ecological Class for the two river sites with surface flows.

## EXECUTE THE FRAI MODEL

The FRAI model makes use of the fish intolerance and preference database that was compiled in 2001 (Kleynhans 2003). This information was built into the FRAI. The approach followed included the ranking, weighting and rating of metric groups. A large component of the FRAI is based on an automated calculation of ranks, weights and ratings.

### Dorp’s River:

Table 40 indicates the weights of the different metric groups on the Dorp’s River. According to this, the physico-chemical metric group carries the most weight followed by the velocity-depth and flow modification groups. The last two have a strong link with flow, and this also have an influence on the physico-chemical metric. At least two introduced fish species are present.

**Table 40**: The weight allocated to the different metric groups in the model.

| WEIGHT OF METRIC GROUPS | |
|---|---|
| **METRIC GROUP** | **WEIGHT (%)** |
| **VELOCITY-DEPTH** | **96.88** |
| **COVER** | **84.38** |
| **FLOW MODIFICATION** | **96.88** |
| **PHYSICO-CHEMICAL** | **100.00** |
| **MIGRATION** | **40.63** |
| **IMPACT OF INTRODUCED** | **43.75** |

The relative FRAI score of this stretch of the river falls within the limits of an ecological state category Class E (33.3%) (Table 41), which means this reach is "Seriously modified." (Table 43). The Class ratings are explained in Table 43.

**Table 41:** The final score as calculated by the FRAI model for the Dorp's River.

| **ADJUSTED** | |
|---|---|
| **FRAI (%)** | **33.3%** |
| **EC: FRAI** | **E** |

| Abbreviations: reference species (introduced species excluded) | Scientific names: reference species (introduced species excluded) | Reference frequency of occurrence | EC:observed & habitat derived frequency of occurrence |
|---|---|---|---|
| AMOS | *Anguilla mossambica* | 2.00 | 0.00 |
| BMAR | *Labeobarbus marequensis* | 5.00 | 2.00 |
| BMAT | *Barbus mattozi* | 3.00 | 1.00 |
| BTRI | *Barbus trimaculatus* | 4.00 | 2.00 |
| BUNI | *Barbus unitaeniatus* | 4.00 | 2.00 |
| CFLA | *Chetia flaviventris* | 5.00 | 2.00 |
| CGAR | *Clarias gariepinus* | 5.00 | 4.00 |
| LCYL | *Labeo cylindricus* | 3.00 | 0.00 |
| LMOL | *Labeo molybdinus* | 4.00 | 0.00 |
| MBRE | *Mesobola brevianalis* | 3.00 | 0.00 |
| OMOS | *Oreochromis mossambicus* | 4.00 | 2.00 |
| PPHI | *Pseudocrenilabrus philander* | 5.00 | 3.00 |
| TSPA | *Tilapia sparrmanii* | 5.00 | 3.00 |
| BPAU | *Barbus paludinosus* | 4.00 | 2.00 |

**Boschfontein Spruit:**

The weights of the different metric groups at the Boschfontein Spruit and Dorp's River sites Table 40 are the same, indicating the similarity of the ecosystem drivers. The relative FRAI score of this stretch of the river also falls within the limits of an ecological state category Class E (35.7%) (Table 42), which means this reach is "Seriously modified." (Table 43). The Class ratings are explained in Table 43.

Due to the lack of surface water in the ephemeral drainage lines of two of the crossing sites, Crossing 3 Kanana Drainage line and Crossing 4 Tierkop Spruit, no freshwater fish are expected to occur here for most of the year. During heavy downpours in the rainy season, these ephemeral drainage lines might start to flow, however the presence of surface water is

of such a temporary nature that fish do not get the opportunity to colonize the short-lived streams.

**Table 42:** The final score as calculated by the FRAI model for the Boschfontein Spruit.

| ADJUSTED | |
|---|---|
| **FRAI (%)** | **35.7%** |
| **EC: FRAI** | **E** |

| Abbreviations: reference species (introduced species excluded) | Scientific names: reference species (introduced species excluded) | Reference frequency of occurrence | EC:observed & habitat derived frequency of occurrence |
|---|---|---|---|
| AMOS | *Anguilla mossambica* | 2.00 | 0.00 |
| BMAR | *Labeobarbus marequensis* | 5.00 | 2.00 |
| BMAT | *Barbus mattozi* | 3.00 | 1.00 |
| BTRI | *Barbus trimaculatus* | 4.00 | 2.00 |
| BUNI | *Barbus unitaeniatus* | 4.00 | 2.00 |
| CFLA | *Chetia flaviventris* | 5.00 | 2.00 |
| CGAR | *Clarias gariepinus* | 5.00 | 4.00 |
| LCYL | *Labeo cylindricus* | 3.00 | 0.00 |
| LMOL | *Labeo molybdinus* | 4.00 | 0.00 |
| MBRE | *Mesobola brevianalis* | 3.00 | 1.00 |
| OMOS | *Oreochromis mossambicus* | 4.00 | 3.00 |
| PPHI | *Pseudocrenilabrus philander* | 5.00 | 3.00 |
| TSPA | *Tilapia sparrmanii* | 5.00 | 3.00 |
| BPAU | *Barbus paludinosus* | 4.00 | 2.00 |

**Table 43:** Ratings for the fish integrity classes

| | FRAI ASSESSMENT CLASSES | |
|---|---|---|
| Class rating | Description of generally expected conditions for integrity classes | Relative FRAI score (% of expected) |
| A | Unmodified, or approximate natural conditions closely | 90 to 100 |
| B | Largely natural with few modifications. A change in community characteristics may have taken place but species richness and presence of intolerant species indicate little modification. | 80 to 89 |
| C | Moderately modified. A lower than expected species richness and presence of most intolerant species. Some impairment of health may be evident at lower limits of this class. | 60 to 79 |
| D | Largely modified. A clearly lower than expected species richness and absence or much lowered presence of intolerant and moderate intolerant species. Impairment of health may become more evident at the lower limit of this class. | 40 to 59 |
| E | Seriously modified. A strikingly lower than expected species richness and general absence of intolerant and moderately intolerant species. Impairment of health may become very evident. | 20 to 39 |
| F | Critically modified. An extremely lowered species richness and an absence of intolerant and moderately intolerant species. Only tolerant species may be present with a loss of species at the lower limit of the class. Impairment of health generally very evident. | 0 to 19 |

**Task 1.2.4 Describe the ecological importance and sensitivity (EIS) as well as the Socio-cultural Importance (SI) of the affected reach/es of the watercourse including the functions.**

**Socio-cultural Importance:** The Hex River is situated near the town of Rustenburg North West Province and is the main regional arterial drainage for the area. It is a source of water supply for many in the region. It flows in a northerly direction and conveys water to the Bospoort Dam east of Rustenburg.

THE city with SA's most positive growth story is Rustenburg in the North West, which in recent years has outstripped the growth of all other urban centres.

North of the Magaliesberg the geology is largely dominated by the Bushveld Igneous Complex. Formations in this complex are extremely rich in minerals and a number of mines have been developed in the area as a result. Platinum, chrome and vanadium mining in particular, are taking place at a large scale.

A regional analysis of gross domestic product (GDP) growth shows that Rustenburg - the belt where the richest platinum deposits are located - grew at 3.9% during 2010. National GDP growth for the same period was 2.8%.

The success of Rustenburg's growth is further underlined by the relative changes in poverty levels in the cities. While the number of people living in poverty in Rustenburg declined marginally, in many other cities it increased significantly.

**Ecological importance** refers to the diversity, rarity or uniqueness of the habitats and biota. Consequently, it reflects the importance of protecting these ecological attributes, from a local, national and even international perspective. **Ecological sensitivity** refers to the ability of the ecosystem to tolerate disturbances and to recover from certain impacts. Therefore, the more sensitive the system is, the lower its tolerance will be to various forms of alteration and disturbance. This serves as a valuable indication of the degree to which a water resource (river, wetland) can be utilized without putting its ecological sustainability at risk.

The EIS/PES data is used in the eco-classification process of DWA (key process in the determination of the Reserve) to determine ecological sensitivity of a river reach as well as the present ecological state of such a river reach. From this an indication is provided whether the river reach is in a health category that is commensurate with its ecological importance and sensitivity. This relates to the determination of the eco-status of the river which refers to its overall condition or health and is based on its biophysical characteristics.

The PESEIS data from the Department of Water and Sanitation Desktop PESEIS assessment (DWA&S, 2014), supplies most of the current status information of the relevant sub-quaternary river reaches (SQRs) for South Africa. The objective of the PESEIS is to provide desktop level information on ecological issues as it relates to the protection and management of SQRs. For management purposes this refers specifically to the consideration of ecological reserve issues, water use licensing issues and EWRM (including the National Aquatic Ecosystem Health Monitoring Programme (NAEHMP) activities) and the determination of priorities for monitoring.

**Table 44:** A summary of the Ecological Importance of the Hex River obtained from the DWA&S PES-EIS model (DWA&S, 2014).

| ECOLOGICAL IMPORTANCE | | | |
|---|---|---|---|
| **FISH SPP/SQ** | 12.00 | **INVERT TAXA/SQ** | 39.00 |
| **FISH: AVERAGE CONFIDENCE** | 4.50 | **INVERT AVERAGE CONFIDENCE** | 4.79 |
| **FISH REPRESENTIVITY PER SECONDARY: CLASS** | MODERATE | **INVERT REPRESENTIVITY PER SECONDARY, CLASS** | HIGH |
| **FISH REPRESENTIVITY PER SECONDARY: CLASS** | MODERATE | **INVERT RARITY PER SECONDARY: CLASS** | VERY HIGH |
| **FISH RARITY PER SECONDARY: CLASS** | HIGH | **ECOLOGICAL IMPORTANCE: RIPARIAN-WETLAND-INSTREAM VERTEBRATES (EX FISH) RATING** | HIGH |
| **ECOLOGICAL IMPORTANCE: RIPARIAN-WETLAND-INSTREAM VERTEBRATES (EX FISH) RATING** | HIGH | **HABITAT DIVERSITY CLASS** | VERY LOW |
| **RIPARIAN-WETLAND NATURAL VEG RATING BASED ON % NATURAL VEG IN 500m (100%=5)** | HIGH | **HABITAT SIZE (LENGTH) CLASS** | VERY HIGH |
| **RIPARIAN-WETLAND NATURAL VEG IMPORTANCE BASED ON EXPERT RATING** | LOW | **INSTREAM MIGRATION LINK CLASS** | LOW |
| | | **RIPARIAN-WETLAND ZONE MIGRATION LINK** | LOW |
| | | **RIPARIAN-WETLAND ZONE HABITAT INTEGRITY CLASS** | MODERATE |
| | | **INSTREAM HABITAT INTEGRITY CLASS** | LOW |

**The Ecological Importance and Sensitivity (EI&S)** for the Hex River is **Riparian-wetland zone habitat integrity class** = "Moderate" and **In-stream habitat integrity class =** "Low" (Table 44). The diversity of habitat and species is low with some localised refugia for slightly sensitive species and protected natural area in the form of a conservancy around Bospoort Dam. The summary of the Ecological Sensitivity of the Hex River obtained from the DWA&S PES-EIS model is listed in Table 45, while Appendix 5 adds information to the PES-EIS model.

**Table 45:** The summary of the Ecological Sensitivity of the Hex River obtained from the DWA&S PES-EIS model (DWA&S 2014).

| ECOLOGICAL SENSITIVITY | |
|---|---|
| **FISH PHYS-CHEM SENS DESCRIPTION** | HIGH |
| **FISH NO-FLOW SENSITIVITY DESCRIPTION** | HIGH |
| **INVERT PHYS-CHEM SENS DESCRIPTION** | HIGH |
| **INVERTS VELOCITY SENSITIVITY** | VERY HIGH |
| **RIPARIAN-WETLAND-INSTREAM VERTEBRATES (EX FISH) INTOLERANCE WATER LEVEL/FLOW CHANGES DESCRIPTION** | HIGH |
| **STREAM SIZE SENSITIVITY TO MODIFIED FLOW/WATER LEVEL CHANGES DESCRIPTION** | LOW |
| **RIPARIAN-WETLAND VEG INTOLERANCE TO WATER LEVEL CHANGES DESCRIPTION** | **LOW** |

Extensive mining activities occur north and east of Rustenburg - mainly in a circular belt around the perimeter of the Bushveld Igneous Complex. These mines are mainly focused on the platina group of metals which are in great demand on the world market at the moment, as well as granite mining. Rustenburg is considered one of the fastest growing cities in Africa because of the platinum mining operations.

To the east and north of the project area occur a number of mines that extract platinum, chrome and granite reserves. The eastern portion of the project area also includes large portions of agricultural land that are cultivated for maize, tobacco, sunflower and citrus produce. The land is also increasingly be used for both formal and informal residence. There is also a significant ecotourism use of the area.

The ecological Importance and Sensitivity Category of the Bospoort Dam can be classified as moderate.

Since the Hex River is the main stem in this catchment, it was evaluated according to the available information, and with that as guideline, the River Crossing Sites on the tributaries will be evaluated.

**Table 46:** A summary for the **River Crossing Sites** compiled from the PES/EIS model and using a regional approach to the four systems involved (Dorps River, Boschfontein Spruit, Kanana Drainage line and Tierkop Spruit).

| **Main stem** | **River Crossing Sites** | **Score and motivation.** |
|---|---|---|
| Aquatic/in-stream biota: rare and endangered | None | 0 |
| Riparian/wetland biota: rare and endangered | Half-collared Kingfisher (*Alcedo semitorquata*) - SA Red Data (Barnes 2000): Near-threatened.<br>Yellow-billed stork (*Mycteria ibis*) SA Red Data (Barnes 2000): Near-threatened.<br>Black stork (*Ciconia nigra*) SA Red Data (Barnes 2000): Near-threatened. | 3 |
| Aquatic/instream biota: unique | None | 0 |
| Riparian/wetland biota: unique | None | 0 |
| Aquatic/instream biota: intolerant no flow | 2 spp of rheophillics | 3 |
| Aquatic/instream biota: intolerant physico-chemical changes | *Labeobarbus marequensis* | 1 |
| Riparian/wetland biota: intolerant | None | 0 |
| Aquatic/instream biota: species/ taxon richness | Approximately 10 fish and 15 macro-invertebrate species present | 1 |
| Riparian/wetland biota: species/ taxon richness | 2 riparian indicator tree species present) | 1 |
| In-stream habitat: diversity of types and features | Mostly slow flowing habitats: backwaters and pools. Overhanging vegatation. | 3 |
| Riparian/wetland habitat: diversity of types and features | Some riparian corridors – not connected | 1 |
| In-stream habitat: refugia and critical | Very little - deep pools. | 1 |
| Riparian/wetland habitat: refugia and critical | None | 0 |
| In-stream habitat: sensitivity to flow changes | Very few stones-in-current habitats. | 1 |
| Riparian wetland habitat: sensitivity to flow changes | Not any more | 0 |
| In-stream: migration route | Fragmented by dams and weirs | 1 |
| Riparian: migration corridor | Some riparian corridors – not connected | 1 |
| Nat parks, wilderness areas, reserves, heritage sites, natural areas | Conservancy around Bospoort Dam | 1 |

**Table 47:** The final EIS scores and overall EIS category for the River Crossing Sites combined.

| Categories | **River Crossing Sites** |
|---|---|
| Median in-stream biota rating | 1.0 |
| Max in-stream biota rating median | 3.0 |
| Median rating: riparian/wetland biota | 1.0 |
| Max rating: riparian/wetland biota | 3.0 |
| Median rating: in-stream habitat | 1.6 |
| Max rating: in-stream habitat | 3.0 |
| Median rating: riparian/wetland habitat | 0.3 |
| Max rating: riparian/wetland habitat | 1.0 |
| In-stream biota flow sensitivity | 1.0 |
| In-stream biota physico-chemical sensitivity | 3.0 |
| Protected and natural areas | 1.0 |
| Biota EIS | 1.0 |

| | |
|---|---|
| Habitat EIS | 1.3 |
| Overall EIS rating | 1.1 |
| Overall EIS category | VERY LOW |

According to the EIS model, the overall EIS rating is 1.1 and thus the overall EIS category is considered to be “VERY LOW”. Thus, the Ecological importance of these river crossings presents low integrity regarding diversity, rarity or uniqueness of the habitats and biota.

**Task 1.2.5 Discuss existing land and water use impacts (and threats) on the characteristics of the watercourse.**

The PESEIS data from the Department of Water and Sanitation Desktop PESEIS assessment (DWA&S, 2014), supplies most of the current information, however, making use of the PESEIS templates the author assessed the current situation in the Hex River and its tributaries (Table 48).

**Table 48:** The current identified impacts on the Hex River and the severity thereof on the system.

| SQ | SQ NAME | MAINSTEM IN QUAT |
|---|---|---|
| **A22J-0878** | **Hex** | **A22J-0878** |
| **METRIC** | **IMPACT/SEVERITY** | **RATINGS** |
| Abstraction, | Serious | 4 |
| Agricultural fields, | Small | 1 |
| Algal growth, | Moderate | 2 |
| Bed and Channel disturbance, | Large | 3 |
| Canalization, | None | 0 |
| Chicken farms, | None | 0 |
| Low water crossings, | Moderate | 2 |
| Large dams, | Moderate | 2 |
| Small (farm) dams, | Large | 3 |
| Erosion, | Moderate | 2 |
| Alien aquatic macrophytes, | Moderate | 2 |
| Alien vegetation, | Moderate | 2 |
| Feedlots, | None | 0 |
| Forestry, | None | 0 |
| Overgrazing/trampling, | Large | 3 |
| Inundation, | Serious | 4 |
| Industries, | None | 0 |
| Inter-basin transfers, | None | 0 |
| Increased flows, | None | 0 |
| Irrigation, | None | 0 |
| Mining, | Serious | 4 |
| Natural areas/nature reserves, | None | 0 |
| Recreation, | Small | 1 |
| Roads, | Large | 3 |
| Runoff/effluent: Industries, | None | 0 |
| Runoff/effluent: Irrigation, | None | 0 |

| | | |
|---|---|---|
| Runoff/effluent: Mining, | Serious | 4 |
| Runoff/effluent: Urban areas, | Large | 3 |
| Sedimentation, | Large | 3 |
| Grazing (land-use), | Small | 1 |
| Urbanization, | Large | 3 |
| Vegetation removal, | Moderate | 2 |

**Table 49:** Explanation of the ratings used to grade the PES levels.

| **Rating** |
|---|
| In a SQ: the taxon with the highest rating (even if it uncommon), will represent the rating for this metric.<br><br>BLANK = NOT ASSESSED<br><br>0=Not sensitive<br>1= Low: Only taxa with a low sensitivity to water level or flow. Suitable level or flow will benefit taxa but they do not have a crucial dependance on this.<br>3= Moderate: Taxa with a moderate sensitivity. Appropriate water level or flow is beneficial during certain life-history stages to maintain viable populations.<br>5=High: Taxa with a high sensitivity to water level or flow changes. Appropriate water level or flow is necessary during certain life-history stages to maintain viable populations. |

**Table 50:** The PES metric ratings regarding the Hex River.

| METRIC | RATING | CONFIDENCE |
|---|---|---|
| **In-stream habitat continuity module** | SERIOUS | 5.0 |
| **Rip/wetland zone continuity module** | SERIOUS | 4.0 |
| **Potential in-stream habitat module activities** | SERIOUS | 5.0 |
| **Riparian-wetland zone module** | LARGE | 4.0 |
| **Potential flow module activities** | SERIOUS | 3.0 |
| **Potential physico-chemical module activities** | SERIOUS | 3.0 |
| **PES overall comment** | The following impacts/activities were identified: CRITICAL: None, SERIOUS: Abstraction, Inundation, Mining, Runoff/effluent: Mining, LARGE: Bed and Channel disturbance, Small (farm) dams, Overgrazing/trampling, Roads, Runoff/effluent: Urban areas, Sedimentation, Urbanization, MODERATE: Algal growth, Low water crossings, Large dams, Erosion, Alien aquatic macrophytes, Alien vegetation, Vegetation removal, SMALL: Agricultural fields, Recreation, Grazing (land-use), | |

**Table 51:** The PES metric ratings and PES categories of the Hex River.

| | PES MEDIAN OF ALL METRICS | PES CATEGORY BASED ON MEDIAN OF METRICS | OVERALL AVERAGE CONFIDENCE |
|---|---|---|---|
| In-stream metrics | **4.0** | **E** | **4.3** |
| Riparian metrics | **4.0** | **E** | **4.5** |

**Table 52:** The final PES category description of the Hex River.

| | |
|---|---|
| **SQ REACH** | A22J-00878 |
| **SQR NAME** | Hex |
| **PES CATEGORY BASED ON MEDIAN OF METRICS** | E |
| **PES CATEGORY DESCRIPTION** | SERIOUS MODIFICATION |

With a PES category description of “Serious Modification”, it is clear that the Hex River catchment is under pressure due to development and utilization. These PES ratings will also reflect in most of the tributaries of the Hex River, especially the lower sections that flows into the main stem.

The project sites at the pipeline crossings, will be evaluated in a similar way in order to establish their Present Ecological Status. This will be discussed in the final chapter (4. Discussion - Present Ecological State).

**Task 1.2.6 List and map sensitive environments in proximity of the project locality-sensitive environments include wetlands, nature reserves, protected areas, etc.**

To establish how important the site is for meeting biodiversity targets, the Land-Use Decision Support Tool (LUDS) was used to compile the LUDS Report (BGIS, 2016). LUDS was developed to facilitate and support biodiversity planning and land-use decision-making at a national and provincial level. Its primary objective is to serve as a guide for biodiversity planning but should not replace specialist ecological assessments.

The key results of the LUDS Report are summarized in Table 53. The information is extracted for the area from national datasets available on Biodiversity Geographic Information System (BGIS). The boundaries for the area (Figure No figure number inserted) was analysed.

**Table 53:** The keys results of the LUDS Report as extracted for the area of interest from national datasets available from BGIS.

| National Data Set | Aspect | Presence |
|---|---|---|
| National terrestrial information: | | |
| National Vegetation Types | Marikana Thornveld (SVcb6) Savanna Biome | Present - Vulnerable |
| Indigenous forest patches | Forest patches | 0 |
| National soil classes | Swelling clay soils | S5 |
| National aquatic information: | | |
| Wetlands (NFEPA) | Central Bushveld Group - Artificial No status | 3 units present |

| | | |
|---|---|---|
| Wetland clusters | Wetland cluster | 0 |
| NFEPA wetlands condition information codes = Z# | Percentage natural land cover < 25% | 20% of total wetland area |
| Sub-quarternary catchments and rivers (NFEPA) | Sub-quarternary catchments – NFEPA ID 878 | 1 |
| NFEPA river units | | 0 |
| National protected area information: North-West Province | Formal protected areas | 0 |
| | Informal protected areas | Conservancy - Bospoort Dam. |
| | NPAES focus areas | 0 |
| Ecosystem status of SA veg type (CR&EN=CBA1 VU=CBA2) | Yes | Vulnerable - Marikana Thornveld |
| Hills and ridges (CBA2) | Yes | 1 |
| Biodiversity corridors | Biodiversity corridor units | 0 |
| Aquatic Information: North-West Province | Critical Biodiversity Area (CBA) and Ecological Support Area (ESA) | 0 |

Although the project area is situated in a vegetation type that is classified as “Ecosystem Status - Vulnerable”, is situated in a built-up area along a national highway where very little natural habitat remains intact (Figures 32). The Hex River does not feature as a NFEPA river and the Bospoort Dam is classified as “Artificial”.

**Conservation value of the project area**

Using the classification of vegetation types based on % of natural habitat remaining, the Biodiversity Act provides for listing threatened and protected ecosystems into the following categories:

- ‘Critically endangered’ ecosystems – that have undergone severe ecological degradation and are at an extremely high risk of irreversible transformation;

- ‘Endangered’, or ‘vulnerable’ ecosystems – being categories of reduced degradation and risk, each less than the previous category above;

- ‘Protected’ ecosystems – being ecosystems that are not threatened but nevertheless are worthy of special protection.

According to the LUDS Report (BGIS, 2016) areas directly around the river crossings are in a built-up area along a national highway where very little natural habitat remains intact (Figure 32). This area is known as a production landscape and should be managed to optimise sustainable utilization of natural resources. Further away from the highway the vegetation type is classified as “Ecosystem Status - Vulnerable”, but will not be affected by the project. The wetland value of the river crossings is not featuring as NFEPA entities, indicating that the aquatic habitat in this area is not considered as very important (Figure 32). The only protected area in the project vicinity is in the form of a conservancy around the Bospoort Dam.

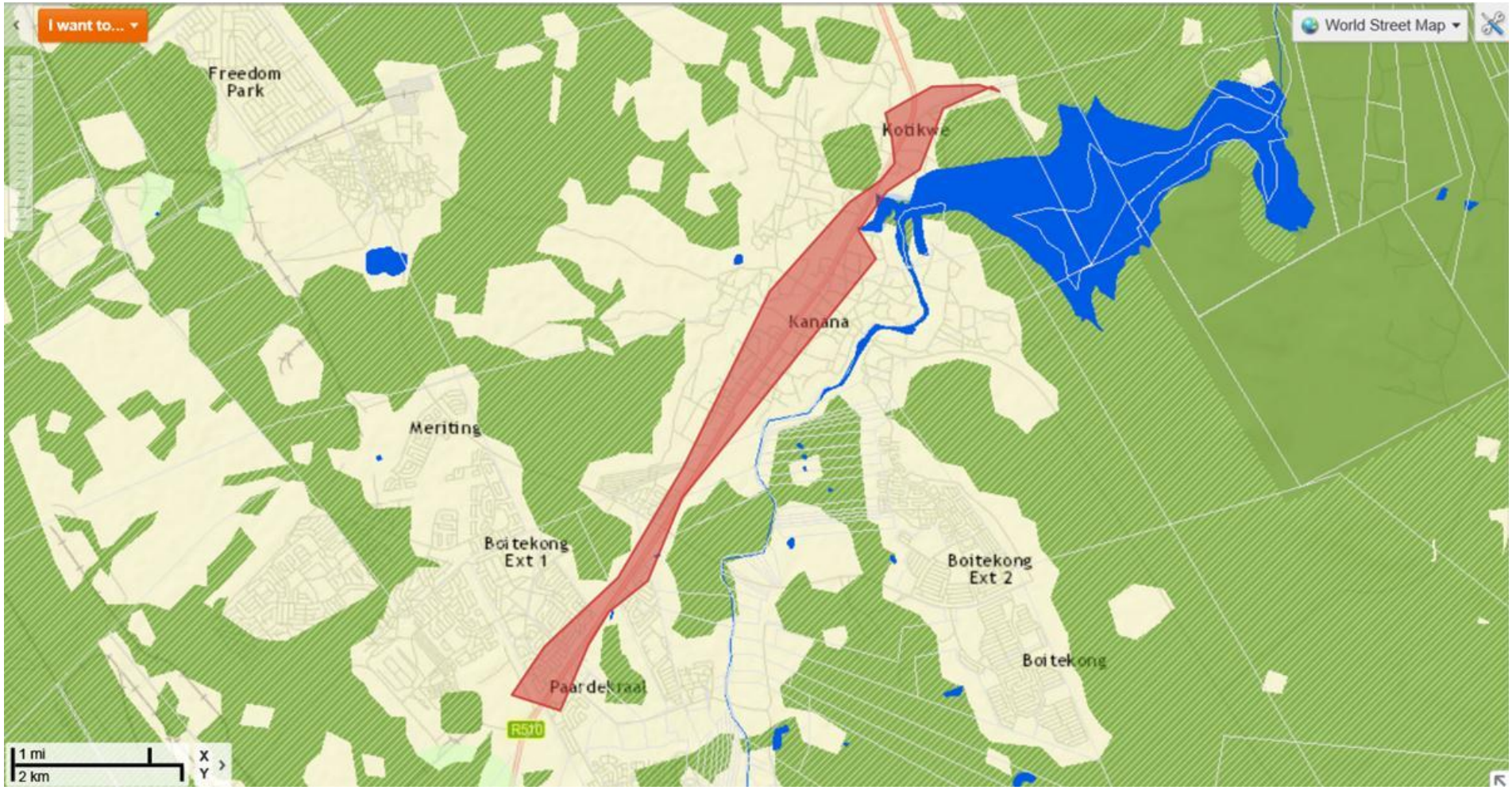


**Figure 32:** The project area (shaded red) is situated in a vegetation type that is classified as “Ecosystem Status - Vulnerable” (shaded green) is situated in a built-up area (shaded white).

## 4. Discussion - Present Ecological State or PES

### EcoClassification

EcoClassification - the term used for the Ecological Classification process - refers to the determination and categorisation of the Present Ecological State (PES; health or integrity) of various biophysical attributes of rivers relative to the natural or close to the natural reference condition. The purpose of the EcoClassification process is to gain insights and understanding into the causes and sources of the deviation of the PES of biophysical attributes from the reference condition. This provides the information needed to derive desirable and attainable future ecological management objectives for the river. The steps followed in the EcoClassification process are as follows:

- Determine reference conditions for each component.
- Determine the Present Ecological State for each component as well as for the EcoStatus. The EcoStatus refers to the integration of physical changes by the biota and as reflected by biological responses.
- Determine the trend (i.e. moving towards or away from the reference condition) for each component as well as for the EcoStatus.
- Determine causes for the PES and whether these are flow or non-flow related.
- Determine the Ecological Importance and Sensitivity (EIS) of the biota and habitat.

### Background information on the Hex River Catchment

In the Hex River, flows are largely managed on demand for anthropological purposes. This results in un-seasonally high pulses of flow in the river and extended periods of low flow. The managed flow regime, when combined with the large numbers of dams and weirs, has resulted in river habitats becoming severely fragmented with what were largely perennial rivers now being distinctly seasonal in nature.

Due to the location and the associated industrial development, mining activities and urbanization (formal and informal) taking place in the catchment, the water quality of the Hex River and its tributaries has progressively deteriorated. The physical and chemical constituent concentrations recorded in the Hex River and its associated tributaries decreased during peak rainfall in the summer months. Higher constituent concentrations were recorded during the dry winter months (Du Plessis, 2006).

According to the River Health Programme the overall EcoStatus for the Lower Hex River during 2005 was “Poor” (RHP, 2005):

The ***Instream Habitat Integrity*** was “Poor”, primarily because of high levels of development especially in terms of mining activities as well as water abstraction for irrigation purposes. There are a number of weirs that comprise the irrigation scheme but their use is limited. Stretches of the river have been diverted for the mines but more recently for the upgrade of the N4 Platinum Toll Highway.

The ***Fish Assemblage Integrity*** was “Poor” - sensitive species are lost due to flow modifications and obstructions. Water quality problems originating from the mines and from agriculture have created stress conditions for fish species.

The ***Macro-invertebrate Integrity*** was “Poor”, the cumulative impacts of reduced water quality and, flow and habitat modifications have had a large effect on invertebrate diversity and abundance.

## Present Ecological State (PES)

The PES of the river is expressed in terms of various components. That is, **drivers** (physico-chemical, geomorphology, hydrology) and **biological responses** (fish, riparian vegetation and aquatic invertebrates), as well as an integrated state, the EcoStatus.

Table 54 summarizes the results from the excel sheet containing the PES model. The information is assembled from a number of known parameters, expert knowledge and other models (fish, macro-invertebrates and vegetation).

**Table 54:** The summary of the Present Ecological State (PES) of the Hex River obtained from the DWA&S PES-EIS model (DWA&S 2014).

| PRESENT ECOLOGICAL STATE | |
|---|---|
| **INSTREAM HABITAT CONTINUITY MOD** | SERIOUS |
| **RIP/WETLAND ZONE CONTINUITY MOD** | SERIOUS |
| **POTENTIAL INSTREAM HABITAT MOD ACT.** | SERIOUS |
| **RIPARIAN-WETLAND ZONE MOD** | LARGE |
| **POTENTIAL FLOW MOD ACT.** | SERIOUS |
| **POTENTIAL PHYSICO-CHEMICAL MOD ACTIVITIES** | SERIOUS |

Interpretation of Impact Ratings:

Ratings are essentially an 'average' or summary of the situation along the length of the SQ, e.g. sections may be better or worse.

None. Reference. No discernible impact or the modification is located in such a way that it has no impact on habitat quality, diversity, size and variability. Rating = 0

Small. The modification is limited to very few localities and the impact on habitat quality, diversity, size and variability are also very small. Rating = 1

Moderate. The modifications are present at a small number of localities and the impact on habitat quality, diversity, size and variability are also limited. Rating = 2

Large. The modification is generally present with a clearly detrimental impact on habitat quality, diversity, size and variability. Large areas are, however, not influenced. Rating= 3

Serious. The modification is frequently present and the habitat quality, diversity, size and variability in almost the whole of the defined area are affected. Only small areas are not influenced. Rating = 4

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 influenced detrimentally. Rating = 5

## Ecological Category (EC)

c) **EcoStatus Definition: "totality of the features and characteristics of the river and its riparian areas that bear upon its ability to support an appropriate natural flora and fauna and its capacity to provide a variety of goods and services". This ability relates directly to the capacity of the system to provide a variety of goods and services.**

The driver components are assessed separately (i.e. an EC for each driver) and not integrated at a driver level to provide a driver-based indication of the EcoStatus. However, the individual metrics of all the driver components are assessed in a combined fashion that allows some comparison between metrics of all drivers. This facilitates deriving the cause-and-effect relationship that is required in the interpretation and assessment of particular biological responses.

The biological responses are assessed separately, but the resulting fish and macro-

invertebrate ECs are integrated to provide an indication of the in-stream EC (Table 55 & 56). Logically, the integration of the riparian vegetation EC and the in-stream EC would provide the EcoStatus. The influence of the riparian vegetation on the in-stream habitat is used to interpret the biological responses and endpoints. This means that in some cases, the integrated in-stream biological responses are deemed to provide a reasonable indication of the EcoStatus.

**d) Table 55: The Ecostatus and Ecoclassification of the river at the Dorp's River crossing site.**

| INSTREAM BIOTA | Importance Score | Weight | EC % | EC |
|---|---|---|---|---|
| **FISH** | | | | |
| 1.What is the natural diversity of **fish** species with different flow requirements | 2 | 95 | | |
| 2.What is the natural diversity of **fish** species with a preference for different cover types | 4 | 70 | | |
| 3.What is the natural diversity of **fish** species with a preference for different flow depth classes | 3 | 80 | | |
| 4. What is the natural diversity of **fish** species with various tolerances to modified water quality | 1 | 100 | | |
| **FISH ECOLOGICAL CATEGORY** | 10 | 345 | **33.3** | **E** |
| **AQUATIC INVERTEBRATES** | | | | |
| 1. What is the natural diversity of **invertebrate** biotopes | 1 | 100 | | |
| 2. What is the natural diversity of **invertebrate** taxa with different velocity requirements | 3 | 90 | | |
| 3. What is the natural diversity of **invertebrate** taxa with different tolerances to modified water quality | 2 | 95 | | |
| **AQUATIC INVERTEBRATE ECOLOGICAL CATEGORY** | **6** | 285 | **34.0** | **E** |
| **INSTREAM ECOLOGICAL CATEGORY (No confidence)** | | 630 | **33.7** | **E** |

| INSTREAM ECOLOGICAL CATEGORY WITH CONFIDENCE | Confidence rating | Proportions | Modified weights |
|---|---|---|---|
| Confidence rating for **fish** information | 4 | 0.50 | 16.65 |

| | | | |
|---|---|---|---|
| Confidence rating for **macro-invertebrate** information | 4 | 0.50 | 17.00 |
| | 8 | 1.00 | 33.65 |
| **INSTREAM ECOLOGICAL CATEOGORY** | **EC** | | **E** |

| RIPARIAN VEGETATION | EC % | EC |
|---|---|---|
| **RIPARIAN VEGETATION ECOLOGICAL CATEGORY** | **56.2** | **D** |

| ECOSTATUS | Confidence rating | Proportions | Modified weights |
|---|---|---|---|
| Confidence rating for instream biological information | 4 | 0.50 | 16.83 |
| Confidence rating for riparian vegetation zone information | 4 | 0.50 | 28.10 |
| | 8 | 1.00 | 44.93 |
| **ECOSTATUS** | **EC** | | **D** |

**e) Table 56: The Ecostatus and Ecoclassification of the river at the Dorp's River crossing site.**

| INSTREAM BIOTA | Importance Score | Weight | EC % | EC |
|---|---|---|---|---|
| **FISH** | | | | |
| 1.What is the natural diversity of **fish** species with different flow requirements | 2 | 95 | | |
| 2.What is the natural diversity of **fish** species with a preference for different cover types | 4 | 70 | | |
| 3.What is the natural diversity of **fish** species with a preference for different flow depth classes | 3 | 80 | | |
| 4. What is the natural diversity of **fish** species with various tolerances to modified water quality | 1 | 100 | | |
| **FISH ECOLOGICAL CATEGORY** | 10 | 345 | **35.7** | **E** |
| **AQUATIC INVERTEBRATES** | | | | |
| 1. What is the natural diversity of **invertebrate** biotopes | 1 | 100 | | |
| 2. What is the natural diversity of **invertebrate** taxa with different velocity requirements | 3 | 90 | | |
| 3. What is the natural diversity of **invertebrate** taxa with different tolerances to modified water quality | 2 | 95 | | |

| | | | | |
|---|---|---|---|---|
| **AQUATIC INVERTEBRATE ECOLOGICAL CATEGORY** | **6** | 285 | **56.2** | **D** |
| **INSTREAM ECOLOGICAL CATEGORY (No confidence)** | | 630 | **46.5** | **D** |

| **INSTREAM ECOLOGICAL CATEGORY WITH CONFIDENCE** | **Confidence rating** | **Proportions** | **Modified weights** |
|---|---|---|---|
| Confidence rating for **fish** information | 4 | 0.50 | 17.85 |
| Confidence rating for **macro-invertebrate** information | 4 | 0.50 | 28.10 |
| | 8 | 1.00 | 45.95 |
| **INSTREAM ECOLOGICAL CATEOGORY** | **EC** | | **D** |

| **RIPARIAN VEGETATION** | **EC %** | **EC** |
|---|---|---|
| **RIPARIAN VEGETATION ECOLOGICAL CATEGORY** | **44.6** | **D** |

| **ECOSTATUS** | **Confidence rating** | **Proportions** | **Modified weights** |
|---|---|---|---|
| Confidence rating for instream biological information | 4 | 0.50 | 22.98 |
| Confidence rating for riparian vegetation zone information | 4 | 0.50 | 22.30 |
| | 8 | 1.00 | 45.28 |
| **ECOSTATUS** | **EC** | | **D** |

In the case of the Dorp's River crossing site (Table 55), the in-stream ecological category (EC) is an E (33.7%), indicating the low level of the aquatic integrity of the site. Due to the somewhat better riparian EC (D=56.2%), the overall EC for the reach is a low D (44.9%).

In the case of the Boschfontein Spruit crossing site (Table 56), the in-stream ecological category (EC) is an E (45.9%), indicating the somewhat better aquatic integrity at the site (compared with the Dorp's River integrity). Due to the riparian EC (D=44.6%), which now is lower than the Dorp's River riparian integrity, the overall EC for the reach is a low D (45.2%). Therefore, the two sites have very similar Ecostatus values, but for different reasons: the Dorp's River has a Category D due to the poor water quality that influences the in-stream biota, while the Boschfontein Spruit has a Category D due to the lack of a riparian zone (removed by humans) which influences the integrity score.

**Table 57: Generic ecological categories for EcoStatus.**

| **ECOLOGICAL CATEGORY** | **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 ecosystem functions are essentially unchanged. | 80-89 |

| ECOLOGICAL CATEGORY | DESCRIPTION | SCORE (% OF TOTAL) |
|---|---|---|
| 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 have occurred. | 40-59 |
| E | Seriously modified. The loss of natural habitat, biota and basic ecosystem functions are extensive. | 20-39 |
| F | Critical/Extremely modified. Modifications have reached a critical level and the system has been modified completely with an almost complete loss of natural habitat and biota. In the worst instances the basic ecosystem functions have been destroyed and the changes are irreversible. | 0-19 |

## 5. Conclusion

The PES of systems encompassing the river crossings has been obtained by using existing information and newly acquired data. The existing data includes long-term data sets and previously obtained and historical data includes:

- Natural hydrology (river flows)
- Water quality

Newly acquired information includes:

- Morphology and physical structure
- Vegetation (riparian delineation and status of riparian vegetation)
- Biota - Aquatic invertebrates and Fish

A combination of existing data and newly acquired information to attain the following:

- ecological importance and sensitivity (EIS)
- Socio-cultural Importance (SI)
- existing land and water use impacts
- ecological category (EC)
- present ecological state (PES)

With this information in hand, the following conclusions relating to the present ecological state could be made:

**Task 1.2.3.1. Flow and sediment regimes at appropriate flows:** In the Hex River, flows are largely managed on demand for anthropological purposes. This results in un-seasonally high pulses of flow in the river and extended periods of low flow. The managed flow regime, when combined with the large numbers of dams and weirs, has resulted in river habitats becoming severely fragmented with what were largely perennial rivers now being distinctly seasonal in nature. For extended periods, weirs and deep pools are the only refuge for any aquatic life.

This situation is reflected in the two river crossing sites with surface water flows: un-seasonally high pulses of flow; large numbers of dams and weirs; severely fragmented; distinctly seasonal; weirs and deep pools are the only refuge.

Due to the lack of surface water in the ephemeral drainage lines of two of the crossing sites, Crossing 3 Kanana Drainage line and Crossing 4 Tierkop Spruit, very little flow is expected to originate from these sources.

**Task 1.2.3.2. Water quality (including the physical, chemical and biological characteristics of the water) in relation to the flow regime:**

Due to the location and the associated industrial development, mining activities and urbanization (formal and informal) taking place in the catchment, the water quality of the Hex River and its tributaries has progressively deteriorated. The physical and chemical constituent concentrations recorded in the Hex River and its associated tributaries decreased during peak rainfall in the summer months. Higher constituent concentrations were recorded during the dry winter months.

Similarly, this situation is reflected in the two river crossing sites with surface water flows: water quality parameters are regularly not meeting the Target Water Quality Range. Due to this, the overall EcoStatus for the Lower Hex River catchment is POOR.

Due to the absence of surface water in the ephemeral drainage lines of two of the crossing sites, Crossing 3 Kanana Drainage line and Crossing 4 Tierkop Spruit, very little water quality impacts are expecting to originate from these sources.

**Task 1.2.3.3 Riparian and In-stream Habitat.**

**Task 1.2.3.3.1 Morphology (physical structure):**

The outcome of the in-stream and riparian IHI evaluated for the rivers with surface flows in the study area (Dorp's and Boschfontein rivers), resulted in an in-stream IHI of 74.2 (C), and a riparian IHI of 79.0 (C), resulting in both being classified as "Moderately modified" according to the Habitat Integrity Categories.

**Task 1.2.3.3.2 Vegetation**

The non-marginal zone condition of the Boschfontein Spruit (61.4% change) seems to be more impacted on than that of the Dorp's Spruit non-marginal zone condition (38.9% change), but the change in the marginal zone condition is very similar at the two sites (48.8% and 49.3% respectively). The combined Level 3 VEGRAI scores per site present a score of 56.2% at the Dorp's Spruit river crossing, and 44.6% at the Boschfontein Spruit river crossing. The final riparian vegetation integrity described by the Ecological Class of both these two sites, are grouped in a Class D (40-59%) which reflects a "Largely modified" vegetation integrity.

Due to the absence of riparian and marginal habitats on the ephemeral drainage lines of the two crossing sites, Crossing 3 Kanana Drainage line and Crossing 4 Tierkop Spruit, the VEGRAI model could not be applied to these reaches.

**Task 1.2.3.4 Biota – Aquatic invertebrates and Fish**

**Aquatic habitat assessment**

During the December 2015 survey, the IHAS and HQI were relatively low due to poor water quality, limited habitats and human related impacts on the aquatic environment (erosion, siltation, vegetation removal, litter, eutrophication, etc.).

At the Dorp's Spruit site the smell of sewage was evident and at the Boschfontein Spruit site the stagnant water could be seen pushing in from the Bospoort Dam. Due to these impacts

on the rivers, habitat scores are quite low at the river crossing sites with surface flows, and are all categorized as “Poor” according to SASS5 values.

#### Task 1.2.3.4.1 Aquatic invertebrate assessment

During the 2015 assessment the relative MIRAI score of the Dorp’s River reach was placed within the limits of an ecological state category Class E (34%), which means this reach is “Seriously modified”. The relative MIRAI score of the Boschfontein Spruit reach was placed within the limits of an ecological state category Class D (56%), which means this reach is “Largely modified”.

These results indicate the effect of the poorer water quality on the macro-invertebrate condition in the Dorp’s River. The Boschfontein Spruit rather has a water quantity problem than water quality problem. Due to the lack of surface water in the ephemeral drainage lines of two of the crossing sites, Crossing 3 Kanana Drainage line and Crossing 4 Tierkop Spruit, no freshwater aquatic macro-invertebrates were expected to occur here for most of the year.

#### Task 1.2.3.4.2 Fish Response Assessment Index (FRAI)

The relative FRAI score of this stretch of the Dorp’s River falls within the limits of an ecological state category Class E (33.3%). The relative FRAI score of the Boschfontein Spruit also falls within the limits of an ecological state category Class E (35.7%), which means that both the river crossings with surface water are affected by an environment that is “Seriously modified”.

Due to the lack of surface water in the ephemeral drainage lines of two of the crossing sites, Crossing 3 Kanana Drainage line and Crossing 4 Tierkop Spruit, no freshwater fish are expected to occur here for most of the year.

### Task 1.2.4 Describe the ecological importance and sensitivity (EIS) as well as the Socio-cultural Importance (SI) of the affected reach/es of the watercourse including the functions.

During the EIS-SI assessment of the River Crossing Sites, a regional approach to the four systems was used. According to the EIS model, the overall EIS rating is 1.1 and thus the overall EIS category is considered to be “VERY LOW”. Thus, the Ecological importance of these river crossings presents low integrity regarding diversity, rarity or uniqueness of the habitats and biota.

The Hex River is situated near the town of Rustenburg North West Province and is the main regional arterial drainage for the area. It is a source of water supply for many in the region. Rustenburg was described as the city with SA's most positive growth story, which in recent years has outstripped the growth of all other urban centres.

The belt with the richest platinum deposits are located near Rustenburg, shows a GDP growth that grew at 3,9% during 2010. National GDP growth for the same period was 2,8%. The success of Rustenburg's growth is further underlined by the relative changes in poverty levels in the cities.

### Task 1.2.5 Discuss existing land and water use impacts (and threats) on the characteristics of the watercourse.

According to the River Health Programme the overall EcoStatus for the Lower Hex River during 2005 was POOR. The In-stream Habitat Integrity was classified as “POOR”, primarily

because of high levels of development especially in terms of mining activities as well as water abstraction for irrigation purposes. There are a number of weirs that comprise the irrigation scheme but their use is limited. Stretches of the river have been diverted for the mines but more recently for the upgrade of the N4 Platinum Toll Highway.

With a PES category description of "Serious Modification", it is clear that the Hex River catchment is under pressure due to development and utilization. These PES ratings will also reflect in most of the tributaries of the Hex River, especially the lower sections that flows into the main stem.

**Task 1.2.6 List and map sensitive environments in proximity of the project locality-sensitive environments include wetlands, nature reserves, protected areas, etc.**

According to the LUDS Report (BGIS, 2016) areas directly around the river crossings are in a built-up area along a national highway where very little natural habitat remains intact. This area is known as a production landscape and should be managed to optimise sustainable utilization of natural resources. Further away from the highway the vegetation type is classified as "Ecosystem Status - Vulnerable", but will not be affected by the project. The wetland value of the river crossings is not featuring as NFEPA entities, indicating that the aquatic habitat in this area is not considered as very important. The only protected area in the project vicinity is in the form of a conservancy around the Bospoort Dam.

**Present Ecological State or PES**

In the case of the Dorp's River crossing site, the in-stream ecological category (EC) is an E (33.7%), indicating the low level of the aquatic integrity of the site. Due to the somewhat better riparian EC (D=56.2%), the overall EC for the reach is a low D (44.9%).

In the case of the Boschfontein Spruit crossing site, the in-stream ecological category (EC) is an E (45.9%), indicating the somewhat better aquatic integrity at the site (compared with the Dorp's River integrity). Due to the riparian EC (D=44.6%), which now is lower than the Dorp's River riparian integrity, the overall EC for the reach is a low D (45.2%). Therefore, the two sites have very similar Ecostatus values, but for different reasons: the Dorp's River has a Category D due to the poor water quality that influences the in-stream biota, while the Boschfontein Spruit has a Category D due to the lack of a riparian zone (removed by humans) which influences the integrity score.

**Table 58:** Summary of the PES values of all the parameters assessed in the study area.

| Parameter | Sub-sections | RHP 2005 – Hex River | 2015 study area |
|---|---|---|---|
| River flows | Surface flows | EC: Serious (impacted) | |
| Water quality | WQ | Poor / EC: Serious (impacted) | SASS5: Poor |
| Morphology (physical structure) | In-stream Habitat Integrity | Poor | Moderately modified |
| | Riparian Habitat Integrity | Fair | Moderately modified |
| Riparian | Non-marginal Zone Condition | | D: Largely modified |
| | Non-marginal Zone Condition | Fair | D: Largely modified |

| | | | |
|---|---|---|---|
| Aquatic biota (ex plants) - invertebrates | Aquatic invertebrate: ASPT | | Poor-Fair |
| | Aquatic invertebrate: MIRAI | Poor | E: Seriously - Largely modified |
| Aquatic biota (ex plants) - fish | Fish: FRAI | Poor | E: Seriously modified |
| Ecological Importance and Sensitivity | EI&S | Moderate | Very low |
| PES | EcoStatus | Poor | D: Largely modified |
| | In-stream Habitat Integrity | Poor / EC: Serious (impacted) | IHAS & HQI: Poor |
| | In-stream ecological category | | E: Seriously modified |
| | Riparian vegetation ecological category | EC: Large (impacted) | D: Largely modified |
| | PES | Serious Modification | D: Largely modified |

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**APPENDICES**

**Appendix 1:**

Supplementary Water Use Information (Section 21 (c) and (i) Water Uses; Section 21(c) - impeding of diverting the flow of water in a watercourse; Section 21 (i) - altering the bed, banks, course or characteristics of a watercourse)."

water affairs
Department:
Water Affairs
REPUBLIC OF SOUTH AFRICA

DW781 suppl

DW775suppl

SUPPLEMENTARY WATER USE INFORMATION
Section 21 (c) and (i) Water Uses
Section 21(c) ~ impeding of diverting the flow of water in a watercourse
Section 21 (i) ~ altering the bed, banks, course or characteristics of a watercourse

Please read:
(1) The requirements of this form should be discussed with the relevant Regional Office and Primary Responsible Official for these water uses during a pre-application consultation meeting and documented agreement reached in terms of:
(a) Assistance and information to be supplied by the Department (e.g. procedures (refer items 1.2.3 and 1.2.4), management objectives etc.) - this is of particular reference to emerging water users that are not in a position to provide the information as required in this form; and
(b) The scale and level of detail required.
(2) Should any of the supporting documentation to the licence application (e.g. Technical Report, Environmental Impact Assessment Report, Environmental Management Plan or Programme) already contain the requested information below, the applicant is not required to duplicate the information. In such instances, a comprehensive list of these documents must be compiled and this form must be completed by referring to the relevant sections in the supporting documentation.
(3) All maps, Google images, drawings and plans must be at an appropriate detailed scale and have sufficient annotations (North arrow, line scale, legend, co-ordinates, etc.).
(4) Information requirements in respect of Section 27 of the National Water Act, 1998 (Act No. 36 of 1998)[NWA] that have to be considered in the issuing of a licence, are appropriately incorporated and indicated in this form (e.g. item 2.2.3 <Provide information to support efficient and beneficial use of water in the public interest [refer Section 27(1)(c)]>).
(5) This form may be updated from time to time as required to comply with best practice and legal requirements. When completing this form, clearly date it since it will be evaluated against the information requirements related to the edition of the form at that time.

| 1. Watercourse Attributes | |
|---|---|
| 1.1Locality | *1.1.1 < Provide a description of the location of the watercourse at which the water use/s is to take place>* |
| | *1.1.2 <Provide a locality map/s indicating the relevant catchment[1], surrounding land use, towns, infrastructure etc.>* |
| | *1.1.3 <Provide the catchment reference number>* |
| 1.2 Description | *1.2.1 <Provide the name and/or description of the affected watercourse>* |
| | *1.2.2 < Provide a map indicating the segment and affected reach/es of the watercourse in which the water use/s is to take place and which indicates/delineates the regulated area including:*<br>*1.2.2.1. The extent of the riparian habitat*<br>*1.2.2.2. The 1:100 year flood line[2]>>* |

1 The order of the catchment is to be verified with the relevant Regional Office and Primary Responsible Official

2 The applicant will require a water use authorisation from the Department for any activity within the *regulated area* which is the outer edge of the riparian habitat or 1:100 year flood line, whichever is the greatest distance from the watercourse. The outer edge of the watercourse must be delineated using the Departmental guideline, *A Practical Field Procedure for Identification and Delineation of Wetlands and Riparian Areas* or *Field method for the delineation of Riparian Zones for South African Rivers*

3 Refer to the WRC Reports on Ecoclassification, specifically Report no TT 329/08 on determining EcoStatus

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| | |
| | *1.2.3 <Describe within context of the immediate catchment and segment, the historic as well as current state (Present Ecological State or PES) of the affected reach/es of the watercourse with regards to the following characteristics (attributes)[3]:*<br>*1.2.3.1. Flow and sediment regimes at appropriate flows*<br>*1.2.3.2. Water quality (including the physical, chemical and biological characteristics of the water) in relation to the flow regime*<br>*1.2.3.3 Riparian and Instream Habitat.* |
| | *1.2.3.3.1 Morphology (physical structure)*<br>*1.2.3.3.2 Vegetation*<br>*1.2.3.4 Biota>* |
| | *1.2.4 <Describe the ecological importance and sensitivity (EIS)as well as the Socio-cultural Importance (SI) of the affected reach/es of the watercourse including the functions[6]>* |
| | *1.2.5 <Discuss existing land and water use impacts (and threats) on the characteristics of the watercourse>* |
| | *1.2.6 <List and map sensitive environments in proximity of the project locality-sensitive environments include wetlands, nature reserves, protected areas, etc.>* |
| 2. Water Use Information | |
| 2.1 Description and Methodology | *2.1.1 <Describe the activities associated with the water use/s>* |
| | *2.1.2 < Describe the project phases for each activity (i.e. planning, construction, operation and maintenance, decommissioning) including, but not limited to, the programme for and duration of the various phases* |
| | *2.1.3 < Provide a basic lay-out plan/s (master plan) indicating the various activities and existing and proposed infrastructure in relation to the 1:100 flood line and edge of the watercourse, etc>.* |
| | *2.1.4 < Provide work method statements for the various water use activities>* |
| | *2.1.5 < Provide engineer design drawing(s) for construction activities within the watercourse>* |

4 The EIS of a watercourse is an expression of its importance to the maintenance of ecological diversity and functioning on local and wider scales. Ecological sensitivity refers to the system's ability to resist disturbance and its capability to recover from disturbance once it has occurred. Both biotic and abiotic components of the system are taken into account.
5 SI reflects the dependency of people on a healthy functioning watercourse and also to its cultural and tourism potential.
6 Refer to the RDM procedure for determining Ecological Importance and Sensitivity
7 Refer to the DWAF *Broad-Based Black Economic Empowerment (BBBEE) Guidelines For Water Allocation, Final Draft, June 2007* and the Department of Trade and Industry's requirements relating to compliance with the BBBEE Act, 2003 (Act No. 53 of 2003)
8 The applicant must provide information on how he/she implements the seven elements of BBBEE (i.e. Ownership, Management, Employment equity, Skills development, Procurement, Enterprise development, Socio-economic development) and how this complies with the relevant Sector Charter and score card (e.g. Construction, Agriculture, Mining, Tourism etc). A BBBEE certificate or external verification must accompany the application (refer list of Verification Agents on the Department of Trade and Industry's website)
9 Consult the relevant Regional Office and Primary Responsible Official
10 Assess the potential impacts with regard to their nature, extent, magnitude, duration, probability and significance – each impact must be described in terms of source of impact, pathway (propagation of impact) and receptor (target that experience the risk or impact)

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|---|---|
| | *2.1.6 < Provide a description and a map/s indicating any Storm Water Management Practices (SWMPs) specifically addressing 'end of pipe' practices>* |
| | *2.1.7 <Provide information on all existing lawful water uses (referSection 21 (1) (a)]>* |
| | *2.1.8 <Provide information on investments already made and to be made by the water user in respect of the proposed water use/s (ReferSection 27 (1) (h)]>* |
| | *2.1.9 <Indicate and motivate the probable duration of any undertaking for which the water use/s should be authorised (refer Section 27 (1)(k)]>* |
| 2.2 Motivation | *2.2.1 < Provide information on the need/intention/objective of the water use/s>* |
| | *2.2.2 < Provide information on contributions to rectify the results of past racial and gender discrimination[7](refer Section 27 (1)(b)[8]]* |
| | *2.2.3 <Provide information to support efficient and beneficial use of water in the public interest (refer Section 27(1)(c)]* |
| | *2.2.4 < Provide information on relevant catchment strategies[9] and local government planning frameworks that support the proposed water uses (refer Section 21(1)(e)]* |
| | *2.2.5 < Provide information on the strategic importance of the water use to be authorised (refer Section 27(1)(i)]* |
| 3. Impact Assessment and Management | |
| 3.1 Impact Prediction and Assessment | *3.1.1 < Provide a prediction and assessment of the likely environmental and socio-economic impacts or effects[10] associated with the water use/s for different phases:*<br>*3.1.1.1 On the watercourse and its characteristics as set out in 1.2.3 above (refer Section 27(1)(f)]*<br>*3.1.1.2 On other water users (refer Section 27(1)(f)]*<br>*3.1.1.3 On the broader public and property*<br>*3.1.1.4 If the water use/s is not authorised (refer Section 27(1)(d)]*<br>*3.1.2 < Provide a description of the methodologies employed to undertake impact prediction and assessment as well as a motivation for these>* |
| 3.2 Risk Assessment | *3.2.1 < Provide an assessment of the risks associated with the water use/s and related activities>* |
| 3.3 Alternatives | *3.3.1 < Describe the alternatives considered to prevent negative impacts on the watercourse with regard to locality, procedures, materials etc.>* |
| 3.4 Mitigation and Management Measures | *3.4.1 < Provide mitigation measures[4] to prevent, reduce, remediate or compensate the pre-determined impacts; also provide emergency response>* |

*4*The mitigation measures should be collated in an Environmental Management Plan (EMP) – refer to the Department of Environmental Affairs and Tourism's regulations, Government Notice No R 385 in Government Gazette No 28753 of 21 April 2006 for minimum standards

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| | *3.4.2 < Provide a site map/s that marks the limits of disturbance to the watercourse and in particular indicates erosion and sediment controls>*<br>*3.4.3<If the developer (and applicant) of water use related infrastructure is not the end user/beneficiary and will not be responsible for long term maintenance of the infrastructure, provide a programme for hand over to the successor-in-title[12] including a brief management/maintenance plan for the infrastructure along with allocation of responsibilities>* |
| 3.5 Changes to the Watercourse | *3.5.1 < Assess to what extent the impacts after mitigation will bring about changes in respect of the PES (and recommended ecological category, if this information is available at the stage of study) and functionality of the watercourse; as well as the socio-economic environment (including redress considerations as well impacts on other water users )>* |
| 3.6 Monitoring and Compliance | *3.6.1 < Provide a detailed monitoring programme and describe the auditing, compliance and reporting mechanisms to ensure execution of the mitigation measures and for informing DWAF of incidents – ensure that these measures are appropriate in relation to the impacts, mitigation measures, status of the watercourse, etc.>* |

**Appendix 2:** A list of riparian plant species and habitats in which they are found (includes alien weeds and invader plants). I think we should state that these are not necessarily all present in the study area.

| FAMILY | *TAXON* | HABITAT |
|---|---|---|
| SALICACEAE | **Populus x canescens* | Variable, but especially vleis and in river valleys |
| SALICACEAE | **Salix babylonica var. babylonica* | Along streams. |
| FABACEAE | *Acacia xanthophloea* | Low-lying, swampy areas |
| ANNONACEAE | *Annona senegalensis* | Sandy soils along rivers, also in mixed scrub or woodland, on rocky outcrops and in swamp forest. |
| POACEAE | *Arundinaria tessellata* | Margins of high altitude forest, along streams and among rocks on mountain tops |
| VERBENACEAE | *Avicennia marina* | Common in mangrove swamps; also encroaching back up feeder streams, and growing on banks of fresh water rivers. |
| SALVADORACEAE | *Azima tetracantha* | Low altitudes in bush, scrub, woodland and thornveld, frequently along watercourses and in riverine thicket. |
| FABACEAE | *Baphia racemosa* | Usually in riverine forest. |
| LECYTHIDACEAE | *Barringtonia racemosa* | Always near water, along banks of rivers, in fresh water swamps and occasionally in less saline areas of mangrove swamps. |
| PROTEACEAE | *Brabejum stellatifolium* | Riverine species with water-dispersed fruits, occurring in sheltered valleys and along streams. |
| ASTERACEAE | *Brachylaena neriifolia* | Stream banks and moist mountain forest. |
| RUBIACEAE | *Breonadia microcephala* | Along banks of permanent streams and rivers, in riverine fringe forest. |
| EUPHORBIACEAE | *Bridelia micrantha* | Riverine forest; patches of relic forest, or in open woodland. |
| RHIZOPHORACEAE | *Bruguiera gymnorrhiza* | On seaward side of mangrove swamps. |
| FABACEAE | *Cassia petersiana* | Most frequently found along rivers and streams in riverine fringe thicket. |
| ULMACEAE | *Chaetacme aristata* | Along streams in wooded grassland, in riverine fringe thicket, in wooded ravines and near the coast, often in scrub and forest. |
| COMBRETACEAE | *Combretum caffrum* | Along river and stream banks and in moist areas. |
| COMBRETACEAE | *Combretum erythrophyllum* | Along river banks where it can form thick stands, with trunks reclining in and overhanging the water. |
| COMBRETACEAE | *Combretum imberbe* | Medium to low altitudes, in mixed woodland, often along rivers or dry watercourses, particularly on alluvial soils. |
| FABACEAE | *Cordyla africana* | Low altitudes in hot areas, most often forming part of riverine forest, and also in swamp forest. |
| EUPHORBIACEAE | *Croton megalobotrys* | On alluvial flats and almost always a |

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| | | constituent of riverine fringe forest or thicket. |
| LAURACEAE | *Cryptocarya angustifolia* | River valleys of the south-western Cape. |
| CUNONIACEAE | *Cunonia capensis* | On stream banks and in moist forest, being abundant in the high, wet forests and in very wet crub forests around Knysna; under harsher conditions it becomes shrubby. |
| CYATHEACEAE | *Cyathea dregei* | Forest margins, wooded kloofs and along streams on grassy mountainsides |
| STERCULIACEAE | *Dombeya cymosa* | In coastal bush or, further inland, along river and stream banks. |
| STERCULIACEAE | *Dombeya pulchra* | In wooded river valleys and along stream banks, also on mountainsides at high altitudes. |
| EUPHORBIACEAE | *Drypetes arguta* | Evergreen forest, often along streams |
| ACANTHACEAE | *Duvernoia adhatodoides* | Evergreen forest, often along stream banks and in ravines. |
| ERICACEAE | *Erica caffra var. caffra* | Mountain ravines, on cliffs, generally in damp situations |
| MORACEAE | *Ficus capreifolia* | Swamps, and frequently forming tangled thickets along river banks and on sandy islands in the larger rivers. |
| MORACEAE | *Ficus sycomorus* | Frequently along river banks, forming a distinctive part of the riverine thicket; also in mixed woodland |
| SCROPHULARIACEAE | *Freylinia lanceolata* | Wide range of altitudes in moist areas, along stream and river banks and fringing vleis. |
| GREYIACEAE | *Greyia radlkoferi* | In mountain forested gullies, along stream banks, fringing evergreen forest and among rocks. |
| CELASTRACEAE | *Gymnosporia bachmannii* | Rocky banks of rivers and streams in evergreen forest. |
| ANACARDIACEAE | *Harpephyllum caffrum* | Riverine forest. |
| MALVACEAE | *Hibiscus diversifolius subsp. rivularis* | In damp places, along rivers or lining lakes, and in thickets. |
| MALVACEAE | *Hibiscus tiliaceus* | Along the coast often fringing estuaries and tidal rivers. |
| SAPINDACEAE | *Hippobromus pauciflorus* | Riverine thicket, scrub, along stream banks and at margins of evergreen forest. |
| LAMIACEAE | *Iboza riparia* | Rocky ourcrops and margins of evergreen forest, often near water. |
| AQUIFOLIACEAE | *Ilex mitis* | Most frequently along river banks and stream beds, in moist evergreen forest, sometimes straggling and leaning over the water. It is believed that the presence of this tree is an indication of underground water near the surface. |
| PROTEACEAE | *Leucadendron conicum* | In mountainous areas from 300 to 1000m asl, always in damp places, in valleys, ravines and along streams. |
| PROTEACEAE | *Leucadendron eucalyptifolium* | Coastal mountains at altitudes 150 to 1600m asl, favouring moist conditions; frequent at |

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| | | edge of forests and along streams. |
| PROTEACEAE | *Leucadendron salicifolium* | On acid soils from 0 to 1000m asl, characteristically forming almost hedge-like screens along the banks of streams. |
| ROSACEAE | *Leucosidea sericea* | At high altitudes along streams and in kloofs, where it forms dense stands |
| OLEACEAE | *Lincociera battiscombei* | Occurring on banks of mountain streams, most frequently in riverine fringes andforested ravines. |
| ACANTHACEAE | *Macaya bella* | Evergreen forest, often along stream and river banks. |
| CAPPARACEAE | *Maerua gilgii* | Arid areas of stony desert, often along river beds and dry watercourses. |
| MYRSINACEAE | *Maesa lanceolata* | Margins of evergreen forest, almost always along rivers and streams, occasionally in open mountaingrassland. |
| MYRTACEAE | *Metrosideros angustifolia* | In mountainous areas, along watercourses and river banks where it can become locally common. |
| RHAMNACEAE | *Noltia africana* | High altitudes, occassionally in open scrub and along stream banks. |
| LOGANIACEAE | *Nuxia oppositifolia* | Along rivers and streams, in riverine thicket, among rocks and reeds. |
| OLEACEAE | *Olea africana* | Variety of habitats, usually near water, on stream banks, in riverine fringes, but also in open woodland, among rocks and in mountain ravines. |
| ARECACEAE | *Phoenix reclinata* | Along river banks in low-lying open grassland |
| EUPHORBIACEAE | *Phyllanthus reticulatus* | Low altitude riverine vegetation and thicket. |
| PIPERACEAE | *Piper capensis* | Moist, shady places, in forests and along streams |
| CUNONIACEAE | *Platylophus trifoliatus* | In forest or on stream banks |
| URTICACEAE | *Pouzolzia hypoleuca* | Open woodland, wooded ravines, riverine thicket and sheltered among boulders on rocky koppies. |
| PRIONIACEAE | *Prionium serratum* | In water courses and river beds. |
| CELASTRACEAE | *Pseudosalacia streyi* | Among rocks along river banks in evergreen forest, seldom far from the sea. |
| APOCYNACEAE | *Rauvolfia caffra* | Nearly always associated with available ground water, along wooded stream banks and at the margins of evergreen forest. |
| RHAMNACEAE | *Rhamnus prinoides* | Along watercourses, in riverine forest and at margins of evergreen forest. |
| RHIZOPHORACEAE | *Rhizophora mucronata* | On inter-tidal mud flats, usually on the seaward side of mangrove swamp forests. |
| ANACARDIACEAE | *Rhus incisa* | Scattered through open scrub and frequently occurring along the banks of rivers. |
| ANACARDIACEAE | *Rhus montana* | Mountain areas, often along river banks. |
| ANACARDIACEAE | *Rhus viminalis* | Along river and stream banks. |
| LYTHRACEAE | *Rhyncocalyx lawsonioides* | Margin of evergreen forest and along rivers. |

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|---|---|---|
| VERBENACEAE | *Rotheca myricoides* | Rocky places in thickets along streams, also in open woodland often associated with termite mounts. |
| SALICACEAE | *Salix mucronata subsp. mucronata* | Stream and river banks, in a wide range of habitats. |
| SALICACEAE | *Salix mucronata subsp. subserrata* | Occurs along river and stream banks and on islands, in places likely to become inundated for at least part of the year. |
| CHENOPODIACEAE | *Salsola aphylla* | Frequently in dry, arid hot areas along dry watercourses. |
| FABACEAE | *Sesbania sesban subsp. sesban* | In low lying areas usually near water, often on river or stream banks. |
| EUPHORBIACEAE | *Spirostachys africana* | Low altitude bush, often along rivers and streams. |
| MYRTACEAE | *Syzygium cordatum subsp. cordatum* | Along stream banks, in riverine thicket and forest, always near water or along watercourses, and in KZN, forming stands of almost pure swamp forest. |
| MYRTACEAE | *Syzygium guineense subsp. guineense* | Open deciduous woodland at medium to low altitudes, frequently fringing vleis, sometimes along river banks. |
| TAMARICACEAE | *Tamarix usneoides* | Occurring in and fringing desert areas, along brackish shore lines, river banks and frequently in dry river beds. |
| ULMACEAE | *Trema orientalis* | Variety of habitats, usually moist soils, on forest margins, along watercourses, often a constituent of riverine fringe thicket, also in ravines and valleys and even along dry, sandy river-beds (smaller in drier habitats). |
| HAMAMELIDACEAE | *Trichocladus ellipticus subsp. ellipticus* | Occurring in rain forest, along streams and rivers where it is frequently dominant, and in swampy places. |
| RHAMNACEAE | *Ziziphus mucronata* | In a wide variety of habitats, in open woodland, often in alluvial soils along rivers, and frequently on termite mounts; it is said to indicate the presence of underground water. |
| RHAMNACEAE | *Ziziphus rivularis* | Occuring among rocks and also along stream banks or in water courses. |

**Appendix 3:** The complete SASS 5 form.

| TAXON | Stones | Vegetation | GSM | Total |
|---|---|---|---|---|
| Porifera 5 | | | | |
| Coelenterata 3 | | | | |
| Turbellaria 3 | | | | |
| Oligochaeta 1 | | | | |
| Leeches 3 | | | | |
| Amphipoda 15 | | | | |
| Potamonautidae 3 | | | | |
| Atyidae (Shrimp) 8 | | | | |
| Palaemonidae 10 | | | | |
| Hydracarinae 8 | | | | |
| Notonemouridae 14 | | | | |
| Perlidae 12 | | | | |
| Baetidae 1 spp 4 | | | | |
| 2 spp 6 | | | | |
| >2 spp 12 | | | | |
| Caenidae 6 | | | | |
| Ephemeridae 15 | | | | |
| Heptageniidae 10 | | | | |
| Leptophlebiidae 13 | | | | |
| Oligoneuridae 15 | | | | |
| Polymitarcyidae 10 | | | | |
| Prosopistomatidae 15 | | | | |
| Teloganodidae 12 | | | | |
| Tricorythidae 9 | | | | |
| Calopterydidae 10 | | | | |
| Chlorocyphidae 10 | | | | |
| Chlorolestidae 8 | | | | |
| Coenagrionidae 4 | | | | |
| Lestidae 8 | | | | |
| Platycnemidae 10 | | | | |
| Protoneuridae 8 | | | | |
| Zygoptera 6 | | | | |
| Aeshnidae 8 | | | | |
| Cordulidae 8 | | | | |
| Gomphidae 6 | | | | |
| Libellulidae 4 | | | | |
| Belostomatidae 3 | | | | |
| Corixidae 3 | | | | |
| Gerridae 5 | | | | |
| Hydrometridae 6 | | | | |
| Naucoridae 7 | | | | |
| Nepidae 3 | | | | |
| Notonectidae 3 | | | | |
| Pleidae 4 | | | | |
| Veliidae 5 | | | | |
| Corydalidae 8 | | | | |
| Sialidae 6 | | | | |
| Dipseudopsidae 10 | | | | |
| Ecnomidae 8 | | | | |
| Hydropsychidae 1= 4 | | | | |
| 2spp = 6 | | | | |
| >2spp =12 | | | | |
| Philopotamidae 10 | | | | |

| | | | | |
|---|---|---|---|---|
| Polycentropodidae 12 | | | | |
| Psychomyiidae/Xip. 8 | | | | |
| Barbarochthonidae 13 | | | | |
| Calamoceratidae 11 | | | | |
| Glossosomatidae 11 | | | | |
| Hydroptilidae 6 | | | | |
| Hydrosalpingidae 15 | | | | |
| Lepidostomatidae 10 | | | | |
| Leptoceridae 6 | | | | |
| Petrothrincidae 11 | | | | |
| Pisuliidae 10 | | | | |
| Sericostomatidae 13 | | | | |
| Dytiscidae 5 | | | | |
| Elmidae/Dryopidae 8 | | | | |
| Gyrinidae 5 | | | | |
| Haliplidae 5 | | | | |
| Helodidae 12 | | | | |
| Hydraenidae 8 | | | | |
| Hydrophilidae 5 | | | | |
| Limnichidae 8 | | | | |
| Psephenidae 10 | | | | |
| Athericidae 13 | | | | |
| Blepharoceridae 15 | | | | |
| Ceratopogonidae 5 | | | | |
| Chironomidae 2 | | | | |
| Culicidae 1 | | | | |
| Dixidae 13 | | | | |
| Emphididae 6 | | | | |
| Ephydridae 3 | | | | |
| Muscidae 1 | | | | |
| Psychodidae 1 | | | | |
| Simuliidae 5 | | | | |
| Syrphidae 1 | | | | |
| Tabanidae 5 | | | | |
| Tipulidae 5 | | | | |
| Ancylidae 6 | | | | |
| Bulininae 3 | | | | |
| Hydrobidae 3 | | | | |
| Lymnaeidae 3 | | | | |
| Physidae 3 | | | | |
| Planorbidae 3 | | | | |
| Thiaridae 3 | | | | |
| Viviparidae 5 | | | | |
| Corbiculidae 5 | | | | |
| Spaeridae 3 | | | | |
| Uniondae 6 | | | | |
| SASS Score | | | | |
| No of families | | | | |
| ASPT | | | | |

Estimated abundance: 1=1; A=2-10; B=11-100; C=101-1000; D=>1000

**Appendix 4.** Names of fish expected in the Hex River reach of the project.

| ABBREVIATION | SCIENTIFIC NAME | ENGLISH COMMON NAME |
|---|---|---|
| AMOS | *ANGUILLA MOSSAMBICA* PETERS 1852 | LONGFIN EEL |
| BMAR | *LABEOBARBUS MAREQUENSIS* SMITH, 1841 | LARGESCALE YELLOWFISH |
| BMAT | *BARBUS MATTOZI* GUIMARAES, 1884 | PAPERMOUTH |
| BPAU | *BARBUS PALUDINOSUS* PETERS, 1852 | STRAIGHTFIN BARB |
| BUNI | *BARBUS UNITAENIATUS GÜNTHER, 1866* | LONGBEARD BARB |
| CCAR | *CYPRINUS CARPIO* LINNAEUS, 1758 | CARP (EX) |
| CFLA | *CHETIA FLAVIVENTRIS* TREWAVAS, 1961 | CANARY KURPER |
| CGAR | *CLARIAS GARIEPINUS* (BURCHELL, 1822) | SHARPTOOTH CATFISH |
| LCYL | *LABEO CYLINDRICUS* PETERS, 1852 | REDEYE LABEO |
| LMOL | *LABEO MOLYBDINUS* DU PLESSIS, 1963 | LEADEN LABEO |
| MBRE | *MESOBOLA BREVIANALIS* (BOULENGER, 1908) | RIVER SARDINE |
| MSAL | *MICROPTERUS SALMOIDES* (LACEPÈDE, 1802) | LARGEMOUTH BASS (EX) |
| OMOS | *OREOCHROMIS MOSSAMBICUS* (PETERS, 1852) | MOZAMBIQUE TILAPIA |
| PPHI | *PSEUDOCRENILABRUS PHILANDER* (WEBER, 1897) | SOUTHERN MOUTHBROODER |
| TSPA | *TILAPIA SPARRMANII* SMITH, 1840 | BANDED TILAPIA |

**Appendix 5:** A summary of the results from the excel sheet containing the PES/EIS model. The information is assembled from available information.

| | | | |
|---|---|---|---|
| **SQ reach** | A22J-00878 | **Frequency(%) of "very high" ratings** | 15.4 |
| **SQR name** | Hex | **Frequency(%) of "high" ratings** | 30.8 |
| **Mean EI class** | MODERATE | **Frequency(%) of "moderate" ratings** | 15.4 |
| **Max EI class** | VERY HIGH | **Frequency(%) of "low/very low" ratings** | 38.5 |
| **Metrics: fish** | **RATINGS** | **Metrics: macro-invertebrates** | **RATINGS** |
| **Fish spp estimated** | See Fish spp estimated below | **Invert taxa estimated** | See Invert taxa estimated below |
| **Fish scientific name** | #N/A | **Confidence of presence of selected taxon in SQ reach** | 5.0 |
| **Confidence of presence of selected spp in SQ reach** | #N/A | **SASS5 value for taxon selected** | 3.0 |
| **Fish: average confidence** | 4.5 | **Invert taxa/SQ** | 39.0 |
| **Fish spp/SQ** | 12.0 | **Invert average confidence** | 4.8 |
| **Fish representivity per secondary: class** | MODERATE | **Invert representivity per secondary, class** | HIGH |
| **Fish rarity per secondary: class** | HIGH | **Invert rarity per secondary: class** | VERY HIGH |
| **Metrics: riparian-wetland vegetation & vertebrates (non-fish)** | **RATINGS & COMMENTS** | **habitat** | **RATINGS & COMMENTS** |
| **Ecological importance: riparian-wetland-instream vertebrates (ex fish) rating** | HIGH | **Habitat diversity class** | VERY LOW |
| **Ecological importance: riparian-wetland-instream verts (ex fish) comments** | See Ecological importance below | **Habitat diversity comments** | See Habitat diversity comments below |
| **Riparian-wetland natural veg rating based on % natural veg in 500m (100%=5)** | HIGH | **Habitat size (length) class** | VERY HIGH |
| **Riparian-wetland natural veg importance based on expert rating** | LOW | **In-stream migration link class** | LOW |
| **Ecological importance: riparian-wetland veg comments** | See Table below | **Riparian-wetland zone migration link** | LOW |
| | | **Riparian-wetland zone habitat integrity class** | MODERATE |
| | | **In-stream habitat integrity class** | LOW |

| | |
|---|---|
| **Fish spp estimated** | BMAR BPAU BTRI BUNI CFLA CGAR LCYL LMOL MBRE OMOS PPHI TSPA |

| | |
|---|---|
| **Invert taxa estimated** | TURBELLARIA OLIGOCHAETA HIRUDINEA POTAMONAUTIDAE ATYIDAE HYDRACARINA BAETIDAE 1 SP CAENIDAE LEPTOPHLEBIIDAE COENAGRIONIDAE AESHNIDAE GOMPHIDAE LIBELLULIDAE BELOSTOMATIDAE CORIXIDAE GERRIDAE HYDROMETRIDAE NAUCORIDAENEPIDAE NOTONECTIDAE PLEIDAE VELIIDAE/MESOVELIIDAE ECNOMIDAE HYDROPSYCHIDAE 1 SP HYDROPTILIDAE DYTISCIDAE GYRINIDAE HYDROPHILIDAE CERATOPOGONIDAE CHIRONOMIDAE CULICIDAE MUSCIDAE SIMULIIDAE TABANIDAE TIPULIDAE ANCYLIDAE LYMNAEIDAE PHYSIDAE PLANORBINAE |

| | |
|---|---|
| **Ecological importance: riparian-wetland-in-stream verts (ex fish) comments** | Total number of spp in Secondary Catchment: 100;<br>Total number of spp in SQ: 67;<br>Representivity Rating: 3;<br>Number of special species: 3; Special species rating: 3;<br>Main habitats: Grassy edges, riparian trees and shrubs, surface flows - rapids, runs, pools, reed beds;<br>Main adverse conditions: Dams, tree removal, urbanization and development, agriculture, abstraction, pollution. |

| | |
|---|---|
| **Ecological importance: riparian-wetland veg comments** | 3 wetland and 7 riparian habitat types, with 14 different types of vegetation cover, and 3 protected and 4 endemic species in this SQ. |

| | |
|---|---|
| **Habitat diversity comments** | Largely Lower foothills. Sensitivity more like a two for riffles etc. Very disturbed. |