ISCOR VANDERBIJLPARK STEEL

ENVIRONMENTAL MASTER PLAN

SPECIALIST REPORT

AQUATIC ECOSYSTEMS

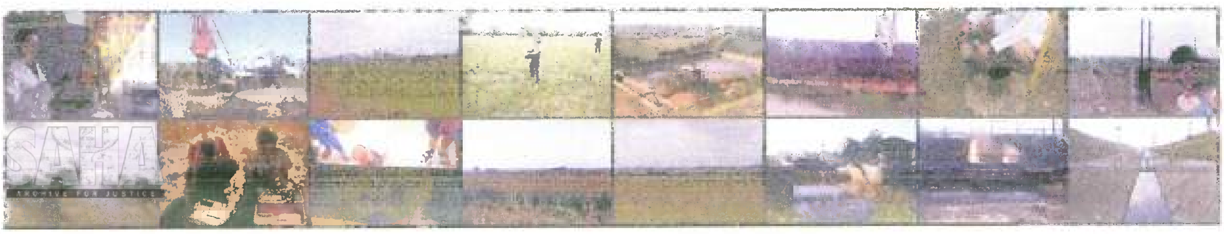
BY

JASPER MÜLLER ASSOCIATES

SERIES IV

DOCUMENT IVS/SR/033

DECEMBER 2002



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FINAL

ISCOR VANDERBIJLPARK STEEL

MASTER PLAN SPECIALIST REPORT

IVS/SR/033

AQUATIC ECOSYSTEMS

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EXECUTIVE SUMMARY

ECOSUN was appointed by Jasper Müller Associates cc to perform a Baseline Aquatic Ecological Assessment for ISCOR Vanderbijlpark Steel, in order to establish baseline data against which future changes in the health of the concerned aquatic system can be evaluated, and to develop a biological monitoring program which complies to industry standards as well as DWAF requirements. The major objectives of this program will be to:

- Conduct a Baseline Assessment for the aquatic system associated *inter alia* with ISCOR Vanderbijlpark Steel
- Establish aquatic baseline data against which future changes in the health of these systems can be evaluated
- On the basis of above, develop a biological monitoring program which complies to industry standards as well as DWAF requirements and which, once implemented, will enable assessment of, and reporting on the health, status and trends of these systems in relation to possible impacts as a result of industrial and/or other anthropogenical activities.

Sampling sites were selected in the in the Vaal River, Rietspruit, Rietkuilspruit and Leeuwspruit to coincide with existing water quality monitoring points and to include a suitable "natural" or "minimally impacted" reference site in the Taaibosspruit.

The first phase of this baseline study comprised the gathering and assessment of available literature for the area. The purpose of this literature survey was to gather and summarize all relevant information pertaining to species diversity and composition of aquatic and riparian vegetation, aquatic invertebrates and aquatic vertebrates (fish, amphibians) of the relevant areas, as well as information with regard to anthropogenically induced changes to the biotic integrity. The baseline assessment involved the characterization of the aquatic environment, habitat, related biota, magnitude and extent of site-related effects (point and non-point sources) in terms of up- and downstream species assemblage comparisons, as well as the current ecological status of the aquatic system. The major goal of the characterization procedure was to determine the current status of the aquatic environment and to evaluate the extent of site related effects in terms of selected ecological indicators, as well as to identify specific important aquatic ecological attributes (Wetlands, Red Data species, etc.).

Data for the Baseline Ecological Assessment were collected during a field survey conducted at the selected sampling sites from 27 November 2001 to 2 December 2001. In order to enable adequate description of the aquatic environment, certain ecological indicators were selected to represent each of the responding, exposed, habitat and stressor components involved in the aquatic environment. These included:

Stressor Indicators
- *In situ* water quality
- Algal biomass

Habitat Indicators
- General Habitat Assessment
- Integrated Habitat Assessment System (IHAS, *version 2*)
- Habitat Integrity Assessment

Response Indicators
- Riparian and Aquatic Vegetation Assessment (to include RVI)
- Aquatic Macroinvertebrates (SASS5)
- Ichthyofauna

Exposure Indicators

- Contaminant concentrations in sediments
- Bioaccumulation

The results indicated *in situ* pH measurements to vary considerably in the study area (6.9 to 9.0 in the Rietkuilspruit, 6.3 to 7.8 in the Rietspruit and 6.5 to 8.4 in the Leeuwspruit). This variation in pH poses a threat towards the aquatic ecosystem. According to the South African Water Quality Guidelines for Aquatic Ecosystems (DWAF, 1996), the pH value should not be allowed to vary from the range of the background pH values for a specific site and time of day, by >0.5 of a pH unit, or by 5% and should be assessed by whichever estimate is the more conservative. The significant variation in pH detected in the study area will therefore have an adverse effect on the aquatic biota, especially fish (as a result of their mobility).

The Integrated Habitat Assessment System (IHAS) focuses on the evaluation of habitat suitability specifically for aquatic macroinvertebrates. This index indicated habitat availability to be poor at sites RS1 and RS2 in the Rietkuilspruit. The habitat however improved towards site RS4 and RS5 (good habitat availability), then decreased again at site RS8 (poor habitat availability). Habitat availability was poor in the Rietspruit, with IHAS values ranging between 24% and 37%. IHAS scores in the Leeuwspruit varied between 29% and 67%, indicating poor to good habitat availability. The Leeuwspruit constituted the most heavily impacted section of the assessed river reaches in terms of in-stream and riparian habitat integrity. Modifications to habitat integrity in this stream have reached a critical level and the lotic system has been modified completely with an almost complete loss of natural ecosystem functioning (Intermediate Habitat Integrity Class F). The Rietkuilspruit, and the 5km reach of the Rietspruit downstream from the Rietkuilspruit confluence was determined as belonging to Intermediate Habitat Integrity Class E, i.e. the loss of natural habitat, biota and basic ecosystem, functions are extensive. The 5km reach of the Rietspruit, upstream of the Rietkuilspruit confluence was determined as belonging to Class C, i.e. a loss and change of natural habitat and biota have occurred, but the basic ecosystem functions are still predominantly unchanged.

The vegetation at all the sites has been modified by anthropogenic factors. At some, perturbations will decrease while at others the current *status quo* will continue. Only a long term monitoring program will determine what changes are taking place and elucidate what the causative agents may be. Prior to this study some of the sites such as LS1, RS2 and RS3 had been seriously affected by recent developments. The draining of the marsh at LS1 is likely to seriously affect the viability of the marsh and its ability to function as a pollutant trap and sponge. Sampling sites along the Rietspruit and Vaal River exhibited higher plant species richness, although mostly with a substantial alien content, than either the Leeuwspruit or Rietkuilspruit. This can be attributed to lower disturbances, as these sites were mostly used for grazing of livestock and not for crop farming. At all sampling sites it was evident that floods and high run-off in the recent past had eroded the stream banks causing the collapse of, and creating vertical banks. These banks are not conducive of being easily colonized by vegetation. Some sites (LS1, LS2, LS4, LS5, RS2, RS3 and RS7) were unsuitable for application of the Riparian Vegetation Index (RVI), because of the type and level of disturbance. The remaining sites were all rated at Class C level, which indicated, from a vegetation point of view, that they were "Moderately Modified", i.e. a loss and change of natural habitat and biota have occurred but the basic ecosystem functions were still predominantly unchanged.

Sampling sites in the study area were characterized by an absence/near absence of the more sensitive aquatic macroinvertebrate families, the only exception being site RS9 on the Rietspruit. Significant spatial variation existed in the Integrity Classes calculated for the different sampling sites in the Leeuwspruit. The Present State Class in the Leeuwspruit varied between Class D and E, with a Class F recorded at site LS5. The latter site receives treated effluent from a sewage works. The Present State Class in the Rietkuilspruit was indicated to be Class E at all sites sampled. The poor Present State Class (F) obtained at site RS6 in the Rietspruit is attributed to the fact that this site displayed limited aquatic macroinvertebrate habitat availability. The Present State Class obtained in the Rietspruit downstream from the Rietkuilspruit confluence was also indicated to represent a Class E biotic integrity.

An insufficient number of indigenous fish species were sampled to apply the Fish Assemblage Integrity Index (FAII). Indigenous species sampled in the Rietkuilspruit, Rietspruit and Leeuwspruit included the more tolerant species such as *Barbus anoplus, Barbus paludinosus, Clarias gariepinus* and *Pseudocrenilabrus philander*. The latter species were only sampled in the Rietspruit and Taaibosspruit. *Labeobarbus aeneus, Labeo umbratus* and *L. capensis* were sampled only at the reference site in the Taaibosspruit and in the Vaal River. Several exotic fish species were sampled. These include *Cyprinus carpio, Gambusia affinus* and *Micropterus salmoides*. Other species expected to occur in the study area based on habitat preferences, but which were not sampled include *Barbus pallidus*, *B. trimaculatus, Labeobarbus kimberleyensis* and *Tilapia sparrmanii*. A significant number of *B. anoplus* specimens sampled was infested with external parasites at sites RS5 and LS4. External abnormalities (lesions on the skin and/or fins) were significant in fish sampled from the Rietkuilspruit (57% of examined fish), Rietspruit (58% of examined fish) and Leeuwspruit (67% of examined fish).

Fluoride concentrations were high in sediments and biota sampled from the Rietkuilspruit, compared to the values recorded at the reference site in the Taaibosspruit. A possible source of fluoride was indicated upstream of site RS4 in the Rietkuilspruit. Fluoride concentrations were also high in the sediments sampled from the Leeuwspruit, decreasing towards the lower reaches of the stream. The high fluoride concentrations detected in the Rietkuilspruit and Leeuwspruit is an issue of concern, given the high toxicity of this constituent towards the aquatic ecosystem. The toxicity of fluoride however is more related to the bioavailability of fluoride ions than to the total fluoride concentration in the water. The very high fluoride concentration detected in crabs sampled from the Rietkuilspruit (>30ppm) indicates high bioavailability of this constituent in the stream. Although fluoride concentrations were high in sediments sampled from the Leeuwspruit, concentrations detected in biota sampled from this stream were comparable to those detected in the Rietspruit and Taaibosspruit, indicating the constituent to be less bioavailable than in the Rietkuilspruit. This is an important aspect to consider with regards to the development of a management plan for the rivers/streams in the study area.

The Rietkuilspruit and Leeuwspruit generally displayed higher sediment contaminant concentrations than those measured in sediments sampled from the reference site in the Taaibosspruit and the Rietspruit (notably concentrations of F, Co, Ca, Cl, SO4, Ba, Mg, Al, Mn, Pb, B, Li, Cr, Zn, Sr and Fe). The sediment phosphate concentrations in the Rietspruit on the other hand were significantly higher than concentrations measured in the Rietkuilspruit and Leeuwspruit. This is attributed to treated sewage effluent from a number of Sewage Treatment Plants situated in the upstream Rietspruit. Sediment concentrations of Co, Ba, Mg, Ni, Mn, Cr and Fe showed distinct peaks at site LS4 (Leeuwspruit downstream from Dicksonville) indicating a significant source of metal enrichment upstream of this point. Site LS5

(Leeuwspruit upstream of Vaal River confluence) showed distinct peaks of Cu, Ca, Na and Sr sediment concentrations in both sediment layers, indicating continued enrichment of these particular constituents. Sediment contaminant data indicated the Rietspruit to contain lower concentrations of most constituents than the Rietkuilspruit and the Leeuwspruit. Bioaccumulation data however indicated the highest concentration of most constituents in crabs sampled from the Rietspruit and also the Vaal River. This phenomenon is probably related to the characteristics of the surface water (pH, hardness, redox potential, ionic strength, concentration of organic complexing agents, etc.) and subsequent bioavailability of the constituents analyzed during the present investigation.

Following the aquatic ecological characterization, a tailored biological monitoring system was developed. In order for a biological-monitoring system to become truly operational as a management tool, information collected during monitoring must be linked with management actions. Linking monitoring, information generation and ecosystem management will facilitate environmentally sustainable utilization of the concerned aquatic system, which is in line with the goal of the National Water Act (Act No 36 of 1998). Information gathered during the Baseline Assessment and information contained in the Preliminary Reserve Determination for Quaternary Catchment C22J (DWAF File No 26/8/3/3/322) was used to recommend management goals for the industry. It is however imperative that all users/pollutant contributers in the concerned sub-catchments adhere to these management goals in order for them to be effective. The major objective of the monitoring framework will be to monitor compliance with the Resource Quality Objectives (RQO). Important ecological indicators to be monitored include aquatic macroinvertebrate assemblages (SASS), fish species occurrence and health, habitat integrity, riparian vegetation integrity, water quality, sediment contaminant analyses, bioaccumulation and Whole Effluent Toxicity (WET) testing. Important considerations, identified during the Baseline Assessment (December 2001) are listed below:

- Any surface water management plan should take cognizance of the synergistic and antagonistic effect of the various water quality parameters in the concerned system, i.e. the protection potential of high TDS against the toxicity of metals and other contaminants.
- Changes in the riparian vegetation as a result of anthropogenical activities will only be evident in the long-term (after at least 5 years). It is therefore imperative that a long-term riparian vegetation monitoring program be implemented.
- Fluoride levels in the biotic and abiotic environment should be monitored during future biomonitoring efforts, so as to give a clearer picture of the environmental fate of this constituent in the study area. During the Baseline Assessment, fluoride was indicated to be a problem in the Leeuwspruit and especially the Rietkuilspruit.
- A Whole Effluent Toxicity (WET) testing program should be implemented. WET tests will indicate the bioavailability of toxic compounds to aquatic organisms, will respond to compounds, which are not readily identifiable or measured by analytical techniques, will respond to unknown compounds and will detect effects due to chemical interaction, e.g. synergism, antagonism and addition. It is recommended that a fish, aquatic macroinvertebrate, algal and bacterial test be included in such a program in order to represent different trophic levels (with different sensitivity levels). This will ensure improved evaluation capacity. Such a whole battery approach will provide the necessary information to:
  - Facilitate internal environmental auditing
  - Measure compliance with set aquatic quality objectives
  - Provide a baseline for Ecological Risk assessments
  - Ensure derivation of toxicity conditions to be used in licence applications

- It is recommended that sediment toxicity assessments be conducted at selected sites within the study area, in order to assess the actual toxicity and bioaccumulation potential of constituents at such areas.
- Formal and informal settlements, Waste Water Treatment Plants, Industries and Farming activities, amongst others, were identified to contribute significantly towards the load of certain constituents in the study area. A management strategy for the Rietspruit and Leeuwspruit catchments should therefore include all these potential contributors and water users in the study area.
- It is recommended that river channels and stream banks be rehabilitated and stabilized. This will result in an overall improvement in the biotic integrity in the study area.
- Several Present Ecological State (PES) Classes of E and F were determined during the present investigation. This is generally unacceptable and the short-term (0-5 years) aim should be to improve these to a Class D. In case of a Class D PES, the aim should be to improve to a Class C, while ecological aspects identified as Class C should be maintained as such.

A tailored Biological Monitoring Program was designed for the area in question.

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1. INTRODUCTION

This report represents one of a series of specialist Baseline Study Reports, compiled in fulfillment of the terms of reference for the compilation of an Environmental Master Plan for ISCOR Vanderbijlpark Steel (IVS).

Although this report represents a stand-alone document, the results generated during this study will be integrated into the Environmental Management and/or Environmental Monitoring actions proposed in the IVS Master Plan.

ECOSUN was appointed by Jasper Müller Associates cc to perform this Baseline Aquatic Ecological Assessment, in order to establish baseline data against which future changes in the health of the concerned aquatic system can be evaluated, and to develop a biological monitoring program which complies to industry standards as well as DWAF requirements.

2. OBJECTIVES

The major objectives of this program will be to:

- Conduct a Baseline Assessment for the aquatic system associated with the Leeuwspruit and Rietkuilspruit, as well as relevant sections of the Rietspruit (up- and downstream of the Rietkuilspruit confluence) and Vaal River (downstream from Leeuwspruit confluence).
- Establish aquatic baseline data against which future changes in the health of these systems can be evaluated
- On the basis of above, develop a biological monitoring program which complies to industry standards as well as DWAF requirements and which, once implemented, will enable assessment of, and reporting on the health, status and trends of these systems in relation to possible impacts as a result of industrial and/or other anthropogenical activities.

3. STUDY AREA

Sampling sites in the Rietspruit and Leeuwspruit were selected to coincide with existing water quality monitoring points and to include a suitable "natural" or "minimally impacted" reference site (Table 1 and Figure 1). Co-ordinates of sampling sites were determined using a Trimble Geographical Positioning System and are listed in Table 1. Photographs of sampling sites are presented in APPENDIX 1.

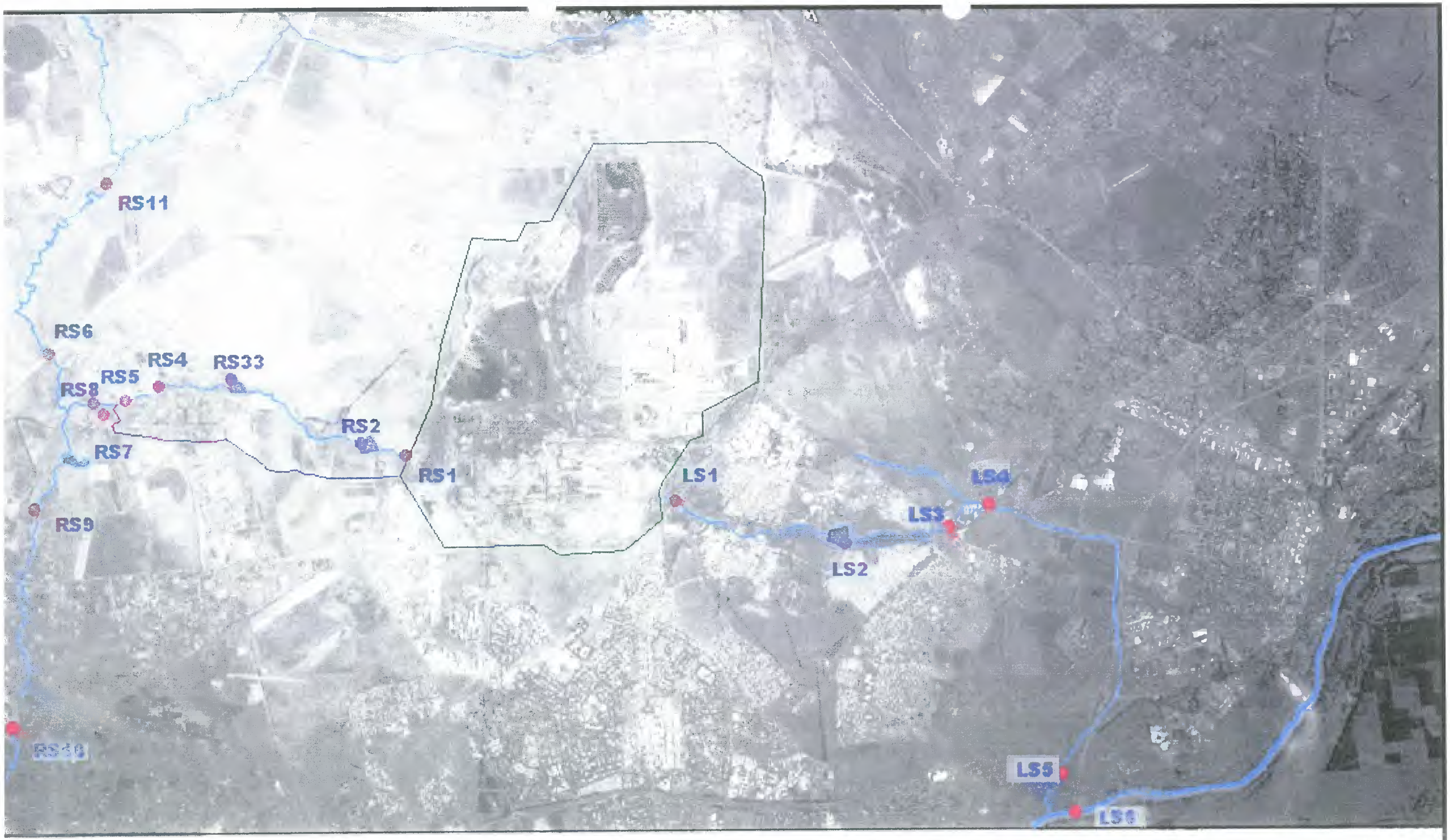

Figure 1: Sampling Sites in streams and rivers associated with the ISCOR Vanderbijlpark Plant

Table 1: Description of sampling sites

Site No.	Description	Co-ordinates
Reference Site	Upper section of the Taaibosspruit	S: 26°51'57.2"; E: 27°56'02.2"
RS1	Rietkuilspruit on Golden Highway downstream from southern industries	S:26°39'40"; E:27°47'56"
RS2	Rietkuilspruit downstream from Farm Dam	S:26°39'36"; E:27°47'34"
RS3	Rietkuilspruit downstream from Farm Dam	S:26°39'09"; E:27°46'34"
RS4	Rietkuilspruit downstream from RS3 on secondary road	S:26°39'07"; E:27°45'45"
RS5	Rietkuilspruit upstream from canal on gravel road	S:26°39'13"; E:27°45'27"
RS6	Rietspruit upstream from confluence (Rietkuilspruit & Canal) on R54	S:26°38'48.8"; E:27°44'48.0"
RS7	Downstream section of canal just upstream from confluence with Rietkuilspruit	S:26°39'18.1"; E:27°45'19"
RS8	Approximately 100m downstream from canal confluence	S:26°39"15"; E:27°45'20"
RS9	Approximately 5km downstream from Rietkuilspruit/Rietspruit confluence in Rietspruit	S:26°39'15.0"; E:27°45'14"
RS10	On Rietspruit at weir	S:26°41'37.7"; E:27°44'22.2"
LS1	Tributary of Leeuwspruit on southeastern side of the IVS works	S:26°40'00.2"; E:27°50'25.9"
LS2	Tributary of Leeuwspruit draining from Boitshepi dumping site	S:26°40'15.2"; E:27°52'05"
LS3	Tributary of Leeuwspruit draining from Ditonville	S:26°40'12"; E:27°52'46"
LS4	Leeuwspruit downstream from tributaries LS1- LS3	S:26°40'03"; E:27°53'13"
LS5	Leeuwspruit upstream from confluence with Vaal River	S:26°42'01"; E:27°53'56"
LS6	Vaal River at the R59 road	S:26°42'30.0"; E:27°53'53.7"

4. APPROACH

The approach recommended for the baseline assessment is presented according to generally accepted aquatic monitoring procedures, which include:

- Characterization and planning components (description of ecological status, identification of problems and important environmental components)
- Data generation components (sample collection and handling, laboratory or field analyses, data handling)
- Evaluation components (quality control & assurance)
- Information generation components (data analyses, reporting & information utilization)

The first phase of this baseline study comprised the gathering and assessment of available literature for the area. The purpose of this literature survey was to gather and summarize all relevant information pertaining to species diversity and composition of aquatic and riparian vegetation, aquatic invertebrates and aquatic vertebrates (fish, amphibians) of the relevant areas, as well as information with regard to anthropogenically induced changes to the biotic integrity.

The baseline assessment involved the characterization of the aquatic environment, habitat, related biota, magnitude and extent of site-related effects (point and non-point sources) in terms of up- and downstream species assemblage comparisons, as well as the current ecological status of the aquatic system. The major goal of the characterization procedure was to determine the current status of the aquatic environment and to evaluate the extent of site related effects in terms of selected ecological indicators, as well as to identify specific important aquatic ecological attributes (Wetlands, Red Data species, etc.). Following the aquatic ecological characterization, a tailored biological monitoring system was developed.

In order for a biological-monitoring program to become truly operational as a management tool, information collected during monitoring must be linked with management actions. Linking monitoring, information generation and ecosystem management will facilitate environmentally sustainable utilization of the concerned aquatic system, which is in line with the goal of the National Water Act (Act No 36 of 1998). Information gathered during the Baseline Assessment was used to recommend management goals for the industry. Aspects taken into account during the setting of these goals, include:

- The current and reference ecological integrity of the study area
- The ecological importance and sensitivity of the concerned aquatic system
- Its importance to the functioning of receiving ecosystems

These management goals were refined, taking into account the Ecological Management Class (DWAF File No: 26/8/3/3/322) proposed for the study area.

Data obtained during the baseline assessment, as well as recommended management goals, were presented during a meeting held on 10 June 2002 at the Jasper Müller Associates Offices in Delmas. Data obtained during the baseline assessment was also presented to relevant role players (including representatives from ISCOR) during a meeting, which was held at Ockie Fourie Toxicologist's offices in Pretoria on 14 June 2002. Input received during these two meetings was incorporated into the current report. Following this, management goals were formulated for ISCOR and a tailored Biological Monitoring Program was designed for the area in question. This program will indicate compliance with the set management goals, identify types and level of threat to the concerned aquatic system and indicate the need for management actions to ameliorate possible undesirable conditions.

5. COLLECTION OF DATA

Data for the Baseline Ecological Assessment were collected during a field survey conducted at the mentioned sampling sites from 27 November 2001 to 2 December 2001. In order to enable adequate description of the aquatic environment, certain ecological indicators were selected to represent each of the responding, exposed, habitat and stressor components involved in the aquatic environment. These included:

Stressor Indicators

- *In situ* water quality
- Algal biomass

Habitat Indicators

- General Habitat Assessment
- Integrated Habitat Assessment System (IHAS, *version 2*)
- Habitat Integrity Assessment

Response Indicators

- Riparian and Aquatic Vegetation Assessment (to include RVI)
- Aquatic Macroinvertebrates (SASS5)
- Ichthyofauna

Exposure Indicators

- Contaminant concentrations in sediments
- Bioaccumulation

A list of parameters monitored at each of the sites selected in the concerned sections of the Rietspruit, Rietkuilspruit, Leeuwspruit and Vaal River is provided in **Table 2.**

Table 2: Parameters monitored at selected sites

Site	*In situ* Water Quality	Algal Biomass	General Habitat Assessment	IHAS	Habitat Integrity Assessment	SASS5	FAII	Riparian and Aquatic Vegetation Description	RVI	Sediment Contaminant Concentrations	Bioaccumulation
Ref	√	√	√	√	√	√	√	√	√	√	√
RS1	√	√	√	√	√	√	√	√	√	√	√
RS2	√	√	√	√	√	√		√		√	
RS3	√	√	√		√	√		√		√	
RS4	√	√	√	√	√	√	√	√	√	√	
RS5	√	√	√	√	√	√	√	√	√	√	√
RS6	√	√	√	√	√	√	√	√	√	√	√
RS7	√	√	√	√	√	√		√		√	
RS8	√	√	√	√	√	√	√	√	√	√	√
RS9	√	√	√	√	√	√	√	√	√	√	√
RS10	√	√	√	√	√	√	√	√	√	√	√
LS1	√	√	√	√	√	√		√		√	

Site	*In situ* Water Quality	Algal Biomass	General Habitat Assessment	IHAS	Habitat Integrity Assessment	SASS5	FAII	Riparian and Aquatic Vegetation Description	RVI	Sediment Contaminant Concentrations	Bioaccumulation
LS2	√	√	√	√	√	√		√		√	
LS3	√	√	√	√	√	√	√	√	√	√	
LS4	√	√	√	√	√	√		√		√	√
LS5	√	√	√	√	√	√		√		√	
LS6	√	√	√	√	√	√	√	√	√	√	√

5.1. *In situ* Water Quality

In situ water quality measurements were determined on site. These included

- TDS (TDScan Meter)
- pH (pHScan Meter)
- Dissolved Oxygen (Hannah Oxygen Meter)
- Temperature (Alcohol Thermometer)
- Flow Velocity (Cyclometer)

5.2. Algal Biomass (Chlorophyll *a*)

Algae represent the primary producer trophic level and exhibit a specific range of sensitivities. It generally have rapid reproduction rates and very short life cycles which make them valuable indicators of short-term impacts. Algal assemblages are furthermore sensitive to some pollutants which may not visibly affect other population assemblages from higher trophic levels, or may only affect other organisms at higher concentrations. Water samples were collected at each of the selected sampling sites on the last day of the field visit (2 December 2001) and submitted to Waterlab Research (Pty)Ltd for analyses.

5.3. Habitat Assessment

Habitat assessment can be defined as the evaluation of the structure of the surrounding physical habitat that influences the quality of the water resource and the condition of the resident aquatic community (Barbour *et al*., 1996). Habitat quality and availability plays a critical role in the occurrence of aquatic biota. For this reason habitat evaluation is conducted simultaneously with biological evaluations in order to facilitate the interpretation of results.

Assessment of physical habitat quality is an integral component of the final evaluation of any impairment. The assessment performed includes a general description of the site (Global Positioning Satellite [GPS] reading; photographs for future identification of major changes and documentation of habitat conditions and watershed features; video footage of each site; physical characterization). These parameters are pertinent to the characterization of an aquatic system. This data provide valuable insight as to the ability of these systems to support a healthy aquatic community.

5.3.1. Integrated Habitat Assessment System (IHAS)

The Integrated Habitat Assessment System (IHAS, *version 2*) was applied at each of the selected sampling sites in order to assess the suitability of biotopes present. The IHAS was developed specifically for use with rapid biological assessment protocols in South Africa (McMillan, 1998), and express the suitability of biotopes as a percentage, where 100% represents ideal habitat availability. This index allows for much less variance between operators than the Habitat Quality Index (HQI) and is to become the nationally accepted habitat assessment system for use with the SASS index. It is presently thought that a total score of over 65% represents good habitat conditions, and over 55% indicates adequate habitat conditions (McMillan, 2002).

5.3.2. Habitat Integrity Assessment

The Intermediate Habitat Integrity Assessment (IHIA) protocol, as described by Kemper *et al.*, (1999), with minor modifications, were used for the purposes of this study. This is a simplified procedure, which is based on the Habitat Integrity approach developed by Kleynhans (1996). The IHIA is conducted as a first level exercise where a comprehensive exercise is not practical. The procedure used was as follows:

- The relevant river reaches were divided into segments approximately 5km in length. **Segment 1** is the most upstream segment in the Leeuwspruit from its source up to the confluence of a small tributary from the north-west; **Segment 2** is the lower section of the Leeuwspruit from the confluence of the tributary up to its confluence with the Vaal River; **Segment 3** constitutes the Rietkuilspruit from its source to confluence with the Rietspruit; **Segment 4** constitutes a 5km reach of the Rietspruit upstream of the Rietkuilspruit confluence; **Segment 5** is a 5km reach of the Rietspruit downstream from the Rietkuilspruit confluence.
- The Habitat Integrity of each stream segment was scored according to 12 different criteria (Table 3), which represent the most important, and easily quantifiable, anthropogenically induced impacts on the system. The instream and riparian zones were analyzed separately, and the final assessment was made separately for each, in accordance with Kleynhans' (1999) approach to Habitat Integrity Assessment. Data for the riparian zone are however primarily interpreted in terms of the potential impact on the instream component.
- The assessment of the severity of impact of modifications is based on six descriptive categories with ratings ranging from 0 (no impact), 1 to 5 (small impact), 6 to 10 (moderate impact), 11 to 15 (large impact), 16 to 20 (serious impact) and 21 to 25 (critical impact), in accordance with the level of the impact created by the criterion (Table 4).
- Analysis of the data was carried out by weighting each of the criteria. The weights given to the different instream and riparian factors used in the Intermediate Habitat Integrity Assessment of the sections of the Leeuwspruit, Rietkuilspruit and Rietspruit under investigation are shown in Table 5.

- Based on the relative weights of the criteria, the impact of each criterion are estimated as follows:
  Rating for the criterion/maximum value (25) x weight (percent)
- The instream and riparian Habitat Integrity for each segment was then calculated by adding the weighted scores of the appropriate criteria separately for each of the two zones and subtracting the resulting values from one hundred, thus obtaining provisional Habitat Integrity scores (expressed as percentages) for instream and riparian habitats.
- In cases where riparian zone criteria and the water abstraction, flow, bed and channel modification, water quality and inundation criteria of the instream component exceeded ratings of large, serious or critical, an additional negative weight was applied. The aim of this is to accommodate the possible cumulative effect (and integrated) negative effects of such impacts (Kemper *et al*. 1999). The following rules were applied in this respect:
  Impact = Large, lower the integrity status by 33% of the weight for each criterion with such a rating.
  Impact = Serious, lower the integrity status by 67% of the weight for each criterion with such a rating.
  Impact = Critical, lower the integrity status by 100% of the weight for each criterion with such a rating.
- The negative weights were added for the instream and riparian facets respectively and the total additional negative weight subtracted from the provisionally determined intermediate integrity to arrive at a final intermediate habitat integrity estimate (Kemper *et al*., 1999)
- The eventual total scores for the instream and riparian zone components are then used to place the habitat integrity of both in a specific intermediate habitat integrity class/category. These classes are indicated in Table 6.
- By calculating the mean of the instream and riparian Habitat Integrity scores, an overall Habitat Integrity score was obtained for each segment.

Table 3: Criteria used in the assessment of habitat integrity (from Kleynhans, 1996)

CRITERION	RELEVANCE
Water abstraction	Direct impact on habitat type, abundance and size. Also impacted in flow, bed, channel and water quality characteristics. Riparian vegetation may be influenced by a decrease in the supply of water.
Flow modification	Consequence of abstraction or regulation by impoundments. Changes in the temporal and spatial characteristics of flow can have an impact on habitat attributes such as an increase in duration of low flow season, resulting in low availability of certain habitat types or water at the start of the breeding, flowering or growing season.
Bed modification	Regarded as the result of increased input of sediment from the catchment or a decrease in the ability of the river to transport sediment (Gordon et al., 1993). Indirect indications of sedimentation are stream bank and catchment erosion. Purposeful alteration of the stream bed, e.g. the removal of rapids for navigation (Hilden & Rapport, 1993) is also included.
Channel modification	May be the result of a change in flow, which may alter channel characteristics causing a change in marginal instream and riparian habitat. Purposeful channel modification to improve drainage is also included
Water quality modification	Originates from point and diffuse point sources. Measured directly or agricultural activities, human settlements and industrial activities may indicate the likelihood of modification. Aggravated by a decrease in the volume of water during low or no flow conditions.
Inundation	Destruction of riffle, rapid and riparian zone habitat. Obstruction to the movement of aquatic fauna and influences water quality and the movement of sediments (Gordon et al., 1992).
Exotic	Alteration of habitat by obstruction of flow and may influence water quality. Dependant

CRITERION	RELEVANCE
macrophytes	upon the species involved and scale of infestation.
Exotic aquatic fauna	The disturbance of the stream bottom during feeding may influence the water quality and increase turbidity. Dependent upon the species involved and their abundance
Solid waste disposal	A direct anthropogenic impact which may alter habitat structurally. Also a general indication of the misuse and mismanagement of the river.
Indigenous vegetation removal	Impairment of the buffer the vegetation forms to the movement of sediment and other catchment runoff products into the river (Gordon et al., 1992). Refers to physical removal for farming, firewood and overgrazing
Exotic vegetation encroachment	Excludes natural vegetation due to vigorous growth, causing bank instability and decreasing the buffering function of the riparian zone. Allochtonous organic matter input will also be changed. Riparian zone habitat diversity is also reduced
Bank erosion	Decrease in bank stability will cause sedimentation and possible collapse of the river bank resulting in a loss or modification of both instream and riparian habitats. Increased erosion can be the result of natural vegetation removal, overgrazing or exotic vegetation encroachment.

Table 4: Descriptive classes for the assessment of modifications to habitat integrity (from Kleynhans, 1996).

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

Table 5: Criteria and weights used for the assessment of intermediate habitat integrity (from Kleynhans, 1996).

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

Table 6: Intermediate Habitat Integrity Assessment Classes/Categories (from Kleynhans, 1996).

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

5.4. Aquatic and Riparian Vegetation

An assessment of the current status of the aquatic and riparian vegetation in the study area (which included wetland areas) was conducted. Diversity and composition was identified. Conservation importance, as well as the presence and distribution of sensitive/Red Data species in the study area were identified. In addition to the above-mentioned comprehensive aquatic and riparian vegetation assessment, the Riparian Vegetation Index (RVI) developed by Kemper (2000) was applied. This index considers the extent of vegetation coverage of the riparian zone, the structural intactness of the riparian zone, the percentage cover of indigenous riparian species as well as the regeneration of indigenous species. The RVI was developed as part of the National River Health Program to provide a rapid, relative simple method for evaluation of the condition and ecological integrity of the riparian vegetation along rivers and streams. However, the highly disturbed nature of several of the sites made such a classification difficult to implement and the results should therefore be regarded as the baseline against which future changes could be monitored.

Traverses were made on foot along both banks of the rivers and streams at each of the 17 sites and all species observed were recorded. References to the right hand bank (RHB) or left hand bank (LHB) were made facing downstream. Sites such as LS1, LS4 and RS7 were canalized while at RS2 the dam which was supposed to be assessed, had been drained. This resulted in the survey of the vegetation below the dam wall. Although it was attempted to survey 200m along each bank at each site, this was not always possible because of physical changes such as dams, weirs or bridges, to the streams above, below or both, at the specific sites, all of which had been previously identified. The lengths of the transects therefore varied from 40-200m per side. However it was found that this did not necessarily result in a higher number of species recorded from a site. What appeared to be more important was the degree of disturbance at a specific site. All recordings were made on a pocket tape recorder and later transcribed.

5.5. Aquatic Macroinvertebrates

The South African Scoring System Index (SASS, *version 5*) was applied (Dickens & Graham, 2001). This index provides an indication of the quality of the aquatic environment in terms of a numerical score that is obtained through recording the presence of various macroinvertebrate families at the sampling site. Scores obtained during the different monitoring efforts can then be compared in order to detect any changes in aquatic ecosystem health.

Benthic macro-invertebrates are collected from all distinguishable biotopes at each of the sampling sites using a net with a pore size of 1000 micron, mounted on a 300mm square frame. In stony bottomed flowing water biotopes (rapids, riffles, runs, etc.) the net is rested on the bottom and the area immediately upstream of the net is disturbed by kicking the stones over and against each other to dislodge benthic invertebrates.

Sandy and muddy bottom and stones-out-of-current are sampled by stirring the bottom and sweeping the net through the water over the disturbed area to catch dislodged organisms. Marginal and aquatic vegetation is sampled by sweeping the net back and forth through the biotope to cover from 1-2 meters. Identification of the organisms will be done to family level.

Habitat is a major determinant of aquatic community potential. Both the quality and quantity of available habitat affect the structure and composition of benthic macroinvertebrate communities. The Integrated Habitat Assessment System (IHAS) was used to semi-qualitatively evaluate the condition of the habitat at each of the different sampling sites and to assess the impact of physical habitat degradation on the SASS scores.

<u>Ecological Integrity, based on SASS results</u>
Reference conditions reflect the best conditions that can be expected in rivers and streams within a specific area and also reflect natural variation over time. SASS and ASPT reference conditions were modeled for the Highveld Ecoregion by DWAF (data obtained from Gauteng Nature Conservation, Mr Piet Muller). Based on these modeled scores (Table 7), the Present State Class of the different sites in the study area is derived.

Table 7: Classification protocol for determining the Present State Class, based on SASS results

Class	SASS4	ASPT	Condition
A	>120	>6	Excellent
B	91-120	5-6	Very Good
C	71-90	4.5 – 5.5	Good
D	56-70	4.5 – 5.5	Fair
E	30-55	Variable	Poor
F	<30	Variable	Very Poor

Above Classification scores is based on SASS4 scores. This was taken into account during classification of the current data.

5.6. Ichthyofauna

Invertebrate communities are good indicators of localized conditions in a river over the short-term, while fish – being relatively long-lived and mobile,

- are good indicators of long-term influences
- are good indicators of general habitat conditions
- integrate effects of lower trophic levels
- are consumed by humans (NBP Report Series No 4, 1996).

Fish sampling was conducted by means of an electroshocker, seine net, dip nets, and gill nets. The presence and relative density (catch per unit effort) of sampled fish species was documented for each sampled flow type. Specimens were released unharmed where possible, except for reference specimens, which will be lodged at the JLB Smith Institute of Ichthyology. Because of the low diversity and abundance of fish species sampled in the study area, application of the Fish Assemblages Integrity Index (FAII) was not possible.

5.6.1. Fish Health Assessment

The health and condition of selected fish species were evaluated by applying a similar protocol to that described by DWAF (1997). Individuals with disease, tumors, fin damage and skeletal abnormalities occur infrequently or are absent from minimally impacted reference sites, but normally occur frequently below point sources and in areas where toxic chemicals are concentrated.

For the purpose of this study the fish health assessment was confined to external examination of the skin and fins, eyes, gills, opercula and the presence of ectoparasites. This approach ensured the minimization of stress and allowed fish to be released unharmed.

5.7. Sediment Contaminant Concentrations

Contaminated sediments are generally thought to be one of the largest risks to the aquatic environment. Although representing only one component of the ecosystem assessment, contaminated sediments are a major source of stress to ecosystem health (Burton, 1992). Sediment data reveals short-term or past-pollution events, which are generally not reflected by grab sample water analyses. Metals released into an ecosystem tend to accumulate in sediments through various adsorption and precipitation processes, thus becoming part of the ecosystem. Metals can be reintroduced into the water in a bio-available form when conditions like pH, hardness, redox potential, ionic strength and concentration of organic complexing agents change (Merian, 1991; Burton, 1992; Gupta, 1992; Coetzee, 1993). Once the metal become available, they may be transformed into more or less toxic forms, or they may migrate from the sediments into benthic organisms from where they can be taken up in the food chain, contaminating fish, wildlife and humans (Burton, 1992). It is therefore important to characterize sediment contaminant levels in order to identify constituents that may pose a threat to the aquatic environment.

Sediment core samples were taken at selected sites in the study area. Different depositional layers in the sediment were visually assessed and distinguished by using colour (to distinguish between primary layers) and texture (to distinguish between secondary layers). Each identified layer was then collected in a separate plastic bag, and transported to the laboratory for analyses.

When metal concentrations in sediment are determined, it is important to distinguish between the different fractions of a sediment sample. More metals and anions will absorb to the smaller particles present (fine sand, silt & clay) than to the large particles (granules and coarse sand). For the purpose of this study the concentrations of Ca, Ba, B, Bi, Sr, Mg, Cu, Al, Co, Cd, Ni, Mn, Fe, Cr, Na, Zn, Li, Pb, Cl, F, Br, NO3, phosphate and sulphate in particles smaller than 0,0625mm were therefore determined. This will allow direct comparison between the concentrations of the different constituents detected at the different sites in the study area. The concentrations represent the fraction of constituents with the potential of becoming available to the surrounding aquatic medium (DWAF, 1990).

5.8. Bioaccumulation

Analyses of contaminant accumulation by aquatic organisms provide a practical method for establishing the link between concentrations of these contaminants in the environment and the effect these may have on the biota. Bioaccumulation studies give an "integrated" record of pollution within the system and were therefore included as part of the baseline assessment. Because of the limited number of fish sampled in the study area, contaminant analyses were confined to the analyses of whole crabs sampled at selected sites in the study area.

Freshwater crabs are known for their ability to bioaccumulate metals and are for various reasons (listed below), very useful as indicator organisms for the timely identification of unacceptable levels of trace metal enrichment in the aquatic environment:

- They are common and widespread
- They are able to adapt to a variety of different habitats
- They are relatively sedentary, therefore allowing for site specific results
- They are able to withstand fairly high levels of anthropogenically induced impacts
- They have a high fecundity and recruitment as a result of parental care

Freshwater crabs were used with great success in the determination of point sources of metal enrichment in other aquatic systems (Steenkamp *et al.*, 1993; 1994; Rall *et al.*, 1995; Department of Water Affairs and Forestry, 1995). Freshwater crabs were therefore analyzed to obtain an indication of levels of enrichment of certain metals in the environment and the bio-availability thereof to the aquatic biota.

Similar sized specimens of freshwater crabs were collected by hand and with baited traps. These crabs were individually packed into plastic bags and then stored at –4°C for later analyses. At the laboratory these crabs were processed and analyzed by means of the Inductively Coupled Plasma (ICP) method. Constituents analyzed include Ca, Ba, Sr, Mg, Cu, Al, Co, Cd, Ni, Mn, Fe, Cr, Na, Zn, Li, Pb, Cl, F, Br, Bi, B, N, phosphate and sulphate.

6. RESULTS

6.1. *In situ* Water Quality

In situ water quality measurements (TDS, temperature, pH, Dissolved Oxygen and Flow Velocity) were determined on site with lightweight compact field equipment and are presented in Table 8. These results are important to assist in the interpretation of biological results because of the direct influence water quality has on aquatic life forms.

Table 8: *In situ* water quality measurements

Site No	Time	pH	TDS mg/l	DO mg/l	Temperature (°C)	Flow Velocity (m/s)
REF	12h00	7.2	195	12	17	3.9
RS1	9h00	7.8	455	10	15	0.5
RS2	10h50	9.0	455	8.6	16	0.6
RS3	12h30	7.9	470	6.9	17	0.2
RS4	15h10	6.9	780	9.2	17	0.75
RS5	8h50	7.1	845	10.3	14	0.9
RS6	15h00	7.5	260	7.4	16.5	3.6
RS7	11h30	7.8	780	5.7	17	4.5
RS8	15h00	7.8	715	6.6	17	4.0
RS9	12h20	7.8	455	7.6	16	4.6
RS10	9h55	6.3	650	5.4	14	2.2
LS1	12h30	6.5	390	4.6	17	0
LS2	14h00	7.4	390	5.3	19	0.75
LS3	15h40	7.5	390	6.4	20	0.81
LS4	8h20	7.9	455	8.3	13	0.94
LS5	11h30	8.4	845	4.3	16	3.8
LS6	8h40	7.8	195	7.9	17	0.36

*DO = Dissolved Oxygen
**TDS = Total Dissolved Salts

In situ TDS measurements increased towards the downstream section of the Rietkuilspruit, from 455mg/l (site RS1) to 845mg/l (site RS5), but decreased to a value of 715mg/l after confluence of the canal (site RS8). *In situ* TDS increased towards the downstream Rietspruit from 260mg/l at site RS6 to 455mg/l at site RS9 and 650mg/l at site RS10 (Table 8). *In situ* TDS measurements increased significantly towards the downstream section of the Leeuwspruit from 390mg/l at sites LS1, LS2 and LS3 to 845mg/l at site LS5 (Table 8).

Macroinvertebrate fauna are sensitive to salinity, with toxic effects likely to occur in most of the sensitive species at salinities in excess of 1000mg/l. It is also important to note that sub-lethal and indirect effects could occur at even lower salinities (Hart *et al*., 1991). It is however, often the rate of change rather than the final salinity that is most critical (Dallas & Day, 1993). According to the South African Water Quality Guidelines for Aquatic Ecosystems (DWAF, 1996), the TDS concentrations should not be changed by more than 15% from the normal cycles of an inland water body under unimpacted conditions at any time of the year, and the amplitude and frequency of natural cycles in TDS concentrations should not be changed.

It is further important to note that the high TDS may act as an antagonist or a synergist in relation to a variety of toxic pollutants. In general, salinity provides some protection against metals, probably by modifying their chemical speciation. The availability, and therefore toxicity, of several metallic and non-metallic ions are further reduced with increased pH.

pH varied considerably in the Rietkuilspruit (6.9 to 9.0) (Table 8). pH values measured in the Rietspruit varied from 6.3 to 7.8 and from 6.5 to 8.4 in the Leeuwspruit (Table 8). The pH target for fish health is presented as ranging between 6.5 and 9.0, as most species will tolerate and reproduce successfully within this pH range (Alabaster & Lloyd, 1980). In the current situation, however, it is the variation in pH that pose a threat towards the aquatic ecosystem. According to the South African Water Quality Guidelines for Aquatic Ecosystems (DWAF, 1996), the pH value should not be allowed to vary from the range of the background pH values for a specific site and time of day, by >0.5 of a pH unit, or by 5%, and should be assessed by whichever estimate is the more conservative. The significant variation in pH detected in the study area, will therefore have an adverse effect on the aquatic biota, especially fish (as a result of their mobility). No species-specific information is available on the effects of pH variation for the aquatic organisms of this area. Effects are however, mainly concerned with changes in the ionic and osmotic balance of individual organisms (DWAF, 1996).

The sections of the Rietspruit and Rietkuilspruit under investigation were well aerated with DO concentrations ranging between 6.6mg/l and 12mg/l, the only exceptions being sites RS7 (DO = 5.7mg/l) and site RS10 (DO = 5.4mg/l). The low DO concentrations measured at site LS2 (DO = 5.3mg/l) and especially sites LS1 (DO = 4.6mg/l) and LS5 (DO = 4.3mg/l) in the Leeuwspruit is cause for concern. The median guideline for DO as set by Kempster *et al.* (1980) is >5mg/l. Dissolved oxygen is probably one of the most important determinants of the health of an aquatic organism. Fish, and also larvae of stoneflies, caddisflies and mayflies are particularly susceptible to low DO concentrations. These organisms respire with gills or by direct cuticular exchange. Low oxygen levels may also increase the toxicity of some toxins such as ammonia and metals (Dallas & Day, 1993).

6.2. Algal Biomass (Chlorophyll-a)

Chlorophyll-a measurements were <1µg/l in samples collected at all sampling sites in the study area (APPENDIX 5). The reason for this is unknown.

6.3. Habitat Assessment

6.3.1. Integrated Habitat Assessment System (IHAS):

The IHAS was developed specifically for use with rapid biological assessment protocols in South Africa (McMillan, 1998), and focuses on the evaluation of the habitat suitability for aquatic macroinvertebrates.

Table 9: IHAS habitat assessment index conducted as part of the Baseline Assessment. Good is scripted in green, adequate/fair is scripted in blue and poor is scripted in red.

Sampling Site	IHAS (%)
REF	68
RS1	45
RS2	25
RS3	-
RS4	66
RS5	82
RS6	24
RS7	51
RS8	53
RS9	37
RS10	29
LS1	42
LS2	66
LS3	67
LS4	64
LS5	29
LS6	30

- Habitat unsuitable for application of index

The habitat availability for aquatic macroinvertebrates was indicated to be good at the reference site in the Taaibosspruit (IHAS = 68%) (Table 9; Figure 2). Habitat availability was poor at sites RS1 and RS2 in the Rietkuilspruit, but improved towards sites RS4 & RS5 (good habitat availability), then decreased again at site RS8 (poor habitat availability) (Table 9). Habitat availability was poor in the Rietspruit, with IHAS values ranging between 24% and 37% (Table 9). IHAS scores in the Leeuwspruit varied between 29% and 67%, indicating poor to good habitat availability (Table 9; Figure 2).

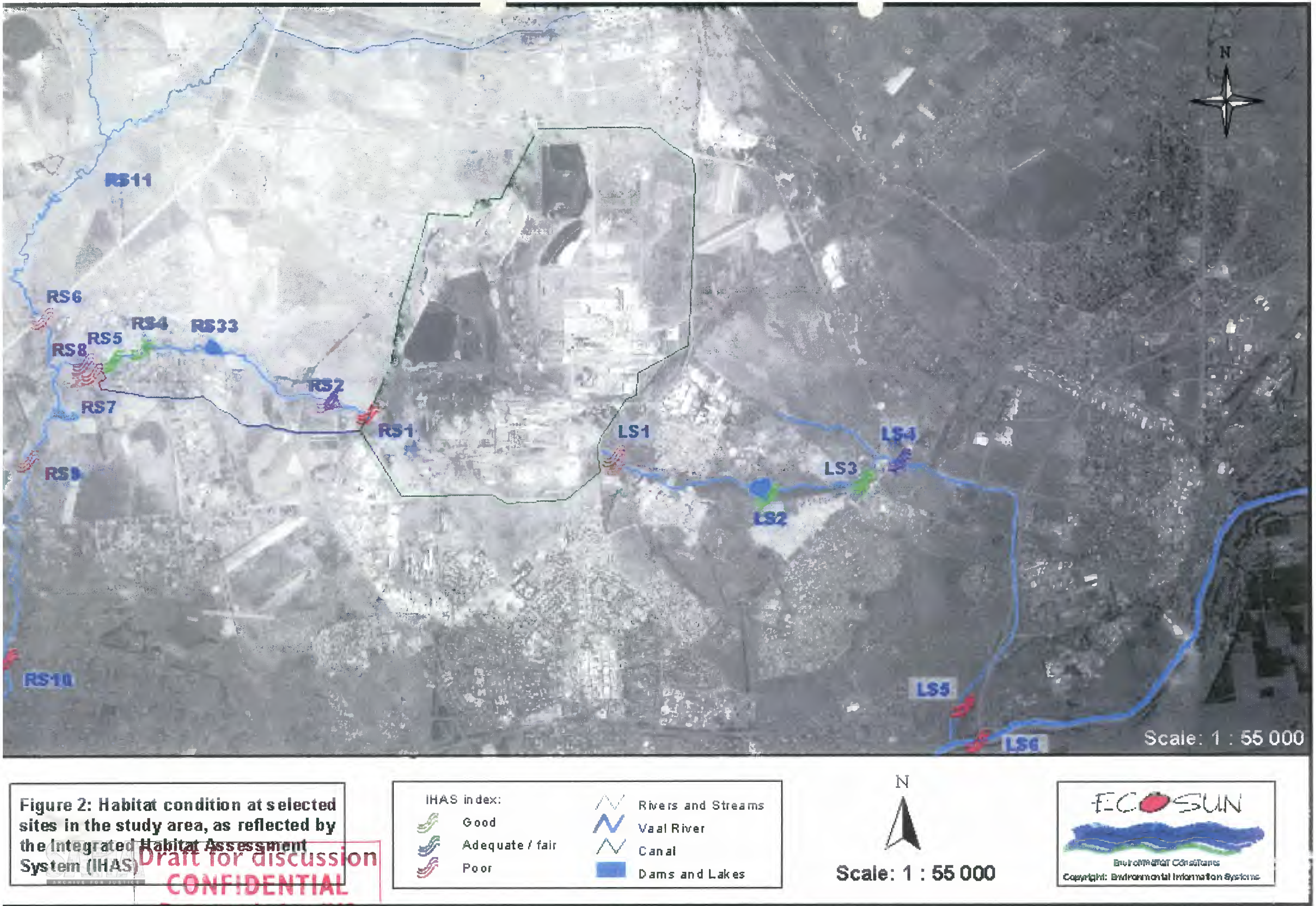

Figure 2: Habitat condition at selected sites in the study area, as reflected by the Integrated Habitat Assessment System (IHAS)

6.3.2. Habitat Integrity Assessment

The ecological integrity of a river is defined as its ability to support and maintain a balanced, integrated composition of physico-chemical and habitat characteristics, as well as biotic components on a temporal and spatial scale that are comparable to the natural characteristics of ecosystems in the region. This definition is based on the concept of biological integrity that has been described as the "ability to support and maintain a balanced, integrated, adaptive community of organisms having a species composition, diversity and functional organization comparable to that of natural habitats of the region" (Karr & Dudley, 1981). Habitat integrity in this sense then refers to the maintenance of a balanced, integrated composition of physico-chemical and habitat characteristics on a temporal and spatial scale that are comparable to the characteristics of natural habitats of the region (Kleynhans, 1996).

Essentially, the habitat integrity status of a river/stream will provide the template for a certain level of biotic integrity to be realized. In this sense the assessment of the habitat integrity of a river can be seen as a pre-cursor of the assessment of biotic integrity. It follows that in this context habitat integrity and biotic integrity together constitutes ecological integrity (Kleynhans, 1996).

The purpose of this section of the study is therefore to assess the habitat integrity of the Leeuwspruit, Rietkuilspruit and associated section of the Rietspruit, based on certain key criteria. The concerned river reaches were divided in 5 segments each approximately 5km in length. The information gathered during this part of the survey was used to determine the current Habitat Integrity of the study area.

Information used in the Habitat Integrity Assessment

The information sources used in the compilation of this section of the report are listed below:

- Notes made during a 'walkover' of the concerned river reaches. This 'walkover' was conducted during a site visit by ECOSUN on the 27th November 2001 to the 2nd December 2001.
- Results of specialist assessments carried out by ECOSUN within the concerned river reaches.
- Existing Reports (McMillan & Todd, 1998)
- 1:50 000 topographical maps (2627DB and 2627DA).
- 1:55 000 aerial image of the study area

Approach

This Habitat Integrity Assessment is based on ratings assigned individually to the 5 segments within the Leeuwspruit, Rietkuilspruit and section of the Rietspruit selected for this Intermediate Habitat Integrity Assessment. The instream and riparian zones were analyzed separately in accordance to the method of Kemper *et al.* (1999).

Results

The instream and riparian Intermediate Habitat Integrity scores for each of the 5 segments assessed are presented in Table 10. The instream and riparian Intermediate Habitat Integrity Classes, as well as the overall Intermediate Habitat Integrity Class, for each of the 5 segments assessed are presented in Table 11.

These assessments are of a generalistic and broad scale nature and should only be used to provide a first indication of condition of the concerned river reaches chosen for the purposes of this study.

Table 10: Intermediate Habitat Integrity Scores (expressed as percentages) assigned to the 5 segments comprising the study area.

Segment	Riparian Habitat Integrity Score	Instream Habitat Integrity Score	Mean Habitat Integrity Score
PROVISIONAL INTERMEDIATE HABITAT INTEGRITY			
1	45.47	39.33	42.40
2	42.32	40.82	41.57
3	56.88	58.16	57.52
4	72.92	70.76	71.84
5	50.12	63.68	56.90
FINAL INTERMEDIATE HABITAT INTEGRITY			
1	7.75	0.53	4.14
2	0	0.55	0.28
3	25.31	32.89	29.10
4	60.38	61.85	61.11
5	18.56	37.35	27.96

Table 11: Intermediate Habitat Integrity Classes/Categories assigned to the 5 segments comprising the study area.

Segment	Riparian Habitat Integrity Class	Instream Habitat Integrity Class	Mean Habitat Integrity Class
PROVISIONAL INTERMEDIATE HABITAT CLASS/CATEGORY			
1	D	C/D	D
2	D	D	D
3	D	D	D
4	C	C	C
5	D	D	D
FINAL INTERMEDIATE HABITAT CLASS/CATEGORY			
1	F	F	F
2	F	F	F
3	E	E	E
4	C	C	C
5	F	E	E

The main factors influencing the Habitat Integrity of each of the 5 selected segments, are briefly described below:

Segment 1 and Segment 2 (Leeuwspruit): These two segments constitute the most heavily impacted section of the assessed river reaches, with several factors (i.e. water abstraction, flow modification, bed modification, channel modification, inundation, indigenous vegetation removal, solid waste disposal, bank erosion, water quality impairment and exotic vegetation encroachment) impacting upon Habitat Integrity. The upper section of the Leeuwspruit is canalized with the overburden from the canal dumped on the bank. This resulted in an increase in weeds. The Leeuwspruit flows past several formal and informal settlements (Boipatong, Sharpeville, Boitshepi) and also an industrial area (Dicksonville Industrial Complex), which also impacts upon the water quality. Several roads bisect the Leeuwspruit, impeding on the natural flow regime of the stream. At site LS2 the only open water lies banked up behind the road crossing, feeding slowly downstream via culverts under the road. At site LS3 the canalization below the road bridge has resulted in increased water velocity, which in turn resulted in erosion of the downstream riverbanks. Here the banks were largely devoid of vegetation. Exotic vegetation encroachment is excessive along the entire reach of the Leeuwspruit (>50%), contributing towards bank instability. Modifications to Habitat Integrity have reached a critical level and the lotic system has been modified completely with an almost complete loss of natural habitat and ecological functioning. Segments 1 & 2 were provisionally determined as belonging to Class D, but since several criteria exceeded ratings of large, serious or critical, an additional negative weight was applied. The aim of this is to accommodate the possible cumulative effect (and integrated) negative effects of such impacts (Kemper *et al.*, 1999). Taking the latter into account the Leeuwspruit was determined as belonging to Class F (Figure 3).

Segment 3 (Rietkuilspruit): This segment constitutes the Rietkuilspruit from its origin to its confluence with the Rietspruit. Several factors impact upon Habitat Integrity in this river reach. These mainly include water abstraction, flow modification, bed modification, channel modification, bank erosion, inundation, indigenous vegetation removal, exotic vegetation encroachment and water quality impairment. It appears as if the Rietkuilspruit is subject to "flash floods" resulting in a continuous undercutting and collapse of its banks. Most of the steeper banks were devoid of vegetation. The riparian vegetation was very impoverished, especially in the lower section of the spruit. Here fallow lands stretch up close to the southern bank of the Rietkuilspruit. The riparian zone was characterized by a high percentage of alien vegetation species, further increasing bank instability. Several dams impede the flow of the stream. Apart from these earth walled dams, the flow of the Rietkuilspruit is also altered by the fast flowing water from the canal entering the spruit upstream of site RS8. The loss of natural habitat, biota and basic ecosystem functions is extensive in the Rietkuilspruit. Segment 3 was provisionally determined as belonging to Class D, but since several criteria exceeded ratings of large, serious or critical, an additional negative weight was applied The Rietkuilspruit was therefore determined as belonging to Class E (Figure 3).

Segment 4 (Rietspruit): This segment constitutes a 5km reach of the Rietspruit upstream of the Rietkuilspruit confluence. Factors impacting upon Habitat Integrity in this segment mainly include water abstraction, flow modification, bed modification, channel modification and bank erosion. Large areas are used for the grazing of livestock. Scouring of river banks resulted in the deposition of sediment in the river channel. Segment 4 in the Rietspruit was determined as belonging to Class C, i.e. a loss and change of natural habitat and biota have occurred, but the basic ecosystem functions are still predominantly unchanged (Figure 3).

Segment 5 (Rietspruit): This segment constitutes a 5km reach of the Rietspruit downstream from the Rietkuilspruit confluence. Several factors impact upon Habitat Integrity in this river reach. These mainly include flow modification, bed modification, channel modification, bank erosion, indigenous vegetation removal, exotic vegetation encroachment and water quality impairment. Most of the surrounding area was used primarily for grazing and livestock. Parts of the steep riverbanks have collapsed as a result of undercutting by floodwaters. The upper banks were nevertheless well vegetated. This segment was floristically more species rich than other river reaches assessed during this study. However, approximately 40% consisted of alien species. Segment 5 was provisionally determined as belonging to Class D, but since several criteria exceeded ratings of large, serious or critical, an additional negative weight was applied. The aim of this is to accommodate the possible cumulative effect (and integrated) negative effects of such impacts (Kemper *et al.*, 1999). Taking the latter into account this section of the Rietspruit was determined as belonging to Class E, i.e. the loss of natural habitat, biota and basic ecosystem functions is extensive (Figure 3).

Figure 3: In-stream and Riparian Habitat Integrity of selected rivers/ streams in the study area

Riparian index:
- Moderately modified
- Largely modified
- Severely to critically modified

- Rivers and Streams
- Vaal River
- Canal
- Dams and Lakes

N

Scale: 1 : 55 000

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6.4. Aquatic and Riparian Vegetation

The sites fall within Veld type 48, or Cymbopogon –Themeda Veld (Acocks 48) or 39, Moist Cool Highveld Grassland (Bredenkamp & Van Rooyen 1996) but, being restricted to riparian zones along streams and dams, do not display characteristics typical for these grasslands as a whole. In addition all of the sites surveyed, reflected different degrees of disturbance, a fact borne out by the condition, species richness and alien content of the vegetation. The vegetation recorded at the sites can be seen in APPENDIX 2. The species richness recorded, varied from 20 – 58 taxa at the 17 sites surveyed of which 9 – 26 comprised alien species. Only one Red Data Book taxon was recorded, *Kniphofia typhoides* listed as Insufficiently Known. In order to highlight such difference, each site is discussed in greater detail below:

Site LS1: Upstream in Leeuwspruit, at Frikkie Meyer Boulevard

At this site, situated some 100m downstream from IVS, where the stream runs under Frikkie Meyer Boulevard, the Leeuwspruit had been canalized. The canal is roughly two meters deep and approximately 2,5 – 3m wide at the top with a channel width of 1-2m, and extended approximately 300-400m from west to east through a large vlei and wetlands situated below Boipatong. What may have been part of the Leeuwspruit was choked with vegetation and meandered to the southeast of the canal. The soils were predominantly turf clay with scattered gravel.

The canal effectively receives water from the Leeuwspruit which mostly flows through a very large marsh dominated by *Typha capensis*, lying to the north between a tar road and Boipatong with its associated informal settlement. Additional water flowsfrom the direction of IVS under the road to the canal. The canal flows through the southern end off the *Typha* marsh, then through a vlei and into a dense reedbed dominated by *Phragmitis australis*.

The canal

Although no riparian zone could be found along the canal, the vegetation on either side was recorded as they formed part of the wetland. Grasses were most prevalent including Kikuyu *Pennisetum clandestinum, Bromus catharticus, Helictotrichon turgidulum, Ischaemum afrum, Setaria incrassata* and *Agrostis lachnantha* with many sedge intrusions, mostly *Cyperus longus* and *Carex* sp. with *Schoenoplectus tabernaemontani* in wetter depressions and along the canal. Forbs were common, mostly weeds and ruderals such as *Cirsium vulgare, Rumex crispus, Melilotus indica, Sonchus oleraceus, Plantago lanceolata* and many others, as well as such species as *Tulbaghia leucantha*, *Berkheya rhapontica* ssp. *rhapontica, Trifolium pratense* and especially *Euphorbia* sp. cf *pubescens*. Most of the overburden of the canal had been dumped on the right hand side, with the result that weeds were more prevalent here than elsewhere.

The 'Leeuwspruit':

Although now largely stagnant, some water remained in the channel at the time of the survey. The stream channel was choked with stands of bulrushes

Typha capensis alternating with the sedge *Schoenoplectus tabernaemontani.* Along the banks *Bromus catharticus* and *Bromus* sp. formed stands alternating with *Agrostis lachnantha* while along the stream *Panicum repens* grew densely. *Helictotrichon turgidulum* was common in patches. Forbs were mostly *Euphorbia* sp. cf *pubescens, Melilotus indica, Rumex crispus, Plantago lanceolata, P. major and Veronica anagallis-aquatica* together with the sedge *Carex* sp. and *Juncus exsertus* ssp. *exsertus*.

Altogether 45 species were recorded here indicating relatively poor species richness as 19 of these were alien taxa.

<u>Site LS2. Leeuwspruit below dam, tributary draining from Boitshepi dumping site.</u>

This site lies along the Leeuwspruit between Sharpeville and Boitshepi where the streams drain through a large marsh on both sides of a road between these two townships. The road therefore bisects the marsh into a western predominantly *Typha capensis* section and an eastern *Typha/Phragmitis australis* section. Water flows throughout the marsh, which is several hundred meters wide. The only open water lies banked up behind the road crossing, feeding slowly downstream via culverts under the road. Water from one of these culverts at the northern end of the road flowed along a 30m stretch of more open vegetation before entering the marsh again. The survey took place along this stretch as well as part of the marsh below the road.

Grasses such as *Paspalum distichum* grew closest to the channel and also along the adjacent floodplain where bulrushes were absent, while *Agrostis lachnantha, Cynodon dactylon*, the alien *Paspalum dilatatum* and *Polypogon monspeliensis*, grew along the banks. Various forbs including *Rorippa nasturtium-aquaticum, Cirsium vulgare, Rumex* sp., *Persicaria limbata, Conyza bonariensis* and *Euphorbia* sp. cf *pubescens* were also recorded. Sedges, *Schoenoplectus decipiens, S. muriculatus* and *Eleocharis* sp. cf *dregeanus* together with forbs such as the alien *Aster squamatus, Rumex crispus* and *Plantago lanceolata* grew at the edge of the marsh.

Inside the marsh, bulrushes *Typha capensis* and scattered reeds *Phragmitis australis* dominated the vegetation. Despite the dense growth of such vegetation many other plants grew amongst them including the sedges *Schoenoplectus tabernaemontani, S. triqueter* and *Eleocharis* sp., the latter locally common in patches. Other species included *Juncus exsertus*, grasses such as *Panicum repens* and *Polypogon monspeliensis,* and forbs including *Persicaria limbata, Rumex crispus* which was very common, *Rumex* sp. and *Cotula anthemoides*.

The ecotone between the marsh and dry land vegetation was very sharp indicating a rapid transition between wetland and dry land, perhaps a result of unnaturally fluctuating water levels. A total of 35 plant species were recorded at this site including 11 alien taxa.

Site LS3. Leeuwspruit prior to Dicksonville

The chosen site was upstream of a bridge on the Leeuwspruit, on the western side of the Dicksonville Industrial complex, as the river downstream of the bridge has been canalized. The site upstream also did not lend itself to an RVI because the *Typha* marsh described at the former site LS2, extended to within 40m of the bridge. The transect was therefore approximately 50m in length and extended partly into the marsh. Like that at the previous sites, the soils were primarily black turf clay, which appeared to be easily eroded.

The marsh was totally dominated by bulrushes *Typha capensis* which largely petered out approximately 30m from the bridge. Several shallow tributaries arising in the surrounding marshland entered the stream in the upper reaches of the transect. 'Spurs' between such streams were partly bare of bulrushes, instead covered by swards of *Cynodon dactylon* and especially the Scottish thistle *Cirsium vulgare*, the latter forming large stands. Forbs such as *Persicaria limbata*, *Veronica anagallis-aquatica*, *Sonchus oleraceus* and especially *Rumex crispus* and other *R.* sp. grew amongst the *Typha* along the banks in the marsh, as well as the sedge *Carex* sp. Much of the soils away from the drainage lines were sparsely vegetated, mostly with bulrushes.

Between the bridge and the marsh, the stream flows in a relatively narrow channel approximately 2m wide, with steep sides as a consequence of erosion along its banks. Such erosion was possibly the result of the canalization below the bridge which had lowered the stream bed and therefore increased the speed of water flowing downstream. The riparian zone is relatively narrow ranging from one metre on the LHB and 1-2m on the RHB. Some *Typha* extends along the LHB but is mostly absent along the hotter and drier north facing right hand bank. Grasses included mostly *Agrostis lachnantha, Paspalum dilatatum, Hemarthria altissima* and *Setaria incrassata* while Kikuyu *Pennisetum clandestinum* was prominent along the RHB together with some *Eragrostis curvula* and *Bromus catharticus*. The grasses covered approximately 40% of the banks. Various sedges such as *Schoenoplectes tabernaemontani* and *Carex glomerabilis* were recorded. Forbs were not abundant and mostly ruderals such as Khakiweed *Tagetes minuta, Ranunculus multifidus, Rumex* sp., *Berula erecta, Ciclospermum leptophyllum, Sonchus oleraceus, Pseudognaphalium luteo-album, Bidens bipinnata, Plantago major, P. lanceolata, Melilotus alba* and *Oenothera rosea.* Some of the floodplain along the RHB was marshy and covered by tussocks of *Carex* sp. and *C. glomerabilis*. *Cirsium* occurred widely.

Downstream of the bridge the vegetation cover was mostly excellent with bulrushes in a narrow strip along the stream and flanked by ruderals and aliens such as *Sonchus oleraceus, Paspalum dilatatum*, especially *Agrostis lachnantha, Cirsium vulgare*, *Sesbania punicea, Picris echioides*, *Veronica anagallis-aquatica* and *Ranunculus multidfidus*. The stream is however incised to a depth of 30cm, the vertical banks largely devoid of vegetation.

Thirty-four plant species were recorded of which 17 comprised alien species.

Site LS4. Leeuwspruit Canal below Dicksonville.

This section of the Leeuwspruit has been canalized and is probably just a continuation of that reported on at LS3. The transect was downstream of the road bridge crossing the Leeuwspruit and below a cattle crossing approximately 50m from the bridge. The transect was 200m in length on both banks of the stream. The stream channel was variable from 1,5–2m wide with a riparian zone which filled the floor of the canal, varying in width on either side in accordance with the meandering of the stream.

The vegetation tended to be most dense adjacent to the stream, tapering off on either side, perhaps more so along the LHB than that on the RHB. Soils were primarily red clay.

A clump of reeds *Phragmitis australis* grew at the start of the transect, after which bulrushes *Typha capensis* grew predominantly on either side, with scattered *Rumex* sp., *Ranunculus multifidus* and large numbers of seedling *Persicaria limbata*. Along the middle to upper riparian zone, grasses such as *Hemarthria altissima* and *Paspalum dilatatum* were most common along the LHB with Kikuyu *Pennisetum clandestinum* contributing to the vegetation cover on the RHB. The Brazilian glory pea *Sesbania punicea* grew mostly along the RHB and together with small *Acacia karroo* formed the only woody vegetation. Forbs were widespread including alien *Lepidium bonariense, Raphanus raphanistrum, Ciclospermum leptophyllum, Picris echioides, Verbena bonariensis, V. tenuisecta, Cirsium vulgare* and indigenous species such as *Haplocarpha scaposa, Senecio erubescens, S. inornatus* and *Gomphocarpus fruticosus*. Few sedges occurred, mostly *Cyperus longus, C.* sp. cf *difformis* and a dry land *Mariscus* sp.

As the area had been recently burnt it was not possible to identify several very large tussocks at the eastern end of the transect, but which appeared to be *Cortaderia jubata*. Including this, 40 plant species were recorded of which 22 were alien taxa.

Site LS5. Leeuwspruit upstream of confluence with the Vaal River.

Most, if not all of the lower Leeuwspruit, to its confluence with the Vaal River flows through dense reed *Phragmitis australis* and bulrush *Typha capensis* beds. At LS5 the stream had again been canalized, with the LHB overgrown with reeds and the RHB open but densely vegetated with sedges and forbs. The RHB was steep, and approximately 1,5 m above the water, whereas the LHB was lower and flood waters could filter through onto the adjacent floodplain,. A track ran parallel to the canal along the RHB, about 3 m distant.

Initially the vegetation along both banks consisted of reeds, within which other species such as *Persicaria lapathifolia, P. limbata, Rumex crispus, Bidens bipinnata, Chenopodium album* and *Fallopia convolvulus* grew. Behind the reeds some Kikuyu *Pennisetum clandestinum* formed dense localized swards. Further away the vegetation of the floodplain was very mixed with *Cyperus longus* very common, together with *Paspalum dilatatum* and the forb *Melilotus alba*. Further along the LHB *P. lapathifolia*, *Euphorbia* sp. cf *pubescens*, *Schoenoplectus tabernaemontani*, *Stachys hyssopoides*, *Salvia reflexa* and some *Cyperus* sp. aff. *difformis* occurred. *Helictotrichon turgidulum*, *Bromus catharticus* and *Cyperus longus* formed extensive stands on the floodplain.

The RHB tended to be mostly covered by Kikuyu together with tussocks of *Bromus catharticus*, the sedge *Cyperus longus* and forbs especially *Melilotus alba* and scattered *Cirsium vulgare*, *Verbena bonariensis*, *Chenopodium album*, *Euphorbia* sp. cf *pubescens*, *Cuscuta campestris* and *Xanthium strumarium*. A few *Asparagus laricinus* were also present.

Only 30 plant species were observed of which 18 comprised alien species.

Site LS6. Vaal River, upstream of Leeuwspruit confluence.

This site lies between the R59 bridge across the Vaal River and the confluence of the Leeuwspruit. On the RHB the riparian vegetation is well developed and up to 50m wide, dominated by *Acacia karroo* woodland mostly 5-6m high, although some trees reach 7-8m. Other woody species include *Eucalyptus* sp., *Rhus pyroides*, *Prosopis* sp., and three alien species. Most of the shrub layer was comprised of *Asparagus cooperi* and *A. laricinus*, both of which dominated this layer, and the young of some of the woody species. The field layer was mostly composed of the grass *Brachiaria deflexa* under the shade of trees together with extensive clumps of *Atriplex semibaccata*, *Physalis viscosa* and to a lesser extent *Achyranthes aspera*, *Bidens bipinnata* and *Salvia runcinata*. The alien climber *Araujia sericifera* was common in the woodland.

Closer to the water the vegetation was more open with extensive stands of *Bromus catharticus*, some *Cynodon dactylon*, the fern ally *Equisetum ramosissimum* and various forbs such as *Convolvulus sagittatus* var. *ulosepalus*, *Melilotus alba*, *Rumex sagittatus* and *Chenopodium album*. Along most of the banks Reeds *Phragmitis australis* were found extending out into the shallow water. In openings, some sedges such as *Cyperus fastigiatus* and the grass *Agrostis lachnantha* grew along the banks.

The riparian vegetation along the LHB has been extensively destroyed, with a row of *Eucalyptus* sp. growing along the upper bank, underneath, which the ground appeared to be bare or covered in patches of *Biden bipinnata*. Only two *Acacia karroo* and a few *Asparagus* shrubs could be seen. Adjacent to the water, much of the bank was covered by *Cyperus longus* and Kikuyu *Pennisetum clandestinum*. Some stands of reeds and bulrushes were scattered along the lower banks and in shallow water.

A total of 54 plant species of which 24 species are alien, were recorded from the site.

Site RS1. Rietkuilspruit on Golden Highway

At RS1 the Rietkuilspruit is a very small stream with a channel approximately 30cm wide, but becoming wider downstream, flowing through fallow lands, the water partially shaded by overhanging grasses. The stream was initially incised to a depth of 10cm but this increased downstream to 70 or 80cm and eventually 100cm about 100m from the start of the transect, with the vertical banks mostly bare of vegetation. Further along the water flow reduces as it enters a pool behind an obstruction, the vertical banks here being approximately 45 cm high.

The extent of degradation of the banks made it difficult to establish the extent of the riparian vegetation, which was estimated to be about 30cm wide on either side, although becoming wider lower down where the stream overflowed its banks under flood conditions. It would appear that the stream was subject to 'flash floods' resulting in the continuous undercutting and collapse of its banks.

Despite a good vegetation cover along the upper banks, the site exhibited a poor species richness with only 23 species being recorded of which 14 were alien taxa. Apart from some *Persicaria lapathifolia*, some *Agrostis lachnantha* and *Cyperus* sp. cf *difformis,* within channel vegetation was very poor.

Grasses predominated along the banks and riparian zone, mostly *Paspalum dilatatum*, *Bromus catharticus, Helictotrichon turgidulum* and *Agrostis lachnantha*. Most of the former were prevalent along the middle and upper banks while. *Agrostis lachnantha* was common along the lower banks adjacent to the water. With the exception of an immature *Rhus pyroides* and an immature unidentified alien tree, no woody vegetation was recorded along the 200m transect. However, numerous ruderals and weeds such as *Sonchus oleraceus, Veronica anagallis-aquatica, Plantago lanceolata, Rumex crispus, Oenothera rosea, Verbena bonariensis* and *Chenopodium ambrosioides* were present amongst the grass and along the lower banks. Sedges such as *Cyperus longus, Schoenoplectus tabernaemontani* and especially *C.* sp. cf *difformis* grew along the channel.

Site RS2. Dam on Rietkuilspruit and downstream.

The dam wall at RS2 had been breached and the dam was, at the time of the survey dry, except for a little rainwater which had accumulated and was flowing out through the breach. Around the perimeter of the dam was a wall of bulrushes *Typha capensis* of varying width. In the dry bed of the dam closer to the dam wall *Persicaria lapathifolia, Rumex crispus* and *Echinochloa crus-gallii* grew, as well as immature *Cyperus* sp. cf *difformis* and *Alisma plantago-aquatica. Typha capensis* also grew extensively along the lower part of the dam wall as well as stands of *Schoenoplectus tabernaemontani*. Numerous trees and shrubs grew along the former dam wall including *Salix babylonica, Rhus pyroides* and especially *Asparagus laricinus*, the latter forming thickets along the top.

Downstream of the dam wall, willows *Salix babylonica* grew as well as an immature *Celtis sinensis*. Most of the area however was covered in grassland which surrounded a large *Typha* marsh, dominated by bulrushes but with stands of the sedge *Schoenoplectus tabernaemontani* interspersed. The marsh extended downstream along the Rietkuilspruit.

Paspalum distichum and *Bromus catharticus* were very abundant immediately below the dam wall and *Paspalum dilatatum* was common. Other grasses included *Polypogon monspeliensis* and *Agrostis lachnantha* and the sedge *Cyperus* sp. cf *difformis* was also common. Forbs such as *Aster squamatus*, *Chenopodium ambrosioides*, *Cirsium vulgar* and *Galinsoga parviflora* were also present. The fern *Marsilea macrocarpa* grew in shallow water amongst the grass. Other wetland species included *Rumex crispus*, *Rorippa nasturtium-aquaticum* and *Alisma plantago-aquatica*.

Along the right hand side of the marsh, swards of *P. distichum* with tussocks of *Agrostis lachnantha*, a *Bromus* sp. and more rarely *Aristida junciformis*, occurred together with stands of *Carex* sp., *Eleocharis dregeana* and colonies of *Marsilea macrocarpa*. Other forbs include *Cotula anthemoides, Plantago lanceolata, Persicaria lapathifolia* and *Ranunculus multifidus*. Towards the drier side *Ciclospermum leptophyllum, Conyza bonariensis, Bidens formosa, B. bipinnata* and *Sonchus oleraceus* grew in the grassland.

Although 42 plant species were observed there was a high incidence of alien species which amounted to 52% of the taxa recorded.

Site RS3. Dam on Rietkuilspruit

The dam at RS3 had recently been cleaned out and the dam wall partly reconditioned. Most of the area surrounding the dam had been scraped and the vegetation was only starting to grow again. Bare soil was still very evident with 50% of the shoreline devoid of vegetation. Most plants around the perimeter were ruderals or annuals, pioneer plants taking advantage of the lack of competition to grow and set seed. There were however patches of the original vegetation evident. The survey encompassed the perimeter of the dam starting at the inlet where the Rietkuilspruit flowed into the dam. Here the original vegetation was still present and comprised mostly of *Typha capensis* along the stream channel flanked on either side by the sedge *Schoenoplectus tabernaemontani* in shallow water. On the outside of this were extensive swards of a *Cyperus* sp. which interdigitated with the grass *Paspalum distichum*. The alien forb *Rumex crispus* grew commonly amongst this but was most frequent amongst the *Cyperus* sp. In drier, less marshy areas, *Cynodon dactylon, Paspalum dilatatum* as well as many seedling *Rumex crispus,* were common.

A track crossed the inlet with shallow water banking up against the road where the fern *Marsilea macrocarpa* was found. At the inflow, bulrushes *Typha capensis* were common and grew scattered around the posterior third of the dam. However they did not form dense stands as most had been removed when the dam had been scoured. Few stands of reeds were seen, one on either side of the dam and some at the dam wall. *Helictotrichon turgidulum* and *Cyperus esculentus* occurred at the upper end of the LHB with *Paspalum distichum* and *Hibiscus trionum* growing prolifically. *Plantago lanceolata* was abundant in parts while patches of *Cyperus* sp. grew scattered on both sides of the dam extending into the water, particularly along the RHB. All around the dam, swards of *Paspalum distichum* and *Cynodon dactylon* were recorded some extending into the water while some *Cynodon transvaalensis* was also observed. Scattered tussocks of other grasses included *Digitaria diagonalis, Echinochloa crus-gallii, Setaria incrassata* and *S. nigrirostris*, mostly along the RHB. Tussocks of *Carex glomerabilis* occurred on both sides of the dam and forbs such as *Ranunculus multifidus, Rumex crispus, Senecio erubescens, Berkheya rhapontica* and *Haplocarpha scaposa* were widespread but sparse.

A total of 45 species were observed of which 15 were alien species.

Site RS4. Rietkuilspruit downstream from RS3 on secondary road.

The site at RS4 was approximately 50m in length between the IVS Security fence and the road, and road bridge crossing the Rietkuilspruit. Beyond this fence a farm dam had also impacted on the stream. Downstream of the road another Security fence and a farm dam precluded a transect there. This section therefore was the only available riparian strip at this site although substantially degraded, lying between the road and the security fence. The stream meandered in an S – bend through grassland, some of which on the LHB, appeared to be seasonally inundated by runoff from the road and the area between the road and the fence to the north. The channel was about 1,5m wide, with the riparian varying from 0,6–1,5m. The disturbed nature of the site made it difficult to establish boundaries. The stream was incised and the banks had collapsed along sections of the stream, a consequence of an increased water flow at times. The soils were of turf clay. The area had been burnt during the past winter or spring prior to the survey.

The vegetation was similar to that previously recorded, mostly *Themeda triandra* grassland on either side, this reaching to the waters edge where the banks had collapsed. Along the water, the grass *Agrostis lachnantha*, sedges such as *Cyperus longus* and *Cyperus* sp. were common as well as *Schoenoplectus tabernaemontani*, *Juncus rigidus* and *J. exsertus*, while forbs such as *Veronica anagallis-aquatica, Sonchus oleraceus, Oenothera rosea* and towards the fence stands of *Typha capensis* grew on either side of the channel the latter concentrated at the fence. Along the banks most of these species were also recorded especially *Cyperus longus, Cyperus* sp. and *Juncus rigidus*, together with *Paspalum dilatatum, Helictotrichon turgidulum, Plantago lanceolata, Cirsium vulgare, Sonchus sp., Sesbania punicea, Conyza bonariensis, Berkheya rhapontica, Trachyandra asperata* and *Kniphofia typhoides*, the latter a Red Data Book species listed as Insufficiently known. These plants were scattered in the adjacent grassland and about five plants were seen.

A total of 31 plant species were recorded at this site of which 9 were alien taxa.

Site RS5 Rietkuilspruit upstream of canal on gravel road.

The area is covered in *Themeda triandra* grassland some of which had been ploughed in the past and now lay fallow, and was currently used for the grazing of livestock. The soils were clayey with rocks and gravel present along the Rietkuil stream bed.

The Rietkuilspruit at this site had been impacted on by the construction of a road across it, the stream flowing downstream via two cement pipes. This has resulted in the backup of water upstream, and the formation of a small marsh dominated by *Typha capensis* and *Schoenoplectus tabernaemontani*, these also extending upstream along the stream channel. *Agrostis lachnantha* formed large tussocks adjacent to the sedges, and forbs such as *Rumex crispus, Sonchus* sp., *Persicaria lapathifolia* and *Tagetes minuta*.were present. Beyond this, swards of *Paspalum distichum* together with *Cirsium vulgare, Sesbania punicea* and the species already mentioned were seen. *Paspalum dilatatum* grew under drier conditions further from the water.

A transect, of approximately 200m, was conducted downstream of the road crossing and started at a point below the confluence of the water from the two culverts. The stream was incised perhaps as a consequence of the road, the height of the banks increasing downstream to 40cm, with the channel being about 2-2,5 m in width. The riparian vegetation varied considerably in width from 0,3 to 7m, if one considers the limits to be determined by the growth of *Themeda triandra*.

Along the channel and banks *Agrostis lachnantha* was very common growing in crevices of rocks along the stream bed, sometimes together with *Polypogon monspeliensis*. Also here were sedges such as *Cyperus* sp., some *Typha capensis* and the forbs *Plantago major, Aster squamatus*, the latter mostly seedlings growing along the channel margin, *Ciclospermum leptophyllum* and *Rumex crispus*. These species also grew along the banks but less common than *Paspalum distichum* and *Hemarthria altissima* which grew widely on the banks and down to the water. The sedges *Cyprus* sp. and *C. longus*, were common along the banks together with many forbs such as *Oenothera rosea, Lactuca serriola, Sonchus oleraceus, S.* sp. and *Plantago lanceolata***.** On the drier sections *Helictotrichon turgidulum* was common as well as *Hemarthria altissima* and other grasses such as *Paspalum dilatatum, Setaria sphacelata* var. *sericea*, *Panicum schinzii* and *Eragrostis curvula.* Forbs included *Oenothera rosea*, *Berkheya rhapontica*, *B. pinnatifida*, *Salvia runcinata, Verbena officinalis* and *Haplocarpha scaposa*.

A small weir or obstruction at the foot of a willow *Salix babylonica*, retarded the flow of the water forming a marshy area about 10-12m wide, dominated by *Paspalum distichum* which formed a sward along the waters edge. *Hemarthria altissima* was also present as were most of the species already mentioned. *Cirsium vulgare* was very common here as well as some *Flaveria bidentis, Oenothera rosea* and *Conyza bonariensis*.

A total of 44 species were recorded of which 19 were alien taxa.

Site RS6. Rietspruit upstream of the confluence with the canal and the Rietkuilspruit.

The transect along the Rietspruit was placed upstream of the R59 bridge for a distance of about 200m. from the fenceline which lay 20 - 30m upstream of the bridge. Most of the area appeared to be used for the grazing of livestock and was covered in *Themeda triandra* grassland on turf clay soils.

Apart from the bridge and associated fencelines and construction effects, the only other degradation was the trampling of the vegetation by livestock and vehicle tracks. The river was incised with vertical banks 30cm or more above the water. Banks were collapsing in part due to the scouring of flood waters, mostly along the outside of bends. Such a collapsed bank had formed a small island about 0,8m wide close to the start of the transect. The Rietspruit was approximately 12m wide at the time of the survey and laden with sediment.

The riparian vegetation varied considerably in width from 0–5 m depending on whether it was along the inside or outside of a bend or where the river broke its banks.

All along the banks of the river a levee of deposition was seen, indicating periodic flooding of parts of the surrounding countryside. An off-channel wetland, which filled via a narrow channel leading off the Rietspruit, occurred along the RHB and extended for about 100m. On the LHB some marshy conditions existed along a vehicle track and adjacent grassland, leading down to the bridge.

The vegetation along the transect consisted mostly of grasses such as *Paspalum distichum, P. dilatatum, Cynodon dactylon, Ischaemum afrum, Hemarthria altissima* and *Eragrostis curvula*. *Agrostis lachnantha* grew mostly along the banks close to the water. Sedges were also very abundant including *Cyperus fastigiatus* which grew in shallow water at the margins of the channel, while *C. longus* and *C. marginatus* were abundant along the banks up to the waters edge, the latter also common along moist depressions. A small drainage line on the LHB incorporated *Schoenoplectus decipiens* together with *Hemarthria*. Forbs were common along the banks including *Rorippa fluviatilis* mostly together with sedges, forming stands in hollows along and behind the banks, where water remained for longer periods. Other species under these conditions included *Paspalum dilatatum, Ischaemum afrum, Agrostis lachnantha, Galium capensis, Rumex crispus, Crinum bulbispermum, Chenopodium ambrosioides, Gynandriris simulans*. Close to the water, species such as *Oenothera rosea, Aster squamatus, Plantago lanceolata, Ciclospermum leptophyllum* and *Rumex crispus* were common. *Falckia oblonga* and *Stachys hyssopoides* grew along the banks. Few plants grew along the very steep banks, these included *Oenothera rosea, Sonchus oleraceus* and *Galium capensis*, usually close to the water.

The off-channel wetland is flanked on either side by stands of sedges such as *Cyperus fastigiatus* growing mostly in shallow water together with *C. longus* and *C. marginatus*. Behind this the vegetation was much the same as that recorded for the Rietspruit with stands of *Rorippa fluviatilis, R. nudiuscula, Galium capensis* and *Crinum bulbispermum* with grasses such as *Paspalum dilatatum* and *Ischaemum afrum* growing in drier conditions.

Similarly the wetland to the east of the river was dominated by *Cyperus marginatus*, with some *Schoenoplectus decipiens* and grasses such as *Agrostis lachnantha* and *Paspalum distichum*.

Floristically the site was quite diverse with 48 plant species being recorded, of which 12 were alien taxa.

<u>Site RS7. Downstream section of canal, just upstream of confluence with the Rietkuilspruit.</u>

This site lay along a stretch of a canal leading water directly off the IVS Complex, and was entirely an artificial system, the water being aerated along periodic inclines prior to being released into the Rietkuilspruit. At this point the canal was approximately 100m long. The canal was typically U–shaped with steep walls approximately two meters deep and 2,5m wide at the bottom. The water flowed strongly, preventing any colonization of the channel by plants.

The RHB was almost totally covered by Kikuyu *Pennisetum clandestinum*, with some *Cyperus* sp. cf *difformis* occupying about 20%. A single poplar *Populus canorus* sapling also grew along the bank. In contrast the LHB was more diverse with *Melilotus alba* being common, but also numerous other species such as *Sonchus oleraceus, Conyza bonariensis, Paspalum dilatatum, Polypogon monspeliensis, Cirsium vulgare*, some *Hyparrhenia hirta* and *Cyperus* sp. cf *difformis*, the latter forming large tussocks leaning out into the water. *Oenothera rosea* formed large bushes along the steep banks. Parts of the bank have swards of *Cynodon dactylon* and *Paspalum dilatatum* growing to the edge. At a rough estimate it seemed unlikely that the indigenous component comprised more than 20 % of the LHB vegetation.

Approximately 10-20% of the bank remained bare of vegetation, particularly where the banks were overhanging, preventing most vegetation to establish except at the water line.

As was to be expected the site was very impoverished with only 20 taxa recorded of which 12 were alien species.

Site RS8. Rietkuilspruit, approximately 100m below canal confluence.

The Rietkuilspruit flowed strongly at this point as a result of the addition of the fast flowing canal water. The channel had a gravel bottom and varied in width from 1,5–3m. The banks of the stream were mostly very steep, with sections collapsing as the sides were undercut. These formed lower terraces as well as small islands, which were well vegetated, but the latter mostly transient as they were eroded by the fast flowing current. Most of the steeper banks were devoid of vegetation and the fast flowing current mostly prevented emergent vegetation being established.

Themeda triandra grassland occurred to the edge of the vertical banks and the riparian zone varied in width from 0–4 or 5m, mostly well vegetated, particularly along the LHB where Kikuyu *Pennisetum clandestinum* grew strongly, forming a barrier to erosion. Other species such as *Paspalum distichum* grew extensively along the lower banks to the edge of the water. *Cyperus* sp. cf *difformis* and *Persicaria lapathifolia* grew along the edge of the water and sometimes even in the channel. *Agrostis lachnantha* and *Polypogon monspeliensis* also grew close to the water. Plants such as *Sonchus oleraceus*, some *Berkeheya rhapontica*, *Cirsium vulgare, Rumex crispus, Melilotus album* and *Plantago lanceolata* grew along the banks. Alien species were very common growing throughout the length of the transect. Some woody species such as *Sesbania punicea* and a single immature *Acacia karroo* also grew along a terrace, but had been burnt during a veld fire in spring.

No Kikuyu grew along the RHB, the banks being up to 50% bare of vegetation due to their steepness. Ruderals grew in the most arid areas, while more perennial species grew closer to the water.

The riparian vegetation was very impoverished perhaps due to the presence of fallow lands close to the southern bank. Only 30 species were recorded of which 14 comprised alien taxa.

Site RS9. Rietspruit, approximately 5km downstream of Rietkuilspruit confluence.

The site lies upstream of a road bridge across the Rietspruit, starting behind a pumphouse on stilts along the RHB for a distance of about 200m. The river forms a U–bend upstream, marking the end of the transect. Like RS6 the river had formed levees on both banks, behind which hollows had formed, which may seasonally be filled with water, as indicated by the vegetation cover. Most of the surrounding area appeared to be used primarily for the grazing of livestock. The river flowed within a channel with steep sides some of which had collapsed during floodwater conditions. Despite this the banks were well vegetated.

The river flowed through *Themeda triandra* grassland on turf clay soils, the dryland grass extending to the edge of the banks in parts. Elsewhere the riparian vegetation extended up to 7m, and was continuous between the arms of the U.

Some emergent species such as *Cyperus fastigiatus* and reeds *Phragmitis australis* formed clumps scattered along the edge of the channel. The banks were mostly covered by grasses and sedges including species such as *Agrostis lachnantha, Paspalum distichum, P. dilatatum, Hemarthria altissima, Cyperus longus, C. marginatus* and *C.* sp. cf *difformis*. Forbs occurred commonly throughout the riparian zone including *Veronica anagallis-aquatica* along the lower banks, *Crinum bulbispermum, Rumex crispus, Galium capensis, Ranunculus multifidus, Oenothera rosea, Plantago lanceolata* and *P major.*

Along the upper banks *Cyperus longus* and *C. marginatus*, *Hemarthria altissima, Crinum bulbispermum, Stachys hyssopoides, Lactuca inermis, Mentha longifolia, Chenopodium ambrosioides*, and especially *Paspalum dilatatum*, the latter especially prevalent along the levees, occurred together with other species. Woody species such as *Sesbania punicea* and a single willow *Salix babylonica* grew along the LHB, the former having been killed by a spring fire which must have swept the area.

Depressions including that between the arms of the U–bend were characterized by the dominance of sedges, *Cyperus longus* and *C. marginatus*. Also found here were the grasses *Agrostis lachnantha* and *Paspalum distichum* and forbs, especially *Rorippa fluviatilis, Rumex crispus, Persicaria serrulata, P. attenuata* and *Crinum bulbispermum.*

Dominance by any species varied constantly according to the microclimate and especially soil moisture along the banks of the river. Some species were more common throughout than others and there appeared to be a specific community of species, which were present throughout, albeit in varying concentrations.

The site tended to be floristically more species rich than most of the other sites with 53 species being recorded of which 19 were alien taxa.

<u>Site RS10. Rietspruit at bridge</u>

The transect was sited upstream of a road bridge across the Rietspruit and another older bridge approximately 50m upstream. The surrounding vegetation was again *Themeda triandra* grassland on turf clay soils, and used primarily for grazing of livestock. The river flows along a channel approximately 5m wide with steep banks up to one meter high above the water. Parts of the banks had collapsed as a result of undercutting by floodwaters.

The riparian vegetation varied in width from 1-5m with levees along the banks, behind which hollows formed which received rain and floodwater, resulting in marshy conditions. The vegetation cover of the banks was dense along the upper banks.

Sedges *Cyperus fastigiatus* grew close to the margins of the channel and along the lower banks adjacent to the water. Other plants here included *Cyperus marginatus, C.* sp. cf *difformis, Agrostis lachnantha, Veronica anagallis-aquatica, Sonchus oleraceus, Oenothera rosea, Aster squamatus* and *Rumex crispus*. Some *Sesbania punicea* also grew on the bank.

Along the top of the banks *Setaria sphacelata* and *Cyperus longus* dominated the vegetation with many forbs especially *Galium capensis,* which on the LHB grew prolifically amongst the grass tussocks. Other species included *Paspalum dilatatum, Imperata cylindrica, Setaria incrassata, Crinum bulbispermum, Salvia reflexa, Oenothera rosea, Stachys hyssopoides, Sida rhombifolia, Mentha longifolia, Rorippa fluviatilis, Trachyandra asperata,* seedling *Xanthium strumarium, Zinnia peruviana* and others. Some woody vegetation included a single *Asparagus laricinus* and many *Sesbania punicea,* the latter having been burnt during a spring fire were now coppicing again, and covered about 25% of the banks.

In hollows behind the levee, depressions contained mostly sedges such as *Cyperus fastigiatus, C. longus* and *C. marginatus*.but also *Hemarthria altissima* and numerous forbs already mentioned.

Despite the relatively short transect the number of species recorded (54) is similar to that for Site RS9, with mostly similar species but with a higher alien content (26).

<u>The Reference Site: Taaibosspruit</u>

The Reference site extended downstream of the Sasolburg – Frankfort road bridge across the Taaibosspruit, for about 200 m, starting about 50m downstream from the bridge. Upstream of the bridge a weir was present, and it was evident that the combined effect of the weir and the bridge had impacted on the system downstream. The river channel was approximately 25 m wide, with bedrock, rocks and gravel. The banks were gentle but with a lower bank rising steeply 0,3 – 1 m above the level of the water. Collapsing banks along the river as a result of increased flow along the banks causing undercutting, may partly be a consequence of the weir and bridge. *Themeda triandra* grassland extended on either side and delineated the extent of the riparian strip. The area appeared to be used primarily for the grazing of livestock.

Along the channel *Cyperus fastigiatus, Phragmitis australis* and *Myriophyllum aquaticum* grew in the water, while *Cyperus longus* and *C. marginatus* were common along the lower banks close to the water together with *Sesbania punicea, Ischaemum afrum, Paspalum distichum, Agrostis lachnantha* and *Juncus exsertus*. Small outcrops in midstream contained some plants including *Gomphostigma virgatum, Cyperus marginatus* and *Sesbania punicea.*

Along the banks *Cyperus longus, C. marginatus* and *C. sphaerospermus* as well as grasses such as *Ischaemum afrum, Hemarthria altissima, Paspalum dilatatum* and *Setaria sphacelata* dominated the riparian strip. Numerous forbs occurred along both banks including *Oenothera rosea, Lactuca inermis, Trifolium pratense, Falckia oblonga, Diclis reptans, Ambrosia artemissiifolia, Plantago lanceolata, Crinum bulbispermum, Commelina subulata, Rorippa nudiuscula, Galium capensis* and *Persicaria limbata*.

No off channel wetlands were observed along the river reach, only a quarry filled with water and surrounded by sedges such as *Cyperus marginatus* and others

This site was floristically the most species rich of the sites with 58 species being recorded of which only 14 were alien species.

All of the sites surveyed had been degraded, a fact reflected in the plant species richness and alien content at each site (APPENDIX 2). The Reference site exhibited the least degree of degradation (in terms of plant biodiversity) with a relatively high species richness and low alien content as opposed to sites RS1, RS7 and LS3 and LS5. This is illustrated below in the form of a matrix using species richness and alien content. At the Reference site 58 plant species were recorded, indicating the upper level of species richness likely to be recorded. This is in accord with the number of species recorded under similar conditions at other sites on the Highveld. At the same time this site exhibited the lowest alien content of 24% although RS6 on the Rietspruit is very similar in this respect. If the proportion of alien species in the riparian community was more than 45% of the total number of species, it was regarded as high. The matrix was therefore subdivided into three categories of species richness and alien content respectively. Ranking the sites in terms of riparian integrity, those with the highest number of species and lowest percentage of alien species ranked the highest, while those with the lowest number of taxa and the highest percentage of alien species ranked lowest.

Matrix of Sites according to Species Richness and Alien content:

<u>Species Richness</u>

High > 45	**Medium** 35 – 44	**Low** < 34	**<u>Alien Content</u>**
RS 10	LS 4 RS 2	LS 3, LS 5 RS 1, RS 7 RS 8	**High** > 45%
LS 1, LS 6	RS 5		**Medium** 35-44,9%
			Low

RS 3, RS 6 RS 9, Ref.	LS 2	RS 4	< 34,9%

From this it can be seen that sites RS3, RS6, RS9 and the Reference Site rank the highest. These are followed by sites LS2 and RS4, then LS1 and LS6, then RS5, RS10, LS4 and RS2, and lastly sites LS3, LS5, RS1, RS7 and RS8. The last five sites are highly impoverished and degraded. If one considers these sites in more detail it is evident that they show signs of greatest disturbance. LS3 is a dam which has recently been scoured by bulldozing and sediment removal, LS5 lies on a canalized section of the Leeuwspruit with a track running parallel about 3m distant, RS1 lies in an area of fallow lands, RS7 consists of the canal draining water from the IVS site and RS8 lies just below the canal confluence with the Rietkuilspruit.

All the sites along the Rietspruit and Vaal River exhibited higher species richness, although mostly with a substantial alien content, than either the Leeuwspruit or Rietkuilspruit. This can be attributed to lower disturbances, as these sites were mostly used for the grazing of livestock and not crop farming.

At all sites it was evident that floods and high runoff in the recent past had eroded the stream banks causing the collapse of, and creating vertical banks. Such banks are not conducive to being easily colonized by vegetation. Only some sedges, the grass *Agrostis lachnantha* and especially ruderals such as *Sonchus oleraceus*, *Oenothera rosea* and *Rumex crispus* grew on such banks or along the waters edge.

Many of the sites were characterized by the high number of ruderals and weeds which formed part of the vegetation communities, placing such communities in a seral condition, transitional to a climax state. These indicated considerable levels of disturbance, mostly related to past issues. However these species were being perpetuated at all sites by the continuous exposure of new soil as banks collapsed, further reducing the extent of the more 'pristine' riparian strip and replacing it with communities which were being maintained in a transitional and degraded state.

6.4.1. <u>The Riparian Vegetation Index</u>

It was attempted to evaluate all sites, using the Riparian Vegetation Index (Kemper 2000), but it became obvious that some of the sites such as LS1, LS2, LS4, LS5, RS2, RS3 and RS7 were unsuitable, because of the type and level of disturbance.

All of the remaining 10 sites were rated at C level, which indicated from a vegetation point of view, that they were 'Moderately Modified". A loss and change of natural habitat and biota have occurred but the basic ecosystem functions were still predominantly unchanged'.

6.5. Aquatic Macroinvertebrates

The monitoring of benthic macroinvertebrate species forms an integral part of the monitoring of the health of a system, because they are relatively sedentary and enable the detection of localized disturbances. Their relatively long life histories (±1 year) allow for the integration of pollution effects. Field sampling is easy and since the communities are heterogeneous and several phyla are usually represented, response to environmental impacts is normally detectable in terms of the community as a whole (Hellawell, 1977).

Aquatic macroinvertebrates sampled in the study area are listed in APPENDIX 3. A total of 37 macroinvertebrate families were sampled during the December 2001 Baseline Survey (5 to 19 taxa per site). Some moderately sensitive taxa occurred in the study area, notably at the reference site (Taaibosspruit) and site RS9 (APPENDIX 3). Sites RS1, RS2, RS3, RS4, RS5, RS6, RS7, RS8, LS3, LS4, LS5 and LS6 were however characterized by an absence/near absence of the more sensitive aquatic macroinvertebrate families.

The current health of the aquatic ecology in the study area was assessed using the South African Scoring System (SASS) Index, version 5 (Dickens & Graham, 2001).

Table 12: SASS5 score, Number of Taxa and ASPT obtained during the December 2001 Baseline Survey

Site No	SASS5 Score	Number of Taxa	*ASPT
REF	82	19	4.3
RS1	44	12	3.7
RS2	35	9	3.9
RS3	-	-	-
RS4	48	13	3.7
RS5	52	14	3.7
RS6	18	5	3.6
RS7	36	11	3.3
RS8	37	12	3.1
RS9	50	9	5.6
RS10	49	14	3.5
LS1	41	10	4.1
LS2	61	15	4.1
LS3	41	10	4.1
LS4	59	17	3.5
LS5	11	5	2.2
LS6	55	14	3.9

- Habitat unsuitable for application of index
*ASPT = Average Score Per Taxon

Evaluation of instream and riparian habitat is critical to any assessment of ecological integrity and are therefore performed simultaneously with biological sampling since the absence of certain habitat types or degraded habitats can sometimes obscure investigations on the effects of pollutants. Habitat index scores obtained (Table 9) indicated habitat availability in the study area to be a potentially limiting factor in the occurrence of aquatic fauna, especially at sites RS1, RS2, RS6, RS7, RS8, RS9, RS10, LS1, LS5 and LS6. The absence of certain biotope types at a site may limit the occurrence of some aquatic macroinvertebrate taxa. To further facilitate interpretation of the data, biotopes were not all sampled together, but rather in three groups according to the SASS5 methodology (APPENDIX 3):

1. Stones-in-current, stones-out-of-current, rock
2. Sand, mud, gravel
3. Vegetation

The Rietkuilspruit (sites RS1, RS2, RS4, RS5, RS8) had low species diversity and abundance, with 9 to 14 taxa recorded per site. SASS index scores obtained in this river reach ranged between 35 and 52 (Table 12). The reduction in SASS5 scores after confluence of the canal (from 52 at site RS5 to 37 at site RS8) is largely attributed to limited habitat availability at the latter site (see Section 6.3.1) and also water quality. SASS5 scores obtained in the Leeuwspruit varied considerably, ranging between 11 and 59 (Table 12). Site LS5 was practically devoid of aquatic life with only 5 taxa sampled. This is largely attributed to limited habitat availability, with an IHAS score of 29% recorded at this site. The poor SASS5 score obtained at site RS6 in the Rietspruit is attributed to limited habitat availability, with only 5 taxa sampled during the field survey (Table 12). SASS5 scores however improved towards the downstream section of the Rietspruit (sites RS9 and RS10), despite no significant improvement in habitat quality (Table 12).

6.5.1. Biotic Integrity, based on SASS results

Reference conditions reflect the best conditions that can be expected in rivers and streams within a specific area and also reflect natural variation over time. SASS data was evaluated against modeled reference data for the Highveld Ecoregion (data obtained from Gauteng Nature Conservation, Mr Piet Muller). The biotic health of the study area was therefore assessed in relation to that expected for the region under unimpacted conditions and is also aimed at identifying problem areas, trends and/or changes specifically with regard to the study area.

Based on the modeled reference condition, the current biotic integrity of the different sites in the study area was derived, using the classification scheme in Table 7. More emphasis was placed on the SASS score than on the ASPT score during determination of the Present State Class, since the ASPT becomes an unreliable indicator when the number of taxa sampled is low, as is the case during the present investigation

Sampling Site	Present State Class
RS1	E
RS2	E
RS3*	-
RS4	E
RS5	E
RS6	F
RS7	E
RS8	E
RS9	E
RS10	E
LS1	E
LS2	D
LS3	E

LS4	D
LS5	F
LS6	E

**Habitat unsuitable for application of SASS index*

Significant spatial variation existed in the Integrity Classes calculated for the different sampling sites in the Leeuwspruit. The Present State Class in the Leeuwspruit varied between Class D and E, with a Class F recorded at site LS5. The latter site receives treated effluent from a sewage works. The Present State Class in the Rietkuilspruit was indicated to be Class E at all sites sampled (Figure 4). The poor Present State Class (F) obtained at site RS6 in the Rietspruit is attributed to the fact that this site displayed limited aquatic macroinvertebrate habitat availability. The Present State Class obtained in the Rietspruit downstream from the Rietkuilspruit confluence was also indicated to represent a Class E biotic integrity (Figure 4).

6.6. Ichthyofauna

6.6.1. Species Occurrence

A total of 132 individuals (10 species) were collected during the December 2001 Baseline Assessment (APPENDIX 4). These included *Barbus anoplus* (Chubbyhead barb), *Barbus paludinosus* (Straightfin barb), *Labeobarbus aeneus* (Smallmouth yellowfish), *Labeo umbratus* (Moggel), *Labeo capensis* (Orange River mudfish), *Cyprinus carpio* (Carp), *Clarias gariepinus* (sharptooth catfish), *Pseudocrenilabrus philander* (Southern mouthbrooder), *Gambusia affinus* (Mosquitofish) and *Micropterus salmoides* (Largemouth Bass) (Table 13).

The fish fauna sampled were dominated by *Barbus anoplus* (Chubbyhead Barb) comprising 34% of the total catch (Table 13). This species is often locally abundant where favorable conditions occur, and has a high degree of resilience and adaptability (Skelton, 1986).

Barbus paludinosus is most frequently encountered in quieter well-vegetated waters. During the field survey 12 specimens were sampled in the Rietspruit downstream from the Rietkuilspruit confluence (sites RS9 & RS10). Only one specimen was sampled in the Rietkuilspruit. This is a hardy species preferring quiet, well-vegetated waters in lakes, marshes and wetlands or near banks of large rivers and slow flowing streams (Skelton, 2001).

Table13: Number and species of fish sampled in the study area.

Species	Common Name	REF	RS1	RS2	RS3	RS4	RS5	RS6	RS7	RS8	RS9	RS10	LS1	LS2	LS3	LS4	LS5	LS6
CYPRINIDAE																		
Barbus anoplus	Chubbyhead Barb	2					14				11	14		1	1	4		
Barbus paludinosus	Straightfin Barb	4					1				5	7						
Labeobarbus aeneus	Smallmouth Yellowfish	4																1
Labeo umbratus	Moggel	2																5
Labeo capensis	Orange River Mudfish	7																6
Cyprinus carpio	Carp					4	1										1	2
CLARIIDAE																		
Clarias gariepinus	Sharptooth Catfish	2							1			1					1	1
CICHLIDAE																		
Pseudocrenilabrus philander	Southern Mouthbrooder	7										4						
POECILIIDAE																		
Gambusia affinis	Mosquitofish			5								8		3				
CENTRARCHIDAE																		
Micropterus salmoides	Largemouth Bass																	2
Number of species		**7**	**0**	**1**	**0**	**1**	**3**	**0**	**1**	**0**	**2**	**5**	**0**	**2**	**1**	**1**	**2**	**6**
Number of fish		**28**	**0**	**5**	**0**	**4**	**16**	**0**	**1**	**0**	**16**	**34**	**0**	**4**	**1**	**4**	**2**	**17**

Labeo capensis (Orange River Mudfish) were sampled only in the Vaal River (site LS6) and at the reference site in the Taaibosspruit. Although also occurring in lentic conditions, these mudfish has specific lothic breeding requirements. *Labeo umbratus* is known to occur abundantly throughout the Orange-Vaal Catchment (Mulder, 1971; Cambray, 1984; Personal observations). During the present survey, however, *Labeo umbratus* (Moggel) occurred in low numbers, also only at Site LS6 in the Vaal River and at the reference site in the Taaibosspruit (5% of the total catch). The Moggel was previously recorded to be a major element in the secondary tributaries of the Vaal River which are in most cases reduced to practically standing waters for long periods (Skelton, 2001).

A total number of 5 Smallmouth Yellowfish (*Labeobarbus aeneus*) specimens were sampled during the field survey (Table 13). *Labeobarbus aeneus* prefers clear water lothic conditions, which is related to their food preference. The species is omnivorous with its main diet consisting of epifauna. It further requires gravel beds in flowing water to spawn (Mulder, 1986). Mulder (1971) and Skelton (2001) reported *L. aeneus* to be one of the dominating larger fish species in the Vaal Catchment. There has however been a notable decline in the numbers of this species in the catchment since the 1960's (Skelton, 1986), probably because of an increase in turbidity and river regulation in the system over the past few decades. The absence of L. *aeneus* in the Rietspruit, Rietkuilspruit and Leeuwspruit could be ascribed to the unsuitability of the available habitat in these streams.

Limited numbers of the Sharptooth Catfish (*Clarias gariepinus*) were observed during the present investigation (Table 13). This hardy species however, occur throughout the Vaal River Catchment (Mulder, 1971; Skelton, 2001) and is adapted to a variety of different conditions (Skelton, 2001). *Pseudocrenilabrus philander* (Southern mouthbrooder) were sampled in the Taaibosspruit and Rietspruit only. This is however a common species, but prefer vegetated areas (Skelton, 1986; 2001).

Some individuals of *Cyprinus carpio* occurred in the Rietkuilspruit and Leeuwspruit. This is a hardy species tolerant of a wide variety of conditions but generally favours large water bodies with slow-flowing or standing water and soft bottom sediments (Skelton, 2001). This exotic species is considered a pest because of its destructive feeding habits.

A total of 16 *Gambusia affinus* were sampled in the study area during the December 2001 survey. This aggressive invader species is tolerant of a wide range of temperatures and salinities (Skelton, 2001). Two individuals of the exotic Largemouth Bass (*Micropterus salmoides*) were sampled in the Vaal River at site LS6).

Species expected to occur in the study area (based on habitat preferences), but which were however not sampled, include *Barbus pallidus* (Goldie Barb), *B. trimaculatus* (Threespot Barb), *Labeobarbus kimberleyensis* (Largemouth Yellowfish) and *Tilapia sparrmanii* (Banded Tilapia).

6.6.2. Presence of Red Data species

Rock-and-stream living *Austroglanis sclateri* (Rock Catfish) is the only Red Data species known to occur in the Vaal River Catchment. This species is listed as rare to indeterminate in the South African Red Data Book for Fishes (Skelton, 1987). This is a very difficult species to sample as a result of its habitat preference and its limited numbers, but is not expected to occur in the Rietkuilspruit or Leeuwspruit as a result of the absence of its preferred habitat. The species may however occur in the Rietspruit. This species is consistently represented in low proportions throughout the Vaal catchment and has a preference for rocky areas closely associated with flow (Skelton, 2001; Niehaus, 1996).

6.6.3. Health Assessment

An insufficient number of adult fish were sampled to conduct a complete Fish Health Assessment Index (FHAI). Results were therefore calculated on the basis of external abnormalities only (APPENDIX 4).

A significant number of *B. anoplus* specimens sampled were infested with external parasites at sites RS5 and LS4. External abnormalities (lesions on the skin and/or fins) were significant in fish sampled from the Rietkuilspruit (57% of examined fish), Rietspruit (58% of examined fish) and Leeuwspruit (67% of examined fish). Low water levels experienced during the field survey limited available fish habitat, with a resultant increase in competitive pressure.

6.7. Sediment Contaminant Concentrations

Fluoride concentrations were high in sediments sampled from the Rietkuilspruit, compared to the values recorded at the reference site in the Taaibosspruit and also values recorded at the Rietspruit. A possible source of fluoride was indicated upstream of site RS4 in the Rietkuilspruit. Fluoride concentrations in the Leeuwspruit were very high at site LS1 (>30ppm), decreasing towards the lower reaches of the stream to a value of <10ppm at site LS5 (Figure Plate 1). The high fluoride concentrations detected in the Rietkuilspruit and Leeuwspruit is an issue of concern, since fluoride plays a major role in causing deterioration of aquatic systems (Mane *et al.*, 1987). The sensitive nature of aquatic organisms to elevated fluoride levels is ascribed to their evolvement in an almost fluoride free environment. They are therefore not well equipped to tolerate increased fluoride levels and even a slight increase in fluoride becomes toxic to aquatic organisms (Gokhale & Mane, 1990). The toxicity of fluoride however, is more related to the bio-availability of fluoride ions than to the total fluoride concentration in the water. Fluoride forms insoluble complexes with certain ions (notably calcium, magnesium, aluminium and phosphate) that settle out and are not easily absorbed by aquatic biota. The high salinity should therefore result in a reduction in the toxicity of fluoride to aquatic organisms. Fluoride nevertheless poses a potential threat to the receiving aquatic environment, since it may become bio-available when conditions like pH, hardness, redox potential and/or the concentration of complexing agents change. This aspect should be addressed as part of any management plan for the rivers/streams of the study area.

Bromide concentrations in the sediments were mostly below the detection limit of the analytical apparatus used, except at sites RS4 and LS1 (Figure Plate 1). Nitrate values were mostly below 100ppm in sediments sampled from the study area, the only exception being sediments sampled from site RS8 in the Rietkuilspruit, where a value of 1352.6ppm were measured in the top depositional layer and 170ppm measured in the second layer (Figure Plate 1).

Sediment copper concentrations increased approximately four fold towards the lower reaches of the Leeuwspruit (Figure Plate 2). Cobalt concentrations were generally higher in the Rietkuilspruit than at the reference site and the Rietspruit. Cobalt concentrations measured in sediments sampled from the Leeuwspruit were very high at site LS4 (>30ppm), decreasing towards the downstream section of the spruit to a value of 21.6ppm in the top depositional layer and 16.6ppm in the second layer (Figure Plate 2). Calcium concentrations in sediments sampled from the Rietkuilspruit were generally higher than those sampled from the Rietspruit. The very high calcium concentration detected in both sediment layers sampled from site LS5 in the Leeuwspruit (>45 000ppm) is cause for concern, indicating a significant source of Calcium salts between sites LS4 and LS5 (Figure Plate 2).

Chloride concentrations measured in the sediments sampled from site RS3 in the Rietkuilspruit was significantly higher than concentrations measured at other sites in the study area (Figure Plate 3). Cadmium concentrations in the sediments sampled from the study area were below the detection limit of the analytical apparatus used (Figure Plate 3). Sediment phosphate concentrations in the Rietspruit were significantly higher than those measured in sediments sampled from the other streams in the study area, with values of >200ppm recorded at sites RS6 and RS10 (Figure Plate 3). This could be attributed to sewage effluent from various Sewage Treatment Plants in the Rietspruit (McMillan & Todd, 1998). The increase in phosphorus in the Leeuwspruit at site LS5 is attributed to the addition of treated sewage effluent upstream of this point.

Sediment sulphate concentrations on the other hand were significantly higher in the Rietkuilspruit that in the other streams investigated. Sulphate concentrations measured in sediments sampled from site LS5 in the Leeuwspruit were high compared to sediment sulphate values recorded at other sites in this stream (Figure Plate 4). Sediment Barium concentrations were high in the Rietkuilspruit and even higher in the Leeuwspruit, compared to values obtained in the Rietspruit (Figure Plate 4). Magnesium concentrations measured in sediments sampled from sites RS4 in the Rietkuilspruit and site LS4 in the Leeuwspruit were high compared to concentrations measured in sediments sampled from other sites in the study area (Figure Plate 4).

Sediment aluminium concentrations were high in the Rietkuilspruit (notably at sites RS1, RS2, RS4 and RS5) compared to concentrations measured at other sites in the study area (Figure Plate 5). Nickel concentrations were highest in sediments sampled from the reference site in the Taaibosspruit and at site LS4 in the Leeuwspruit. Sediment Manganese concentrations were high in the Rietkuilspruit and Leeuwspruit compared to values recorded in sediments sampled from the reference site in the Taaibosspruit and the Leeuwspruit. Manganese concentrations were especially high at site RS1 and site LS4 (Figure Plate 5).

Chromium concentrations were also higher in the Rietkuilspruit and especially in the Leeuwspruit than sediment chromium concentrations measured in the Taaibosspruit and Rietspruit (Figure Plate 6). The very high Chromium concentration (>300ppm) detected in the sediments sampled from site LS4 indicates a source of this constituent upstream of this site (Figure Plate 6). Zn concentrations were generally higher in sediments sampled from the Rietkuilspruit and Leeuwspruit than in sediments sampled from the Rietspruit and Taaibosspruit reference site (Figure Plate 6). The zinc concentration measured in the top depositional sediment layer sampled at site RS2 in the Rietkuilspruit was especially high (Figure Plate 6). Sediment Sodium concentrations were high at sites RS2 and LS5 compared to concentrations measured in sediments sampled from other sites in the study area (Figure Plate 6).

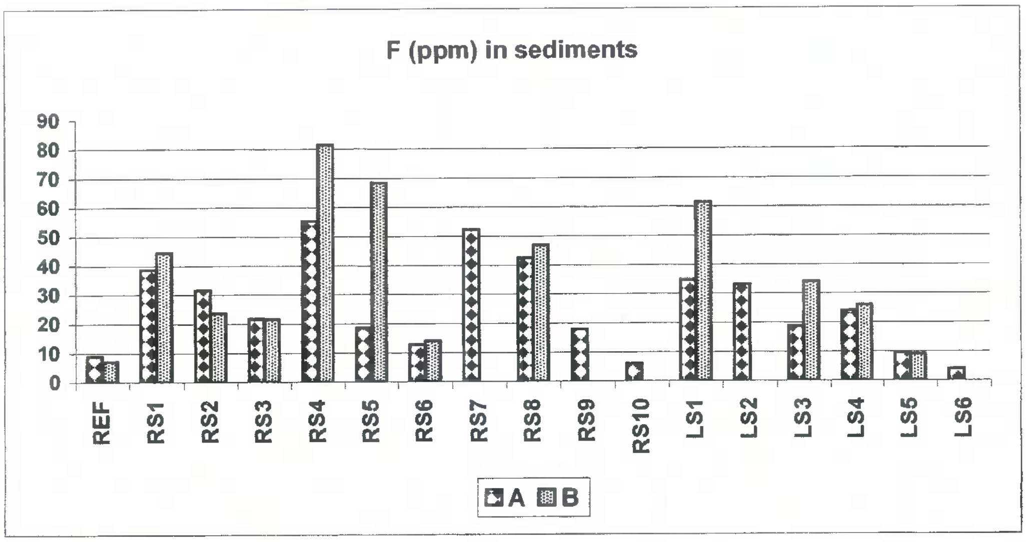
Lead concentrations were high in both sediment layers sampled from the reference site in the Taaibosspruit, Sites RS1 and RS2 in the Rietkuilspruit and Sites LS3, LS4 and LS5 in the Leeuwspruit. Boron concentrations showed significant spatial variation in the study area with highest concentrations measured in sediments sampled from Sites RS1 and RS2 in the Rietkuilspruit and site LS1 in the Leeuwspruit (Figure Plate 7). Lithium concentrations were generally higher in sediments sampled from the Rietkuilspruit and Leeuwspruit than in sediments sampled from the Rietspruit and Taaibosspruit (Figure Plate 7), with a significant peak at site RS2 (Figure Plate 7).

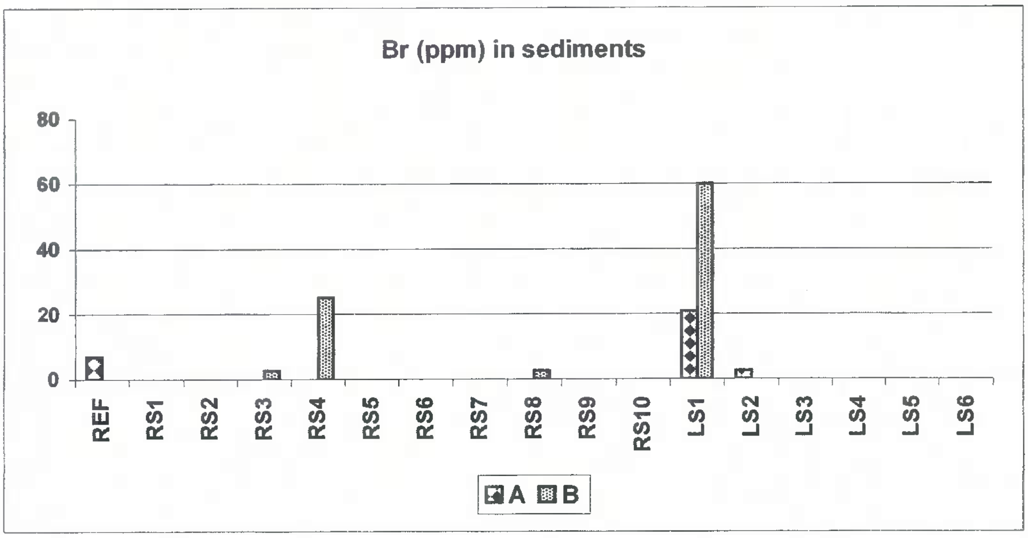
The Rietkuilspruit and Leeuwspruit sediments also displayed generally higher Iron concentrations than those in the Taaibosspruit and Rietspruit (Figure Plate 8).

Strontium concentrations measured in sediments sampled from the study area are comparable to those sampled at the reference site in the Taaibosspruit, the only exception being site LS5, where sediment Strontium concentrations of >140ppm were measured in both sediment layers (Figure Plate 8). Bismut concentrations in the sediments sampled from the study area were below the detection limit of the analytical instrument used (Figure Plate 8).

It can be concluded that the Rietkuilspruit and Leeuwspruit generally displayed higher sediment contaminant concentrations than those measured in sediments sampled from the reference site in the Taaibosspruit and the Rietspruit (notably concentrations of F, Co, Ca, Cl, SO_4, Ba, Mg, Al, Mn, Pb, B, Li, Cr, Zn, Sr and Fe). The sediment phosphate concentrations in the Rietspruit on the other hand were significantly higher than concentrations measured in the Rietkuilspruit and Leeuwspruit.

Sediment concentrations of Co, Ba, Mg, Ni, Mn, Cr and Fe showed distinct peaks at site LS4 in the Leeuwspruit indicating a significant source of metal enrichment upstream from this point. This site is situated downstream of the Dicksonville Industrial Area. Similarly site LS5, situated in the Leeuwspruit upstream of the Vaal River confluence, showed distinct peaks of Cu, Ca, Na and Sr sediment concentrations in both sediment layers, indicating continued enrichment of these particular constituents. Apart from receiving the combined effluents and stormwater runoff from upstream industrial areas, urban areas and settlements, this site also receives treated effluent from a Sewage Treatment Plant.





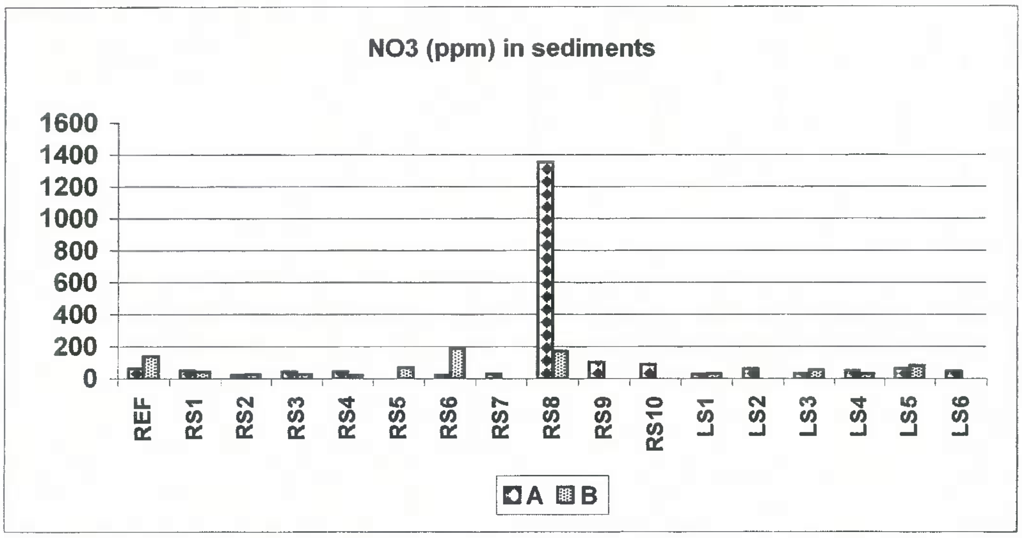


Figure Plate 1:

Contaminant concentrations in sediments sampled from selected sites in the study area
A = top depositional layer; B = second depositional layer

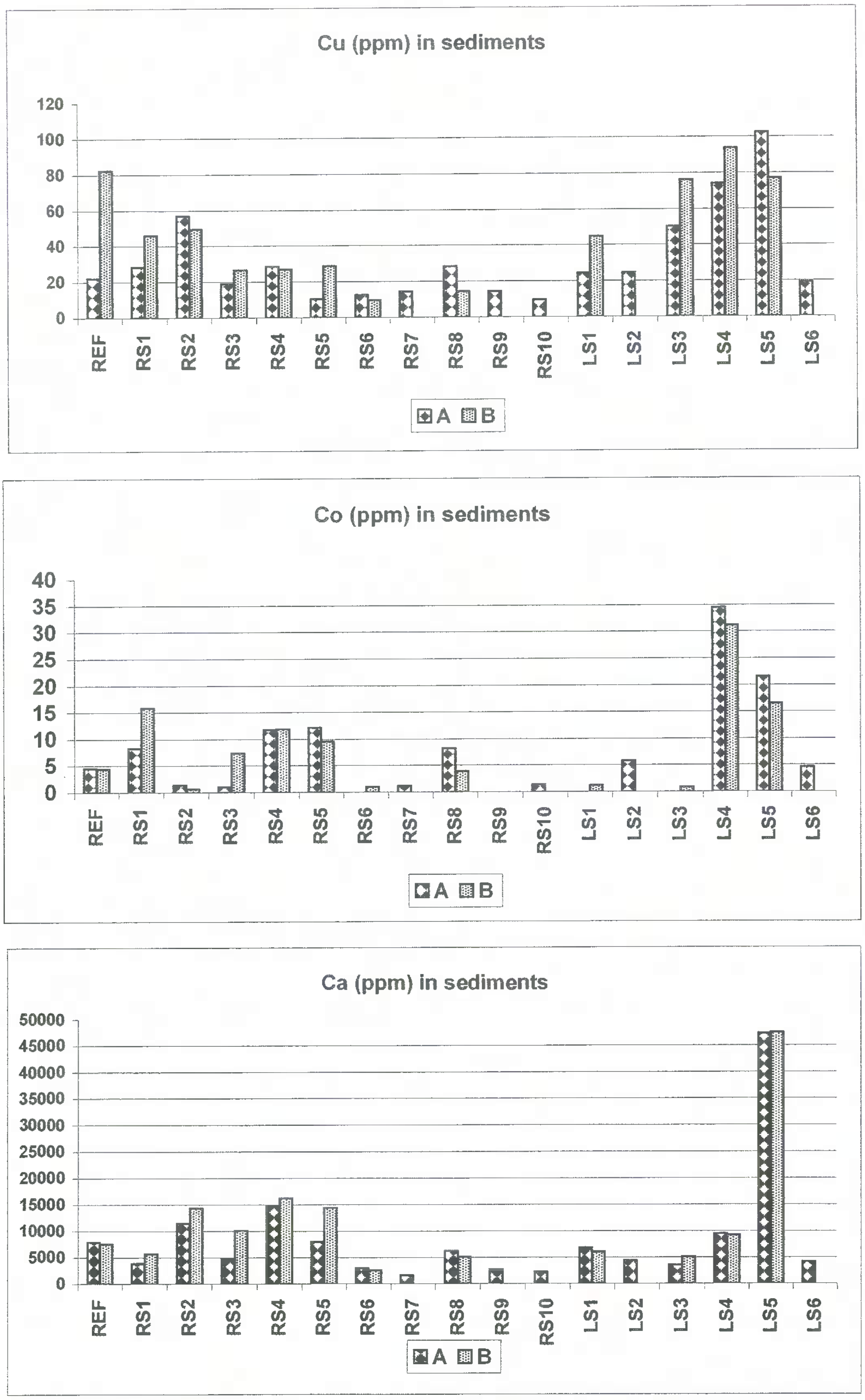
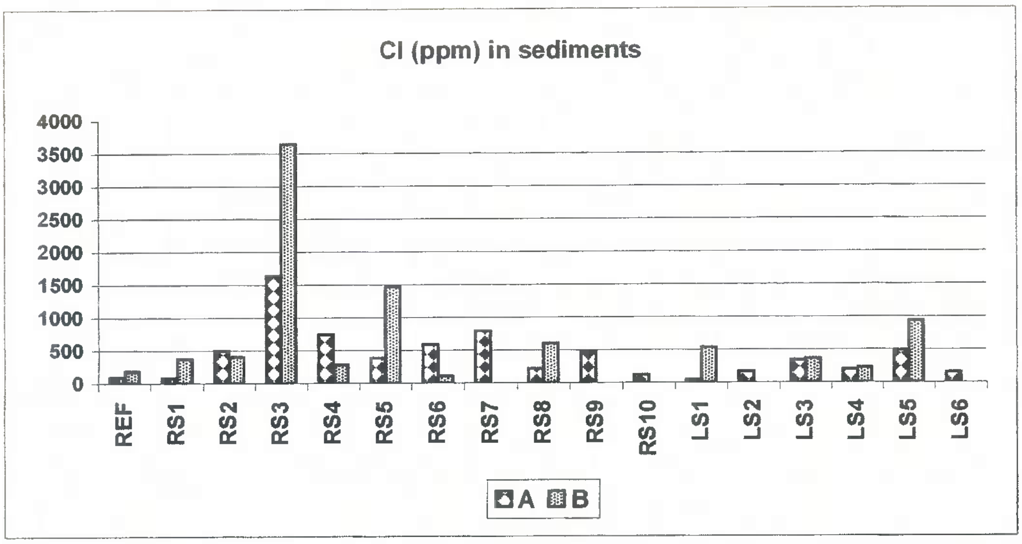
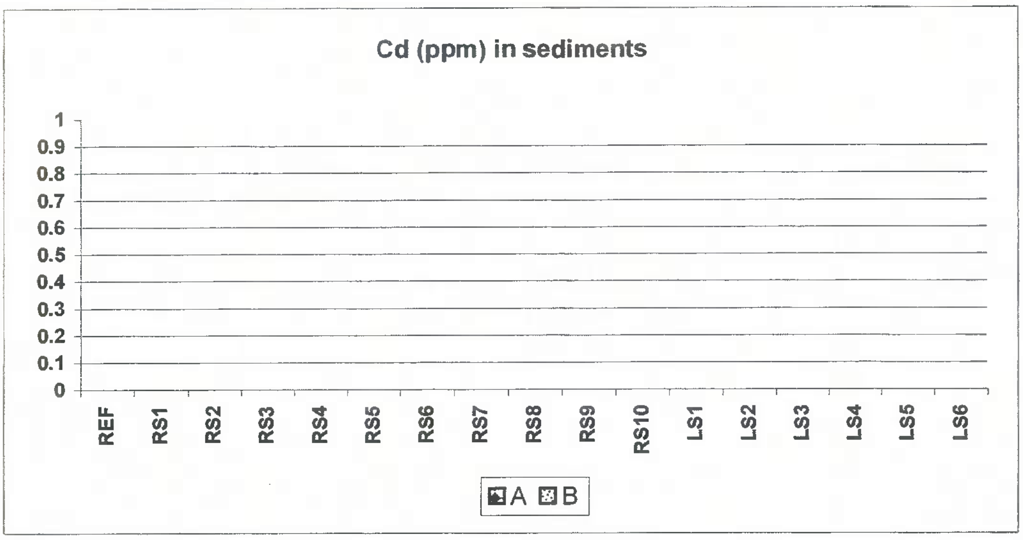


Figure Plate 2:

Contaminant concentrations in sediments sampled from selected sites in the study area

A = top depositional layer; B = second depositional layer





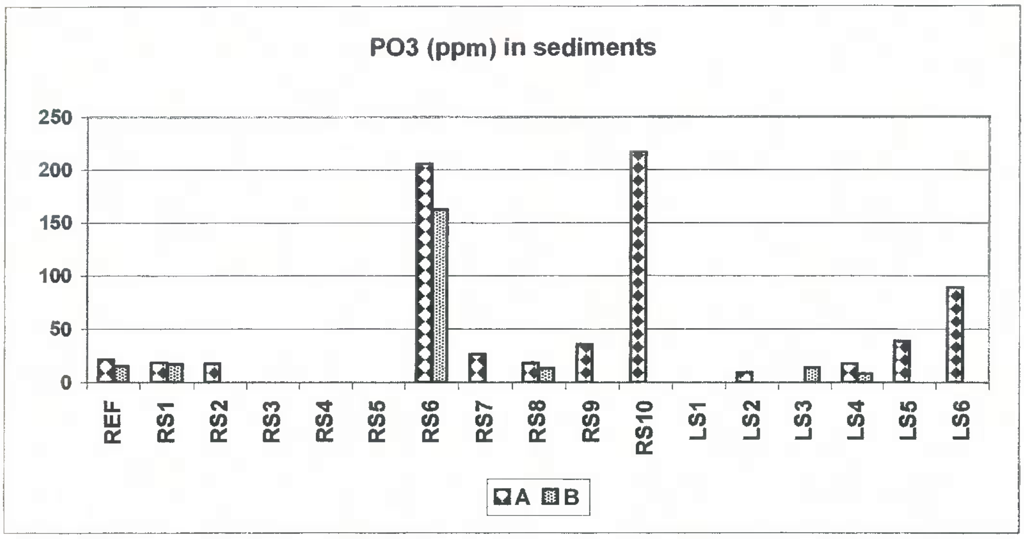


Figure Plate 3:

Contaminant concentrations in sediments sampled from selected sites in the study area

A = top depositional layer; B = second depositional layer

Figure 4: Present State Class at selected sites in the study area, based on SASS results

SASS index:
- Integrity Class A
- Integrity Class B
- Integrity Class C
- Integrity Class D
- Integrity Class E/F
- Rivers and Streams
- Vaal River
- Canal
- Dams and Lakes

N

Scale: 1 : 55 000

ECOSUN
Environmental Consultants
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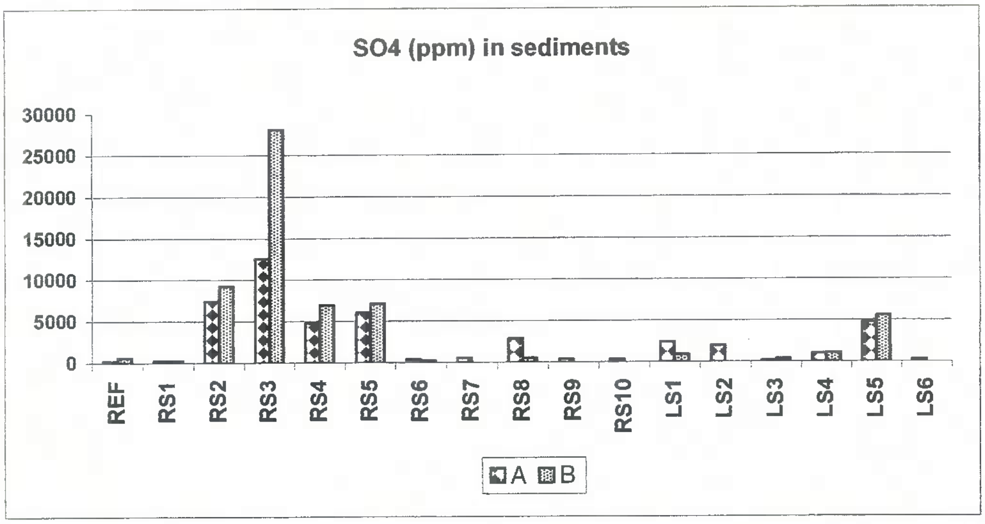
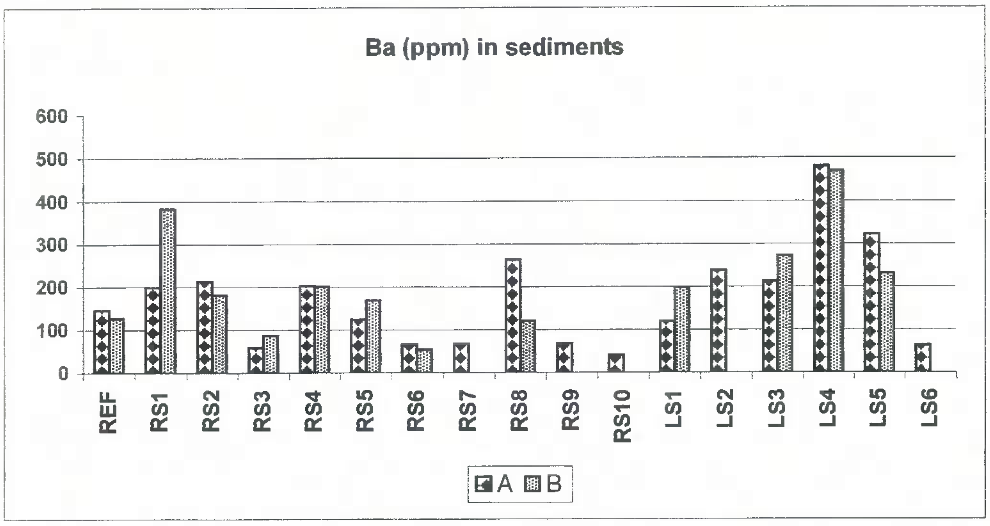




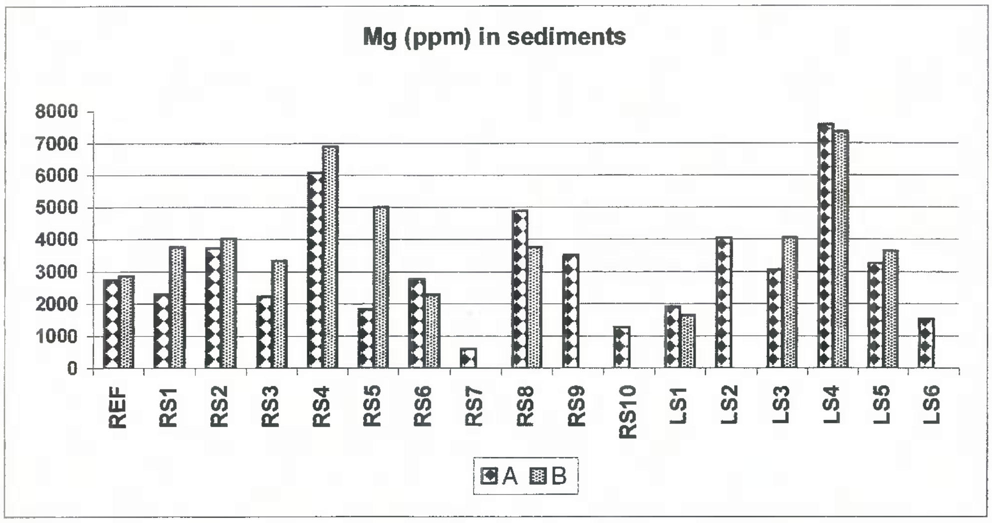
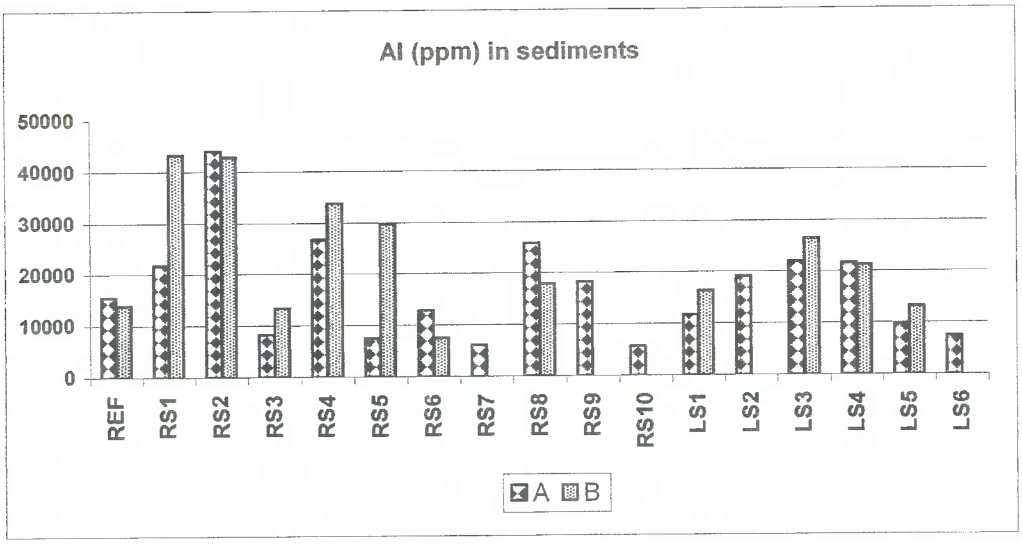
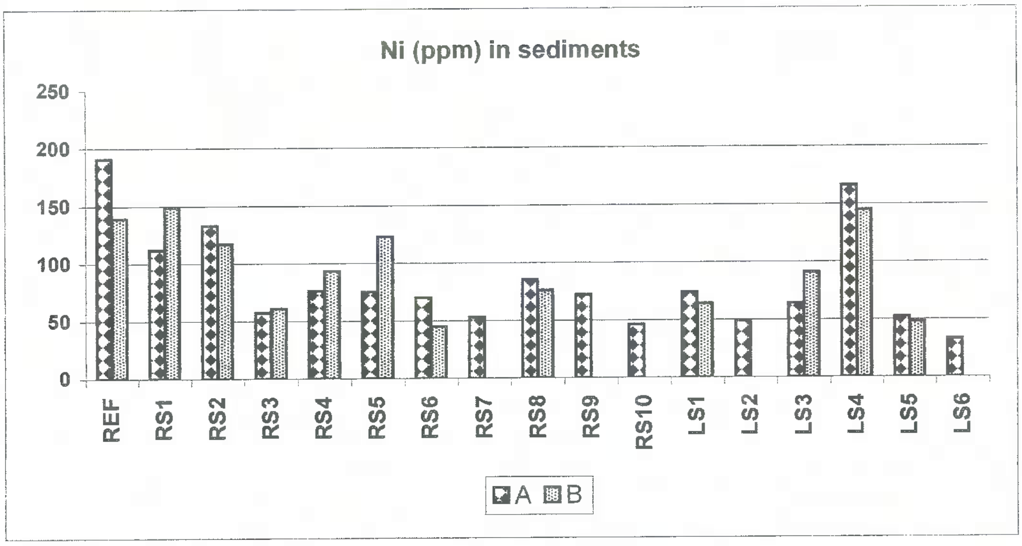


Figure Plate 4:
Contaminant concentrations in sediments sampled from selected sites in the study area
A = top depositional layer; B = second depositional layer





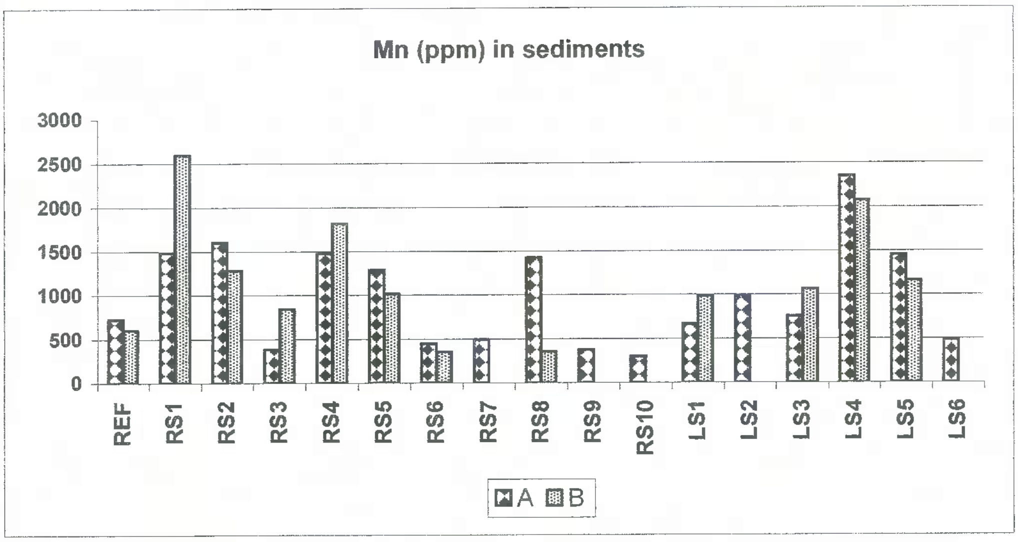


Figure Plate 5:

Contaminant concentrations in sediments sampled from selected sites in the study area

A = top depositional layer; B = second depositional layer

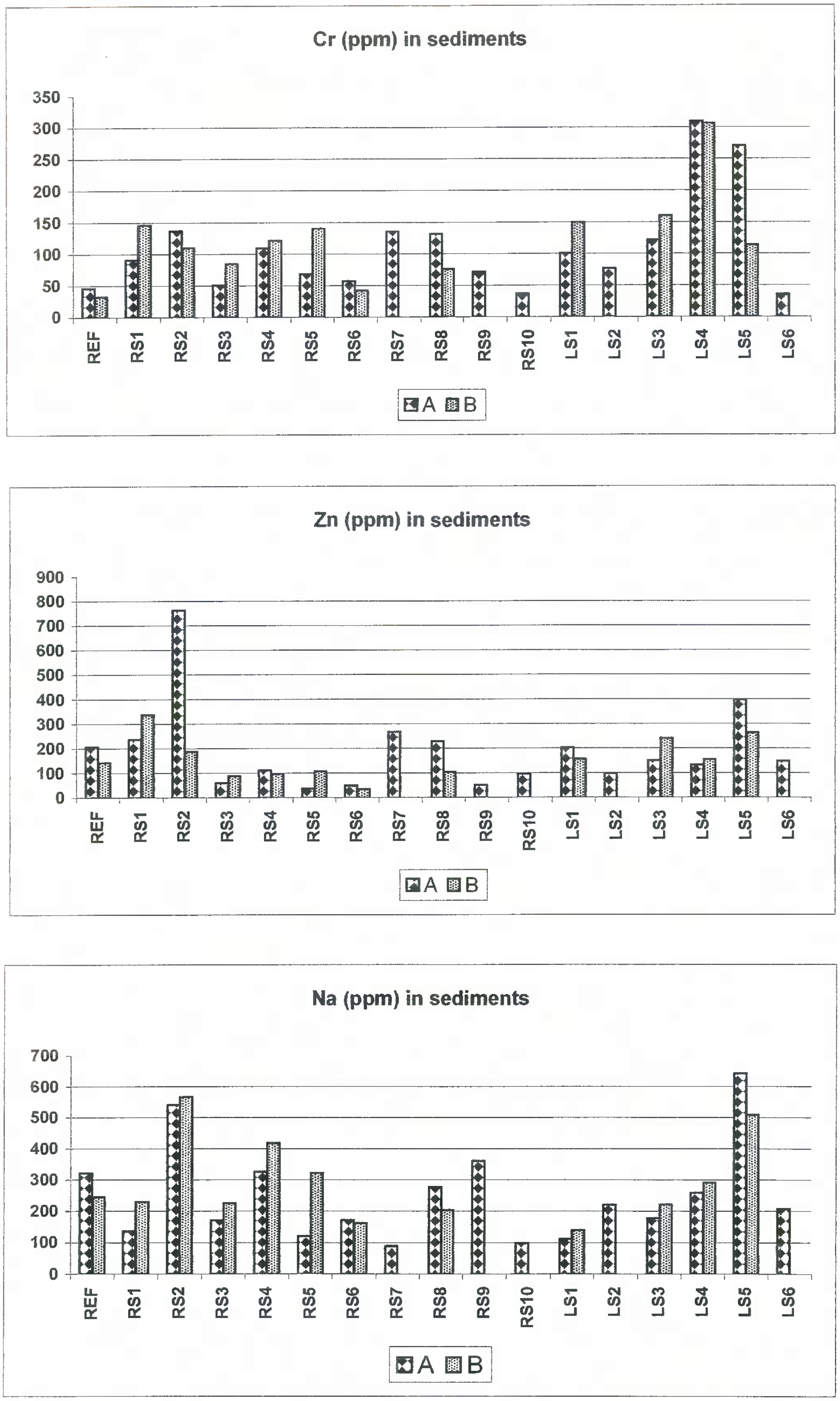
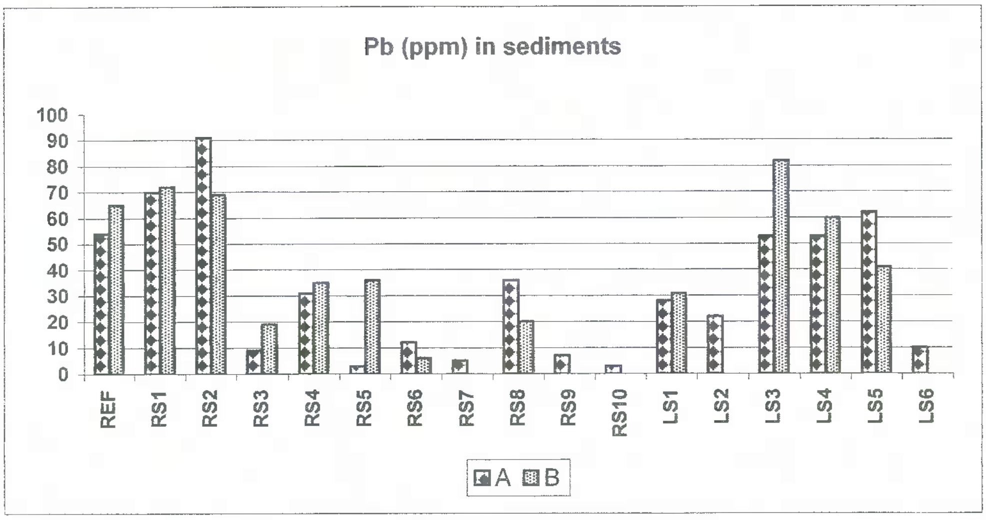
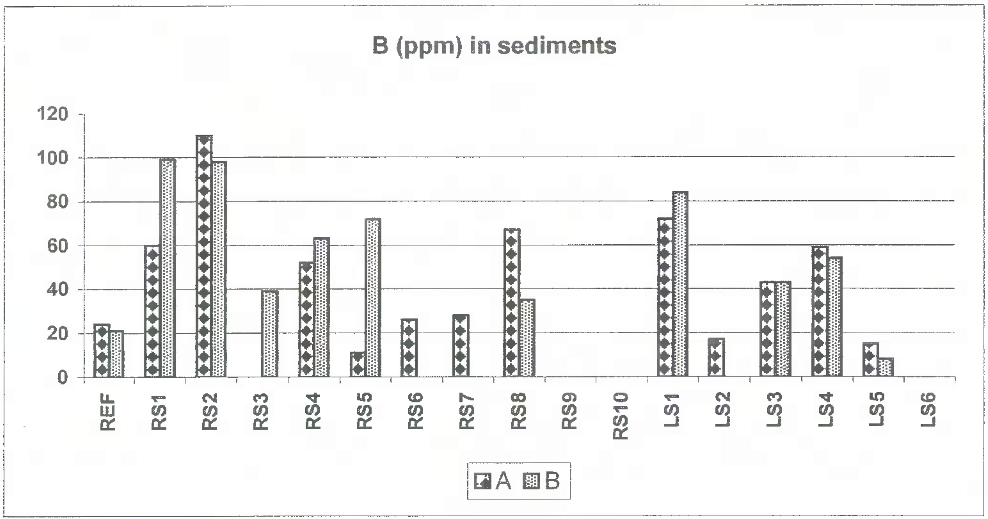


Figure Plate 6:

Contaminant concentrations in sediments sampled from selected sites in the study area

A = top depositional layer; B = second depositional layer





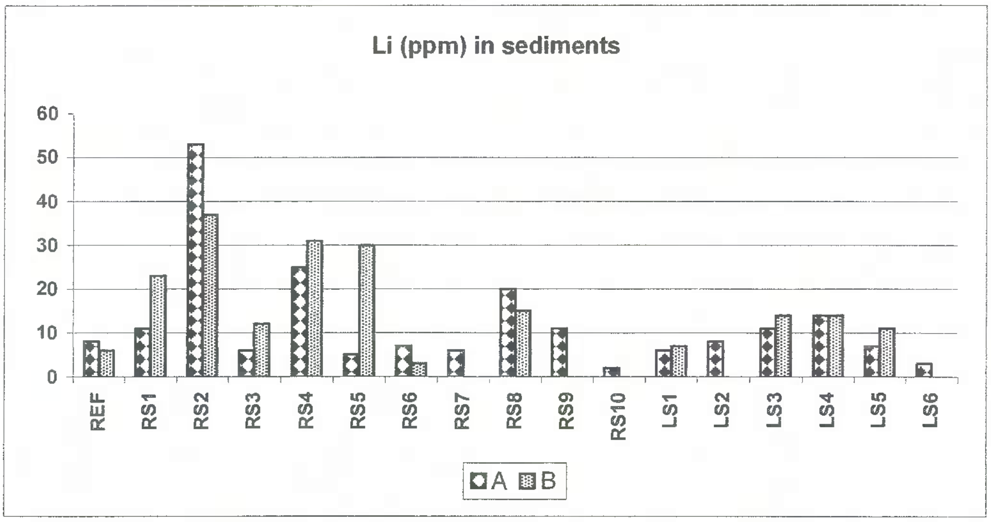
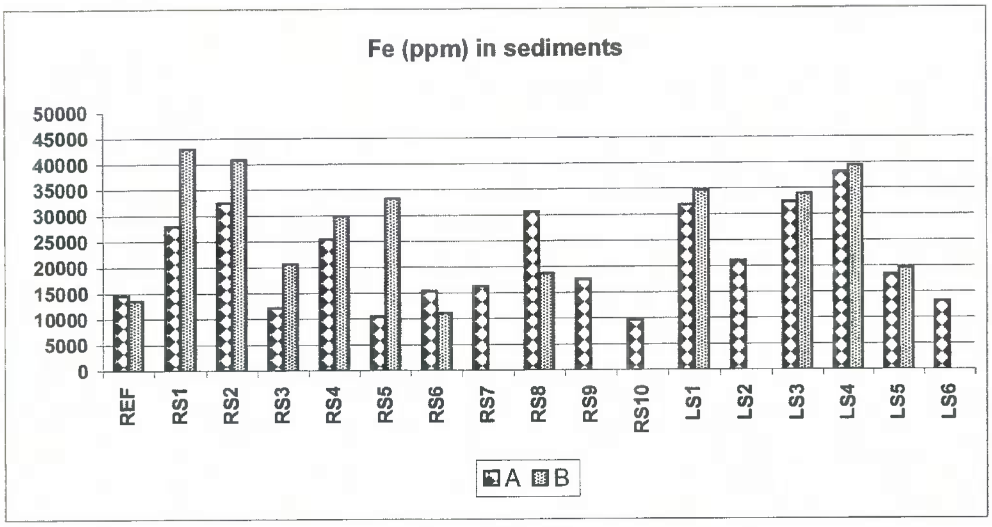
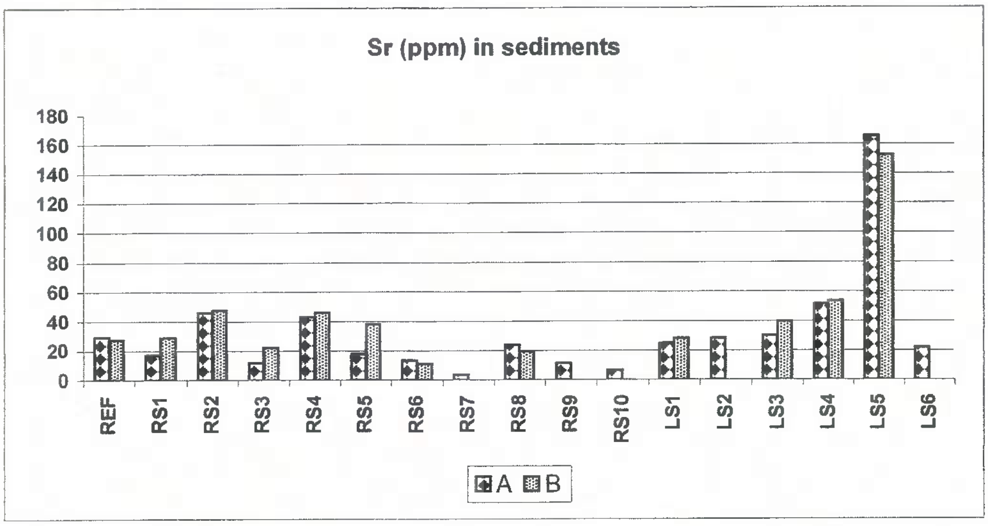


Figure Plate 7:

Contaminant concentrations in sediments sampled from selected sites in the study area

A = top depositional layer; B = second depositional layer





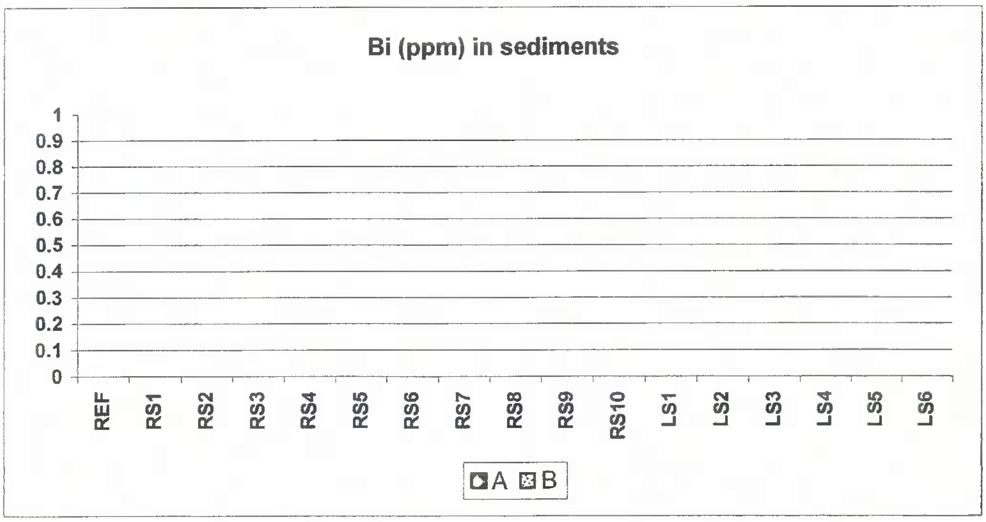


Figure Plate 8:

Contaminant concentrations in sediments sampled from selected sites in the study area

A = top depositional layer; B = second depositional layer

6.8. Bioaccumulation

Fluoride concentrations in crabs increased towards the downstream section of the Rietkuilspruit, to reach a mean value of >30ppm in crabs sampled from site RS8 (Figure Plate 9). Fluoride concentrations were also indicated to be high in sediments sampled from the Rietkuilspruit. This is a cause for concern taking into account the potential toxicity of this constituent towards the receiving aquatic system (see Section 6.7).

No significant differences were detected in nitrogen concentrations in crabs sampled from the different streams in the study area (Figure Plate 9). Phosphate concentrations were high in crabs sampled from the Taaibospruit (reference site) and site RS10 in the Rietspruit. Sediment data also indicated the phosphate load in the Rietspruit to be significantly higher than that measured in the Rietkuilspruit and Leeuwspruit (see Section 6.7). Bromide concentrations in crabs sampled from site LS4 were high compared to concentrations measured in crabs sampled from the Rietkuilspruit and Rietspruit (Figure Plate 9). Highest concentrations of chloride were measured in crabs sampled from the Rietspruit (sites RS9 and RS10). Bismut were undetectable in the sediments sampled from the study area. High concentrations of this constituent were however detected in crabs sampled from site RS8 in the Rietkuilspruit (Figure Plate 9). Boron concentrations in crabs sampled from the study area showed significant spatial variation from below the detection limit (sites RS1, RS3, RS5, RS6 and RS8) to >6ppm in crabs sampled at site RS7 (Figure Plate 9).

Manganese concentrations decreased in crabs towards the lower reach of the Rietkuilspruit (from 613.6ppm at site RS1 to 365ppm at site RS5 to 256.8ppm at site RS8) (Figure Plate 10). High manganese concentrations were detected in the Rietspruit, with a mean value of 779ppm measured in crabs sampled from site RS6 and a mean of 744ppm measured in crabs sampled from site RS10. Crabs sampled from site LS4 in the Leeuwspruit also had high Manganese concentrations with a mean value of 828.5ppm recorded (Figure Plate 10). Highest iron concentrations were measured in crabs sampled from the reference site in the Taaibosspruit and site RS9 in the Rietspruit (Figure Plate 10). Chromium concentrations were highest in crabs sampled from the Rietspruit and Vaal River (Figure Plate 10). No significant differences were measured in sodium concentrations in crabs sampled from the study area, the only exception being those sampled at site LS4 (>8000ppm) (Figure Plate 10). Zinc concentrations measured in crabs sampled from the Vaal River (site LS6) were significantly higher than concentrations measured in crabs sampled from other streams in the study area (Figure Plate 10). A similar trend was observed for Lithium. This constituent were undetectable in crabs sampled from the study area (<1ppm), the only exception being crabs sampled from site LS6 in the Vaal River, with a mean Lithium concentration of 2.4ppm (Figure Plate 10). The Lead concentration in crabs sampled from the study area was below the detection limit of the analytical apparatus used.

Highest Barium concentrations were measured in crabs sampled from the Rietspruit (sites RS6 and RS9). Sediment data indicated the Barium concentration in the sediments of the Rietspruit to be low. The high concentration in crabs could be related to the water characteristics and subsequent bioavailability of the constituent.

Strontium and Copper concentrations were significantly higher in crabs sampled from the Vaal River than in crabs sampled from other sites in the study area (Figure Plate 11). Crabs sampled from site RS9 in the Rietspruit displayed high Al concentrations compared to crabs sampled from other sites in the study area (Figure Plate 11). Cadmium concentrations in crabs were below the detection limit of the analytical apparatus used (<1ppm).

Sediment data indicated the Rietspruit to contain lower concentrations of most constituents than the Rietkuilspruit and the Leeuwspruit. Bioaccumulation data however indicated the highest concentration of most constituents in crabs sampled from the Rietspruit and also the Vaal River. This phenomenon is probably related to the characteristics of the surface water (pH, hardness, redox potential, ionic strength, concentration of organic complexing agents, etc.) and subsequent bioavailability of the constituents analysed during the current investigation.

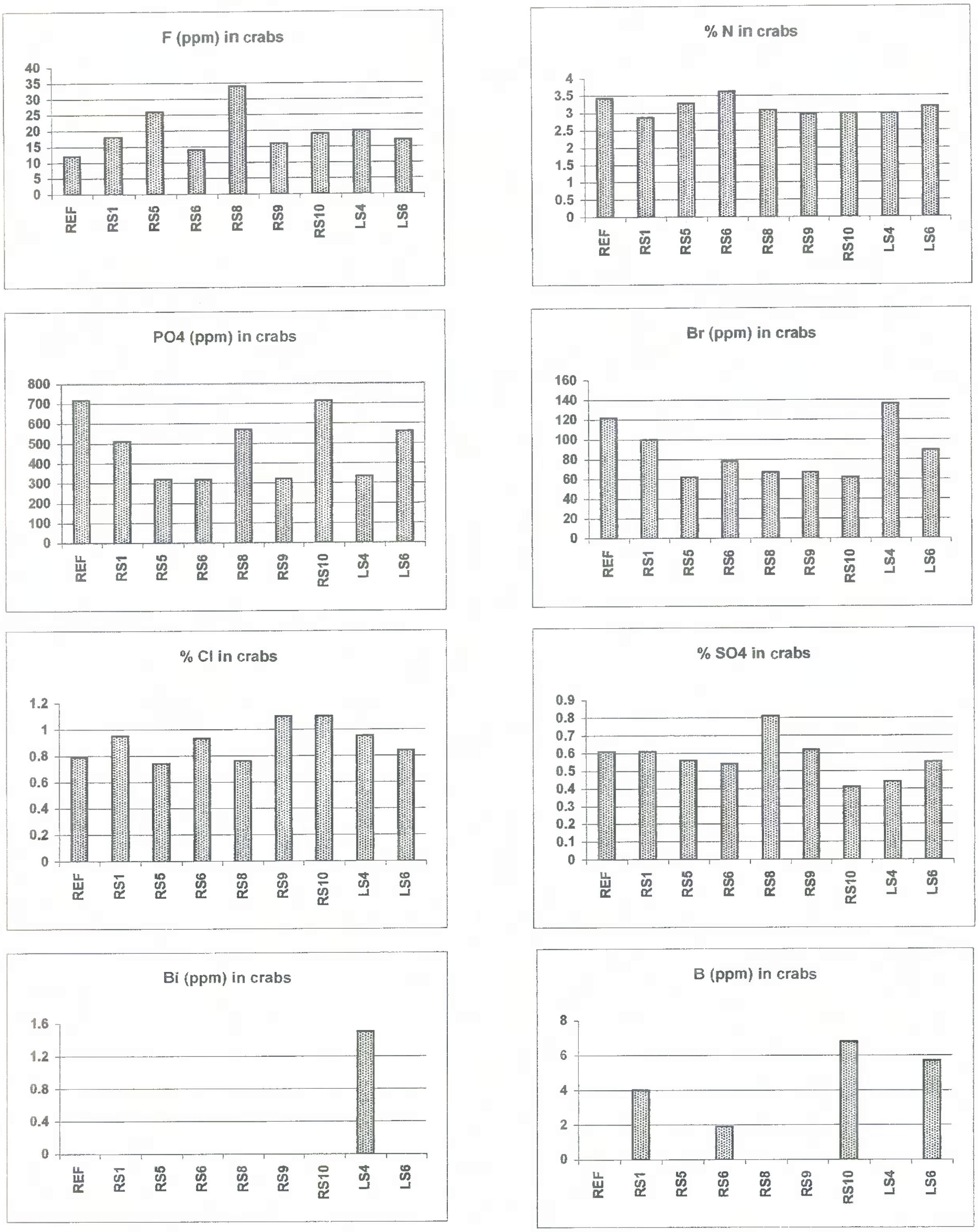


Figure Plate 9:

Contaminant concentrations in crabs sampled from selected sites in the study area

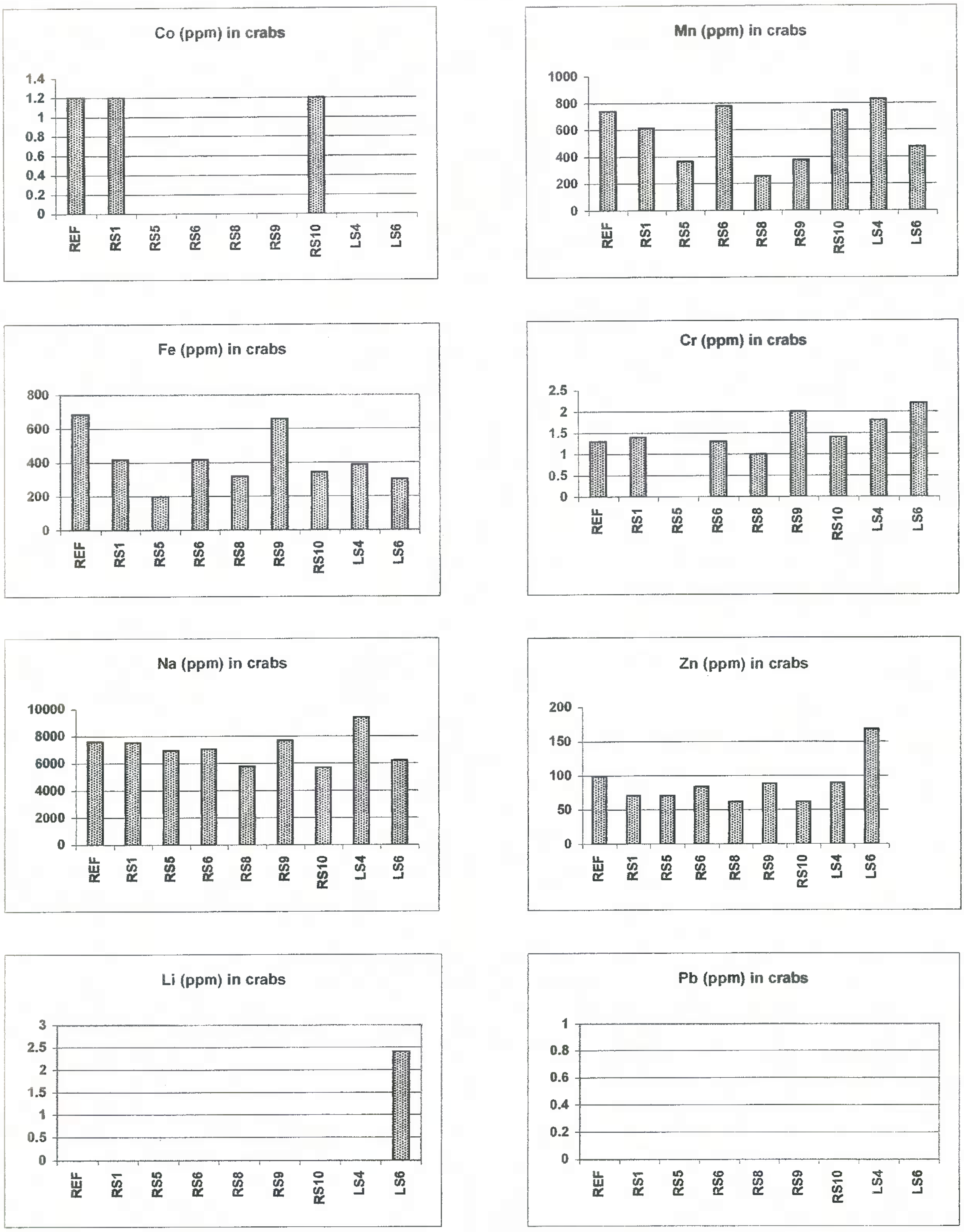


Figure Plate 10:
Contaminant concentrations in crabs sampled from selected sites in the study area

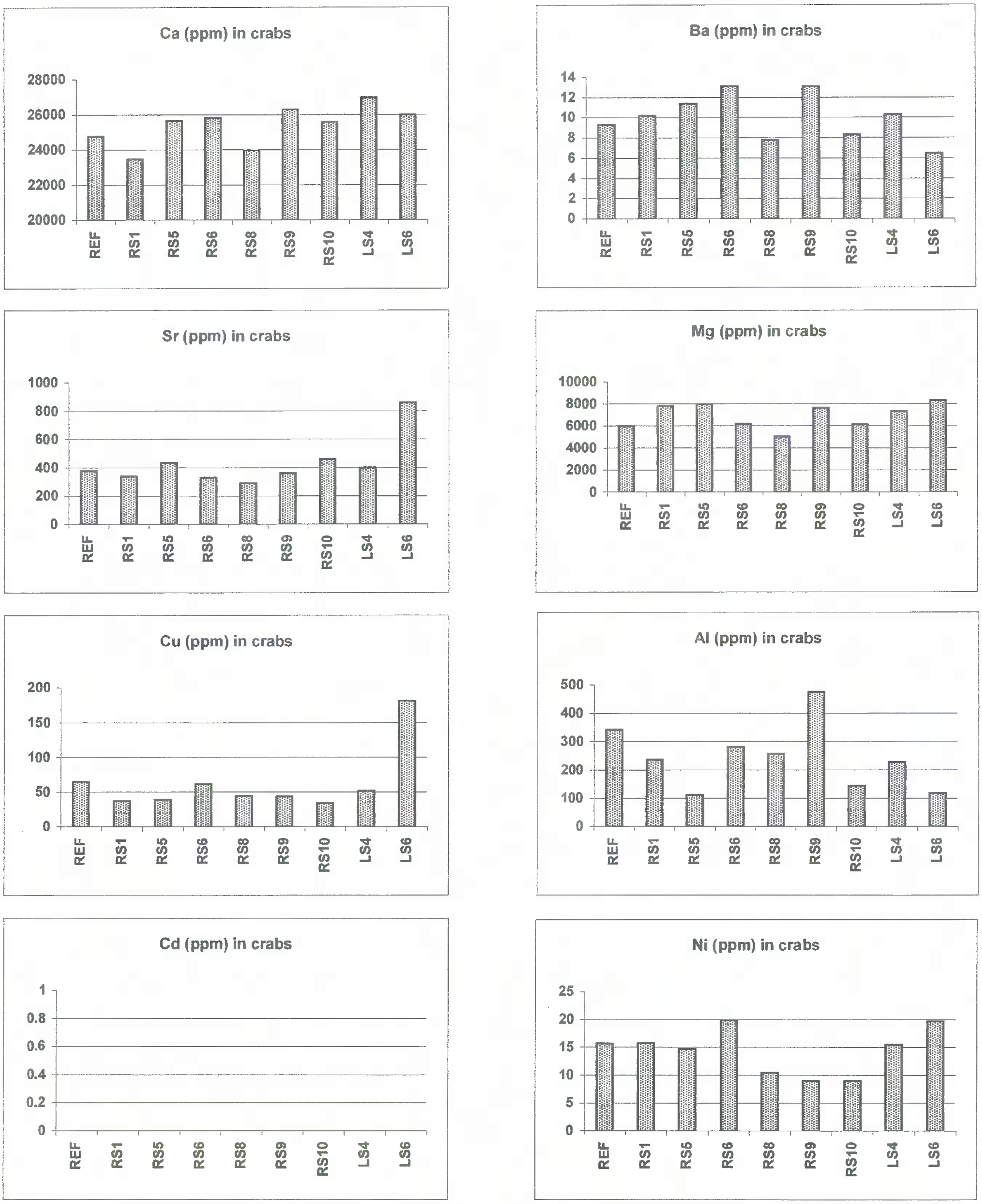


Figure Plate 11:

Contaminant concentrations in crabs sampled from selected sites in the study area

7. CONCLUSIONS

- *In situ* pH measurements varied considerably in the study area (6.9 to 9.0 in the Rietkuilspruit, 6.3 to 7.8 in the Rietspruit and 6.5 to 8.4 in the Leeuwspruit). This variation in pH poses a threat towards the aquatic ecosystem. According to the South African Water Quality Guidelines for Aquatic Ecosystems (DWAF, 1996), the pH value should not be allowed to vary from the range of the background pH values for a specific site and time of day, by >0.5 of a pH unit, or by 5% and should be assessed by whichever estimate is the more conservative. The significant variation in pH detected in the study area will therefore have an adverse effect on the aquatic biota, especially fish (as a result of their mobility).
- The Integrated Habitat Assessment System (IHAS) focuses on the evaluation of habitat suitability specifically for aquatic macroinvertebrates. This index indicated habitat availability to be poor at sites RS1 and RS2 in the Rietkuilspruit. The habitat however improved towards site RS4 and RS5 (good habitat availability), then decreased again at site RS8 (poor habitat availability). Habitat availability was poor in the Rietspruit, with IHAS values ranging between 24% and 37%. IHAS scores in the Leeuwspruit varied between 29% and 67%, indicating poor to good habitat availability.
- The Leeuwspruit constituted the most heavily impacted section of the assessed river reaches in terms of in-stream and riparian habitat integrity. Modifications to habitat integrity in this stream have reached a critical level and the lotic system has been modified completely with an almost complete loss of natural ecosystem functioning (Intermediate Habitat Integrity Class F). The Rietkuilspruit, and the 5km reach of the Rietspruit downstream from the Rietkuilspruit confluence was determined as belonging to Intermediate Habitat Integrity Class E, i.e. the loss of natural habitat, biota and basic ecosystem, functions are extensive. The 5km reach of the Rietspruit, upstream of the Rietkuilspruit confluence was determined as belonging to Class C, i.e. a loss and change of natural habitat and biota have occurred, but the basic ecosystem functions are still predominantly unchanged.
- Several factors in the study area are impacting on the ecological integrity of the assessed river reaches and the poor aquatic ecosystem health recorded during the present investigation cannot be attributed to any single cause. The study area is characterized by formal and informal settlements, Waste Water Treatment Plants, industries and faming activities, all contributing towards the poor habitat and biotic integrity. Impacts identified include water abstraction, flow modification, bed modification, channel modification, inundation, indigenous vegetation removal, solid waste disposal, bank erosion, water quality impairment and exotic vegetation encroachment.
- The vegetation at all the sites has been modified by anthropogenic factors. At some, perturbations will decrease while at others the current *status quo* will continue. Only a long term monitoring program will determine what changes are taking place and elucidate what the causative agents may be. Prior to this study some of the sites such as LS1, RS2 and RS3 had been seriously affected by recent developments. The draining of the marsh at LS1 is likely to seriously affect the viability of the marsh and its ability to function as a pollutant trap and sponge.
- Sampling sites along the Rietspruit and Vaal River exhibited higher plant species richness, although mostly with a substantial alien content, than either the Leeuwspruit or Rietkuilspruit. This can be attributed to lower disturbances, as these sites were mostly used for grazing of livestock and not for crop farming.

- At all sampling sites it was evident that floods and high run-off in the recent past had eroded the stream banks causing the collapse of, and creating vertical banks. These banks are not conducive of being easily colonized by vegetation.
- Some sites (LS1, LS2, LS4, LS5, RS2, RS3 and RS7) were unsuitable for application of the Riparian Vegetation Index (RVI), because of the type and level of disturbance. The remaining sites were all rated at Class C level, which indicated, from a vegetation point of view, that they were "Moderately Modified", i.e. a loss and change of natural habitat and biota have occurred but the basic ecosystem functions were still predominantly unchanged.
- Sampling sites in the study area were characterized by an absence/near absence of the more sensitive aquatic macroinvertebrate families, the only exception being site RS9 on the Rietspruit.
- Significant spatial variation existed in the Integrity Classes recorded in the Leeuwspruit (based on SASS5 results). The Present State Class in the Leeuwspruit varied between Class D and E, with a Class F recorded at site LS5. The latter site receives treated effluent from a sewage works. The Present State Class in the Rietkuilspruit was indicated to be Class E at all sites sampled. The poor Present State Class (F) obtained at site RS6 in the Rietspruit is attributed to the fact that this site displayed limited aquatic macroinvertebrate habitat availability. The Present State Class obtained in the Rietspruit downstream from the Rietkuilspruit confluence was also indicated to represent a Class E biotic integrity.
- An insufficient number of indigenous fish species were sampled to apply the Fish Assemblage Integrity Index (FAII). Indigenous species sampled in the Rietkuilspruit, Rietspruit and Leeuwspruit included the more tolerant species such as *Barbus anoplus, Barbus paludinosus, Clarias gariepinus* and *Pseudocrenilabrus philander*. The latter species were only sampled in the Rietspruit and Taaibosspruit. *Labeobarbus aeneus, Labeo umbratus* and *L. capensis* were sampled only at the reference site in the Taaibosspruit and in the Vaal River. Several exotic fish species were sampled. These include *Cyprinus carpio, Gambusia affinus* and *Micropterus salmoides*. Other species expected to occur in the study area based on habitat preferences, but which were not sampled include *Barbus pallidus*, *B. trimaculatus, Labeobarbus kimberleyensis* and *Tilapia sparrmanii*.
- A significant amount of *B. anoplus* specimens sampled was infested with external parasites at sites RS5 and LS4. External abnormalities (lesions on the skin and/or fins) were significant in fish sampled from the Rietkuilspruit (57% of examined fish), Rietspruit (58% of examined fish) and Leeuwspruit (67% of examined fish). Low water levels experienced during the field survey limited available fish habitat, with a resultant increase in competitive pressure.
- Fluoride concentrations were high in sediments and biota sampled from the Rietkuilspruit, compared to the values recorded at the reference site in the Taaibosspruit. A possible source of fluoride was indicated upstream of site RS4 in the Rietkuilspruit. Fluoride concentrations were also high in the sediments sampled from the Leeuwspruit, decreasing towards the lower reaches of the stream. The high fluoride concentrations detected in the Rietkuilspruit and Leeuwspruit is an issue of concern, given the high toxicity of this constituent towards the aquatic ecosystem. The toxicity of fluoride however is more related to the bioavailability of fluoride ions than to the total fluoride concentration in the water. The very high fluoride concentration detected in crabs sampled from the Rietkuilspruit (>30ppm) indicates high bioavailability of this constituent in the stream. Although fluoride concentrations were high in sediments sampled from the Leeuwspruit, concentrations detected in biota sampled from this stream

were comparable to those detected in the Rietspruit and Taaibosspruit, indicating the constituent to be less bioavailable than in the Rietkuilspruit. This is an important aspect to consider with regards to the development of a management plan for the rivers/streams in the study area.

- The Rietkuilspruit and Leeuwspruit generally displayed higher sediment contaminant concentrations than those measured in sediments sampled from the reference site in the Taaibosspruit and the Rietspruit (notably concentrations of F, Co, Ca, Cl, SO4, Ba, Mg, Al, Mn, Pb, B, Li, Cr, Zn, Sr and Fe).
- The sediment phosphate concentrations in the Rietspruit on the other hand were significantly higher than concentrations measured in the Rietkuilspruit and Leeuwspruit. This is attributed to treated sewage effluent from a number of Sewage Treatment Plants situated in the upstream Rietspruit.
- Sediment concentrations of Co, Ba, Mg, Ni, Mn, Cr and Fe showed distinct peaks at site LS4 (Leeuwspruit downstream from Dicksonville) indicating a significant source of metal enrichment upstream of this point. Site LS5 (Leeuwspruit upstream of Vaal River confluence) showed distinct peaks of Cu, Ca, Na and Sr sediment concentrations in both sediment layers, indicating continued enrichment of these particular constituents.
- Sediment contaminant data indicated the Rietspruit to contain lower concentrations of most constituents than the Rietkuilspruit and the Leeuwspruit. Bioaccumulation data however indicated the highest concentration of most constituents in crabs sampled from the Rietspruit and also the Vaal River. This phenomenon is probably related to the characteristics of the surface water (pH, hardness, redox potential, ionic strength, concentration of organic complexing agents, etc.) and subsequent bioavailability of the constituents analyzed during the present investigation.

8. PROPOSED MANAGEMENT GOALS AND OBJECTIVES

8.1. Background

A water resource can be defined as an ecosystem which includes the physical or structural aquatic habitats (both instream and riparian), the water, the aquatic biota, and the physical, chemical and ecological processes which links habitats, water and biota. The Water Resources Protection Policy (WRPP) was implemented in South Africa in order to ensure that basic human water quality and quantity needs are met, that ecosystem structure and function are protected and that water requirements are met within these specific constraints (DWAF, 1999).

The National Water Act identifies a "Reserve", which will give effect to the policy of protection of the resource. The "Reserve" refers to the degree of utilization, which can be sustained by a water resource before resilience is lost. Implementation of the policy is based on the following regulatory activities (from DWAF, 1999):

1. Resource-directed measures (RDM) - setting the Reserve and Resource Quality Objectives (RQO)
2. Source-directed controls - controlling impacts (e.g. registration, permits, licenses, prosecution)
3. Managing demands on water resources - utilization within limits
4. Monitoring - ensuring compliance with RQO.

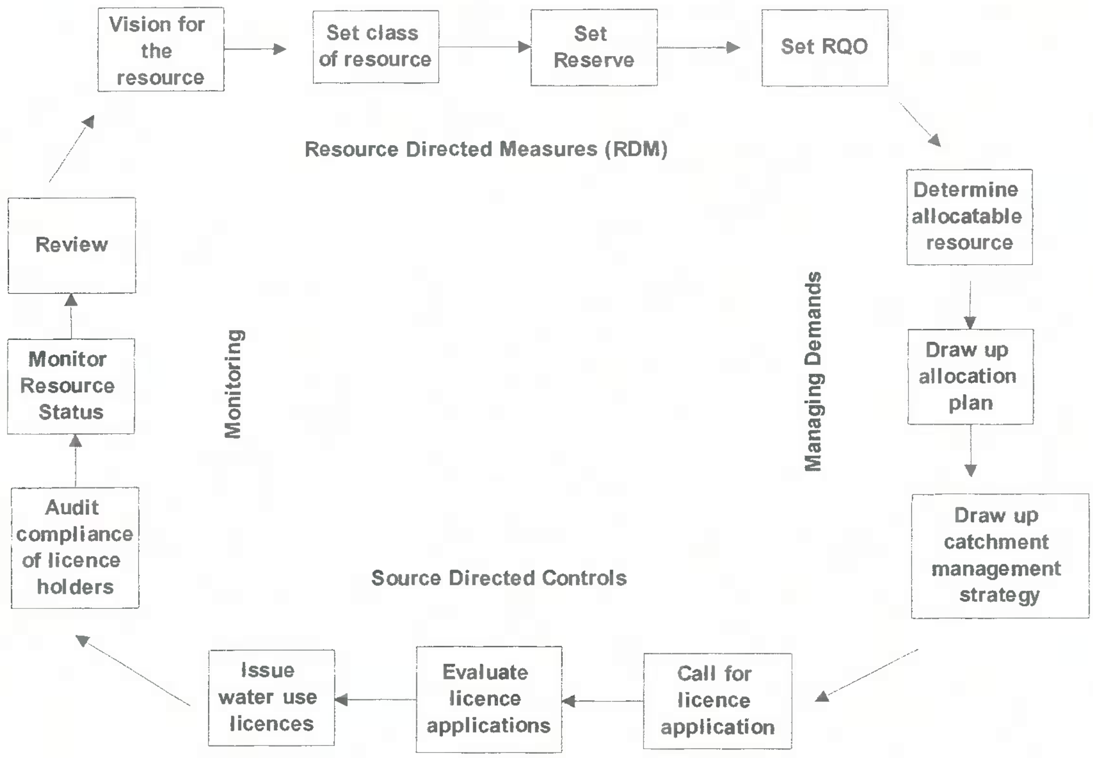


Figure 5: Water Resources Protection Policy (adapted from MacKay, 2000)

The RQO for a water resource is a numerical, descriptive statement of the conditions, which should be met in the receiving water resource, in terms of resource quality, in order to ensure its protection (DWAF, 1999). Critical components of RQO include:

- Requirements for water quantity (Instream Flow Requirements)
- Requirements for water quality (based on the South African Water Quality Guidelines)
- Requirements for habitat integrity (physical structure of instream and riparian habitats, vegetation aspects)
- Objectives for biotic integrity (health, community structure and distribution of biota)

Once RQO have been set for a resource, they would serve as a basis for water resources management. The RQO have a number of purposes in the context of resource management (DWAF, 1999):

- They represent a definite goal for the desired protection level and resource quality status of a water resource
- They provide a clearly understood line between acceptable and non-acceptable impacts
- They provide a quantifiable, verifiable baseline for measuring the success of resource management activities and for reviewing the effectiveness of source-directed control and regulatory activities
- They give a stable framework for decision making and planning

8.2. Current status of the RDM process in the study area

The National Water Resource Protection Policy (DWAF, 1997) and the National Water Act (No 36 of 1998) require that the Reserve be determined for all water resources in South Africa, starting with priority catchments. A Preliminary Reserve was determined for this catchment (Quaternary Drainage Region C22J) in support of lisence applications by Iscor Vanderbijlpark and South Deep Mines (DWAF File No 26/8/3/3/322) (APPENDIX 6)

8.3. Management objectives

It is recommended that a responsibility driven approach be implemented with regard to the management of the aquatic resource investigated during this study, using the Preliminary Reserve Determination as basis. It is also recommended that such a management strategy include all industries and water users associated with the sections of the Rietspruit and Leeuwspruit Catchments under investigation. It is also recommended that biological data gathered during the Baseline Assessment (December 2001), as well as information contained in the Preliminary Reserve Detemination (DWAF File No 26/8/3/3/322) be used to define Resource Quality Objectives (RQO's) for the study area to facilitate management of the concerned aquatic system. Several PES Classes of E and F were determined during the present investigation. This is unacceptable and the short-term (0-5 years) aim should be to improve these to a Class D. In case of a Class D PES, the aim should be to improve to a Class C, while ecological aspects identified as Class C should be maintained as such.

The monitoring system proposed is outlined in Figure 6. Data collected should include RQO relevant indicators such as aquatic macroinvertebrate assemblages (SASS), fish species occurrence and health, habitat integrity, riparian vegetation integrity, water quality, sediment contaminant analyses, bioaccumulation and Whole Effluent Toxicity (WET) testing. If RQO are not being met, the cause must be identified. If the cause is known, relevant mitigation measures must be implemented. If the cause is unknown, the monitoring system must be evaluated and amended in terms of sampling sites, frequency of sampling and methodologies used, in order to enable identification of impacts. A risk assessment approach to the identification of impacts is recommended:

- Set objectives for impact identification
- Collect relevant information in context of impact
- Characterize the cause and impact components
- Describe the impact in terms of the RQO
- Implement mitigative actions.

A disaster, such as toxic spills and fish kills, is a legal liability and may result in RQO not being met. The monitoring system must therefore include an action plan to deal with such disasters. Investigations must be made promptly and with great care so that the resultant data verify the actual cause. A "chain-of-custody" to deal with these kinds of disasters must be developed as part of the monitoring system for inclusion in Quality Assurance and Quality Control Manuals.

It is of utmost importance to ensure that the monitoring system is maintained as an interactive process with the major purpose to address problems or issues relevant to the impact contributors. Continued focus and the implementation of relevant corrective actions can only be achieved if the overall monitoring system is subject to regular evaluations. This evaluation should include an assessment

- of the need to implement corrective actions
- of the need to conduct an ecological risk assessment
- of the adequacy of the monitoring program in terms of
  - The identification of inadequate or excessive sampling strategies
  - Sampling of irrelevant data or too many sampling sites, with associated unnecessary high costs
  - Erroneous omission of important environmental components
  - Analyses of too few samples or ecological indicators to detect statistically significant trends
  - Sampling of too few, or wrongly selected sites, preventing separation between the effects of anthropogenical activities and natural variability.

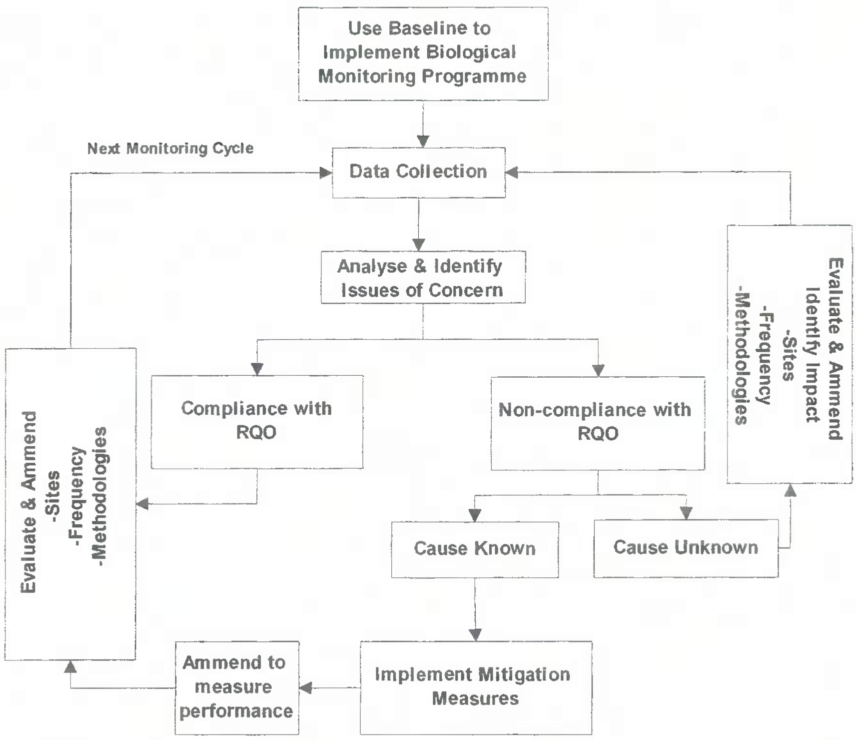


Figure 6: Proposed Monitoring System

8.4. Management goals

The major objective of the monitoring framework will be to monitor compliance with the RQO. Important ecological indicators to be monitored include aquatic macroinvertebrate assemblages (SASS), fish species occurrence and health, habitat integrity, riparian vegetation integrity, water quality, sediment contaminant analyses, bioaccumulation and Whole Effluent Toxicity (WET) testing. Important considerations, identified during the Baseline Assessment (December 2001) are listed below:

- Any surface water management plan should take cognizance of the synergistic and antagonistic effect of the various water quality parameters in the concerned system, i.e.

the protection potential of high TDS against the toxicity of metals and other contaminants.

- Changes in the riparian vegetation as a result of anthropogenical activities will only be evident in the long-term (after at least 5 years). It is therefore imperative that a long-term riparian vegetation monitoring program be implemented.

- Fluoride levels in the biotic and abiotic environment should be monitored during future biomonitoring efforts, so as to give a clearer picture of the environmental fate of this constituent in the study area. During the Baseline Assessment, fluoride was indicated to be a problem in the Leeuwspruit and especially the Rietkuilspruit.

- A Whole Effluent Toxicity (WET) testing program should be implemented. WET tests will indicate the bioavailability of toxic compounds to aquatic organisms, will respond to compounds, which are not readily identifiable or measured by analytical techniques, will respond to unknown compounds and will detect effects due to chemical interaction, e.g. synergism, antagonism and addition. It is recommended that a fish, aquatic macroinvertebrate, algal and bacterial test be included in such a program in order to represent different trophic levels (with different sensitivity levels). This will ensure improved evaluation capacity. Such a whole battery approach will provide the necessary information to:
    - Facilitate internal environmental auditing
    - Measure compliance with set aquatic quality objectives
    - Provide a baseline for Ecological Risk Assessments
    - Ensure derivation of toxicity conditions to be used in licence applications

- It is recommended that sediment toxicity assessments be conducted at selected sites within the study area, in order to assess the actual toxicity and bioaccumulation potential of constituents at such areas.

- Formal and Informal Settlements, Waste Water Treatment Plants, Industries and Farming activities, amongst others, were identified to contribute significantly towards the load of certain constituents in the study area. A management strategy for the Rietspruit and Leeuwspruit catchments should therefore include all industries and water users in the study area.

- It is recommended that river channels and stream banks be rehabilitated and stabilized. This will result in an overall improvement in the biotic integrity in the study area.

- Several PES Classes of E and F were determined during the present investigation. This is unacceptable and the short-term (0-5 years) aim should be to improve these to a Class D. In case of a Class D PES, the aim should be to improve to a Class C, while ecological aspects identified as Class C should be maintained as such.

9. MANAGEMENT MEASURES

In order to reach above-mentioned management goals (section 8.4) an Action Plan is needed. A conceptual recommended action plan is presented in Figure 7.

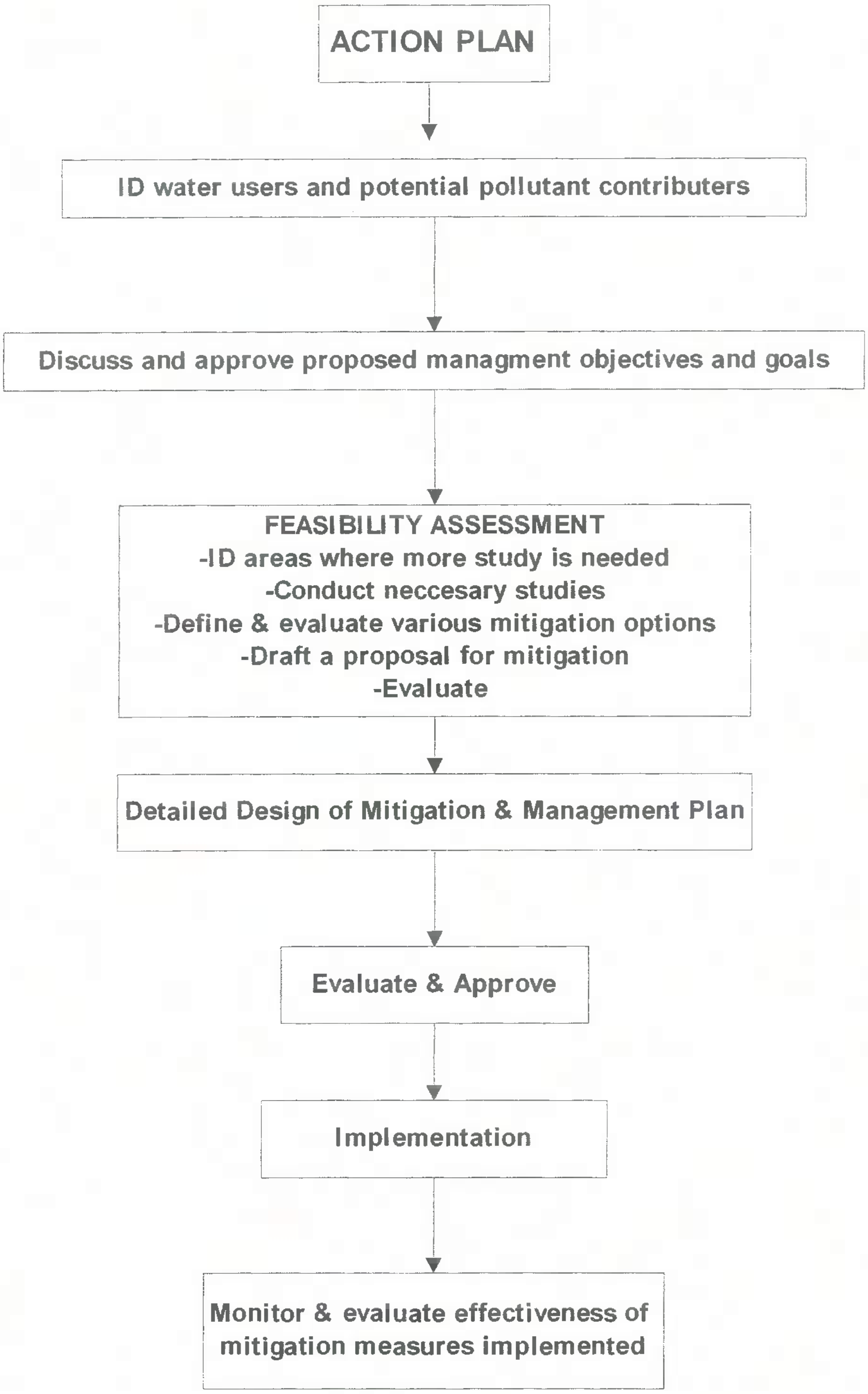


Figure 7: Proposed Action Plan

As mentioned previously the complexity and variety of impacts affecting the rivers/streams in the study area are so intertwined that a comprehensive aquatic ecosystem based approach is required. In order to reach the proposed management goals (section 8.4), an integrated strategy across potential pollutant contributers, water resource users and legislators will therefore be required. Implemetation of such an integrated strategy is regarded, as the only viable approach that will result in a meaningful and positive outcome to solving the aquatic ecological concerns relevant to the sections of the Rietspruit and Leeuwspruit catchments under investigation.

A first step will be to identify all relevant role players and to convene a workshop during which the proposed management goals and objectives are discussed and approved. Public participation should be initiated in parallel to this process. During this phase of the Action Plan it is recommended that identified water users and potential pollutant contributors undertake a field visit to assess the study area in view of the proposed management objectives and goals and to identify areas where more study is needed. If more studies is needed these should be conducted, whereafter various mitigation options should be defined and evaluated in terms of economic feasibility, environmental impact, engineering implications and therequirements of the National Water Act (e.g. Reserve).

The preffered mitigation measures should be identified and a proposal for mitigation should be drafted for evaluation by all relevant role players (including the Authorities). Upon acceptance a detailed Mitigation and Management Plan should be designed as part of the overall Catchment Management Strategy. The whole process right through to implementation should be facilitated by the Catchment Management Agency (CMA).

10. MONITORING

10.1. Monitoring Infrastructure/Sites/Localities

Eighteen sampling sites were selected in the Rietspruit and Leeuwspruit Catchments. The following is a list of the sampling points sampled during the Baseline Assessment, and is provisionally applicable to the routine monitoring of the aquatic system:

Table 14: Sites to be sampled during routine biological monitoring

Monitoring Site	Description	Co-ordinates
TS1	Natural or Minimally Impacted ecological reference site in the Taaibosspruit	S:26°51'57.2" E:27°56'02.2"
FA	Final Effluent	S: 27°47'49.5" E:26°39'50.3"
RS0	Effluent Stream originating from the industrial area situated to the south of IVS	S: 26°40'14.6" E: 27°48'17.2"
RS1	Rietkuilspruit on Golden Highway downstream from the southern industries & IVS	S:26°39'40" E:27°47'56"
RS2	Rietkuilspruit downstream from Farm Dam	S:26°39'36" E:27°47'34"
RS3	Rietkuilspruit downstream from Farm Dam	S:26°39'09" E:27°46'34"
RS4	Rietkuilspruit downstream from RS3 on secondary road	S:26°39'07" E:27°45'45"
RS5	Rietkuilspruit upstream from canal on gravel road	S:26°39'13" E:27°45'27"

Monitoring Site	Description	Co-ordinates
RS6	Rietspruit upstream from confluence (Rietkuilspruit & Canal) on R54	S:26°38'48.8" E:27°44'48.0"
RS7	Downstream section of canal just upstream from confluence with Rietkuilspruit	S:26°39'18.1" E:27°45'19"
RS8	Approximately 100m downstream from canal confluence	S:26°39'15" E:27°45'20"
RS9	Approximately 5km downstream from Rietkuilspruit/Rietspruit confluence in Rietspruit	S:26°40'13.0" E:27°44'39.1"
RS10	Approximately 5km downstream from R59 on Rietspruit at weir	S:26°41'37.7" E:27°44'22.2"
LS1	Tributary of Leeuwspruit on southeastern side of the IVS works	S:26°40'00.2" E:27°50'25.9"
LS2	Tributary of Leeuwspruit draining from Boitshepi dumping site	S:26°40'15.2" E:27°52'05"
LS3	Tributary of Leeuwspruit draining from Ditonville	S:26°40'12" E:27°52'46"
LS4	Leeuwspruit downstream from tributaries LS1-LS3	S:26°40'03" E:27°53'13"
LS5	Leeuwspruit upstream from confluence with Vaal River	S:26°42'01" E:27°53'56"
LS6	Vaal River at the R59 road	S:26°42'30.0" E:27°53'53.7"
LS7	Vaal River downstream from the Leeuwspruit confluence	S:26°42'35" E:27°53'40"

10.2. Data Capture Protocols

10.2.1. <u>Sampling Frequency</u>

It is recommended that Whole Effluent Toxicity (WET) testing on selected effluents/receiving waters be conducted every second month. The Invertebrate Habitat Assessment System (IHAS), aquatic macroinvertebrate assessment (SASS) and *in situ* water quality measurements should be conducted six-monthly, during intermediate low-high and high-low flow conditions. An assessment of the contaminant concentration in sediments, bioaccumulation, fish species occurrence and health, riparian vegetation integrity and Habitat Integrity should be conducted annually.

A lay-out of the frequency of activities proposed for the different sites for the next monitoring cycle are presented in Table 15.

Table 15: Proposed frequency of activities for different sampling sites (2002 monitoring cycle).

Frequency	Activity	Sampling Site																			
		TS1	FA	RS0	RS1	RS2	RS3	RS4	RS5	RS6	RS7	RS8	RS9	RS10	LS1	LS2	LS3	LS4	LS5	LS6	LS7
Every second month	WET Testing		X	X	X				X	X	X	X	X		X						
*Twice per year	SASS	X			X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	Habitat Assessment	X			X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	In situ Water Quality	X			X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Once per annum	Aquatic and Riparian Vegetation				X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	Sediment Contaminant Analyses	X			X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	Bioaccumulation	X			X				X	X		X	X	X				X		X	X
	Ichthyofauna				X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	Habitat Integrity Assessment				X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X

* Twice per year during intermediate high-low and low-high flow periods

10.2.2. <u>Sampling Technique</u>

Whole Effluent Toxicity (WET) Testing:

Throughout the sampling procedure care must be taken to obtain a sample that meets the requirements of the sampling program. It must be handled in such a way that it does not deteriorate or become contaminated before it reaches the laboratory.

- Glass or plastic bottles can be used to collect toxicity test samples
- Before filling the sample bottle, rinse the bottle two to three times with the sample being collected, unless the bottle contains a preservative or dechlorinating agent.
- Fill the container to the top
- In rivers, grab samples should be collected at midstream and at mid depth if accessible.
- Avoid surface scum when collecting a sample from surface waters
- If the sample collected has been chlorinated, the total residual chlorine must be measured immediately following sample collection.
- When relevant state whether or not the sample has been filtered
- Information can be printed on disposable bottles or use a label or tag. Record sufficient information to provide positive sample identification at a later date (e.g. sample number), including the name of the sampler, the date and hour of collection, as well as the exact location and any other data that may be needed for correlation, such as weather conditions, water level, stream flow and post sample handling. Provide space on the label for the initials of those assuming sample custody and for the time and date of receipt in the laboratory.
- Aeration during collection and transfer of samples should be minimized to reduce the loss of volatile substances. All the sample containers must be filled completely, leaving no head space between the constituents and the lid.
- Sufficient sample must be collected to perform the required toxicity test. The minimum volume required are stated below:

  Vibrio fischeri bioluminescent toxicity test = 1 liter
  Algal toxicity test = 1 liter
  Daphnia pulex acute toxicity test = 1 liter
  Poecilia reticulata acute toxicity test = 2 liter
- Samples collected for off-site toxicity testing are to be chilled and shipped to the testing laboratory. Sufficient ice or ice-packs should be placed with the sample in the shipping container to ensure that ice/icepacks will still be cold when the sample arrives at the laboratory.

General Habitat Assessment and Invertebrate Habitat Assessment System (IHAS):

Habitat in aquatic systems, including surrounding topographical features, is a major determinant of aquatic community potential. Assessment of physical habitat quality is therefore an integral component of the final evaluation of any impairment. The assessment that will be performed includes a general description of the site (Global Positioning Satellite [GPS] reading; photographs for future identification of major changes and documentation of habitat conditions and watershed features; video footage of each site; physical characterization). These parameters are pertinent to the characterization of an aquatic system and will provide valuable insight as to the ability of these systems to support a healthy aquatic community. The Invertebrate Habitat Assessment System (IHAS) score sheet must be completed. The monitoring of habitat condition is to be co-ordinated with the water quality monitoring program in order to describe the presence of chemical stressors. Water quality data must be integrated with biological data during interpretation of results.

Aquatic Macroinvertebrate Assessment (SASS):
Benthic macro-invertebrates is to be collected from all distinguishable biotopes at each of the sampling sites using a net with a pore size of 1000 micron, mounted on a 300mm square frame. In stony bottomed flowing water biotopes (rapids, riffles, runs, etc.) the net is rested on the bottom and the area immediately upstream of the net is disturbed by kicking the stones over and against each other to dislodge benthic invertebrates. Sandy and muddy bottom and stones-out-of-current are sampled by stirring the bottom and sweeping the net through the water over the disturbed area to catch dislodged organisms. Marginal and aquatic vegetation is sampled by sweeping the net back and forth through the biotope to cover from 1-2 meters. Identification of the organisms should be done to family level. The most recent SASS procedure must be applied (currently SASS5).

In situ water quality measurements:
In situ water quality measurements (TDS, pH, Dissolved Oxygen, Temperature, Flow Velocity) should be determined on site with field equipment. These results are important to assist in the interpretation of biological results because of the direct influence water quality has on aquatic life forms. Although these measurements only provide a "snapshot" it can sometimes provide valuable insight into the characteristics of a specific sampling site.

Sediment contaminant concentrations:
Samples are collected from depositional zones in the river/stream with a coring apparatus capable of sampling sediments up to one meter in depth. The core sampler must be pushed into the sediment until it becomes unyielding or until the maximum sampling depth of the corer is reached. A core of sediment should then be extracted. The difference between layers in the sediment should be visually assessed and distinguished by using color (to distinguish between primary layers) and texture (to distinguish between secondary layers) Each identified layer should then be collected in a separate plastic bag and labeled. The samples are to be chilled and transported to the testing laboratory. Sufficient ice or ice-packs should be placed with the sample in the shipping container to ensure that ice/icepacks will still be cold when the sample arrives at the laboratory.

Bioaccumulation:
Crabs must be collected with baited traps (±5 specimens per site). Collected specimens must be placed in individual plastic bags and labeled. The samples are to be chilled and shipped to the testing laboratory. Sufficient ice or ice-

packs should be placed with the sample in the shipping container to ensure that ice/icepacks will still be cold when the sample arrives at the laboratory.

Fish Species Occurrence & Health Assessment:
Fish sampling to be conducted by means of

- Electroshocker: 40 min total or 150m stream length whichever comes first, representing different flow classes and cover types. Specimens should be released unharmed where possible.
- Seine net (10m x 1.5m, 9mm mesh): five attempts total at each site, representing as many flow classes and cover types present, not more than two attempts in the same flow/cover type
- Seine net (50m x 2m, 9mm mesh): two attempts total at each site, representing as many of the flow classes and cover types present, not more than two attempts in the same flow/cover type
- Gill nets: series of gill nets in impounded areas (depth > 1,5m)

The health assessment is conducted in such a way as to derive numeric values, which reflect the status of fish health. The percentage fish with externally evident disease or other anomalies must be used in the scoring of this metric, according to the method described by Kleynhans (1999). The following procedure must be followed to score the health of individual species at a site:

- Frequency of affected fish >5%, score = 1
- Frequency of affected fish 2-5%, score = 3
- Frequency of affected fish <2%, score = 5

This approach is based on the principle that even under unimpaired conditions, a small percentage of individuals can be expected to exhibit some anomalies.

Riparian Vegetation Integrity:
An assessment of the current status of the aquatic and riparian vegetation in the study area (to include wetland areas) must be conducted annually. Diversity and composition must be identified. The Riparian Vegetation Index (RVI) developed by Kemper (2000) must be applied in suitable areas. This index considers the extent of vegetation coverage of the riparian zone, the structural intactness of the riparian zone, the percentage cover of indigenous riparian species as well as the regeneration of indigenous species. The RVI was developed as part of the National River Health Program to provide a rapid, relative simple method for evaluation of the condition and ecological integrity of the riparian vegetation along rivers and streams

10.2.3. Sampling Equipment

The following equipment is needed for the biological monitoring indicators listed above:

- 2l Glass or plastic sampling bottles
- Pencil, Marking Pen
- Notebook
- Field data sheets

- Masking tape
- *In situ* TDS meter
- pH meter
- Thermometer
- Dissolved Oxygen Meter
- Flow Meter
- Geographical Positioning System (GPS)
- Camera/Video Camera
- 1:50 000 topographical maps
- Sampling net with a pore size of 1000 micron, mounted on a 300mm square frame
- Specimen containers
- Magnifying Glass
- Buckets (x3)
- Forceps
- Sampling tray (light colour)
- Formalin/Ethanol
- Waders
- Electroshocker
- Seine net (10m x 1.5m, 9mm mesh)
- Seine net (50m x 2m, 9mm mesh)
- Gill nets
- Traps
- Plastic Bags
- Cooler
- Ice/icepacks
- Dip net
- Sediment Corer

10.2.4. Sample Preservation

Samples for Whole Effluent Toxicity (WET) testing, sediment contaminant concentrations and bioaccumulation assessments should be placed in a cooler with ice/icepacks.

The sampler may need to take aquatic macroinvertebrate and fish samples for verification of identity. These should be preserved in 10% formalin or 80% ethanol.

10.3. Information Generation Protocols

10.3.1. Reporting Frequency

The following table summarizes the frequency of reporting.

Frequency	Type of Report
Two-monthly Reports	Whole Effluent Toxicity Report
Six-monthly Interim Report	To contain biomonitoring data obtained during the high-low flow biomonitoring effort
Annual Report	Comprehensive annual report containing all biomonitoring data generated. Annual status report.

10.3.2. Report Content

The following information should be contained in the two-monthly WET Reports:

- A toxicity classification based on the *Poecilia reticulata, Daphnia pulex, Vibrio fischeri* and *Selenastrum capricornutu* acute toxicity tests

The following information should be contained in the six-monthly Interim Report:

- Description of sampling localities
- Description of habitat quality at each site (IHAS)
- Description of the biotic integrity, based on the South African Scoring System (SASS) Index

The following information should be contained in the annual comprehensive Aquatic Ecosystems Monitoring Report:

- Ecological status of the aquatic ecosystem, based on the following indicators:
  - General Habitat Assessment
  - Invertebrate Habitat Assessment System (IHAS)
  - In-stream and Riparian Habitat Integrity (IHIA)
  - South African Scoring System (SASS) Index
  - Fish Species Occurrence & Health Assessment
  - Riparian Vegetation Integrity
  - Whole Effluent Toxicity (WET) toxicity classification
  - Sediment contaminant concentrations
  - Bioaccumulation
  - Evaluation of the existing water quality data to assess the fitness thereof towards the aquatic ecosystem
- An evaluation of changes/trends/irregularities in aquatic ecosystem health

- Compliance with Resource Quality Objectives
- The ecological importance and sensitivity of the concerned aquatic ecosystem
- Evaluation of the adequacy of the monitoring program in terms of frequency, sampling sites and methodologies.

10.4. Management Protocols

The following table summarizes the management protocols relating to the sampling- and reporting frequency of the Aquatic Ecosystem monitoring sites

	Sampling Frequency	Reporting Frequency
Two-monthly	Whole Effluent Toxicity (WET) testing on effluents/receiving waters, to include the battery of tests approved by DWAF (*Poecilia reticulata, Daphnia pulex, Vibrio fischeri* and *Selenastrum capricornutum*)	Two-monthly Reporting
Six-monthly (during intermediate low-high and high-low flow conditions)	Invertebrate Habitat Assessment System (IHAS), Aquatic Macroinvertebrate Assessment (SASS), *In situ* water quality	Six-monthly Reporting
Annually	Contaminant concentrations in sediments and bioaccumulation, Fish Species Occurrence & Fish Health Assessment, Riparian and Aquatic Vegetation Integrity (including RVI), Habitat Integrity Assessment	Annual Reporting

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APPENDIX 1
PHOTOGRAPHS OF SAMPLING SITES

LS1

LS4

LS2

LS5

LS3

LS6

RS1

RS4

RS2

RS5

RS3

RS6

RS7

RS10

RS8

Taaibosspruit Reference Site

RS9

APPENDIX 2
Plant Species Lists

LIST OF PLANTS RECORDED FROM SITE LS1 ON THE LEEUWSPRUIT, VANDERBIJLPARK.

MONOCOTYLEDONAE

Typhaceae

Typha capensis

Poaceae

Agrostis eriantha
" lachnantha
Bromus catharticus *
" sp.
Helictotrichon turgidulum
Hyparrhenia hirta
Ischaemum afrum
Koeleria capensis
Panicum repens
Paspalum dilatatum *
Pennisetum clandestinum *
Setaria incrassata
" sphacelata ssp. sericea

Cyperaceae

Carex sp.
Cyperus longus ssp. tenuiflorus
Schoenoplectus tabernaemontani
" sp. cf decipiens

Juncaceae

Juncus exsertus ssp. exsertus
" punctorius

Alliaceae

Tulbaghia leucantha

DICOTYLEDONAE
Polygonaceae

Persicaria lapathifolia *
Rumex crispus *

Chenopodiaceae

Chenopodium album *

Brassicaceae

Rorippa nasturtium-aquaticum *

Ranunculaceae

Ranunculus multifidus

Fabaceae

Melilotus indica *
Trifolium pratense *

Euphorbiaceae

Euphorbia sp. cf pubescens

Apiaceae

Berula erecta

Onagraceae

Oenothera rosea *

Convolvulaceae

Convolvulus sagittatus ssp. ulosepalus

Verbenaceae

Verbena bonariensis *

Solanaceae

Datura stramonium *
Solanum retroflexum

Scrophulariaceae

Veronica anagallis-aquatica

Plantaginaceae

Plantago lanceolata *
" major *

Asteraceae

Aster squamatus *
Berkheya rhapontica ssp. rhapontica
Bidens bipinnata *
Cirsium vulgare *
Felicia muricata
Lactuca serriola *
Sonchus oleraceus *

*** denotes alien species recorded.**

LIST OF PLANTS RECORDED FROM SITE LS2 ON THE LEEUWSPRUIT, VANDERBIJLPARK.

PTERIDOPHYTA
Marsileaceae

Marsilea macrocarpa

MONOCOTYLEDONAE
Typhaceae

Typha capensis

Poaceae

Agrostis lachnantha
Bromus catharticus *
Cynodon dactylon
Eragrostis plana
Panicum repens
Paspalum dilatatum *
" distichum
Phragmitis australis
Polypogon monspeliensis *

Cyperaceae

Cyperus esculentus
Eleocharis sp.
Kyllinga melanosperma
Mariscus sp.
Schoenoplectus decipiens
" muriculatus
" tabernaemontani
" triqueter
Scirpoides dioecus

Juncaceae

Juncus exsertus ssp. exsertus

DICOTYLEDONAE
Polygonaceae

Persicaria limbata *
Rumex crispus *
" sp.

Brassicaceae

Rorippa nasturtium-aquaticum *

Ranunculaceae

Ranunculus multifidus

Euphorbiaceae

Euphorbia sp. cf pubescens

Apiaceae

Ciclospermum leptophyllum *

Scrophulariaceae

Veronica anagallis-aquatica

Plantaginaceae

Plantago lanceolata *

Asteraceae

Aster squamatus *
Cirsium vulgare *
Conyza bonariensis
Cotula anthemoides
Senecio inaequidens
Sonchus oleraceus *

LIST OF PLANTS RECORDED FROM SITE LS3 ON THE LEEUWSPRUIT, VANDERBIJLPARK

MONOCOTYLEDONAE
Typhaceae

Typha capensis

Poaceae

Agrostis lachnantha
Bromus catharticus *
Cynodon dactylon
Eragrostis curvula
Helictotrichon turgidulum
Hemarthria altissima
Paspalum dilatatum *
Pennisetum clandestinum *
Setaria incrassata

Cyperaceae

Carex glomerabilis
" sp.
Schoenoplectus tabernaemontani

DICOTYLEDONAE
Polygonaceae

Persicaria limbata *
Rumex crispus *
" sp.

Ranunculaceae

Ranunculus multifidus

Fabaceae

Melilotus alba *
Sesbania punicea *

Apiaceae

Berula erecta
Ciclospermum leptophyllum *

Onagraceae

Oenothera rosea *

Scrophulariaceae

Veronica anagallis-aquatica

Plantaginaceae

Plantago lanceolata *
" major *

Asteraceae

Bidens biternata *
" pilosa *
Cirsium vulgare *
Conyza bonariensis
Picris echioides *
Pseudognaphalium luteo-album
Senecio inaequidens
Sonchus oleraceus *
Tagetes minuta *

LIST OF PLANTS RECORDED FROM SITE LS4 ON THE LEEUWSPRUIT, VANDERBIJLPARK.

MONOCOTYLEDONAE
Typhaceae

Typha capensis

Poaceae

Bromus catharticus *
Cortaderia jubata *
Hemarthria altissima
Paspalum dilatatum *
Pennisetum clandestinum *
Phragmitis australis

Cyperaceae

Cyperus longus ssp. tenuiflorus
" sp. cf difformis
Mariscus sp.

Juncaceae

Juncus punctorius

DICOTYLEDONAE
Polygonaceae

Persicaria limbata *
Rumex sp.

Chenopodiaceae

Chenopodium ambrosioides *

Ranunculaceae

Ranunculus multifidus

Brassicaceae

Lepidium bonariense *
Raphanus raphanistrum *

Fabaceae

Acacia karroo
Sesbania punicea *

Apiaceae

Ciclospermum leptophyllum *

Onagraceae

Oenothera rosea *

Asclepiadaceae

Gomphocarpus fruticosus

Verbenaceae

Verbena bonariensis *
" braziliensis *
" officinale *
" tenuisecta *

Lamiaceae

Salvia repens var. repens

Solanaceae

Solanum sp.

Scrophulariaceae

Veronica anagallis-aquatica

Plantaginaceae

Plantago lanceolata *

Asteraceae

Bidens biternata *
" pilosa *
Berkheya rhapontica ssp. rhapontica
Cirsium vulgare *
Haplocarpha scaposa
Picris echioides *
Senecio erubescens
" inornatus
Sonchus oleraceus *
Xanthium strumarium *

LIST OF PLANTS RECORDED FROM SITE LS5 ON THE LEEUWSPRUIT, VANDERBIJLPARK.

MONOCOTYLEDONAE
Typhaceae

Typha capensis

Poaceae

Agrostis lachnantha
Bromus catharticus *
Helictotrichon turgidulum
Pennisetum clandestinum *
Phragmitis australis

Cyperaceae

Cyperus longus ssp. tenuiflorus
Schoenoplectus tabernaemontani

Asparagaceae

Asparagus laricinus

DICOTYLEDONAE
Salicaceae

Salix babylonica *

Polygonaceae

Fallopia convolvulus *
Persicaria lapathifolia *
" limbata *
Rumex crispus *
" sp.

Chenopodiaceae

Chenopodium album *

Fabaceae

Melilotus alba *

Euphorbiaceae

Euphorbia sp. cf pubescens

Convolvulaceae

Convolvulus sagittatus ssp. ulosepalus
Cuscuta campestris *
Ipomoea purpurea *

Verbenaceae

Verbena bonariensis *

Lamiaceae

Salvia repens var. repens
Stachys hyssopoides

Asteraceae

Bidens biternata *
Cirsium vulgare *
Lactuca serriola *
Sonchus oleraceus *
Tagetes minuta *
Xanthium strumarium *

LIST OF PLANTS RECORDED FROM SITE LS6 ON THE VAAL RIVER, VANDERBIJLPARK.

PTERIDOPHYTA
Equisetaceae

Equisetum ramosissimum

MONOCOTYLEDONAE
Typhaceae

Typha capensis

Poaceae

Agrostis lachnantha
Brachiaria deflexa
Bromus catharticus *
Chloris gayanus
Cynodon dactylon
Eragrostis curvula
Pennisetum clandestinum *
Phragmitis australis

Cyperaceae

Cyperus fastigiatus
" longus ssp. tenuiflorus
" sp. cf difformis

Asphodelaceae

Anthericum fasciculatum

Hyacinthaceae

Ledebouria revoluta
Ornithogalum tenuifolium

Asparagaceae

Asparagus cooperi
" laricinus

Commelinaceae

Commelina benghalensis

DICOTYLEDONAE
Salicaceae

Salix babylonica *

Ulmaceae

Celtis sinensis *

Polygonaceae

Persicaria limbata *

Rumex sagittatus
" sp.

Chenopodiaceae

Alternanthera pungens
Atriplex semibaccata *
Chenopodium album *

Amaranthaceae

Achyranthes aspera
Amaranthus viridis *

Brassicaceae

Lepidium bonariense *
Sisymbrium turczanowii

Fabaceae

Acacia karroo
Melilotus alba *
Prosopis sp. *

Anacardiaceae

Rhus pyroides

Malvaceae

Sida rhombifolia

Myrtaceae

Eucalyptus sp. *

Apiaceae

Conium chaerophylloides

Onagraceae

Oenothera rosea *

Convolvulaceae

Convolvulus sagittatus ssp. ulosepalus

Asclepiadaceae

Araujia sericifera *

Verbenaceae

Verbena bonariensis *

Lamiaceae

Salvia runcinata

Stachys hyssopoides

Solanaceae

Physalis viscosa *
Solanum retroflexum

Asteraceae

Bidens bipinnata *
" pilosa *
Cirsium vulgare *
Conyza bonariensis
Lactuca serriola *
Sonchus oleraceus *

Unidentified alien trees (2) *

LIST OF PLANTS RECORDED FROM SITE RS1 ON THE RIETKUILSPRUIT VANDERBIJLPARK.

MONOCOTYLEDONAE
Poaceae

Agrostis lachnantha
Bromus catharticus *
Cynodon dactylon
Helictotrichon turgidulum
Paspalum dilatatum *

Cyperaceae

Cyperus sp. cf difformis
Schoenoplectus tabernaemontani

DICOTYLEDONAE
Polygonaceae

Fallopia convolvulus *
Persicaria lapathifolia *
Rumex crispus *

Chenopodiaceae

Chenopodium ambrosioides *

Amaranthaceae

Amaranthus viridis *

Nyctaginaceae

Mirabilis jalapa *

Brassicaceae

Lepidium bonariense

Ranunculaceae

Ranunculus multifidus

Anacardiaceae

Rhus pyroides

Onagraceae

Oenothera rosea *

Verbenaceae

Verbena bonariensis *

Scrophulariaceae

Veronica anagallis-aquatica

Plantaginaceae

Plantago lanceolata *

Asteraceae

Cirsium vulgare *
Sonchus wilmsii

Unidentified alien tree (1) *

LIST OF PLANTS RECORDED FROM SITE RS2 ON THE RIETKUILSPRUIT, VANDERBIJLPARK.

PTERIDOPHYTA
Marsileaceae

Marsilea macrocarpa

MONOCOTYLEDONAE
Typhaceae

Typha capensis

Alismataceae

Alisma plantago-aquatica *

Poaceae

Agrostis lachnantha
Aristida junciformis
Bromus catharticus *
" sp.
Cynodon dactylon
Echinochloa crus-galli
Panicum repens
Paspalum dilatatum *
" distichum
Polypogon monspeliensis *

Cyperaceae

Carex glomerabilis
Cyperus esculentus
" sp. cf difformis
Eleocharis sp. cf dregeana
Schoenoplectus tabernaemontani

Juncaceae

Juncus exsertus var. exsertus

Asparagaceae

Asparagus laricinus

DICOTYLEDONAE
Salicaceae

Salix babylonica *

Ulmaceae

Celtis sinensis *

Polygonaceae

Persicaria lapathifolia *
Rumex crispus *
" sp.

Chenopodiaceae

Chenopodium ambrosioides *

Brassicaceae

Rorippa nasturtium-aquaticum *
Sisymbrium sp. cf turczanowii

Anacardiaceae

Rhus pyroides

Apiaceae

Ciclospermum leptophyllum *

Asclepiadaceae

Gomphocarpus fruticosa

Plantaginaceae

Plantago lanceolata *

Asteraceae

Aster squamatus *
Bidens biternata *
" pilosa *
Cirsium vulgare *
Conyza bonariensis
Cosmos formosae *
Galinsoga parviflora *
Schkuhria pinnata *
Sonchus oleraceus *
Tagetes minuta *

LIST OF PLANTS RECORDED FROM SITE RS3 ON THE RIETKUILSPRUIT, VANDERBIJLPARK.

PTERIDOPHYTA
Marsileaceae

Marsilea macrocarpa

MONOCOTYLEDONAE
Typhaceae

Typha capensis

Poaceae

Agrostis lachnantha
Cortaderia jubata *
Cynodon dactylon
" transvaalensis
Digitaria diagonalis
Echinochloa crus-galli
Eragrostis curvula
Helictotrichon turgidulum
Panicum schinzii
Paspalum dilatatum *
" distichum
Pennisetum clandestinum *
Phragmitis australis
Setaria incrassata
" nigrirostris
" sphacelata var. sericea
Urochloa panicoides

Cyperaceae

Carex glomerabilis
Cyperus esculentus
" sp.
Schoenoplectus decipiens
" tabernaemontani

Juncaceae

Juncus rigidus

DICOTYLEDONAE
Salicaceae

Salix babylonica *

Polygonaceae

Persicaria lapathifolia *
Rumex crispus *

Chenopodiaceae

Chenopodium album *

Amaranthaceae

Amaranthus viridis *

Brassicaceae

Lepidium bonariense *
Sisymbrium turczaninowii

Ranunculaceae

Ranunculus multifidus

Malvaceae

Hibiscus trionum *

Solanacae

Datura stramonium *

Plantaginaceae

Plantago lanceolata *
" major *

Asteraceae

Berkheya rhapontica ssp. rhapontica
Cirsium vulgare *
Cotula anthemoides
Flaveria bidentis *
Haplocarpha scaposa
Lactuca inermis
Senecio erubescens
Sonchus sp.

LIST OF PLANTS RECORDED FROM SITE RS4 ON THE RIETKUILSPRUIT, VANDERBIJLPARK.

MONOCOTYLEDONAE
Typhaceae

Typha capensis

Poaceae

Agrostis lachnantha
Helictotrichon turgidulum
Hemarthria altissima
Paspalum dilatatum *
Pennisetum sphacelatum
Polypogon monspeliensis *
Themeda triandra

Cyperaceae

Cyperus longus ssp. tenuiflorus
" sp.
Schoenoplectus tabernaemontani

Juncaceae

Juncus exsertus ssp. exsertus
" rigidus

Asphodelaceae

Kniphofia typhoides (RDB – K)
Trachyandra asperata

DICOTYLEDONAE
Ranunculaceae

Ranunculus multifidus

Fabaceae

Argyrolobium sp. cf tuberosum
Melilotus alba *
Sesbania punicea *

Onagraceae

Oenothera rosea *

Lamiaceae

Salvia runcinata

Scrophulariaceae

Veronica anagallis-aquatica

Plantginaceae

Plantago lanceolata *
" major *

Asteraceae

Berkheya rhapontica ssp. rhapontica
Cirsium vulgare *
Conyza bonariensis
Haplocarpha scaposa
Senecio erubescens
Sonchus oleraceus *
" sp.

- denotes alien species

LIST OF PLANTS RECORDED FROM SITE RS5 ON THE RIETKUILSPRUIT, VANDERBIJLPARK.

MONOCOTYLEDONAE
Typhaceae

Typha capensis

Poaceae

Agrostis lachnantha
Cynodon transvaalensis
Eragrostis curvula
Helictotrichon turgidulum
Hemarthria altissima
Paspalum dilatatum *
" distichum
Pennisetum clandestinum *
Polypogon monspeliensis *
Setaria sphacelata var. sericea

Cyperaceae

Carex glomerabilis
Cyperus longus ssp. tenuiflorus
" sp.
Schoenoplectus tabernaemontani

Juncaceae

Juncus exsertus ssp. exsertus

DICOTYLEDONAE
Salicaceae

Salix babylonica *

Polygonaceae

Persicaria lapathifolia *
Rumex crispus *

Ranunculaceae

Ranunculus multifidus

Geraniaceae

Monsonia angustifolia

Fabaceae

Sesbania punicea *

Euphorbiaceae

Chamaesyce prostrata

Apiaceae

Ciclospermum leptophyllum *

Onagraceae

Oenothera rosea *

Verbenaceae

Verbena officinale *

Lamiaceae

Salvia runcinata

Plantaginaceae

Plantago lanceolata *
" major *

Lobeliaceae

Lobelia sp. cf angolensis

Asteraceae

Aster squamatus *
Berkheya pinnatifida
" rhapontica ssp. rhapontica
Cirsium vulgare *
Conyza podocephala
Flaveria bidentis *
Haplocarpha scaposa
Lactuca serriola *
Pseudognaphalium luteo-album
Senecio erubescens
Sonchus oleraceus *
" sp.
Tagetes minuta *
Taraxacum officinale *

LIST OF PLANTS RECORDED FROM RS 6 ON THE RIETSPRUIT, VANDERBIJLPARK.

MONOCOTYLEDONAE
Poaceae

Agrostis lachnantha
Cynodon dactylon
" transvaalensis
Eragrostis curvula
Helictotrichon turgidulum
Hemarthria altissima
Ischaemum afrum
Panicum schinzii
Paspalum dilatatum *
" distichum
Setaria sphacelata var. sericea
Themeda triandra

Cyperaceae

Cyperus esculentus
" fastigiatus
" longus ssp. tenuiflorus
" marginatus
Schoenoplectus decipiens

Hyacinthaceae

Ledebouria cooperi

Iridaceae

Gynandriris simulans

Amaryllidaceae

Crinum bulbispermum

DICOTYLEDONAE
Polygonaceae

Rumex crispus *

Chenopodiaceae

Chenopodium ambrosioides *

Brassicaceae

Rorippa fluviatilis ssp. caledonica
" nudiuscula

Ranunculaceae

Ranunculus multifidus

Onagraceae

Oenothera rosea *

Apiaceae

Ciclospermum leptophyllum *

Loganiaceae

Gomphostigma virgatum

Convolvulaceae

Falckia oblonga

Asclepiadaceae

Asclepias gibba
Gomphocarpus fruticosus

Verbenaceae

Verbena officinale *

Lamiaceae

Stachys hyssopoides

Solanaceae

Datura stramonium *

Scrophulariaceae

Diclis reptans

Rubiaceae

Galium capensis

Plantaginaceae

Plantago lanceolata *

Asteraceae

Aster squamatus *
Berkheya rhapontica ssp. rhapontica
Bidens bipinnata *
Cirsium vulgare *
Conyza bonariensis
" podocephala
Gazania sp. aff. krebsiana
Haplocarpha scaposa
Lactuca inermis
Senecio inornatus
Sonchus oleraceus *

LIST OF PLANTS RECORDED AT SITE SITE RS7 ON THE ISCOR CANAL, VANDERBIJLPARK.

MONOCOTYLEDONAE
Poaceae

Agrostis lachnantha
Cynodon dactylon
Hyparrhenia hirta
Paspalum dilatatum *
Pennisetum clandestinum *
Polypogon monspeliensis *
Setaria sphacelata var. sphacelata

Cyperaceae

Cyperus sp. cf difformis

DICOTYLEDONAE
Salicaceae

Populus tremulus *

Polygonaceae

Rumex crispus *

Fabaceae

Melilotus alba *

Onagraceae

Oenothera rosea *

Verbenaceae

Verbena bonariense *

Solanaceae

Solanum retroflexum

Asteraceae

Cirsium vulgare *
Conyza bonariensis
Flaveria bidentis *
Sonchus oleraceus *
" sp.
Tagetes minuta *

LIST OF PLANTS RECORDED FROM SITE RS8, ON THE RIETKUILSPRUIT, VANDERBIJLPARK.

MONOCOTYLEDONAE
Poaceae

Agrostis lachnantha
Bromus catharticus *
Lolium perenne *
Paspalum dilatatum *
" distichum
Pennisetum clandestinum *
Polypogon monspeliensis *
Setaria sphacelata var. sericea
Themeda triandra

Cyperaceae

Cyperus esculentus
" longus ssp. tenuiflorus
" sp. cf difformis
" sp. cf dives
" sp.

DICOTYLEDONAE
Polygonaceae

Persicaria lapathifolia *
Rumex crispus *

Ranunculaceae

Ranunculus multifidus

Fabaceae

Acacia karroo
Melilotus alba *
Sesbania punicea *

Verbenaceae

Verbena officinalis *

Lamiaceae

Salvia runcinata

Plantaginaceae

Plantago lanceolata *
" major *

Asteraceae

Berkheya rhapontica ssp. rhapontica
Cirsium vulgare *
Conyza bonariensis

"   podocephala
Gazania sp.
Sonchus oleraceus *

LIST OF PLANTS RECORDED FROM SITE RS9 ON THE RIET SPRUIT, VANDERBIJLPARK.

MONOCOTYLEDONAE

Poaceae

Agrostis lachnantha
Cynodon dactylon
Eragrostis curvula
Hemarthria altissima
Ischaemum afrum
Paspalum dilatatum *
" distichum
Phragmitis australis
Polypogon monspeliensis *
Setaria incrassata
" sphacelat var. sericea
Themeda triandra

Cyperaceae

Cyperus fastigiatus
" longus ssp. tenuiflorus
" marginatus
" sp. cf difformis
" sp.

Hyacinthaceae

Albuca sp.

Amaryllidaceae

Crinum bulbispermum

DICOTYLEDONAE

Salicaceae

Salix babylonica *

Polygonaceae

Persicaria pulchrum
" serrulata
Rumex crispus *
" sp.

Chenopodiaceae

Chenopodium ambrosioides *

Brassicaceae

Lepidium bonariense *
Rorippa fluviatilis var. caledonica
" nudiuscula

Ranunculaceae

Ranunculus multifidus

Fabaceae

Sesbania punicea *

Apiaceae

Ciclospermum leptophyllum *

Onagraceae

Oenothera rosea *

Loganiaceae

Gomphostigma virgatum

Asclepiadaceae

Gomphocarpus fruticosus

Verbenaceae

Verbena bonariense *
" braziliensis *
" officinalis *

Lamiaceae

Mentha longifolia ssp. polyadena
Stachys hyssopoides

Scrophulariaceae

Veronica anagallis-aquatica

Rubiaceae

Galium capensis

Plantaginaceae

Plantago lanceolata *
" major *

Asteraceae

Aster squamatus *
Conyza bonariensis
" podocephala
Lactuca inermis
Pseudognaphalium luteo-album
" undulatum *
Senecio inornatus
Sonchus oleraceus *
Tagetes minuta *
Xanthium strumarium *

LIST OF PLANTS RECORDED FROM SITE RS10 ALONG THE LOWER RIETSPRUIT, VANDERBIJLPARK.

MONOCOTYLEDONAE
Poaceae

Agrostis lachnantha
Cynodon dactylon
Digitaria diagonalis
Hemarthria altissima
Imperata cylindrical
Ischaemum afrum
Paspalum dilatatum *
Setaria incrassata
" sphacelata ssp. sericea

Cyperaceae

Cyperus fastigiatus
" longus ssp tenuiflorus
" marginatus
" sp.
Pycreus sp.

Asphodelaceae

Trachyandra asperata

Asparagaceae

Asparagus laricinus

Amaryllidaceae

Crinum bulbispermum

DICOTYLEDONAE
Polygonaceae

Rumex crispus *
" sp.

Chenopodiaceae

Chenopodium album *
" ambrosioides *

Amaranthaceae

Achyranthes aspera
Amaranthus viridis *

Brassicaceae

Rorippa fluviatilis var. caledonica

Fabaceae

Melilotus alba *

Prosopis sp. *
Sesbania punicea *

Oxalidaceae

Oxalis corniculata *

Euphorbiaceae

Euphorbia sp. cf pubescens

Malvaceae

Sida rhombifolia

Onagraceae

Oenothera rosea *

Convolvulaceae

Convolvulus sagittatus var. ulosepalus

Verbenaceae

Verbena bonariense *

Lamiaceae

Mentha longifolia ssp. polyadena
Salvia reflexa *
Stachys hyssopoides

Solanaceae

Datura stramonium *
Physalis angulata *

Scrophulariaceae

Veronica anagallis-aquatica

Rubiaceae

Galium capensis

Plantaginaceae

Plantago lanceolata *

Asteraceae

Aster squamatus *
Berkheya rhapontica ssp. rhapontica
Bidens bipinnata *
" formosa *
Cirsium vulgare *
Conyza bonariensis
Galinsoga parviflora *
Schkuhria pinnata *

Sonchus oleraceus *
Tagetes minuta *
Xanthium strumarium *
Zinnia peruviana *

LIST OF PLANTS RECORDED FROM THE REFERENCE SITE ALONG THE TAAIBOSSPRUIT, SASOLBURG, FREE STATE.

MONOCOTYLEDONAE
Poaceae

Agrostis lachnantha
Aristida congesta
" junciformis
Digitaria diagonalis
Eragrostis capensis
" curvula
" plana
Hemarthria altissima
Imperata cylindrica
Ischaemum afrum
Panicum schinzii
Paspalum dilatatum *
" distichum
Setaria nigrirostris
" sphacelata var. sericea
Themeda triandra

Cyperaceae

Cyperus fastigiatus
" longus ssp. tenuiflorus
" marginatus
" sphaerospermus
Ficinia ovata
Kyllinga erecta

Juncaceae

Juncus exsertus ssp. exsertus

Commelinaceae

Commelina subulata

Hyacinthaceae

Ledebouria graminicola
" ovata

Amaryllidaceae

Ammocharis coranica
Crinum bulbispermum

DICOTYLEDONAE
Polygonaceae

Persicaria lapathifolia *
" limbata *

Chenopodiaceae

Chenopodium ambrosioides *

Brassicaceae

Rorippa nudiuscula

Fabaceae

Sesbania punicea *
Trifolium pratense *

Oxalidaceae

Oxalis corniculata *

Euphorbiaceae

Euphorbia striata

Onagraceae

Ludwigia stolonifera
Oenothera rosea *

Haloragaceae

Myriophyllum aquaticum *

Apiaceae

Centella asiatica
Peucedanum sp.

Loganiaceae

Gomphostigma virgatum

Convolvulaceae

Falckia oblonga

Verbenaceae

Verbena officinale *

Lamiaceae

Ajuga ophrydis
Salvia runcinata

Scrophulariaceae

Diclis reptans
Mimulus gracilis

Rubiaceae

Galium capensis

Plantaginaceae

Plantago lanceolata *

Asteraceae

Ambrosia artemissiifolia *
Berkheya rhapontica ssp. rhapontica
Bidens bipinnata *
Gazania krebsiana
Haplocarpha scaposa
Hypochoeris radicata *
Lactuca inermis
Senecio erubescens

APPENDIX 3
Aquatic Macroinvertebrate Data

Aquatic macroinvertebrates sampled December 2001

Taxon	Common Name	Sampling Site																
		REF	RS1	RS2	RS3	RS4	RS5	RS6	RS7	RS8	RS9	RS10	LS1	LS2	LS3	LS4	LS5	LS6
Turbellaria																		
Annelida																		
Oligochaeta	Segmented Aquatic Worms		A	A			A		B	A		A		D	A	A	C	
Hirudinea																		
	Leeches	A		A					A	A				A		A		A
Crustacea																		
Potamonautidae	Crabs		A				A		A	A				A	A	A		
	Shrimps																	
Atyidae		A									A							A
Hydracarina					A						A							
Hydrachnellae	Water Mites																	
Ephemaroptera																		
Baetidae 1sp	Small Minnow Mayflies	B	A	A	A		A	A		A	A		A	C	A	B	A	
Baetidae 2spp	Small Minnow Mayflies					A												B
Baetidae >2spp	Small Minnow Mayflies																	
Caenidae	Cainflies	B														A		
Leptophlebiidae		A																
Odonata																		
Lestidae	Damselflies																	
Coenagrionidae	Damselflies	A	A				B		A	A	A	A		A		A		A
Gomphidae	Dragonflies							A				B	B					
Aeshnidae	Dragonflies				A		B							A				
Libellulidae	Dragonflies	A	A	B	A	B	B						A	A				
Platycnemidae																		
Hemiptara																		
Notonectidae	Backswimmers	A			A	A	A	A				A	A					A
Pleidae	Pygmy backswimmers				A	A	B					A			A	A		
Nepidae	Water scorpions																	
Belostomatidae	Giant Water Bugs	A			A	A						A		A		A	A	
Corixidae	Water Boatman	A			A	B	A	B	A		A	A	A	A	A	A		A
Gerridae	Pond Skaters	A					A									A		
Naucoridae																		
Veliidae	Ripple bugs	A				A					A	A			A	A		A
Trichoptera																		
Hydropsychidae 1s	Caddis flies								A	B								A
Leptoceridae	Caddis larvae									B			A					
Coleoptera																		
Dytiscidae	Predacious Diving Beetles	A	A	A	C	A	A		A				A	B	B	A		
Elmidae/Dryopidae	Riffle Beetles/Long-toed Water Beetles										A			A				
Gyrinidae	Whirligig Beetles		A	A					B	A			A	A				A
Hydrophilidae	Water Scavenger Beetles		A	A	A	A						A		B	A			A
Haliplidae			A	A														
Hydraenidae											A				A			
Diptera																		
Culicidae	Mosquitoes		A		A	A	B		A	A		A						
Chironomidae	Midges	A	A		A	A	B	A	A	A		A	B	A		A	C	A
Psychodidae	Moth flies										A						A	A
Simuliidae	Black flies	B	A				C									A		
Muscidae	House Flies	A				A				A								
Tipulidae									A									
Gastropoda																		
Planorbidae	Orb snails				A											A		
Physidaa	Pouch snails			B						A		A		B	A	A		A
Lymnaeidae	Pond snails	A											B					A
Ancylidae	Limpets	A				A						A						
Pelecypoda																		
Sphaeridae	Clams	A										A						
	Number of Taxa	**19**	**12**	**9**	**13**	**13**	**14**	**5**	**11**	**12**	**9**	**14**	**10**	**15**	**10**	**17**	**5**	**14**
BIOTOPE SCORES																		
Stone & Rock		37	22	0	0	13	17	0	25	19	0	0	8	13	6	39	0	0
Gravel, Sand & Mud		42	0	0	0	19	11	18	10	26	4	0	17	9	12	23	11	20
Vegetation		56	25	35	53	38	42	0	26	30	46	49	32	52	37	42	0	46

APPENDIX 4
Fish Data

Site No	Species	Fin	Skin	Eyes	Operculum	Gill	Ext Parasites
REF	*Labeo capensis*						
	Labeo capensis						
	Labeo capensis						
	Labeo capensis						
	Labeo capensis						
	Labeo capensis						
	Labeo capensis						
	Barbus aeneus						
	Barbus aeneus						
	Barbus aeneus						
	Barbus aeneus						
	Pseudocrenilabrus philander						
	Pseudocrenilabrus philander						
	Pseudocrenilabrus philander						
	Pseudocrenilabrus philander						
	Pseudocrenilabrus philander						
	Pseudocrenilabrus philander						
	Pseudocrenilabrus philander						
	Barbus paludinosus						
	Barbus paludinosus						
	Barbus paludinosus						
	Barbus paludinosus						
	Barbus anoplus						
	Barbus anoplus						
	Labeo umbratus						
	Labeo umbratus						
	Clarias gariepinus						
	Clarias gariepinus						
RS2	*Gambusia affinus*	5	4	4	5		5
	Gambusia affinus	4	5	5	5		5
	Gambusia affinus	5	4	4	5		5
	Gambusia affinus	5	4	4	5		5
	Gambusia affinus	4	4	5	5		5
RS4	*Cyprinus carpio*	5	5	5	5		5
	Cyprinus carpio	5	5	5	5		5
	Cyprinus carpio	5	5	5	5		5
	Cyprinus carpio	5	5	5	5		5
RS5	*Barbus anoplus*	5	5	5	5		5
	Barbus anoplus	5	4	5	5		5
	Barbus anoplus	5	5	5	5		4
	Barbus anoplus	5	5	4	5		5
	Barbus anoplus	3	3	5	5		4
	Barbus anoplus	4	5	5	5		5
	Barbus anoplus	3	4	5	5		5
	Barbus anoplus	5	5	5	5		4
	Barbus anoplus	4	3	5	5		4
	Barbus anoplus	5	5	5	5		5
	Barbus anoplus	5	4	5	5		4
	Barbus anoplus	5	5	5	5		4
	Barbus anoplus	5	5	5	5		4
	Barbus anoplus	4	4	5	5		4
	Cyprinus carpio						
	Barbus paludinosus						
RS7	*Clarias gariepinus*						
RS9	*Barbus anoplus*						
	Barbus anoplus						
	Barbus anoplus						
	Barbus anoplus						
	Barbus anoplus						
	Barbus anoplus						
	Barbus anoplus						
	Barbus anoplus						
	Barbus anoplus						
	Barbus anoplus						

	Barbus anoplus						
	Barbus paludinosus						
	Barbus paludinosus						
	Barbus paludinosus						
	Barbus paludinosus						
	Barbus paludinosus						
RS10	*Gambusia affinus*	4	4	5	5		5
	Gambusia affinus	5	4	5	5		5
	Gambusia affinus	4	4	4	5		5
	Gambusia affinus	5	5	5	5		5
	Gambusia affinus	5	5	5	5		5
	Gambusia affinus	5	6	5	5		5
	Gambusia affinus	4	5	5	5		5
	Gambusia affinus	4	5	5	5		5
	Barbus anoplus						
	Barbus anoplus						
	Barbus anoplus						
	Barbus anoplus						
	Barbus anoplus						
	Barbus anoplus						
	Barbus anoplus						
	Barbus anoplus						
	Barbus anoplus						
	Barbus anoplus						
	Barbus anoplus						
	Barbus anoplus						
	Barbus anoplus	5	5	5	5	5	4
	Barbus anoplus	5	4	5	5	5	4
	Barbus paludinosus	4	4	5	5		5
	Barbus paludinosus	4	5	5	5		5
	Barbus paludinosus	5	5	5	5		5
	Barbus paludinosus	5	5	5	5		5
	Barbus paludinosus	4	4	5	5		4
	Barbus paludinosus	4	5	5	5		5
	Barbus paludinosus	4	5	4	5		5
	Clarias gariepinus						
	Pseudocrenilabrus philander	5	5	5	5		5
	Pseudocrenilabrus philander	5	5	5	5		5
	Pseudocrenilabrus philander						
	Pseudocrenilabrus philander						
LS2	*Barbus anoplus*	4	4	5	5	4	5
	Gambusia affinus	4	5	5	5		5
	Gambusia affinus	4	5	5	5		5
	Gambusia affinus	5	5	5	5		5
LS3	*Barbus anoplus*	5	5	4	5	5	5
LS4	*Barbus anoplus*	5	4	5	5		4
	Barbus anoplus	5	5	5	5		4
	Barbus anoplus	5	4	5	5		5
	Barbus anoplus	5	5	5	5		4
LS5	*Clarias gariepinus*						
	Cyprinus carpio						
LS6	*Labeo umbratus*						
	Labeo umbratus						
	Labeo umbratus						
	Labeo umbratus						
	Labeo umbratus						
	Labeo capensis						
	Labeo capensis						
	Labeo capensis						
	Labeo capensis						
	Labeo capensis						
	Labeo capensis						
	Cyprinus carpio						
	Cyprinus carpio						
	Barbus aeneus						

Clarias gariepinus
Micropterus salmoides
Micropterus salmoides

APPENDIX 5
Chlorophyll-*a* Data

Waterlab (Pty) Ltd / (Edms) Bpk
(Reg Nr/No 83/09165/07)

Management & Laboratory Services for Water and Wastewater
Environmental Monitoring and Impact Assessment

PO Box 11508 Hatfield 0028 (T) 012-349-1044/1066 (F) 012-349-1072
E-mail: waterlab@iafrica.co.za

WATERLAB

CERTIFICATE OF ANALYSIS

ATTENTION: Mrs. V. Rall | **DATE SUBMITTED: 03/12/2001** | **DATE COMPLETED : 04/12/2001**
REPORT NO: 8016 | **PROJECT NO: 4029** | **SAMPLES: 3986 - 4002**

ECOSUN
CHLOROPHYLL-a

Sample Identification	Chlorophyll-a (µg/l)
R51	<1
R52	<1
R53	<1
R54	<1
R55	<1
R56	<1
R57	<1
R58	<1
R59	<1
R510	<1
L51	<1
L52	<1
L53	<1
L54	<1
L55	<1
L56	<1
REF	<1

Sample Vol: 500ml ; Extract (EtOH) Vol: 50ml

per............................
Waterlab Research (Pty) Ltd

APPENDIX 6
Preliminary Reserve determined for Quaternary Drainage Region C22J in support of lisence applications by Iscor Vanderbijlpark and South Deep Mines (DWAF File No 26/8/3/3/322)

File No: 26/8/8/3/215

SUBMISSION TO THE DIRECTOR-GENERAL

THE ATTACHED DOCUMENTS DEALING WITH THE SUBJECT MENTIONED HEREUNDER, ARE BEING SUBMITTED FOR YOUR PERUSAL AND FORWARD TRANSMISSION TO THE DIRECTOR-GENERAL, IF YOU APPROVE.

PRELIMINARY RESERVE DETERMINATION: CUMULATIVE AT THE OUTLET OF QUATERNARY DRAINAGE REGION C22J

FILE NO. 26/8/3/3/322

Harm van Vliet

CHIEF DIRECTOR: SCIENTIFIC SERVICES

DATE:

SUBMISSION PERUSED COMMENTS/INITIAL

DEPUTY DIRECTOR-GENERAL: WATER RESOURCES

Ms L Hill

336 7875

26/8/3/3/322/7

DIRECTOR GENERAL

PRELIMINARY RESERVE AND RESOURCE CLASS DETERMINATION - QUATERNARY CATCHMENT C22J

Attached is the above preliminary determination of the Reserve and resource class in quaternary catchment C22J.

MOTIVATION FOR RESERVE DETERMINATION

This Reserve determination has been undertaken in support of licence applications by Iscor Vanderbijlpark and South Deep Mines for various water uses in the Leeuspruit and Rietspruit, (Rietspruit catchment) in quatemary catchment C22J.

STUDY AREA

The Rietspruit (of which the Leeuspruit is a tributary) drains into the Vaal River upstream of the Vaal Barrage (Upper Vaal Water Management Area) and is located approximately 25 kilometres southwest of Johannesburg.

Due to the urgency of this request a low confidence preliminary Reserve was determined on the Rietspruit, cumulative at the outlet of quatemary catchment C22J.

ECOLOGICAL IMPORTANCE AND SENSITIVITY

The ecological importance and sensitivity of quaternary catchment C22J is moderate.

PRESENT STATE OF CATCHMENT

The overall present state of both the Rietspruit and the Leeuspruit is in a category D. Biologically however the condition of both the Leeuspruit and the Rietspruit varies between poor to very poor (category E - F).

The Rietspruit catchment is relatively small with various water treatment and sewage works, industrial point sources, expanding formal and informal settlements, areas of spray irrigation using treated effluent, and pastures, all of which contribute to nonpoint contamination of water courses.

REQUEST

Please indicate your approval of the above mentioned, attached preliminary determination of the Reserve by signing where indicated.

CHIEF DIRECTOR: SCIENTIFIC SERVICES

DATE:

PRELIMINARY DETERMINATION OF THE RESERVE AND RESOURCE CLASS IN TERMS OF SECTION 14(1)(b) AND 17 (1) (b) OF THE NATIONAL WATER ACT, 1998 (ACT NO. 36 OF 1998)

I, ARNOLD MICHAEL MULLER, in my capacity as Director-General of the Department of Water Affairs and Forestry, and duly authorised in terms of section 63 of the National Water Act, 1998 (Act No. 36 of 1998), do hereby declare the preliminary determination of the Reserve and preliminary resource class as contained below.

DIRECTOR GENERAL: WATER AFFAIRS AND FORESTRY

DATE:

---

1. Description of Water Resource

River(s) : Rietspruit
Drainage Region : C22J
Water Management Area : Upper Vaal

2. Preliminary determination of the Reserve for Water Quantity in terms of section 17(1)

14.2% of the Mean Annual Runoff of **22.85 million cubic metres**

NOTE: This amount accounts for both ecological and basic human needs Reserve.

3. Preliminary determination of the Reserve for Water Quality in terms of section 17(1)

3.1 GENERAL CHEMISTRY

Parameter	Ecological Reserve	Basic Human Needs Reserve[1]	Water Quality Reserve
TDS (mg/l)	<1090	<1000	<1000
Sodium (mg/l)	<166	<200	<166
Magnesium (mg/l)	<17	<100	<17
Potassium (mg/l)	<46	<50	<46
Chloride (mg/l)	<346	<200	<200
Sulphate (mg/l)	<360	<400	<360
Calcium (mg/l)	<121	<80	<80

[1] ref: *Quality of Domestic Water Supplies, Volume 1: Assessment Guide, 2nd Ed.*1998. Water Research Commission Report No: TT 101/98. Pretoria, South Africa

3.2 NUTRIENTS AND NUTRIENT RATIOS

Parameter	Ecological Reserve	Basic Human Needs Reserve	Water Quality Reserve
Ortho-phosphate (mg/l)	<0.1	n/a	<0.1
Total inorganic nitrogen: Total phosphorus ratio	36	n/a	36

3.3 PHYSICAL WATER QUALITY

Parameter	Ecological Reserve	Basic Human Needs Reserve[1]	Water Quality Reserve
pH	6.5-8.5	5.0 - 9.5	6.5-8.5
Dissolved Oxygen saturation	94%	n/a	94%

[1] ref: *Quality of Domestic Water Supplies, Volume 1: Assessment Guide, 2nd Ed.* 1998. Water Research Commission Report No: TT 101/98. Pretoria, South Africa

3.4 TOXIC SUBSTANCES AND COMPLEX MIXTURES

Parameter	Ecological Reserve	Basic Human Needs Reserve 1)	Water Quality Reserve2)
Ammonia (mg-N/l as NH_3)	< 0.1	n/a	< 0.1
Toxics	Acute toxicity: 100% TUa ≤1 Chronic toxicity: 99% TUc<5 or 90%≤ TWQR, 99%< CEV, 100%<AEV	< TWQR	Acute toxicity: 100% TUa ≤1 Chronic toxicity: 99% TUc<5 **or** 90%≤ TWQR, 99%< CEV, 100%<AEV **or** < TWQR (more protective value selected)

where: TUa is acute toxicity units (TUa = 100/LC_{50} or EC_{50})
TUc is chronic toxicity units (TUc = 100/NOEC)
LC50 is the lethal concentration that causes mortality of 50% of the population
NOEC is the no observed effect concentration
TWQR is the Target Water Quality Range
CEV is the Chronic Effect Value
AEV is the Acute Effect Value

1) ref: *South African Water Quality Guidelines, Volume 1: Domestic Water Use, 2nd Ed.* 1996. Department of Water Affairs and Forestry. Pretoria, South Africa.
2)ref: *South African Water Quality Guidelines, Volume 7: Aquatic Ecosystems*, 1996. Department of Water Affairs and Forestry. Pretoria, South Africa

Note: Where a difference in the water quality values for the present ecological status and basic human needs was found, the lesser or more protective value was selected for the water quality Reserve

4. Preliminary determination of the resource class in terms of section 14(1)(b)

Equivalent to the present ecological status category D. Category D represents a largely modified state.

5. Applicability

5.1 This preliminary determination of the Reserve in terms of section 17(1)(a) is applicable to the following water resource or part of the resource:

Rietspruit, cumulative at the outlet of quaternary catchment C22J.

5.2 This preliminary determination of the Reserve in terms of section 17(1)(b) is applicable to the authorising of following water use:

- Section 21(a) - taking water from a water resource
- Section 21 (b) - storing water
- Section 21 (c) - impeding or diverting the flow of water in a watercourse
- Section 21(g) - disposing of waste in a manner which may detrimentally impact on a water resource
- Section 21(i) - altering the bed, banks, course or characteristics of a watercourse
- Section 21(j) - removing, discharging or disposing of water found underground if it is necessary for the efficient continuation of an activity or for the safety of people

6. Supporting documentation

Supporting documentation is provided in the following Annexures-

Annexure A: Preliminary Ecological Reserve – Water Quantity	☒
Annexure B: Preliminary Ecological Reserve – Water Quality	☒
Annexure C: Preliminary Basic Human Needs	☒
Annexure D: Background and record of decision	☒
Annexure E: Methodology	☒
Annexure F: Specialist reports	☒
Annexure G: Map of study area	☒

ANNEXURE A

PRELIMINARY ECOLOGICAL RESERVE – WATER QUANTITY

Table 2: Summary of IFR Rule Curves for Quaternary Catchment C22J, Cumulative at the outlet of the quaternary.

Summary of IFR rule curves for :
Total Runoff : Quaternaries C22J
Regional Type : Vaal
EMC = D

Data are given in m^3 * 10^6 monthly flow volume

Month	% Points 10%	20%	30%	40%	50%	60%	70%	80%	90%	99%
Oct	0.272	0.265	0.251	0.226	0.189	0.147	0.109	0.083	0.070	0.067
Nov	0.655	0.634	0.588	0.512	0.411	0.308	0.228	0.181	0.162	0.047
Dec	1.565	1.248	0.986	0.754	0.455	0.338	0.250	0.202	0.184	0.087
Jan	0.519	0.447	0.382	0.319	0.237	0.196	0.166	0.151	0.145	0.145
Feb	0.851	0.710	0.590	0.478	0.333	0.267	0.218	0.191	0.181	0.077
Mar	0.476	0.462	0.434	0.386	0.324	0.260	0.210	0.181	0.169	0.167
Apr	0.395	0.387	0.370	0.341	0.298	0.249	0.203	0.172	0.157	0.154
May	0.232	0.229	0.222	0.210	0.192	0.172	0.153	0.139	0.132	0.131
Jun	0.184	0.182	0.176	0.167	0.154	0.138	0.123	0.112	0.106	0.104
Jul	0.145	0.143	0.139	0.132	0.122	0.109	0.097	0.088	0.083	0.081
Aug	0.123	0.121	0.118	0.112	0.103	0.092	0.082	0.075	0.071	0.069
Sep	0.088	0.087	0.084	0.080	0.073	0.065	0.058	0.053	0.050	0.050
Natural Duration curves										
Oct	2.567	1.787	1.137	0.697	0.597	0.547	0.377	0.247	0.157	0.087
Nov	5.577	2.277	1.527	1.347	1.177	1.027	0.857	0.467	0.297	0.047
Dec	5.517	2.117	1.757	1.387	1.127	0.907	0.687	0.517	0.337	0.087
Jan	6.547	2.847	1.927	1.597	1.197	0.907	0.767	0.637	0.367	0.177
Feb	9.047	2.687	1.577	1.247	1.157	1.047	0.827	0.587	0.347	0.077
Mar	6.467	2.637	2.097	1.637	1.397	1.087	0.807	0.677	0.467	0.177
Apr	4.757	2.427	2.027	1.667	1.277	1.057	0.837	0.637	0.547	0.197
May	2.797	1.847	1.467	1.247	0.957	0.757	0.597	0.497	0.347	0.207
Jun	2.227	1.377	0.937	0.767	0.667	0.577	0.477	0.407	0.347	0.277
Jul	1.597	0.957	0.747	0.677	0.597	0.497	0.427	0.377	0.327	0.257
Aug	1.047	0.787	0.617	0.517	0.467	0.417	0.377	0.307	0.287	0.227
Sep	0.977	0.627	0.497	0.397	0.357	0.317	0.257	0.227	0.187	0.147

ANNEXURE B

PRELIMINARY ECOLOGICAL RESERVE – WATER QUALITY

RIVER ECOSYSTEMS COMPONENT – WATER QUALITY

Table 1. Data used for the low/medium confidence water quality Reserve

Aspect	Description
Data station	C2H005Q01 Rietspruit at Kaalplaats
Full data period	1995-2001
Number of records	423
Trend significance	high
Known point sources upstream	Sewage works; old mine slimes dams; Iscor wastewater

ANNEXURE C

PRELIMINARY BASIC HUMAN NEEDS

BASIC HUMAN NEEDS RESERVE

The basic human needs reserve provides for the essential needs of individuals served by the water resource in question and includes water for drinking, food preparation and for personal hygiene. A lifeline amount of 25 litres per person per day was used.

Quantity Reserve

Quaternary	Population (current requirement)	Per capita need (litres / day)	BHN Reserve required	
			MCM / annum	% VMAR
C22J	34 860	25	0.32	1.4

MCM: million cubic metres
VMAR: virgin mean annual runoff

The cumulative VMAR at the outlet of quaternary drainage region **C22J,** is 22.85 million cubic metres.

ANNEXURE D

BACKGROUND AND RECORD OF DECISION

BACKGROUND

1. Study team

DWAF	L Hill	RDM Office
	P Vos	RDM Office
	T Papo	IWQS
	M E Matseba	Gauteng Regional Office

2. Motivation for Reserve determination:

This preliminary Reserve determination has been undertaken in support of the evaluation of various licence applications in the Rietspruit catchment (on the Riet- and Leeuspruit) by Iscor Vanderbijlpark and South Deep Mines for the following water uses:

- Section 21(a) - taking water from a water resource
- Section 21 (b) - storing water
- Section 21 (c) - impeding or diverting the flow of water in a watercourse
- Section 21(g) - disposing of waste in a manner which may detrimentally impact on a water resource
- Section 21(i) - altering the bed, banks, course or characteristics of a watercourse
- Section 21(j) - removing, discharging or disposing of water found underground if it is necessary for the efficient continuation of an activity or for the safety of people

3. Scope of study:

A preliminary determination of the water quality and water quantity component of the Reserve (river ecosystem) on the Rietspruit, cumulative at the outlet of quaternary catchment C22J.

ANNEXURE E

METHODOLOGY

ANNEXURE F

SPECIALIST REPORTS

SPECIALIST REPORTS

- Department of Water Affairs and Forestry, Directorate: Institute for Water Quality Studies. Author: T Papo. Rietspruit Ecological Water Quality Reserve, October 2001.

ANNEXURE G

MAP OF STUDY AREA

RIVER ECOSYSTEMS COMPONENT – WATER QUANTITY

Level of confidence of the determination: Low

1) The determination is applicable to the cumulative quaternary catchment at the outlet of quaternary catchment C22J. The instream flow requirement at the outlet of the quaternary catchment is based on the natural flow contribution from the total upstream catchment.

2) Table 1 provides a summary of the flow characteristics and IFR requirements.

3) Table 2 provides a summary of IFR rule curves for the water quantity component of the ecological reserve.

Table 1: Summary of IFR Estimate for Quaternary Catchment C22J, Cumulative at the outlet of the quaternary

Summary of IFR estimate for Quaternary Catchment Area :
Total Runoff : Quaternaries C22J

Annual Flows (Mill. cu. m or index values):

MAR	=	22.853
S.Dev.	=	21.519
CV	=	0.942
Q75	=	0.427
Q75/MMF	=	0.224
BFI Index	=	0.429
CV(JJA+JFM) Index	=	2.627

IFR Management Class = D

Total IFR	=	2.928 (12.81 %MAR)
Maint. Lowflow	=	1.312 (5.74 %MAR)
Drought Lowflow	=	1.312 (5.74 %MAR)
Maint. Highflow	=	1.616 (7.07 %MAR)

Monthly Distributions (Mill. cu. m.)
Distribution Type : Vaal

Month	Natural Flows			Modified Flows (IFR)			
				Low flows		High Flows	Total Flows
	Mean	SD	CV	Maint.	Drought	Maint.	Maint.
Oct	1.333	2.679	2.010	0.053	0.053	0.129	0.182
Nov	3.691	10.434	2.827	0.123	0.123	0.331	0.453
Dec	3.037	6.923	2.280	0.125	0.125	0.540	0.666
Jan	2.693	4.644	1.724	0.132	0.132	0.117	0.249
Feb	3.119	6.673	2.139	0.155	0.155	0.234	0.389
Mar	2.513	3.624	1.442	0.149	0.149	0.163	0.312
Apr	1.939	2.239	1.155	0.142	0.142	0.103	0.245
May	1.362	1.299	0.954	0.130	0.130	0.000	0.130
Jun	0.927	0.762	0.822	0.103	0.103	0.000	0.103
Jul	0.769	0.629	0.817	0.081	0.081	0.000	0.081
Aug	0.646	0.605	0.937	0.069	0.069	0.000	0.069
Sep	0.822	2.543	3.092	0.049	0.049	0.000	0.049