EASTERN CAPE RIVER HEALTH PROGRAMME

DRAFT TECHNICAL REPORT: BUFFALO RIVER MONITORING, 2002 - 2003

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EXECUTIVE SUMMARY

The South African National River Health Programme (NRHP) involves the use of biomonitoring (biological monitoring) tools so as to determine the ecological condition of South Africa's freshwater ecosystems. The programme aims to promote standardised and continuous monitoring and to provide reports on river health.

This report provides the technical input which will underlie the State-of-Rivers Report to be produced for the Buffalo River, Eastern Cape, by June 2004. This forms a product of Phase II of the Eastern Cape River Health Programme (ECRHP), initiated in July 2002.

The report provides results and recommendations for three monitoring surveys (spring, autumn and winter) of 12 sites spread throughout the upper, middle and lower Buffalo River catchment, including selected tributaries. Indices used for monitoring include SASS5 (macroinvertebrates), Fish Assemblage Integrity Index, geomorphology and a water quality present state assessment using information from DWAF gauging weirs on the main stem of the river. Riparian vegetation monitoring was conducted at selected sites as an exercise in producing a modified index specifically for use in the Eastern Cape, i.e. the Integrated Riparian Vegetation Index.

Chapter 8 (the Final discussion, conclusion and recommendations) provides a diagrammatic representation of the state of health of the rivers at the 12 selected sites per index, allocating the state of health of each indicator as either Natural, Good, Fair or Poor. The assessment varies from indicator to indicator, but general trends for biological indicators are as follows:

SITE NUMBER	DESCRIPTION OF LOCATION	DESCRIPTION OF STATE OF HEALTH OF BIOLOGICAL INDICATORS
1	Buffalo River above Maden Dam	Good (RVI) to Fair
2	Buffalo River at Horseshoe Bend	Fair to Poor
3	Maqakwebe tributary	Good to Fair
4	Ngqokweni tributary	Fair (no RVI)
5	Yellowwoods River at Leonsdale bridge	Fair (no RVI)
6	Yellowwoods River 2	Fair (to Poor for fish) (no RVI)
7	Buffalo River below King Williams Town, and above Zwelitsha	Poor (no RVI)
8	Buffalo River below Zwelitsha	Poor (no RVI)
9	Buffalo River at Buffalo Pass	Good
10	Nahoon River upstream of Nahoon Dam	Poor (no RVI)
11	Shangani Stream draining Mdantsane	Fair to Poor (no RVI)
12	KwaNxamkwane Stream draining Potsdam	Fair to Poor (no RVI)

TABLE OF CONTENTS

ABBREVIATIONS AND ACRONYMS

ASPT	Average Score Per Taxon
DWAF	Department of Water Affairs and Forestry
EC	Electrical Conductivity
ECRHP	Eastern Cape River Health Programme
EVC	Extent of vegetation cover.
GRC	Geomorphological Reference Condition
IHAS	Integrated Habitat Assessment System
IRVI	Integrated Riparian Vegetation Index
MAF	Mean Annual Flood
NGO	Non–governmental organisation
NRHP	National River Health Programme
PCIRS	Percentage Cover of Riparian species
PES	Present Ecological State
PGS	Present Geomorphological State
RHP	River Health Programme
RIP	RIPARI-MAN (vegetation index)
RIRS	Recruitment of Riparian Species
RVI	Riparian Vegetation Index
SASS5	South African Scoring System Version 5
SI	Structural Intactness
SRP	Soluble Reactive Phosphate
TDS	Total Dissolved Salts
TIN	Total Inorganic Nitrogen
WFW	Working for Water
WRC	Water Research Commission

CHAPTER 1

RIVER HEALTH AND BIOLOGICAL MONITORING

1.1 INTRODUCTION: SOUTH AFRICAN RIVER HEALTH PROGRAMME

Biomonitoring is a method for determining the state of ecological health of a system. It involves the use of living components of an ecosystem (the biota), as well as abiotic components (e.g. geomorphology and water quality), as indicators of the health of that system. Biological monitoring is based on recognition that monitoring of physico-chemical water variables only is not sufficient to achieve integrated ecosystem monitoring, but that the additional monitoring of biological communities offers a more holistic approach. As aquatic organisms are found in rivers all the time, they are continuously affected by the conditions in the river, and monitoring of these communities should show the impacts of conditions over time. Biomonitoring is therefore an *effects or response-oriented* approach which measures various indicators, and from these measurements, an assessment can be made about the health of the aquatic ecosystem. The information provided by these indicators (e.g. fish or aquatic invertebrates) can be summarised to produce either a single number (an index), or a series of numbers (indices) describing ecosystem state. The focus of this approach is therefore the resource, specifically the status of that resource (Uys et al., 1996; Roux, 2003).

Biological indicators are therefore able to provide early warning of deterioration of the system or of unsustainable use of its resources, and act as *red flags* indicating that deterioration may be taking place, but without providing any causal links. The biomonitoring technique is therefore favoured for its speed, simplicity, effective results and ease of interpretation as well as for recognizing that a freshwater ecosystem is made up of many mutually dependent parts. Biomonitoring techniques take into account a variety of ecosystem components, for example, biological indicators such as macroinvertebrates, fish and riparian vegetation; and physical indicators such as channel geomorphology, water quality and flow regime. Catchment characteristics are also evaluated during field assessments.

The South African National River Health Programme (NRHP) involves the evaluation of the present state of the country's riverine ecosystems relative to their natural state, and projection of long-term trends in river health. At a national level, the programme focuses on "state-of-environment" reporting, and aims to achieve the following objectives (Hohls, 1996):

- To identify areas of sustainable water use and areas of unacceptable ecological deterioration.
- To develop the information base needed to support scientifically and ecologically sound decisions regarding the wise use of the country's river systems.
- To evaluate the effectiveness of management strategies and actions related to water resources.
- To educate the public regarding the health of the country's rivers.

Results and information are stored on a standardised database (the Rivers Database), which is networked nationally. This database represents an invaluable asset to water resource managers and the Department of Water Affairs and Forestry (DWAF) for water quality assessments, catchment management planning and development of guidelines and policies

(Murray, 1999). In addition to the aims of national monitoring, provincial monitoring can incorporate the following additional aims:

- To identify where impacts are occurring.
- To assess the extent of impacts (pre- and post-impact monitoring).
- To audit compliance with regulatory standards or objectives.

1.1.1 River health classification

When interpreting results from biomonitoring surveys, it is necessary to know what changes are considered part of the natural variation of the river, i.e. distinguishing between natural and unnatural (rates of) change. A method by which this distinction can be made is to establish a natural benchmark or reference condition, or identify reference sites, with which conditions at monitoring sites can be compared. The RHP relies on this comparison of conditions at monitoring sites vs. reference sites or condition. Due to the absence of pristine areas in most catchments and river systems in the country, *miminally impacted sites* are used as surrogates for reference sites. Dallas (2000) has provided guidance regarding the establishment of reference conditions, with her work conducted in Mpumalanga during the pilot-scale phase of the NRHP.

In order to standardize the output of the different indices, to allow comparisons between different rivers and areas of the country, and relate these outputs to river condition categories, the following river health classification system has been developed (Table 1.1). This classification system allows for the results of each index to be expressed as a river health class, with ecological and management perspectives.

Table 1.1 The river health classification system used in the NRHP (Roux, 2003).

RIVER HEALTH CLASS	ECOLOGICAL PERSPECTIVE	MANAGEMENT PERSPECTIVE
Natural	No or negligible modification of in-stream and riparian habitats and biota.	Protected rivers; relatively untouched by human hands; no discharges or impoundments allowed.
Good	Ecosystem essentially in good state; biodiversity largely intact.	Some human-related disturbance, but mostly of low impact potential.
Fair	Sensitive species may be lost; lower abundances of biological populations are likely to occur: or sometimes, higher abundances of tolerant or opportunistic species occur.	Multiple disturbances associated with need for socio-economic development, e.g. impoundment, habitat modification and water quality degradation.
Poor	Habitat diversity and availability have declined; mostly only tolerant species present; species present are often diseased; population dynamics have been disrupted.	Often characterized by high human densities or extensive resource exploitation. Management intervention is needed to improve river health, e.g. to restore flow patterns, river habitats or water quality.

1.2 INDICATORS USED IN THE RHP

The goal of RHP-type of monitoring is therefore to generate information, meaning that monitoring is less intensive and less costly. Monitoring constitutes rapid monitoring of a large number of sites distributed over a wide area.

The concept of an *ecological indicator* or *indicator species* is therefore fundamental to biological monitoring. Indicator organisms may include any member of the flora or fauna of an aquatic habitat. Organisms most commonly used as indicators of water quality changes include fish, birds, macroinvertebrates, protozoa, algae, yeasts, fungi, bacteria, and viruses. The groups most commonly used are macroinvertebrates and fish (Uys et al., 1996; Roux, 2003).

However, the assessment of the ecological status of an aquatic ecosystem should include an assessment of all environmental factors that affect the aquatic ecosystem. These include the biota, as well as chemical variables, flow regime, geomorphological structures, and habitat assessments. The inclusion of all these parameters will assist with the interpretation of changes seen in the biological indicators. Macroinvertebrates, fish and riparian vegetation are termed *biological indicators*, while environmental factors such as habitat availability, hydrology, water quality and geomorphology serve a broader, supportive and interpretive role in biomonitoring, and are therefore termed *secondary* or *ecosystem indicators*. These indices therefore provide the framework for the interpretation of monitoring results. Indices available for use include the following:

Physical indicators
- Geomorphological Index (GI)
- Hydrological Index (HI)
- Habitat Integrity Index (HII)
- Water Quality Index (WQI)

Biological indicators
- Riparian Vegetation Index (RVI)
- Fish Assemblage Integrity Index (FAII)
- SASS (macroinvertebrates)
- Habitat Assessment Matrix (HAM) or Integrated Habitat Assessment System (IHAS) – used in combination with SASS monitoring

Additional information regarding each index, and the recommended spatial scale and frequency of monitoring (*according to the guidelines of the NRHP*) are shown in Tables 1.2 - 1.4. Note that the results of Buffalo River monitoring may result in different recommendations for this river system (see Chapters 3-8).

Table 1.2 Biological and physical indicators used during biomonitoring (Murray, 1999).

ECOSYSTEM COMPONENT	RELEVANCE TO BIOMONITORING
Fish	Fish comprise one of the main biological components of aquatic ecosystems. Because they are relatively long-lived and mobile, they can indicate long-term influences (years) and general habitat conditions in a river reach. They represent a variety of trophic levels and hence integrate effects of environmental changes.
Macroinvertebrates	Invertebrate communities respond relatively quickly to localized conditions in a river, especially water quality, though their existence also depends on habitat diversity. They are common, have a wide range of sensitivities, and have a suitable life-cycle duration that indicate short- to medium-term impacts of water quality.
Riparian vegetation	Healthy riparian zones maintain channel form and serve as important filters for light, nutrients and sediment. Riparian vegetation regulates river flow, improves water quality, provide habitats for faunal species and corridors for their movement, controls river temperatures, provides nutrients and maintains bank stability. Changes in riparian vegetation, structure and function are commonly associated with changes in river flow, exploitation for firewood or changing use of the riparian zone (e.g. grazing or ploughing).
Habitat	Habitat availability and diversity determine aquatic community structure. Habitat degradation adversely affects biological communities.
Flow / Hydrology	Flow conditions in a river affect the distribution and abundance of biota by creating dynamic habitats characterized by current speed, water depth, and (in the longer term) substratum characteristics.
Water quality	Aquatic ecosystems and their biota are affected by turbidity, suspended solids, temperature, pH, salinity, concentrations of dissolved ions, nutrients, oxygen, biocides and trace metals. Changes in these due to pollution, geomorphological or hydrological factors can have detrimental or even lethal effects on aquatic organisms.
Geomorphology	Geomorphological processes determine river channel morphology which provides the physical environment within which stream biota live. Changes to channel form occurs both naturally and as a result of man-made changes to rivers or their catchments (e.g. impoundments, water transfers, agriculture).

Table 1.3 Summary of the main indices, associated ecosystem components and typical spatial scale (Murray, 1999).

INDEX	COMPONENT	SPATIAL SCALE
Biological indicators		
SASS5	Macroinvertebrates	Up to 20 m
FAII	Fish	Homogeneous fish segments, typically kms
RVI	Riparian vegetation	10s of metres
Physical indicators		
IHI	Habitat	5 km
IHAS	In-stream habitat (invertebrates)	Up to 20 m
GI	Geomorphology	10s of metres

Table 1.4 Typical sampling frequencies for various biomonitoring indices (Murray, 1999).

INDEX	FREQUENCY	COMMENTS
SASS5 and IHAS	2-3 times per year	Preferably during dry season, end of dry season, and at end of wet season
FAII	Every 3 years	
RVI	Every 3 years	To coincide with fish monitoring
IHI	Every 3-5 years	Depending on rate of developments within the catchment.
GI	Annually during low flow period	Baseline assessment done initially for all rivers; then after major hydrological events or upstream disturbances such as a forest fire or major change in land use.

1.3 BACKGROUND TO THE EASTERN CAPE RIVER HEALTH PROGRAMME

The RHP aims to conduct river health monitoring as a team-based approach with a team leader or provincial champion ensuring that a selected river is surveyed and long-term monitoring is initiated. In July 2002 Dr Patsy Scherman of Coastal & Environmental Services (CES), Grahamstown, was commissioned to undertake the leadership of a biomonitoring team and to initiate a River Health Programme in the Eastern Cape. The river selected for the first phase of the provincial RHP was the Buffalo River, primarily due to the large database of historical data available for the system, its central location in the province, and the availability of flow and water quality data from DWAF gauging weirs. Note that this report focuses only on river sites. Methods were developed for flowing-water systems, and dams, wetlands, and the Buffalo Estuary were not assessed during this study.

The main objectives of the Eastern Cape River Health Programme (ECRHP) at the initiation of this study were as follows:

- Conduct monitoring surveys of the Buffalo River using selected indices.
- Produce a State-of-Rivers report for the Buffalo River.
- Produce a Technical Report for the Buffalo River.
- Train DWAF staff in biomonitoring methods, so as to produce a functioning and effective team.

This report therefore fulfils Task 3, namely the production of a Technical Report for the Buffalo River. The State-of-Rivers report will be produced by June 2004.

1.3.1 Biological monitoring of the Buffalo River

Twelve sites were selected along the Buffalo River for biological monitoring. The catchment and biomonitoring sites are described in Chapter 2. The following indices were selected for monitoring – selection was based on importance and available expertise within the Eastern Cape:

- Macroinvertebrates (SASS5) and IHAS – Chapter 3 and Appendix 1
- Fish - Chapter 4 and Appendix 2
- Riparian vegetation – Chapter 5 and Appendix 3; selected sites only as part of the development of a modified riparian vegetation index, i.e. the Integrated Riparian Vegetation Index.
- Geomorphology – Chapter 6 and Appendix 4
- Water quality – Chapter 7 and Appendix 5

Each chapter will provide background, methods, results, discussion and recommendations for future monitoring. Chapter 8 is the final discussion and conclusion of the report.

CHAPTER 2

THE BUFFALO RIVER CATCHMENT AND STUDY SITES

2.1 GENERAL DESCRIPTION

The Buffalo River is located on the east coast of South Africa and is considered to be a small system of 125 km, with a catchment area of 1276 km^2. The river begins in the Amatole Mountains between King Williams Town and Stutterheim, passes through Zwelitsha and Mdantsane, and runs through low altitude coastal forest in the lower reaches, i.e. from Bridle Drift Dam to the head of the estuary in East London (O'Keeffe et al., 1996). The major tributaries of the Buffalo River are the Mgqakwebe, Ngqokweni and Yellowwoods Rivers, and all three join the mainstream above Laing Dam (CES, 2003). The mean annual rainfall is 736 mm (O'Keeffe et al., 1996) ranging from 500 to 2000 mm (Palmer and O'Keeffe, 1990). There is a distinct seasonality, where the summer has approximately double the amount of rain than in winter (O'Keeffe et al., 1996). The river is characterized by clear turbulent water beginning in the mountain reaches. The water in the upper reaches is of high quality and supplies approximately 40% of the water in this catchment area (O'Keeffe et al., 1996).

2.1.1 Geology

The river is generally deeply incised, creating large rock cliffs up to 120 m in height (O'Keeffe et al., 1996). The catchment contains mostly (78%) Lower Beaufort Series mud and sandstones with the remaining 22% being doleritic intrusions (Palmer and O'Keeffe, 1990). Most of the catchment and the middle and lower reaches have a high concentration of dissolved salts due to the sediment being of marine origin, indicating recent geological submergence beneath the sea (O'Keeffe et al., 1996).

2.1.2 Vegetation

There are four main vegetation types through which the Buffalo River passes: False macchia, Afro-montane forest, False Thornveld, Valley Bushveld and Coastal and Forest Thornveld (O'Keeffe et al., 1996). Unfortunately most of these natural vegetation types can no longer be seen, except for the forest surrounding the catchment. Due to the steep nature of the rock cliffs in the upper section of the river, the yellowwood trees have been preserved in the natural montane forest. Much of the land has been taken over for grazing and some agricultural usage (O'Keeffe et al., 1996).

2.1.3 Land and water use

Extensive and intensive agriculture occurs in the upper reaches of the catchment, i.e. from Rooikrans Dam to King Williams Town. However, a large portion of the potential yield in the upper reaches of the Buffalo River is used for forestry and the environment. The Pirie and Rooikrans trout hatcheries are also located in the upper section of the Buffalo River. Due to the impact trout and exotics such as the Marron crayfish (bred at Rooikrans hatchery in the 1980s) were having on indigenous fish populations, breeding was terminated at both hatcheries. The Rooikrans hatchery was closed down approximately 5 years ago, and breeding stoped at the Pirie hatchery in 2002 (Qonya, EC Nature Conservation, pers. comm.). On the coastal plain, i.e. between Laing and Bridle Drift Dams, extensive agriculture is the dominant land use (CES, 2003).

Due to its proximity to the urban-industrial complex of East London and King Williams Town, water from the Buffalo River and its tributaries is used extensively in the surrounding urban and industrial areas. According to the draft Local Economic Development Plan for the Buffalo City municipality (CES, 2003), industry (manufacturing) employs around 28 752 people (second only to community service - 35 614 people employed). Industrial development therefore impacts quite significantly on the environment, resulting in the loss of terrestrial and aquatic habitats and the consequent decline in biodiversity of flora and fauna in the region. Furthermore, the pollution output of industries is very high, contributing to air, soil and water contamination.

The greatest water quality problem in the area is therefore discharge of effluent from wastewater treatment works and industries around Zwelitsha, King Williams Town and East London, with the Buffalo River being heavily impacted. The Da Gama Textile factory has caused significant pollution of the Buffalo River, resulting in the widespread death of fish. This disaster occurred when holding dams over-flowed during periods of intense rain. The Buffalo and Nahoon Rivers are affected by a variety of point and non-point sources of pollution, including bacterial contamination, eutrophication and elevated salinities (WRC 1981, 1993 and others, cited in DWAF, 1999). The sewers of Mdantsane overflow directly into Bridle Drift Dam, which has experienced a number of algal blooms of toxic nature (CES, 2003).

The ever-increasing population also threatens the water quality of the major rivers in this region, amongst them the Buffalo and Nahoon rivers, and a number of streams – the Shangani, Tindeli and Sitotana that drain Mdantsane - which discharge into the lower reaches of the Buffalo River. The pressures facing these water resources include microbial contamination (due to inadequate access to sanitation), solid waste pollution (due to lack of disposal sites), increased sediment load and nutrient (eutrophication) concentrations (due to erosion from over-grazing and vegetation clearance). Another major problem in this region is the fact that most households rely on run-of-river as their water source, i.e. they drink water directly from the polluted rivers (CES, 2003).

A new development within the Buffalo River catchment is the East London Industrial Development Zone (EL IDZ). It is expected that this development may impact on the quality of surface and groundwater sources. However, a water quality monitoring programme is currently underway to establish baseline conditions, and an Environmental Manager is in position to ensure that the Environmental Management Plan for the IDZ is strictly adhered to (CES, 2003).

A number of large impoundments are found in the Buffalo River catchment. These include Maden Dam; Rooikrantz Dam which supplies King Williams Town; Laing Dams supplying Zwelitsha, Bisho and parts of Mdantsane; and Bridle Drift Dam which supplies East London and Mdantsane. Laing Dam is situated downstream of King Williams Town and Zwelitsha, and receives treated domestic and industrial effluent. Four small tributaries carry domestic sewage into Bridle Drift Dam from Mdantsane.

2.2 SITE SELECTION FOR RIVER HEALTH MONITORING OF THE BUFFALO RIVER

Provisional sites to be monitored during the Buffalo River survey were selected using 1: 50 000 maps of the Buffalo River catchment during a planning workshop held in Grahamstown on 27 August 2002. Maps used for assessing the catchment, were the following:

3227CB Stutterheim – upper reaches to Rooikrans Dam
3227CD King William's Town – from Rooikrans Dam to Laing Dam
3227DC Berlin –from Laing Dam to Bridle Drift Dam
3227DD Cambridge – loop of the Buffalo River between Bridle Drift Dam and the sea
3327BA Kidd's Beach – showing the stream from Needs Camp toward the Buffalo River
3327BB East London – lower reaches of the Buffalo River

Representative sites were selected in the upper, middle and lower reaches of the river. The upper reaches were defined as the section above King Wiliams Town, the middle reaches between King Williams Town and Bridle Drift Dam, and the lower reaches below Bridle Drift Dam to the estuary. Both reference (in unimpacted areas) and monitoring sites were selected, with two reference points selected per reach (where possible). Sites were ground-truthed during a site selection survey in October 2002, photographed and positions determined by GPS.

The following sites were finally selected for biological monitoring. Descriptive information is taken from Maseti (in prep.). Three sampling surveys were undertaken, i.e. October 2002, April and August 2003. Specific chapters of the report will provide relevant detailed information of each site for monitoring purposes per indicator.

Site 1 – Buffalo River above Maden Dam

GPS coordinate: 32º 43' 21" S, 27º 17' 46" E
This site was selected as a potential *reference site* for the upper reaches of the catchment. The closest DWAF gauging weir is R2H001.

The average width of the stream was 12-14 metres. Banks were mostly vegetated by indigenous vegetation, although little marginal vegetation was present. Water was clear with medium flow. Substrate was mainly in the form of pebbles and cobbles, with fallen trees and logs providing additional habitat.

Site 2 – Buffalo River at Horseshoe Bend

GPS coordinate: 32º 49' 21" S, 27º 22' 49" E
This site was selected as the first *monitoring site* for the upper reaches of the catchment. The closest DWAF gauging weir is R2H005 on the Mgqakwebe tributary.

The average width of the stream was 8 – 10 metres. Substrate was mostly cobbles, with a small riffle area and large pools up- and downstream of the site. Marginal and fringing vegetation was approximately 2 m in width. There was evidence of sand-mining on the left bank, with a low-water bridge and cattle crossing across the stream.

Site 3 – Mgqakwebe tributary

GPS coordinate: 32º 47' 17" S, 27º 14' 59" E
This site was the second *reference site* selected for the upper reaches of the catchment. The closest DWAF gauging weir is R2H005.

The river is sinuous and meandering, with average width 4 m. Cobbles and pebbles were found in long stretches of riffle. Marginal vegetation was dominated by trees and shrubs, and pools were shallow. There is a major cattle crossing in the area, with a cemetery 50-60 m from the site.

Site 4 – Ngqokweni tributary

GPS coordinate: 32º 54' 59" S, 27º 22' 45" E
This site was selected as the first *reference site* of the middle reaches of the catchment. The closest DWAF gauging weir is R2H009.

The average width of the stream was 10-15 m. Substrate was mostly bedrock and boulders, with small patches of riffles. Deep pools were present. Aquatic and marginal vegetation was present. *Acacia* in the riparian zone is used by surrounding communities as a source of firewood.

Site 5 – Yellowwoods River at Lonsdale bridge

GPS coordinate: 32º 48' 30" S, 27º 22' 45" E

This site was selected as a *reference site* in the middle reaches of the catchment. No gauging weirs are found in the area.

The average width of the stream was 8-10 m. The water was discoloured with low flow. The substrate varied from cobbles, gravel and sand. Sedges and reeds dominated aquatic and marginal vegetation. Pools were shallow and livestock have eroded the banks and formed gullies.

Site 6 – Yellowwoods River 2

GPS coordinate: 32º 55’ 14.2” S, 27º 29’ 18.0” E
This site was selected as a *monitoring site* for the middle reaches of the catchment. The closest DWAF gauging weir is R2H011.

The average stream width was 8-10 m. Substrate was mainly bedrock and boulders, with small riffle areas. Marginal vegetation was minimal and found in pool areas. Small waterfalls were seen upstream.

Site 7 - Buffalo River below KWT, and above Zwelitsha town

GPS coordinate: 32º 54' 49.1" S, 27º 24' 37.0" E
This site was selected as the second *monitoring site* for the middle reaches. No gauging weirs are found in the area.

This is a braided section of the river, with suitable riffle areas for invertebrate sampling. Pools for fish sampling are available. Downstream of the site is a pipeline crossing so as to deliver water to Bonke town. Sweetwater stream, which drains Zwelitsha, joins the Buffalo River downstream of the site. Sand mining and bulldozing is evident on left bank; builders rubble can also be seen on this bank.

Site 8 - Buffalo River below Zwelitsha town, but above Zwelitsha sewage treatment works.

GPS coordinate: 32º 55' 54.4" S, 27º 26' 22.1" E
This site was selected as a *monitoring site* for the middle reaches of the catchment. The closest DWAF gauging weir is R2H010.

This site is found upstream of the Denis Radue bridge. The average width of the river is 8-10 m. The water was green and eutrophication levels were high. Substrate was sand, cobbles and boulders.

Site 9 - Buffalo River at Buffalo Pass

GPS coordinate: 33º 00’ 31.6” S, 27º 29’ 32.6” E
This site was selected as the first *monitoring site* for the lower reaches. The closest DWAF gauging weir is R2H002.

This is a very good site for monitoring all indices, and is a site used during the Amatole study. The site is located at the Umtiza Nature Reserve. The average width of the stream is between 40 and 50 m. The water was murky, turbid and fast-flowing in all seasons. Substrate was predominantly bedrock with few cobbles.

Site 10 – Nahoon River upstream of Nahoon Dam

GPS coordinate: 32º 52’ 01.6” S, 27º 45’ 55.1” E
Due to the absence of reference sites for the lower reaches of the Buffalo River, this site was selected as the *reference site* as it is geographically placed in the same ecoregion as the lower stretch of the Buffalo River, and therefore can serve as a surrogate reference site.

The average river width was 10-15 m. Boulders and bedrock dominated the substrate although cobbles and gravel were present. Vegetation along the banks was mostly natural. Little marginal vegetation was seen upstream, but was present in deep pools.

Site 11 – Shangani Stream draining Mdantsane

GPS coordinate: 32º 58' 11.1" S, 27º 42' 37.3" E
This site was selected as a *monitoring site* for the lower reaches. No DWAF gauging weirs are found in the area.

A good riffle area was found upstream of the bridge and sand road. Potsdam Sewage Treatment Works pumps failure overflows into this stream, which also drains Mdantsane.

The site is located downstream of Bridle Drift Dam. The average river width is 3-5 m. Substrate was predominantly bedrock and boulders.

Site 12 – KwaNxamkwane Stream draining Potsdam town

GPS coordinate: 32º 59’ 06.7” S, 27º 38’ 19.5” E
This site was selected as a *monitoring site* for the lower reaches. The closest DWAF gauging weir is R2H027.

This stream drains into the Buffalo River further downstream. The average river width is 4-6 m. A long area is present. Grass and sedges dominated the marginal vegetation; the riparian zone was mostly indigenous, with cemeteries present further up the banks.

2.3 MAP OF THE STUDY AREA

Figure 2.1 is a map of the study area showing the sites selected for monitoring, DWAF gauging weirs present in the catchment, as well as land use, dams, towns and tributaries.

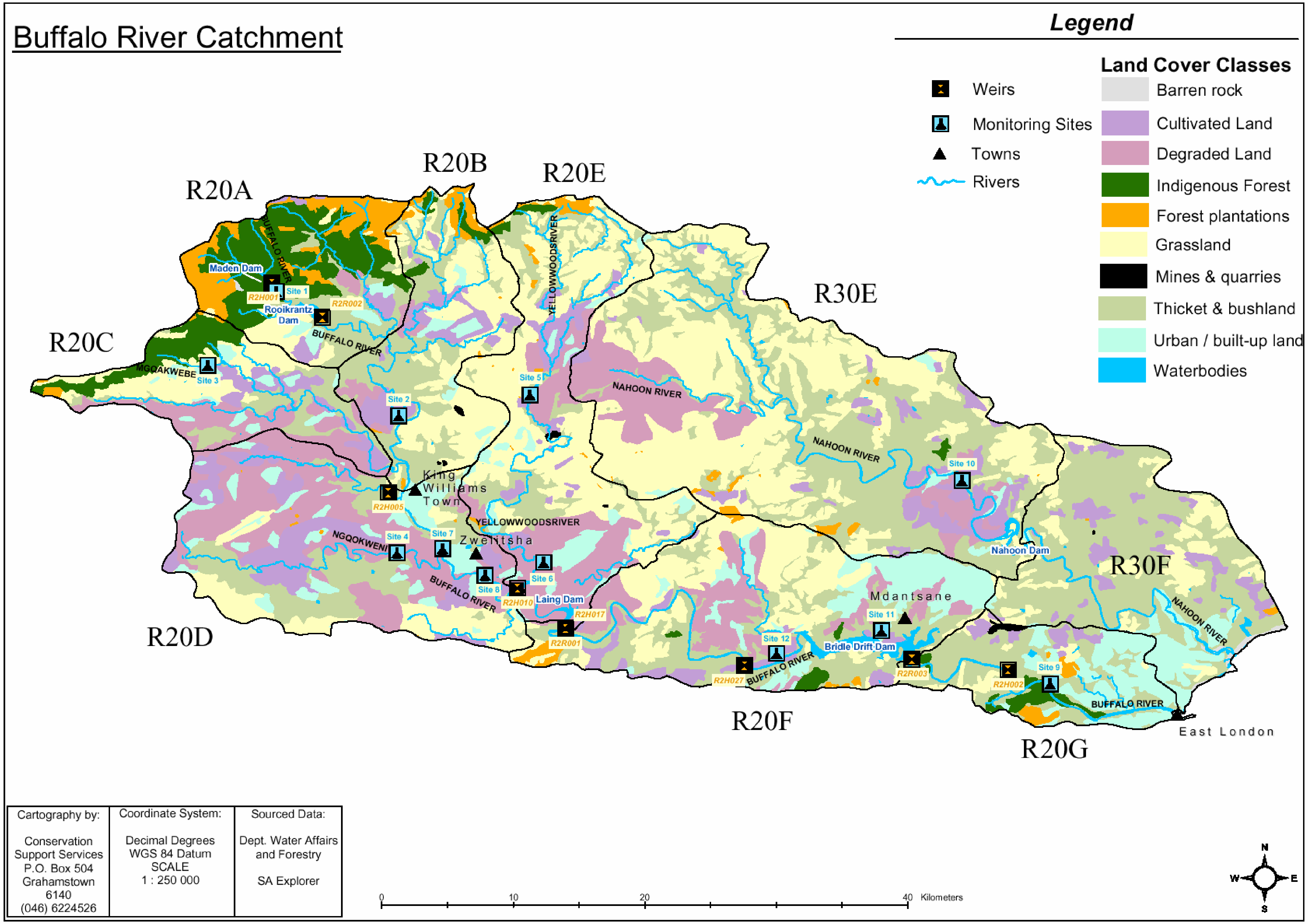

Figure 2.1 Map of the Buffalo River catchment.

CHAPTER 3

MACROINVERTEBRATES

3.1 INTRODUCTION

In-stream macroinvertebrates are known to respond to changes in their chemical and physical environment and they are commonly used to assess environmental water quality (Rosenberg and Resh, 1993). Although methods for using macroinvertebrates to assess environmental water quality are known world-wide, the early attempts to develop similar systems for South Africa yielded methods which were cumbersome and time consuming and, in addition, required detailed knowledge of taxonomy of the macroinvertebrates that inhabit local streams and rivers. In 1998, Chutter described a scoring system which was considered suitable for assessing water quality in South African rivers and streams and this method has been used successfully, particularly in River Health Programme initiatives. The method is largely based on the Biological Monitoring Working Party used in the United Kingdom and adjusted to suit South African fauna and conditions (Chutter, 1998). The South African Scoring System (SASS) has been through a number of iterations, including formal SASS Forum meetings, to optimise and standardise the method. Iterations of the SASS2, SASS3 and SASS4 methods involved reaching consensus regarding the sampling methods as well as taxa to be included in the schore sheet and their associated scores. The method has undergone extensive testing and its current iteration provides a more prescriptive method as well as adjusted sensitivity scores of some taxa and inclusion of more families whose sensitivity to water quality are known to vary significantly (Dickens and Graham, 2002).

SASS has become the standard accepted method for the rapid assessment of rivers (river water quality and river health) in South Africa and is currently in version 5 (Dickens and Graham, 2002). In the SASS method, invertebrate taxa are allocated a score between 1 (tolerant) and 15 (sensitive), depending on their known sensitivities. These scores are added to give a sample score (SASS score) and the number of taxa is used to calculate the Average Score Per Taxon (ASPT). The ASPT provides an indication of the average sensitivity of invertebrates to water quality at a particular site.

SASS is used optimally when there are a variety of biotopes available at a selected site, particularly when riffles (or rapids) are present (Dickens and Graham, 2002). It is, however, important to interpret SASS results in relation to habitat availability and quality as well as flow as these are known to significantly influence SASS results. Presence of aquatic invertebrates at particular sites is influenced by the availability of habitat, and the absence of certain habitats may substantially reduce the final SASS and ASPT scores. Tolerant organisms occur in almost all habitats and results from polluted sites tend therefore not to be influenced by the diversity of habitats present (Uys et al., 1996). It is therefore important that a habitat assessment was undertaken when doing a SASS survey. The habitat assessment method used in this study is the Integrated Habitat Assessment System (IHAS; McMillan, 1998) and is designed to assess the range of habitats which could potentially be used by in-stream macroinvertebrates, as well as more general stream characteristics and impacts (human or natural). This method is, however, still under development, and should be used with caution in association with SASS.

3.1.1 Overview of previous macroinvertebrate sampling

A number of studies have been conducted on macroinvertebrates of the Buffalo River. A list of selected major works are as follows:

- Adaptations to feeding strategies in blackflies: Dr Rob Palmer, Ph D study while at the Institute for Water Research (then Institute for Freshwater Studies), Rhodes University.
- The development of Functional Feeding Groups for macroinvertebrates of the Buffalo River: Prof Carolyn Palmer, Ph D study while at the Institute for Water Research (then Institute for Freshwater Studies), Rhodes University.
- A range of M Sc studies (e.g. Ms T Zokufa and Ms P Maseti) and Honours projects using macroinvertebrates from the Buffalo River.
- Research at the Albany Museum, Grahamstown, on a range of macroinvertebrates, particularly mayflies (Ms Helen Barber-James) and caddisflies (Dr Ferdi de Moor). The Albany Museum is also the national repository for macroinvertebrate collections, and records show the intensive sampling that has taken place in this catchment over the past years.

3.2 MATERIALS AND METHODS

Macroinvertebrates were sampled using SASS5 at each of the selected sites (see Chapter 2 for site information) during three seasons (spring, autumn and winter) over the period of one year (sampling commenced in October 2002). As the method is designed for low (or moderate) flow, the method could not be applied during the high flow season (summer) (Dickens and Graham, 2002). At each of the sites, all of the available biotopes were sampled and scored independently of each other. This allows comparison between biotopes and sites to be undertaken, and is especially important when not all biotopes are available for each of the sites.

The biotopes, as they are used on the SASS5 score sheet (Appendix 1, Figure 1), are defined according to Dickens and Graham (2002) as follows:

- Stones biotope: moveable stones, bedrock or any solid object both in and out of current (where current is defined as sufficient flow to prevent settling of fine silt) are sampled. Samples from both in and out of current are combined into a single sample. Stones are either kicked, or rubbed, to dislodge macroinvertebrates into the net. This biotope is sampled for approximately 2 to 5 minutes, taking care not to exceed 5 minutes as sampling effort may significantly affect the resultant score.
- Vegetation biotope: marginal vegetation hanging into or growing at the edge of the stream are sampled both in and out of current. A total length of 2 metres is sampled, ideally over more than one location and more than one vegetation type (if present). Aquatic vegetation (usually submerged or floating vegetation) can also be sampled, and is combined with the marginal vegetation to provide a single vegetation biotope score.
- Gravel, sand and mud biotope: a single sample is collected by sampling each of the gravel, sand and mud biotopes separately, both in and out of current. This biotope is sampled for no more than 1 minute.

Collecting protocols for SASS5 were defined by Dickens and Graham (2002) to ensure standardised collection and thereby allow comparison between sites and studies. The standardised collecting methods are used to sample each of the biotopes using a standard SASS net (mesh size 1000 µm, and a frame of 30 cm x 30 cm). Contents of the net are emptied into an identification tray and macroinvertebrates are identified to family level for no more than 15 minutes or 5 minutes since last having identified a new family. The identification protocol must be adhered to as identification time may significantly affect the resultant score. Families present in each of the biotopes, as well as their abundances, are recorded on the SASS sheet. There may be families (biota) present which are not listed on the SASS score sheet (e.g. frogs): these are recorded, but are not scored in the final assessment (although may aid the interpretation of results). Once all biotopes have been sampled and families identified, the total SASS score, the total number of taxa and the ASPT values are obtained and recorded on the SASS sheet. This is done per biotope and an overall site score is also obtained.

Water quality parameters (pH, temperature, dissolved oxygen and conductivity) are measured at the site at the time of sampling.

A habitat assessment is undertaken by recording information on the IHAS datasheet. (Appendix 1, Figure 2). Observations of the site (sampling habitat) and general stream condition are recorded to provide an overall site assessment. The total IHAS score is calculated and the score is also recorded on the SASS score sheet.

3.3 RESULTS

In the site selection phase, the Buffalo River catchment was divided into 3 sections i.e. upper, middle and lower reaches (see Chapter 2), each with both *reference sites* and *monitoring sites*. Sites were selected on the mainstem of the Buffalo River as well as on tributaries which were considered to have significant potential water quality impact on the Buffalo River. These are listed in Table 3.1. However, the first sampling survey revealed that the division of the Buffalo River into three reaches was not entirely appropriate and these will have to be reconsidered for future studies. The inadequacy of the reference sites identified in the desktop and site selection exercise was confirmed by the results of the macroinvertebrate survey.

Table 3.1 Sites assigned as either reference sites or monitoring sites for the Upper, Middle and Lower Reaches of the Buffalo River. Sites marked with an asterisk are on tributaries of the Buffalo River.

CATCHMENT REACH	REFERENCE SITES	MONITORING SITES
Upper	1, 3*	2
Middle	4*, 5*	6*, 7, 8
Lower	10*	9, 11*, 12*

SASS scores, total number of families and ASPTs are listed per site for samples taken during each of the sampling seasons in Table 3.2. IHAS scores have also been included in Table 3.2. The taxa recorded at each of the sites during each of the surveys is summarised in Appendix 1 (Table 1). A total site score as well as the individual biotope scores are provided, to allow comparisons between biotopes as well as sites. Table 3.2 shows seasonal differences within sites as well as differences between reference sites and monitoring sites for SASS and ASPT scores as well as IHAS scores.

Table 3.2 SASS scores, number of taxa and ASPT for each site for each of the sampling surveys. Empty cells denote that the biotope was not present for sampling. The IHAS sample score has been included in the table to allow for easier comparison.

	SPRING			AUTUMN			WINTER		
	SASS	No. Taxa	ASPT	SASS	No. Taxa	ASPT	SASS	No. Taxa	ASPT
SITE 1									
Stones	31	6	5.2	24	4	6	42	6	7
Vegetation				19	5	3.8			
Gravel, Sand, Mud				40	8	5	38	9	4.2
Total Site Score	31	6	5.2	73	15	4.9	71	13	5.5
IHAS	45			70			52		
SITE 2									
Stones	120	19	6.3	94	14	6.7	98	17	5.8
Vegetation	95	16	5.9	44	7	6.3	77	13	5.9
Gravel, Sand, Mud							84	14	6
Total Site Score	154	27	5.7	101	16	6.3	146	26	5.6
IHAS	61			50			62		
SITE 3									
Stones	158	22	7.2	134	19	7.1	92	13	7.1
Vegetation	77	12	6.4	84	17	4.9	66	12	5.5
Gravel, Sand, Mud	74	10	7.4	86	14	6.1	9	3	3
Total Site Score	188	26	7.2	181	30	6.0	119	19	6.3
IHAS	80			71			72		
SITE 4									
Stones	63	10	6.3	54	10	5.4	71	12	5.9
Vegetation	61	11	5.6	28	7	4	50	10	5
Gravel, Sand, Mud	53	11	4.8	34	9	3.8	28	7	4
Total Site Score	120	20	6	77	17	4.5	97	18	5.4
IHAS	68			64			70		
SITE 5									
Stones	71	13	5.5	81	16	5.1	74	15	4.9
Vegetation	73	13	5.6	80	18	4.4	79	15	5.3
Gravel, Sand, Mud	53	10	5.3	44	10	4.4	34	8	4.3
Total Site Score	116	21	5.5	127	26	4.9	114	23	5
IHAS	73			75			56		

	SPRING			AUTUMN			WINTER		
	SASS	No. Taxa	ASPT	SASS	No. Taxa	ASPT	SASS	No. Taxa	ASPT
SITE 6									
Stones	59	12	4.9	74	13	5.7	55	10	5.5
Vegetation	60	11	5.5	41	9	4.6	36	8	4.5
Gravel, Sand, Mud	23	6	3.8	39	9	4.3	44	10	4.4
Total Site Score	99	18	5.5	97	18	5.4	84	18	4.7
IHAS	58			63			67		
SITE 7									
Stones	64	14	4.6	13	5	2.6	15	5	3
Vegetation	43	9	4.8	36	9	4	13	5	2.6
Gravel, Sand, Mud	28	8	3.5	33	9	3.7	10	3	3.3
Total Site Score	78	17	4.6	47	12	3.9	16	6	2.7
IHAS	67			62			60		
SITE 8									
Stones	64	13	4.9	49	11	4.5	26	7	3.7
Vegetation	44	10	4.4	35	9	3.9	29	8	3.6
Gravel, Sand, Mud	38	10	3.8						
Total Site Score	69	16	4.4	57	13	4.4	46	12	3.8
IHAS	63			64			51		
SITE 9									
Stones	104	17	6.1	86	15	5.7	61	8	7.6
Vegetation	51	11	4.6	62	12	5.2	101	16	6.3
Gravel, Sand, Mud	61	10	6.1				45	7	6.4
Total Site Score	140	24	5.8	120	21	5.7	141	20	7.1
IHAS	70			58			71		
SITE 10									
Stones	38	9	4.2	52	11	4.7	65	12	5.4
Vegetation	34	8	4.3				54	12	4.5
Gravel, Sand, Mud	20	5	4	37	9	4.1	39	10	3.9
Total Site Score	52	13	4	66	14	4.7	90	19	4.7
IHAS	77			43			60		
SITE 11									
Stones	38	9	4.2	33	9	3.7	15	5	3
Vegetation	22	7	3.1	47	10	4.7	12	4	3
Gravel, Sand, Mud	20	6	3.3	41	8	5.1	7	3	2.3
Total Site	64	14	4.6	83	17	4.9	15	5	3

	SPRING			**AUTUMN**			**WINTER**		
	SASS	**No. Taxa**	**ASPT**	**SASS**	**No. Taxa**	**ASPT**	**SASS**	**No. Taxa**	**ASPT**
Score									
IHAS	62			60			65		
SITE 12									
Stones	54	12	4.5	71	13	5.5	54	12	4.5
Vegetation	82	16	5.1	31	7	4.4	61	14	4.6
Gravel, Sand, Mud	21	5	4.2				50	11	4.6
Total Site Score	110	24	4.6	94	18	5.2	100	21	4.8
IHAS	68			52			62		

Site 1, a reference site in the upper reaches of the Buffalo River, showed some of the lowest IHAS scores, and this reduced habitat quality is also reflected in the reduced SASS (low diversity) and ASPT (tolerant organisms) scores and is therefore not considered further in this assessment. Site 3, also a reference site, had high IHAS scores, as well as the highest SASS and ASPT scores for the upper reaches of the Buffalo River catchment. Site 2, a monitoring site for the upper catchment, revealed lowered scores, which may be a result of a combination of poor habitat conditions (absent biotopes) and impaired water quality. Although some of the SASS scores were high, overall the ASPT scores were low, suggesting the presence of many but tolerant organisms.

Reference sites for the middle reaches (Sites 4 and 5) were also on tributaries of the Buffalo River, as no other suitable reference sites could be identified. IHAS scores at these sites were higher than for the monitoring sites (Sites 6, 7 and 8) and this, alongside better water quality, could account for the higher SASS and ASPT scores at the reference sites when compared to the monitoring sites. The Yellowwoods River tributary (Sites 5 and 6) showed a reduction in both macroinvertebrate diversity and sensitivity from upstream to downstream sites, and this is likely to be a result of a combination of reduced water quality as well as reduced habitat scores (there is a large settlement immediately upstream of Site 6). Sites 7 and 8, downstream of King Williams Town and Zwelitsha respectively, revealed low diversity of tolerant organisms when compared to either of the reference sites. Although these sites also had reduced IHAS scores when compared to the reference sites, impaired water quality is likely to exacerbate the reduced macroinvertebrate diversity.

The reference site for the lower reaches of the Buffalo River was shown to be inappropriate as a reference site (Site 10). Reduced scores (IHAS, SASS and ASPT) suggest that while the site was upstream of obvious sources of impact which could affect macroinvertebrate diversity, clearly there was an impact affecting biotope scores as well as in-stream diversity and sensitivity. Site 9, the most downstream monitoring point on the Buffalo River showed high IHAS scores as well as high macroinvertebrate diversity with reasonably sensitive organisms (the highest ASPT recorded in this study was at this site). This site is a considerable distance downstream of sources of impact (settlements, dams etc.) and there may have been sufficient downstream recovery to yield the high diversity of reasonably sensitive organisms. Sites 11 and 12 confirmed that these streams are contributing impaired water quality to the Buffalo River: although their habitat scores were within the expected range (compared to other sites in the study) the ASPT scores showed that the macroinvertebrates were mostly tolerant (low ASPT scores).

Results for water quality parameters measured during the biomonitoring surveys are reported in Table 3.3. Measurements recorded during the biomonitoring surveys for conductivity and pH were within the ranges recorded at these sites (see Chapter 7). Seasonal changes in conductivity can be seen at half of the sites, and these can be ascribed to reduced flows during winter months. This same pattern is not evident at those sites receiving water from the transfer scheme (Site 5 on the Yellowwoods River), as well as those sites which appear to be dominated by input from Sewage Treatment Works and run-off from urban areas and rural settlements (Sites 6, 7, 8, 11 and 12). Conductivity measurements at Site 10 (Nahoon River site) were higher than those at Sites 2 and 9, supporting the idea that this site is not appropriate as a reference site for the Buffalo River (this site also had lower SASS and ASPT scores).

3.4 DISCUSSION AND CONCLUSION

Seasonal differences are expected, related to reduced temperature (affecting macroinvertebrate diversity) and likely reduced flow (this is a summer rainfall area). Generally, the highest SASS scores were found in spring, associated with greatest macroinvertebrate diversity. The lowest SASS scores were in winter, which is to be expected with reduced water temperature and lower flow. The exception to this pattern was Site 10, and there is no obvious explanation for the increased scores. This same pattern was not as discernable for the ASPT scores, confirming the suggestion that ASPT is less affected by habitat than the SASS score (Chutter, 1998).

The stones biotope tended to have the highest SASS scores, supporting the importance of this biotope for macroinvertebrate biomonitoring surveys. Generally, the ASPT scores of the stones biotope were also higher than for the vegetation biotopes suggesting that not only is this biotope important for macroinvertebrate diversity, but that this is also where the more sensitive organisms can be found.

Based on the surveys undertaken for this study, Site 1 is not considered an appropriate reference site for the Buffalo River catchment. Although the site is in a protected area (indigenous forest) poor habitat scores and possible impaired water quality at this site result in reduced macroinvertebrate diversity and resultant SASS and ASPT scores. Site 3, although on a small tributary of the Buffalo River, may be a more appropriate reference site, although it may occasionally have significantly reduced flows (even no flows) - a combination of its size and the fact that there is a cattle drinking point immediately upstream of the site. However, it appears that while Site 2 has a lowered IHAS score, macroinvertebrates found at this site are reasonably sensitive (ASPT scores higher than 5.6), and this site may be appropriate as a reference site for the lower reaches of the Buffalo River catchment. Similarly, Site 10 is not considered an appropriate reference site (reduced SASS and ASPT scores when compared to Buffalo River sites, and increased conductivity levels) and should be omitted from future biomonitoring of the Buffalo River catchment.

The Yellowwoods River was included in this study as it is considered a major tributary of the Buffalo River, and this study shows the impaired nature of this contribution to the Buffalo River (it also receives transfer water from Wriggleswade Dam). However, the river discharges into Laing Dam and it is not clear how significant the effect of the reduced water quality is on the Buffalo River or Laing Dam (assessments of dams were excluded from this study as assessments were restricted to flowing water environments). In order to streamline future biomonitoring surveys, it may be possible to omit surveys on this tributary, focussing on the

Table 3.3 Measurements of water quality parameters measured during biomonitoring surveys (S: spring; A: autumn; W: winter) (EC: electrical conductivity, mS/m; Temp: water temperature, °C; DO: dissolved oxygen, recorded as mg/ℓ unless stated as % saturation) (blank cells indicate that no measurements were made).

SITE	**1**			**2**			**3**			**4**			**5**			**6**		
Season	**S**	**A**	**W**	**S**	**A**	**W**	**S**	**A**	**W**	**S**	**A**	**W**	**S**	**A**	**W**	**S**	**A**	**W**
EC	8.1	7.5	12	52	40	107	93	98	161	116	143	153	103	59	57		167	234
pH	6.5	7.5	7.5	7.5	7.5	8.3	6.8	7.9	7.6	8.1	8.4	8.9	7.8	7.5	8.7		8.2	8.4
Temp	15	18	10	22	22	16	16	19	11	28	23	14	21	18	17		20	19
DO	115%	8.02	11.1	105%	6.5	6.9		7.5	7.4	114%	8.5	10.8	122	6.04	12.9		7.5	11.2
Site	**7**			**8**			**9**			**10**			**11**			**12**		
Season	**S**	**A**	**W**	**S**	**A**	**W**	**S**	**A**	**W**	**S**	**A**	**W**	**S**	**A**	**W**	**S**	**A**	**W**
EC	81	58	79	89	68	79	46	53	48	135	173	291	93	82	68	124	91	62
pH	7.4	7.4	7.8	8.3	7.4	8.3	7.1	7.9	8.3	7.4	8.1	8.2	6.7	7.8	7.5	7.5	8.7	9.4
Temp	22	22	16	23	22	15	19	24	16	22	26	17	20	22	13	22	28	13
DO	68%	4.7	8.2	114%	4.3	11	90%	7.6	10.3	86%	8.7	10	86%	6.7	7.5	104%	9.8	7.8

mainstem of the Buffalo River, unless there is a change in the operation of the transfer scheme to the Yellowwoods River.

As the ASPT scores are the most likely to yield consistent results, an average ASPT score was calculated per site and compared to the default benchmark boundary values provided in the current water quality Ecological Water Requirements (Rivers) method (Palmer et al., in prep) (Table 3.4). The mean ASPT values and the resultant site assessments are found in Table 3.5. These overall class assessments support the results of the findings presented in this report.

Table 3.4 The default benchmark category boundaries for the biotic index (SASS).

CLASS BOUNDARY	RANGE OF ASPT SCORES
Natural	7
Good	6
Fair	5
Poor	<5

Table 3.5 Mean ASPT scores per site and overall site assessment for macroinvertebrate sensitivity for the Buffalo River catchment.

SITE	MEAN ASPT	OVERALL SITE ASSESSMENT
1	5.2	Fair
2	5.9	Fair / Good
3	6.5	Good
4	5.3	Fair
5	5.1	Fair
6	5.2	Fair
7	3.7	Poor
8	4.2	Poor
9	6.2	Good
10	4.5	Poor
11	4.2	Poor
12	4.9	Poor

It is recommended that SASS sampling be conducted in the Buffalo River catchment at a sampling frequency of twice per year, preferably during spring and winter. Although Site 1 (Buffalo River above Maden Dam) was not an appropriate reference site for the upper reaches, it is recommended that sampling continue at this site, so as to determine the cause of low scores evident during these surveys.

CHAPTER 4

ASSESSMENT OF FISH ASSEMBLAGE INTEGRITY OF THE BUFFALO RIVER

4.1 INTRODUCTION

The Buffalo River has been considerably modified by the construction of large dams at frequent intervals along its short 100 km length (Jackson, 1982). Fish were not of primary consideration during the planning and construction of these major mainstream dams and consequently they have impacted the natural movements of, and availability of habitats for fish in the Buffalo River (Jackson, 1982). Furthermore, the Pirie trout hatchery was built in the 1950's on the upper Buffalo River and resulted in the introduction and establishment of trout in the upper Buffalo River system. The resultant predation on native species by these introduced trout has been reported by a number of authors (Anon, 1953 and Place, 1955 as cited in Jackson, 1982).

The integrity of native fish assemblages within a river has been one of the selected biological indicator groups (along with aquatic invertebrates and riparian vegetation) identified as being suitably representative of the integrity of larger aquatic ecosystems. Indices have been developed to measure the integrity of these indicator groups. The Fish Assemblage Integrity Index (FAII) aims to use readily available and measurable fish assemblage attributes that are responsive to human-induced environmental changes (Kleynhans, 1999). The emphasis of the FAII is on fish assemblage "integrity", which represents a comparison with near-natural conditions, rather than "health" which represents a condition desired by humans but not necessarily natural (Karr, 1996 as cited in Kleynhans, 1999). Objectives of the FAII are discussed in Kleynhans (1999) and briefly outlined below:

- The index must provide information to inform the South African public of the state of the nation's rivers on a regular basis.
- It must be usable within the limits of the available information, labour, expertise and financial resources.
- It should provide information against which the appropriateness of specified ecological requirements (for the Ecological Reserve) can be assessed.
- The index should be flexible enough to be useful in all the ecoregions of South Africa. The fundamental structure of the index should be generic and should allow for modification and adaptation for specific environmental conditions.
- The index should be developed so that provision is made for different levels of monitoring intensity.

4.2 MATERIALS AND METHODS

4.2.1 Study sites and sampling regime

Sampling was conducted in all available habitats up- and/or downstream of the sites identified for biomonitoring (see Chapter 2). Kleynhans (1999) recommends at least two sites per fish habitat segment should be sampled, however, due to limited time available for each field trip, sampling was only conducted at one site per fish habitat segment (for an explanation of fish habitat segments see Section 4.2.3.). Sites 1-5 were considered to be within the upper catchment, and Sites 6-12 within the lower catchment (Table 4.1). Sampling was conducted on three occasions: 21-24 October 2002, 7-10 April 2003 and 23-27 August 2003, and the data combined for analysis. Fish sampled were placed directly into 10% formalin solution for preservation during transport. On completion of each sampling occasion fish were transported to the South African Institute for Aquatic Biodiversity (SAIAB) and identification to species confirmed by Roger Bills of SAIAB. Fish specimens were then transferred to 60% propanol for storage in the SAIAB fish collection.

Table 4.1 Sites sampled during the Buffalo River biomonitoring surveys.

SITE NUMBER	DESCRIPTION OF LOCATION
1	Buffalo River above Maden Dam
2	Buffalo River at Horseshoe Bend
3	Maqakwebe tributary
4	Ngqokweni tributary
5	Yellowwoods River at Leonsdale bridge
6	Yellowwoods River 2
7	Buffalo River below King Williams Town, and above Zwelitsha
8	Buffalo River below Zwelitsha
9	Buffalo River at Buffalo Pass
10	Nahoon River upstream of Nahoon Dam
11	Shangani Stream draining Mdantsane
12	KwaNxamkwane Stream draining Potsdam

4.2.2 Equipment

Sampling was undertaken with an electrofisher (DEKA 3000) and a seine net (length 5m, depth 1.5m, mesh size 0.5cm). The seine net could not always be used due to the presence of cobbles, boulders and dead wood in the riverbed. Water quality parameters were measured with a WTW OXI 330i/SET Dissolved Oxygen Meter, a Cyberscan 200 Conductivity Meter and a Cyberscan 20 pH Meter. Water quality results are presented in Chapter 3.

4.2.3 Data analysis

The FAII is the recognised method for assessing the fish assemblage integrity for the River Health Programme and has undergone considerable revision as the programme has developed. Due to certain limitations of this index and the sampling protocol used in this assessment, three methods of data analysis were used and compared. The problems associated with each methods are discussed in Section 4.4.

Fish Assemblage Integrity Index

The FAII was used according to methods outlined in Kleynhans (1999). Briefly; the river is divided into segments or “fish habitat segments”. These are defined as stretches of river in which the fish community would be expected to remain generally homogenous due to the relative uniform nature of the physical habitat (Ramm, 1988). The FAII consists of the calculation (explained in detail in Kleyhans, 1999) of an expected and observed value for each segment. The expected value serves as a baseline or reference for each fish habitat segment, against which the observed value is compared. Consequently a reference biological condition for each segment can be established according to the following three attributes:

- The indigenous fishes expected to occur in the segment;
- their frequency of occurrence; and
- general health and well-being (parasite infestation is noted but not used in the assessment due to the lack of correlation between parasite burden and environmental health (Simon and Lyons, 1995 as cited in Kleynhans, 1999)).

Sampling at each site is conducted in four fish velocity-depth classes (if available): slow deep; slow shallow; fast deep; fast shallow. Fish caught are identified to species, with the number of juveniles and the presence of abnormalities recorded. Flow conditions, water quality, habitat cover, instream use and surrounding land use, and the estimated impact of modifications are recorded for each site (see Appendix 2.1 for a copy of a FAII sampling sheet).

As only one site per fish habitat segment was sampled, the frequency of occurrence could not be calculated. Fish were therefore recorded as being present or absent at only one site within a fish habitat segment, which is not considered suitably representative of the entire fish habitat segment. The integrity of the indigenous fish assemblages in the Buffalo River at each site was therefore only assessed according to two of the three attributes.

A comparison of the expected and observed score produces a relative FAII score, which is interpreted as a FAII assessment category A, B, C, D, E or F using the table in Appendix 2.2 (adapted from Kleyhans, 1999). This table also provides the method used for converting FAII assessment categories A-F to the RHP classes of Natural, Good, Fair or Poor.

The FAII is, however, not considered suitable for the assessment of streams with naturally low fish species richness. Kleynhans (1999) states that a natural fish species richness of less than five is probably not amenable to assessment with the FAII. Consequently, a Qualitative Fish Assemblage Assessment (QFAA) and a Decision Support Tree were also used in order to provide an alternative perspective of fish integrity at each site.

Qualitative Fish Assemblage Assessment
The QFAA was developed by Neels Kleynhans of Resource Quality Services (RQS, DWAF) for the Thukela Reserve study (2001-2004). It is a qualitative assessment of fish assemblage integrity based on seven determinants (Appendix 2.3):

- Native/indigenous species richness;
- presence of native intolerant species;
- abundance of native species;
- native species frequency of occurrence;
- health/condition of native and introduced species; and
- instream habitat modification.

Each site is rated as a score of between 0-5 for each determinant. An equation using the ratings for each determinant generates a score which is then used to assign a Fish Assessment Category (A-F) for each site. This method is set up as an Excel spreadsheet and was obtained from Dr Kleynhans (Appendix 2.3).

The QFAA was adapted to the assessment of the Buffalo River by removing two determinants: native species frequency of occurrence was removed because only one site per fish habitat segment was sampled; and health condition of native and introduced species was removed due to the low correlation between perceived abnormalities and disease. Unless careful evaluation of fish tissue is undertaken (not suitable for a rapid assessment), correlations are low. Within each of the remaining determinants a score was chosen based on rules assigned specifically for the Buffalo River assessment (Appendix 2.4).

Like the FAII, the QFAA produce categories A-F for rating fish assemblage integrity. Appendix 2.2 gives an explanation of the method used to convert QFAA categories A-F to RHP classes Natural-Poor.

Decision Support Tree
As the suitability of the FAII in river systems with low native species diversity is questionable (and the Buffalo River, it could be debated, is such a system), and as the QFAA is primarily descriptive assessment, it was decided to use a Decision Support Tree (Appendix 2.5) to provide an alternative process for the assessment of River Health class for each site. This Decision Support Tree is adapted from the one used in the RHP study conducted on the Hartenbos and Klein Brak River systems (River Health Programme, 2003) (pers. com., Dean Impson, Cape Nature Conservation).

4.3 RESULTS

The Buffalo River has not been extensively sampled for fish, however there are records of fish species from smaller sampling expeditions within this system (Table 4.2). In addition, a report by Jackson (1982) lists all fish known to occur in the Buffalo River at the time (Table 4.2). Thirteen indigenous and 10 alien species have been recorded from the Buffalo River system. Amoung the indigenous fishes recorded are the critically endangered Border Barb (*Barbus trevelyani*) and the endangered Eastern Cape Rocky (*Sandelia bainsii*) (Table 4.2).

At the conclusion of the RHP sampling surveys, 11 species of indigenous fishes and six species of alien fishes were recorded (Table 4.3). The critically endangered Border Barb (*Barbus trevelyani*) was recorded, but only at Site 3 on the Mgqakwebe Stream. The endangered Eastern Cape Rocky (*Sandelia bainsii*) was not recorded. Two new species were added to the list of known fishes in the Buffalo River; the indigenous Goldie Barb (*Barbus pallidus*) sampled at Site 8 only and the introduced Sharptooth Catfish (*Clarias gariepinus*) (Table 4.3). Of the species previously recorded in the Buffalo River but not sampled during current RHP expeditions was the indigenous fishes *Gilchristella aestuaria* (Estuarine Round-Herring), and introduced fishes *Micropterus dolomieu* (Smallmouth Bass), *Micropterus salmoides* (Largemouth Bass), *Oncorhynchus mykiss* (Rainbow Trout) and *Salmo trutta* (Brown Trout).

Table 4.2 Fish species previously recorded in the Buffalo River.

SPECIES NAME	COMMON NAME	LOCATION: UPPER AND/OR LOWER REACHES	INDIGENOUS (I) OR ALIEN (A) *
Anguilla marmorata	Giant Spotted Eel [2]	both	I
Anguilla mossambica	Longfin Eel [1, 2]	both	I
Awaous aeneofuscus	Freshwater Goby [2]	both	I
Barbus anoplus	Chubbyhead Barb [1, 2]	both	I
Barbus trevelyani #	Border Barb [1, 2]	upper	I
Clarias gariepinus	Sharptooth Catfish [1]	both	A
Cyprinus carpio	Carp [1, 2]	both	A
Gilchristella aestuaria	Estuarine Round-Herring [1, 2]	lower	I
Glossogobius callidus	River Goby [1]	both	I
Labeo umbratus	Moggel [1, 2]	lower	A
Lepomis macrochirus	Bluegill Sunfish [1, 2]	both	A
Micropterus dolomieu	Smallmouth Bass [2]	lower	A
Micropterus punctulatus	Spotted Bass [1]	both	A
Micropterus salmoides	Largemouth Bass [2]	lower	A
Monodactylus falciformis	Oval Moony [2]	lower	I
Mugil cephalus	Flathead Mullet [2]	lower	I
Myxus capensis	Freshwater Mullet [1, 2]	lower	I
Oncorhynchus mykiss	Rainbow Trout [2]	upper	A
Oreochromis mossambicus	Mozambique Tilapia [1, 2]	lower	I
Tilapia sparrmanii	Banded Tilapia [1, 2]	both	A
Salmo trutta	Brown Trout [1, 2]	upper	A
Sandelia bainsii †	Eastern Cape Rocky [1, 2]	upper	I

Source: [1] The South African Institute for Aquatic Biodiversity database of previous Buffalo River System fish collections (pers. com., Sally Terry, SAIAB)
[2] Jackson (1982)

Notes: # Conservation status = critically endangered (Skelton, 2001)
† Conservation status = endangered (Skelton, 2001)
* The term "alien" indicates species introduced to this catchment through anthropogenic activities

Table 4.3 Fish species recorded in Buffalo River system during River Health Programme sampling 2002-2003.

SPECIES NAME	COMMON NAME	SITE (UPPER OR/AND LOWER CATCHMENT)	INDIGENOUS (I) OR ALIEN (A) *	JUVENILES SAMPLED (SITE)
Anguilla mossambica	Longfin Eel	9,10 (lower)	I	yes (10)
Anguilla marmorata	Giant Mottled Eel	9 (lower)	I	no
Awaous aeneofuscus	Freshwater Goby	9 (lower)	I	no
Barbus anoplus	Chubbyhead Barb	1,2,3,4,5,6,11, 12 (both)	I	yes (1,2,3,4,5,6)
Barbus pallidus	Goldie Barb	8 (lower)	I	no
Barbus trevelyani #	Border Barb	3 (upper)	I	yes (3)
Clarias gariepinus	Sharptooth Catfish	6,7 (lower)	A	yes (6,7)
Cyprinus carpio	Carp	7,8,10 (lower)	A	yes (7,8,10)
Glossogobius callidus	River Goby	9,10,11,12 (lower)	I	yes (12)
Labeo umbratus	Moggel	1,2,4,7,8,10 (both)	A	yes (1,2,4,7,8)
Lepomis macrochirus	Bluegill Sunfish	10 (lower)	A	yes (10)
Micropterus punctulatus	Spotted Bass	10 (lower)	A	yes (10)
Monodacty-lus falciform-is	Oval Moony	9 (lower)	I	yes (9)
Mugil cephalus	Flathead Mullet	9 (lower)	I	yes (9)
Myxus capensis	Freshwater Mullet	9 (lower)	I	yes (9)
Oreochromis mossambicus	Mozambique Tilapia	9,11,12 (lower)	I	yes (9,11,12)
Tilapia sparrmanii	Banded Tilapia	1,2,4,7,8,9,11, 12 (both)	A	yes (1,2,4,7,8,9,11 , 12)

Notes: # Conservation status = critically endangered (Skelton, 2001)
* The term "alien" indicates species introduced to this catchment through anthropogenic activities

Despite parasite infestation not being used in the FAII assessment due to the lack of correlation between parasite burden and environmental health (Simon and Lyons, 1995), it is suggested that in the course of conducting the FAII such infestations are noted (Kleynhans, 1999). Two indigenous species: the Chubbyhead Barb (*Barbus anoplus*) and the Border Barb (*Barbus trevelyani*) were recorded with parasitic infestation (small black cysts randomly positioned on the body). A greater proportion of the Chubbyhead Barbs sampled from the upper reaches were affected by cysts compared to sites from the lower reaches (Table 4.4). Two alien species, the Moggel (*Labeo umbratus*) and the Banded Tilapia (*Tilapia sparrmanii*) also possessed cysts, suggesting parasitic infestation. In the case of the Banded Tilapia, a greater proportion sampled from the upper reaches were affected by cysts when compared to sites from the lower reaches (Table 4.4).

Table 4.4 Percentage of the fish sampled with parasitic infestation.

SPECIES	SITE (N = NUMBER FISH SAMPLED)	% WITH INFESTATION
Indigenous species		
Barbus anoplus	1 (n = 36)	63
	2 (n = 6)	100
	3 (n =17)	0
	4 (n = 57)	46
	5 (n =117)	59
	6 (n = 55)	2.5
	11 (n = 1)	0
	12 (n = 2)	0
Barbus trevelyani	3 (n = 20)	15
Alien species		
Labeo umbratus	1 (n = 1)	0
	2 (n = 12)	83
	4 (n = 14)	36
	7 (n = 11)	27
	8 (n = 18)	28
	10 (n = 11)	0
Tilapia sparmanii	1 (n = 3)	3
	2 (n = 7)	43
	4 (n = 51)	22
	7 (n = 18)	0
	8 (n = 1)	0
	9 (n = 2)	0
	11 (n = 2)	0
	12 (n = 6)	0

Table 4.5 shows the results of all three assessment methods, with an overall recommended RHP class for each site.

Table 4.5 Resultant fish assemblage class ratings for each site for the various assessment methods, and overall recommended class.

ASSESSMENT METHOD	SITES 1	2	3	4	5	6	7	8	9	10	11	12
FAII result (%)	15	15	33	15	15	9	0	11	71	18	22	17
FAII assemblage category	F	F	E	F	F	F	F	F	C	F	E	F
Corresponding RHP class	Poor	Poor	Poor	Poor	Poor	Poor	Poor	Poor	Good	Poor	Poor	Poor
QFAA result (%)	52	36	72	52	56	40	12	32	72	32	40	56
QFAA assemblage category	D	E	C	D	D	D	F	E	C	E	D	D
Corresponding RHP class	Fair	Poor	Good	Fair	Fair	Fair	Poor	Poor	Good	Poor	Fair	Fair
Decision tree	Fair	Poor	Good	Fair	Good	Fair	Poor	Poor	Fair	Poor	Poor	Fair
Recommended RHP class for each site *	**Fair to Poor**	**Poor**	**Fair to Good**	**Fair to Poor**	**Fair**	**Fair to Poor**	**Poor**	**Poor**	**Good**	**Poor**	**Poor to Fair**	**Fair to Poor**

Notes: * Determined by taking into account the results of the three assessment methods and perceptions gained from sampling each of the sites.

The FAII assessment classed the integrity of fish assemblages at all sites as Poor, except for Site 9 which was classed Good (Table 4.5). The QFAA assessment classed Sites 2, 7, 8 and 10 as Poor; Sites 1, 4, 5, 6, 11 and 12 as Fair; and Sites 3 and 9 Good. The Decision Tree by comparison classed Sites 7, 8, 10 and 11 as Poor; Sites 1, 4, 6, 9 and 12 as Fair; and Sites 3, and 5 Good (Table 4.5). Generally the FAII was the most conservative, producing the most number of low classes, followed by the QFAA and then the Decision Tree. After considering the three methods and relying on perceptions obtained when sampling each site, the following fish assemblage integrity classes for each site were recommended: Sites 2, 7, 8 and 10 were classed as Poor; Site 11 as Poor to Fair; Sites 1, 4, 6 and 12 were classed Fair to Poor; Site 3 as Fair to Good; and Site 9 as Good (Table 4.5).

4.4 DISCUSSION AND RECOMMENDATIONS

The FAII tends to under-estimate the fish assemblage integrity of a site (Kleynhans, 1999). This can be attributed to the use of historical data to compile a list of expected species. As historical data is often insufficient to compile the expected species list for each individual site, expert knowledge is relied upon to identify all species that could possibly have occurred there. This has the potential to result in a greater number of species being added to the expected list than is realistic. The greater the number of species in the expected list not sampled during the RHP, the lower the relative FAII score will be. Furthermore, the expected species list is based on historical presence in all habitat types at a site, and due to time, labour and equipment limitations, not all habitats are adequately sampled (Kleynhans, 1999). A further limitation of the FAII is omission of alien species, which are not considered in the calculation of the index, but are known to have severe impacts on the composition of native fish assemblages.

In contrast, the Decision Tree and QFAA do not take into account the absence of native species at a site, but assess the present assemblage attributes with no comparison to historical or reference conditions. In addition, although they take into account the presence of alien species they favour sites where no alien fishes are encountered. Consequently, they tend to overestimate the integrity of the fish assemblage at a site.

The list of fish species present in the Buffalo River indicates the extent to which alien species occupy nearly every site sampled. The predacious nature of these introduced alien species and their ability to out-compete indigenous species for habitat space and food (Skelton, 2001) suggests that the remaining indigenous fishes within the Buffalo River system are severely threatened. The fish assemblage integrity classes produced by all three assessment methods at Sites 1, 2, 4 and 10 appear to primarily reflect this dominance by alien fishes, and to a lesser extent the dams downstream. All these sites, despite being influenced very little by industrial activities or human settlements, were classed either Poor or Fair. Only at Sites 3 and 5 were no alien fishes sampled. As there were indications of good recruitment and no evidence of health problems, the QFAA and Decision Tree classed these sites Good to Fair. In contrast, as only two of the six expected indigenous fishes were sampled at Site 3 and one of the six at Site 5, the FAII classed both sites Poor.

The impact of industrial activities and informal settlements on indigenous fish assemblages can be clearly seen at Sites 7 and 8, and to a lesser extent at Sites 6, 11 and 12. Destruction of habitat and very poor water quality at Sites 7 and 8 resulted in them being classed as Poor by all three of the assessment tools used. Sites 6, 11 and 12 were classed as Poor by the FAII as only one, three and two of the eleven expected indigenous species were sampled at each site respectively. Being less influenced by loss of expected indigenous species, the QFAA classed all three sites as Fair, and the Decision Tree Sites 6 and 12 Fair, and Site 11 Poor.

The self-cleansing nature of rivers and importance of protecting the natural ecosystem functioning is evident when comparing the assemblage integrity classes of Sites 7, 8, 12 and 11 with that of Site 9. Site 9 is downstream of these four sites and thus should receive the same poor quality water. However, for a number of kilometres upstream of Site 9, the river runs through an unimpacted nature conservation area, where access is very limited and thus anthropogenic impacts low. Within this relatively short distance, the FAII fish integrity class changes from Poor at Site 11 to Good at Site 9.

Using the results from the three methods a recommended River Health Class was assigned to each site (Table 4.5) and should be used for future reference as they take into account the limitations of each method and include the professional judgement of the specialists undertaking the field studies.

4.4.1 Problems experienced during the Buffalo River FAII assessment

In conducting this RHP assessment of the Buffalo River a number of issues and problems regarding the FAII assessment method were encountered, suggesting it does not satisfy the objectives (briefly mentioned in Section 4.1) for which it was designed:

- **Historical data:** It was not usable within the limits of available information. Most river systems in South Africa have not been adequately sampled in the past and thus the historical data needed to determine expected indigenous species for each fish habitat segment is inadequate or often non-existent, seriously affecting confidence in this method's results.
- **Accessibility of information**: Access to data sheets and documents needed for calculations (e.g. fish intolerance ratings) is limited or difficult to obtain. It is recommended that these documents be made available through the RHP web page, in much the same way as those for SASS5.
- **FAII methods**: The FAII lacks a clear and easily understandable set of instructions for selecting monitoring sites and implementing the sampling procedure. Instructions in Kleynhans (1999) were considered difficult to understand to many of the technicians and researchers (both from DWAF and academic institutions) involved in the Buffalo River RHP. This reduced the effectiveness of sampling and confidence in results. A step-by-step guide for the practical implementation of the FAII, which is clear and can easily be followed by people new to the project, needs to be developed. This will ensure that the methods are standardised as far as possible, and that all the data required for the correct calculation of the index are collected during the field surveys. These methods should be readily available and conferred to all people currently involved in RHP projects.
- **Continuity of staff:** During the study there was a change in staff responsible for undertaking the FAII component of the Buffalo River RHP. There were therefore difficulties in the practical implementation of the methods and lack of continuity as different individuals had different interpretations of the FAII requirements leading to inadequate field sampling. Unless rectified this will result in problems in future surveys. This further highlights the need for a clear set of guidelines for the implementation of the FAII methods. Until this occurs, accurate and reliable data may

be best obtained through establishing a small pool (e.g. three) of experienced practitioners to conduct all RHP fish assessments.

- **Sampling effort:** The RHP aims to utilise rapid assessment methods for evaluating the ecological state of river systems, and standard methods such as SASS5 have proven to provide a good indication of the health. Recently a riparian vegetation assessment method has been established and is being tested in this study. Fish, however, are highly mobile and move and utilise different habitats on a diurnal and seasonal basis. In order to ensure representative sampling a variety of techniques are available, however many of these methods require longer time frames and defeat the objectives of a rapid assessment. A compromise between rapid assessments and sampling effort and duration needs to be decided upon.
- **Sampling process and equipment:** Only two sampling methods were used in this survey and it is felt that it was not sufficient to obtain a representative sample of the fish assemblage. Trout are known to occur at Site 1 and could be seen during sampling, however, the low conductivity of the water reduced the effectiveness of the electroshocker, and seine nets snagged on dead wood and boulders on the riverbed resulting in none being caught. In addition, eels were observed darting away from the electroshocker at a number of the lower catchment sites, suggesting this method is not an effective way of capturing these fishes. Sampling gear such as gill nets for deep slow habitats and fyke nets for targeting eel species would improve confidence that all species present at a site were captured. However, these nets are usually left in the water for up to twelve hours and thus the process would fail to be a rapid assessment method. A compromise for the use of gill nets could be a cast net, however this method necessitates some degree of skill to operate effectively. This may also be an alternative for sites with low conductivity. However, the issue of effectively sampling eels needs further attention.
- **Species diversity:** The index is not as applicable in areas of low indigenous fish species diversity. Methods like the QFAA and the Decision Support Tree also do not satisfactorily assess integrity in these areas. Currently, a new model is being validated by RQS, DWAF, and reportedly has the potential to provide better estimates of fish assemblage integrity in areas of low species diversity (pers. comm., Neels Kleynhans, Resource Quality Services). However, until this method is made available it is recommended that a workshop for all RHP fish assessment practioners from areas with low indigenous species diversity (e.g. Eastern and Western Cape) is held, together with experts in FAII, in order to generate a modification of the FAII that will be used consistently in all RHP fish assessments in these areas.

CHAPTER 5

RIPARIAN VEGETATION ASSESSMENT OF SELECTED SITES ON THE BUFFALO RIVER

5.1 INTRODUCTION

Riparian vegetation is the flora which occurs in the riparian zone near to, or on the banks of, rivers and streams. Riparian zones are those areas which are influenced by the river. They are often visually distinguishable from areas further away from the river or stream by virtue of their different physical appearance and vegetation composition. Riparian vegetation is specifically adapted to the mesic zones and occasional periods of inundation that occur in the riparian area, as well as the specific soil and microclimate conditions associated with rivers. It is usually characterized by having a higher biodiversity, both in terms of flora and fauna, than that of surrounding areas, and plays an important role in the ecological functioning of the river. A functional riparian zone contains vegetation which improves water quality and regulates flow as well as providing flood control services. In terms of fauna, it provides habitat to species which are often very specific to the riparian zone, as well as providing a migratory corridor for those species which do not necessarily function only in riparian zones. These migratory corridors are particularly important where the river runs through, or near to, residential or other built-up areas. (Kemper, 2001; Kotze et al., 1997)

Intact riparian areas are a source of direct social benefits in terms of recreational use and use of natural resources for food, fuel and medicine. These areas are also however favoured for agriculture and often become degraded due to unsustainable land use practises. Because the health of the riparian vegetation has a direct impact on river health, it is beneficial for biomonitoring programmes to assess riparian vegetation concurrently with other indicators such as habitat integrity, fish and aquatic invertebrates.

5.1.1 Review of available literature

It is customary when assessing riparian vegetation to formulate a perception of the perceived reference state of a river since it is in some respects assessed according to its observed deviation from the expected norm. Although it is often possible to arrive at a perceived reference state from evidence observed at each site; there are those sites that have been highly degraded along their length, with little evidence remaining of 'natural' vegetation. At these sites, where a natural reference state or perceived reference are not immediately evident from site characteristics, it is helpful to consult historical evidence - whether anecdotal or more scientific, e.g. aerial photographs - where available. During the assessment of riparian vegetation along the Buffalo River, access to historical evidence was limited. The following sources of literature were accessed for information on vegetation of the area:

- Acocks, J P (1988) *Veld types of South Africa.* Botanical Research Institute, Department of Agriculture and Water Supply, South Africa
- Low, A B and Robelo, A G (1998) (eds) *Vegetation of South Africa, Lesotho and Swaziland*. Department of Environmental Affairs and Tourism, Pretoria.

5.1.2 Riparian vegetation assessment process in South Africa

Under direction from the Water Research Commission (WRC), Nigel Kemper of IWR Environmental at the time, was requested to develop a Riparian Vegetation Index (RVI) in 2001 (see Kemper, 2001,WRC Report No. 850/3/01). The purpose of this exercise was to develop a rapid vegetation index for use in the National River Health Programme (NRHP) that could be used as a biomonitoring tool for riparian vegetation, firstly in the Mpumalanga area, but also aimed at application on a National basis. The index was required to produce scores that are comparable with the six Ecological Reserve assessment classes in accordance with the National Water Act requirements for water resource monitoring. The Ecological Reserve assessment classes grade the present condition of a water resource relative to a hypothetical pristine (or minimally impacted) reference condition. They are a practical management measure to indicate the present capacity of a water resource to maintain its sustainability and provide a means for comparable reporting across a range of disciplines (Jooste, 2001). Table 5.1 below shows the six Ecological Reserve assessment classes alongside the equivalent RVI scores (Kemper, 2001).

Table 5.1 Comparison of RVI and Ecological Reserve assessment scores.

RVI SCORE	ECOLOGICAL RESERVE ASSESSMENT CLASS	DESCRIPTION
19 – 20	A	Unmodified, natural.
17 – 18	B	Largely natural with few modifications. A small change in natural habitats and biota may have taken place but the ecosystem functions are essentially unchanged.
13 – 16	C	Moderately modified. A loss and change of natural habitat and biota have occurred but the basic ecosystem functions are still predominantly unchanged.
9 –12	D	Largely modified. A large loss of natural habitat, biota and basic ecosystem functions have occurred.
5 – 8	E	The loss of natural habitat, biota and basic ecosystem functions are extensive
0 – 4	F	Modifications have reached a critical level and the system has been modified completely with an almost complete loss of natural habitat and biota. In worst instances the basic ecosystem functions have been destroyed and the changes are irreversible.

During development the RVI took into account other early forms of assessment systems such as RIPARI-MAN, which was being used to assess the more urban rivers in Kwazulu-Natal. RIPARI-MAN (RIP) was developed by DC Kotze, NS Steytler and S Kirkman of the Institute for Natural Resources in 1998, for use by a wide range of organisations, but primarily for public participation in riparian system management. It was already in use at the time of development of the RVI. Besides being a tool for monitoring the health of rivers, RIP also serves as an environmental education resource material.(Kotze et al., 1998)

Two riparian vegetation assessment methods available for use were therefore the RVI and RIP (see Appendix 3 for samples of the data sheets). Challenges with riparian vegetation monitoring, such as the complex nature of riparian systems due to diversity of species, growth forms and simultaneous impacts from both natural and human sources, were noted during developmental stages of the RVI. Since the RVI was developed in Mpumalanga it was also acknowledged that the refinement of the RVI would be necessary for use in different regions due to variances in vegetation types (Kemper, 2001).

An aim of Phase 1 of the Eastern Cape River Health Programme (ECRHP) was therefore to assess the use of current riparian vegetation indices available for use, and to undertake a refinement of these methods for specific use in the Eastern Cape. This project is seen as long-term, with the initial testing and modification stages presented in this report.

In the resulting **Integrated Riparian Vegetation Index (IRVI)**, developed during a workshop in May 2003, aspects of RIP, RVI, Working for Water (WFW) requirements and the Wetlands vegetation index were combined with input from a range of specialists.

While the formula for scoring was not changed in anyway, thereby retaining the value of the index for necessary integration of riparian vegetation information into the RHP, other aspects of the index were altered so as to result in a format more specific to the needs of the Eastern Cape. The testing phase of the indices included a field survey of selected sites in April 2003 to test the RVI and RIPARI-MAN. The IRVI was developed in May 2003 and tested in the field at selected sites in February 2004.

5.2 MATERIALS AND METHOD

Due to the developmental nature of this component of the ECRHP, four sites, representative of a range of ecological areas with different characteristics of the Buffalo River catchment, were surveyed, as apposed to assessments of all 12 sites considered for other indices. Initially three of the sites namely: – Buffalo River at Maden Dam, Site 1; Buffalo River at Horseshoe Bend, Site 2; and Mgqakwebe tributary, Site 3, were assessed in April 2003 using the RVI and RIP indices. Subsequent to this initial testing, the developmental workshop for IRVI was conducted in May 2003.

The following 3 sites were then surveyed in February 2004 using the IRVI, i.e. Buffalo River at Horseshoe Bend, Site 2; Mgqakwebe tributary, Site 3; as well as an additional site at the Umtiza Forest in the lower reaches of the river, i.e. Buffalo River at Buffalo Pass, Site 9. Since it was also the aim of the development of the riparian vegetation index to test the modified index at different vegetation types along the Buffalo River, it was decided to test one of the sites in the lower reaches of the river, which had not been previously assessed, i.e. Site 9.

During the developmental workshop of IRVI, assessment of each of the RVI and RIP indices was considered on the basis of perceived strengths and weaknesses in relation to the specific needs of the ECRHP, and in relation to each index's own objectives.

5.2.1 Description and assessment of the Riparian Vegetation Index

The site-based RVI (Kemper, 2001) is designed for the assessment of components by technical staff from appropriate organisations. It is designed to be used by staff who have received some training in the assessment of riparian vegetation and to be used in conjunction with the field manual.

Some objectives of RVI include the following:

- Compliance with broad specifications provided by the River Health Programme (RHP).
- Aimed at application on a national basis to a broad spectrum of rivers within South Africa.
- Be usable by a single assessor if necessary, who does not necessarily have a high level of vegetation knowledge and experience.
- Be as qualitative as possible and avoid technical and quantitative considerations.
- Be applied simultaneously with other biomonitoring components and therefore be achievable in 20 to 45 minutes.
- Be integrated with the Ecological Reserve process with output conforming to the six present state assessment classes.
- Provide a condition index derived from a combination of sub-criteria scores which reflect pertinent characteristics of each site.
- Be housed in a central database and provide a description of site characteristics and determine changes in condition over time along with apparent reasons for such changes (Kemper, 2001).

The RVI provides detailed information on the vegetation of an area which includes among other things, species lists, evidence of recruitment and details of the types and distribution of cover components. It also records selected physical attributes of the river (see Table 5.2 for a more comprehensive list of data recorded in the RVI).

RVI reaches a final score based on the following attributes of the riparian zone:

- Extent of vegetation cover (EVC) (combined disturbance and vegetation cover scores).
- Structural intactness (SI) (obtained from deviation of distribution of vegetation components from percieved reference state).
- Percentage cover of indigenous riparian species (PCIRS) (obtained from EVC minus the combined invasion from exotic, terrestrial and reed invaders).
- Recruitment of indigenous riparian species (RIRS).

It is calculated using the following formula which was developed from the Streamside Zone Index used in Australia and which summarises the quantity and quantity of streamside vegetation: RVI = [(EVC) + ((SI x PCIRS) + (RIRS))]

Limitations to the application of RVI

- **Time requirements**: The time factor was considered a weakness since the average time taken to assess each site was about 1.5 hours. (This excluded the drawing of maps which is a requirement of the fieldsheets). It was found that in sites with a high biodiversity the initial walkabout recording species was very time-consuming, even when assessors were able to identify most of the plant species immediately. Since many rivers of the Eastern Cape are densely vegetated, the RVI will not meet its objective in terms of coinciding with the time requirements of other components, in its present format. For those assessors who did not have a reasonable level of plant identification skills, the process would have taken many more hours since they would have been obliged to collect and process samples for later identification.

The listing of invasive species separately in order of perceived extent of invasion proved also to require significant amounts of time.

- **Complexity and relevance of information in relation to time restraints:** The RVI also requires individual plants to be counted and entered in their appropriate size class. Information pertaining to the size class feeds into those sections of the fieldsheet relating to recruitment. Apart from the sheer volume of individual plants to be recorded, the size classes for recruitment would not be appropriate for all species in the riparian zone. For example woody understorey species such as *Carissa bispinosa* or *Draceana aletriformis* under 2 m, could be considered mature specimens of that species, but would be entered into that part of the form which records juveniles, thereby affecting the quality of information on species composition with regard to dominance by recruitment. The recording of size classes for each individual also contributes significantly to the amount of time required to undertake the assessment. The recording of numbers of individual trees was also considered impractical for inclusion in a rapid assessment in terms of time requirements, particularly in the densely vegetated riparian areas of the Eastern Cape.

- **Skills requirements:** Conflict arises between time requirements for the field asessment of each site and the level of skills required. Although it is an objective of the RVI that it be usable by an assessor who does not necessarily have a high level of vegetation knowledge and experience, it is also a requirement that the assessment be completed within 45 minutes. Due to the time taken to process and collect plant samples for identification, the time requirement cannot be met by an assessor who is unskilled in plant identification.

  Judgements are required on the extent of invasion of alien and indigenous terrestrial species as recruitment of indigenous species. Knowledge of terrestrial versus riparian species as well as whether or not a plant is exotic or indigenous, is required in order to make these judgments. This information directly affects the final score in that it is required for determination of the PCIRS and RIRS scores. It also requires decisions about vegetation relative to a perceived reference state. Therefore, in order to obtain meaningful results it is concluded that the assessor should have a reasonable knowledge of riparian vegetation in the site being assessed.

- **Community involvement**: The RVI was developed initially for application on the Crocodile, Sabie and Olifants Rivers which are largely rural or wilderness areas with relatively low overall population densities. It includes no requirements for community involvement or the sharing of pertinent information with landowners and other stakeholders, probably since it is assumed that this information will be shared publicly via the State-of-the-Rivers Reports produced by the RHP from information supplied by these assessments.

Strengths of the RVI

Detailed information pertaining to most physical characteristics of the site as well as the riparian vegetation is recorded by the RVI. It produces an outcome that can be integrated with the Ecological Reserve assessment classes and it complies with the broad specifications of the NRHP. The outputs are suitable for inclusion in a central database so that changes over time, as well as apparent reasons for such changes, can be monitored and determined over time. The RVI acknowledges the need for further refinement of the index.

5.2.2 Description and assessment of RIPARI-MAN

The development of RIP was driven by the Institute of Natural Resources, government and various NGO's for the purpose of management of riparian systems, chiefly near urban areas. An aim was for improved social benefits, and to increase community awareness of the environmental issues surrounding riparian areas. It was designed for use by a wide range of end-users with varying levels of skill and who did not necessarily have specific technical training.

The primary objectives of RIPARI-MAN include the following:

- To inform people of the potential benefits of local riparian areas;
- to facilitate collaborative management between communities and managers;
- through collaborative management to provide management institutions assistance with their roles relevant to the management of the riparian areas;
- to provide relevant information to assist users in informed decision-making and planning;
- to make educational materials available to and applied by educational institutions; and
- to enable local people to manage their riparian systems (Kotze et al., 1998).

The RIPARI-MAN index provides information regarding the physical characteristics of the site as well as information on surrounding land use and disturbances (See Table 5.2 for a comprehensive list of the type of information obtained by RIP and the other indices).

RIP reaches a final score based on 6 criteria namely:

- Extent of alteration of streambank morphology by humans through straightening or channelisation.
- Extent of erosion along stream banks.
- Percentage of the total area altered by human activity.
- Extent of litter.
- Percentage total plant cover.
- Percentage cover by invasive alien plants.

The final score classes of RIP in relation to the six Ecological Reserve assessment classes are represented in Table 5.2. The RIP scores do not differentiate between those ecosystems where loss of habitat and functioning is extensive, and those in which loss of habitat and ecosystem functioning has reached a critical level.

Table 5.2 Comparison of RIP and Ecological Reserve scoring systems.

RIP SCORE	DESCRIPTION	ECOLOGICAL RESERVE ASSESSMENT CLASS	DESCRIPTION
>120	High	A	Unmodified, natural.
`90 - 120	Moderate –High	B	Largely natural with few modifications. A small change in natural habitats and biota may have taken place but the ecosystem functions are essentially unchanged.
60 - 90	Moderate	C	Moderately modified. A loss and change of natural habitat and biota have occurred but the basic ecosystem functions are still predominantly unchanged.
30 - 60	Moderate -Low	D	Largely modified. A large loss of natural habitat, biota and basic ecosystem functions have occurred.
O - 30	Low	E	The loss of natural habitat, biota and basic ecosystem functions are extensive
		F	Modifications have reached a critical level and the system has been modified completely with an almost complete loss of natural habitat and biota. In worst instances the basic ecosystem functions have been destroyed and the changes are irreversible.

Limitations of RIP in relation to requirements of THE ECRHP
RIP supplies limited information regarding riparian vegetation. No information is supplied for example on the following:

- Evidence of recruitment of riparian vegetation. This would give an indication of whether a population is declining or increasing and therefore indicates a trajectory of change.
- Extent of invasion by different vegetation types i.e. terrestrial, exotic, or reeds.
- Percentage cover of different vegetation components i.e. trees, shrubs, forbs, grasses, sedges etc.
- Comparative distribution cover per vegetation component of present state vs percieved reference state.
- RIP assesses the riparian zone chiefly through the extent and type of disturbance rather than indigenous vegetation.
- RIP does not produce an outcome that is immediately integratable with the Ecological Reserve assessment classes.

Strengths of RIPARI-MAN
- RIP meets the time requirements that allow simultaneous application with other biomonitoring aspects in the field.

- RIP is usable by assessors who do not necessarily have a high level of knowledge of riparian vegetation.
- RIP provides information to educate local community members about aspects of riparian areas.
- RIP enables local community members to engage in collaborative management of aspects of their riparian areas.
- RIP provides information on characteristics of riparian areas more pertinent to urban situation that is provided in RVI. For examples, the extent of litter through the riparian zone and extent of canalisation of the river is recorded.

5.2.3 Development of IRVI

The objectives for development of the IRVI included the combination of the positive aspects of the RVI and RIP, while removing or reducing limitations of either index where possible. The primary focus of development of IRVI, and which forms the basis of this discussion, was the development of an appropriate data sheet for use in the field (and not other aspects of the process such as preliminary work required prior to fieldwork). It is acknowledged that further work will be required to refine the preliminary process as well as the data sheets. The aim was also to incorporate, where possible, any additional elements necessary for a more comprehensive description of the river without increasing the data sheet to an impractical size.

The RVI formula has been retained as is in IRVI since it has already undergone extensive testing and produces outcomes that comply with requirements of the NRHP. It is also compatible with the National Rivers Database. Since it primarily assesses vegetation, as opposed to general physical characteristics of the general riparian area, it was also considered to be more appropriate for a vegetation index than the RIP scoring system, particularly for the densely vegetated rivers of the Eastern Cape.

The primary characteristic of RVI excluded from IRVI, is the recording of numbers of individuals of a species in size classes. This information is not directly required for calculation of the RVI formula and adds considerably to the time taken to complete the data sheet. It does not lead to sufficiently accurate information, so as to justify its retention in the data sheet in relation to the time required to record it.

Two primary elements of RIP required for incorporation into IRVI were:

a) those physical characteristics not already found in RVI (such as channel depth).
b) incorporation of inter-organisational information-sharing to enable more immediate action on riparian management issues requiring urgent action. This pertains particularly to the recording of information regarding the presence of particular invasive alien species that have *red flag* status with the DWAF and the Working-for-Water (WFW) project.

Further discussion around the Wetlands vegetation data sheet as well as the National Rivers Database, WFW and Landcare requirements resulted in the addition of the following characteristics to be recorded in IRVI:

- Altitude
- Gradient

- Type of bank instability
- Type of channel instability
- Extent of channel sedimentation
- Suitability of invasive alien species for harvesting
- Accessibility of alien invaders on left and right banks
- Presence of certain water weed invaders
- Presence of red flag invader species such as *Pereskia*

During testing and refinement of the RVI one of the challenges was to provide a range of scores which reflected the diverse characteristics on site but which also realistically conformed to the Ecological Reserve assessment classes. To help with calibration of the RVI score the subjective assignment of a *gut condition score* for each site was done by each assessor for comparison. (Kemper, 2001). For evaluative purposes this gut score has been left in on the IRVI forms, but will best serve evaluation of the IRVI if the assessor in question for that site has sufficient knowledge of riparian areas and plant species in order to make such a subjective judgement about the ecological functioning and habitat integrity.

The resulting IRVI data sheet which was tested in February 2004 can be seen in Appendix 3. Table 5.3 summarises the information on those characteristics of the riparian zone which are recorded in each of the indices.

Table 5.3 Summary comparison of information recorded on RVI, RIP and IRVI datasheets.

SUMMARY COMPARISON OF INFORMATION RECORDED BY RIPARIAN VEGETATION INDICES			
Description of River characteristics	**RVI**	**RIP**	**IRVI**
-			
Site details:			
Date of assessment	y	y	Y
Name of assessor	y	y	Y
Name of River	y	y	Y
Segment of river	y	y	Y
Reach of river	y	y	Y
Longitude and Latitudinal position	y	y	Y
Site description:			
Altitude			Y
Gradient			Y
Length of reach	y	y	Y
Substrate type in river	y		Y
Soil Types		y	Y
Channel type	y		Y
Channel depth		y	Y
Active channel width	y	y	Y
Width of riparian zone	y		
Idealised channel cross section		y	Y
Extent of meander		y	Y
Disturbances and human impacts and land use			
Surrounding land use categories e.g. industrial activities, resources	y	y	Y
Current use of riparian area		y	Y
Types of disturbance general	y		
Order of impact of disturbance	y		
Extent of Disturbance	y		
Extent of alteration of streambank by straightening or channelisation by humans		y	Y
Percentage of area altered by human activity		y	Y
Presence and extent of litter		y	
Extent of erosion along erosion stream banks		y	Y
Type of bank instability			Y
Type of channel instability			Y
Extent of channel sedimentation			Y

SUMMARY COMPARISON OF INFORMATION SUPPLIED BY RIPARIAN VEGETATION INDICES cont.			
Description of river characteristics	**RVI**	**RIP**	**IRVI**
Riparian vegetation			
% of total vegetation cover	y	y	y
% of cover by declared alien invaders	y	y	y
Harvestability of alien invaders			y
Accessibility of alien invaders on left and right banks			y
Presence of water weed invaders			y
Presence of red slag species of alien invaders e.g. *Pereskia*			y
Extent of invasion of declared alien invaders (very low - very high) (includes species names and evidence of recruitment)	y		y
Extent of invasion by terrestrial plants (very low - very high)	y		y
Extent of invasion by reeds (very low - very high)	y		y
Percentage cover of different cover components e.g. trees, shrubs, grass, forbs	y		
Distribution cover /component of present state vs perceived reference state	y		y
Extent of recruitment of indigenous riparian species	y		y
Species composition general list	y	y	y
Species domination by recruitment	y		
Species dominance by biomass	y		
Species richness in terms of number of different indigenous species	y		y
Species richness in terms of number of different alien species	y		y
Vegetation type			y
General:			
Subjective overall assessment by means of gut score	y		y
Method of calculation of score			y
Place for calculation of score on fieldsheet		y	y
Explanation and indication of ER status			
Complete manual provided.		y	
Immediate community involvement required		y	y
Possible Immediate action required.			y

5.3 RESULTS

In February 2004 IRVI was tested on three sites of the Buffalo River. Two of the sites were those previously surveyed using RVI and RIP i.e. the Buffalo River at Horseshoe Bend, Site 2; and Mgqakwebe tributary, Site 3. A third site in the lower reaches of the river, i.e. BuffaloRiver at Buffalo Pass, Site 9, was also surveyed. Table 5.4 below summarises aspects of the application of the riparian vegetation indices.

Table 5.4 Information on application of the three riparian vegetation indices to sites on the Buffalo River.

SUMMARY COMPARISON OF GENERAL CHARACTERISTICS OF RIPARIAN VEGETATION INDICES			
Description of River characteristics:	**RVI skilled assessors**	**RIP**	**IRVI skilled assessors**
General:			
Average time taken to complete data sheet in the field. (excluding the map drawing & using assessors with a reasonable knowledge of riparian vegetation) (this will vary according to complexity of the site)	2 hours	30 min	1.25 hours
Number of field sheets to fill in (A4 pages, excluding species list or map)	3	1	4
Relative quantity of information supplied for vegetation (scale of 1-5, with 1 being little information required)	4	2	3
Relative quantity of information supplied for physical characteristics and disturbances (scale of 1-5, with 1 being little information required)	3	3	4
Produces results comparable with Ecological Reserve assessment classes	yes	no	yes
Equipment required:			
Clipboard, pencil and field sheets	yes	yes	yes
GPS (if co-ordinates not taken from maps during site selection)	yes	yes	yes
Plant press and other plant collection requirements	yes		yes
Waders or gumboots	possibly	no	possibly
Boat	possibly		possibly

A main outcome of development and use of IRVI was the acknowledgement that end-users would be required to have a reasonable knowledge of riparian vegetation in order to meet the time requirements for application simultaneously with other biomonitoring components. It is recommended that these assessors still undergo basic training in the use of IRVI. Should it not be a requirement that end-users have prior riparian vegetation skills, a comprehensive manual will need to be compiled for use with the IRVI forms.

Some conclusions regarding IRVI can be made from information from Tables 5.2, 5.3 and 5.4 above:

- The IRVI data sheets consist of 1 more A4 page than the RVI but three more A4 pages than RIP (Table 5.4). It is therefore more cumbersome to use in the field, particularly in comparison to RIP, but it records a wider variety of information than either the RVI or RIP (Table 5.3). (Attention to layout here will solve this problem and reduce the number of pages to 3).
- From Table 5.2 it is apparent that the score results of RIP do not completely integrate with the Ecological Reserve assessment classes.
- IRVI takes less time to complete in the field than RVI (Table 5.4).

Table 5.5 below shows the results of each of the outcomes of each of the indices with regard to sites surveyed:

Table 5.5 Comparison of riparian vegetation indices results.

RIPARIAN VEGETATION INDICES RESULTS				
Site	**RVI**	**RIP**	**Gut score**	**IRVI**
Site 1 - Maden Dam	**B**	**A**	**B**	
Site 2 - Horseshoe Bend	**E**	**D**	**D**	**E**
Site 3 - Mgqakwebe tributary	**C**	**A**	**C**	**C**
Site 9 – Buffalo River Pass			**C**	**D**

Data from the field sheets (see Appendix 3) affords the following descriptions of sites along the Buffalo River.

5.3.1 Site 1: Buffalo River at Maden Dam

This first study site in the upper catchment of the river falls within an area of indigenous forest managed by the Department of Water Affairs and Forestry (DWAF) and is dominated by climax afromontane forest. The forest appears to be in a near pristine state, similar to that which could be considered as the perceived reference condition.

The present forest structure consists of a continuous canopy cover of evergreen and deciduous trees to a height of approximately 20 m, as well as various understorey layers with a diverse mix of sparse and dense foliage. Key tree species consist of Forest Elder, Cape Fig, Common Yellowwood, Cape Chestnut and White Stinkwood. The area has a high extent of cover of indigenous riparian species and recruitment of these species is also evident, particularly the Yellowwoods. The river in this area is approximately 20 m wide, with the channel bed being a rocky cobble substrate. Although ecosystem functions are essentially unchanged, some human impacts have resulted in changes to the natural habitat and biota. (RVI score and Gut Score = B) Previous harvesting of yellowwoods for wood has resulted in changes in compositional structure of the forest. This disturbance is a contributing factor to the invasion of exotic species and is responsible for a change in species composition. (Data sheets confirm presence of alien species and species composition.) There may currently be a trajectory of change toward a return to original species composition as is indicated in the data sheets by the recruitment of Yellowwood trees. Confirmation of this can only be achieved after more data is recorded over time. The RIP index scored this site as having a high status or category **A**. This result is conflicting in that it means it is unmodified or natural, but at the same time acknowledges disturbance through the presence of exotic and invasive species and constructions such as weirs.

Disturbance is low as indicated on RVI data sheets, but exotic and alien invasive species such as *Quercis palustris* and *Acacia mearnsii* are present. Control of these species is under DWAF management. Due to this area having the status of protected state forest, current pressures from human activities are limited to forest management and recreational activities centred on ecotourism. There is also potential for sustainable harvest of medicinal plants. (The species list contains plants known to be used for medicinal purposes.) This area is an important conservation area in terms of recreational and educational services. (It has a high biodiversity of indigenous species and represents a section of nearly structurally intact afromontane forest).

Recommendations are therefore that management priorities should include the prevention of further encroachment of alien species and the continued application of measures for sensitive management of the forest.

5.3.2 Site 2: Buffalo River at Horseshoe Bend

Site 2 is found a few hundred metres east of and about 10km north along the road between King Williams Town and Stutterheim, close to a school in a rural area. It is representative of the middle reaches of the Buffalo River. Remnant riparian woody vegetation in this area is indicative of Eastern Thorn Bushveld and transitional Valley Thicket. Due to the heavily eroded river banks and highly degraded nature of this site (evident from the high level of disturbance recorded on the data sheets and high number of aliens, it is difficult to assess how wide the reference riparian area would have been. It is estimated to have been around 20 m on either side of the river banks, which are incised and unstable in sections. The river substrate is a combination of alluvial sand which is eroded to bedrock in sections. Vegetated sandy islands occur both upstream and downstream of the low bridge crossing. It is expected that the area would have contained a closed canopy wooded thicket to an approximate height of about 7 m. Dominant indigenouse tree species currently include *Combretum caffrum*, *Ziziphus mucronata* and *Acacia karoo*, while more shrublike species include *Scutia myrtina* and *Gymnosporia buxifolia*.

Vegetation disturbance is high, with at least 25% of the area showing exposed soil. Alien infestation levels are also high with the most common species being Eucalyptus, Black Wattle and *Sesbania punicea*. Alien vegetation can be found over approximately 35% of the area. Relatively large sections of the site have been disturbed due to river sand mining activities. Population density is relatively high in the area and there is a nearby school. Adjacent fields are used for cultivating crops or grazing. The wreck of a car near the low-water bridge, as well as dumping and removal of wood, are disturbances impacting on the area. This site has a gut score of D but data recorded puts the area in Ecological Reserve category **E**, which indicates that the loss of habitat and ecosystem functions are extensive.

Initial recommendations are that management priorities should include an alien vegetation control programme as well as the implementation of structural bank restoration procedures. The land care management programme could play a role in the education of the local community in conjuction with WFW programmes which would provide social benefits and also play a role in education with regards to environmental issues.

5.3.3 Site 3: Mgqakwebe tributary

This area falls in the vicinity of rural settlements in the upper catchment area. The study area is situated at an informal crossing of the Mgqakwebe River which is a tributary lying to the west of the Buffalo River and is adjacent to a rural residential area. It consists chiefly of riparian forest, some of which is relatively intact and some of which is in various stages of secondary succession. This is interspersed with open grassed areas that appear to previously have been cleared for agricultural purposes. Through comparison with similar areas nearby it can be inferred that the perceived reference condition would have consisted of continuous forest vegetation with a lower overall height than that of Site 1. Understorey vegetation is dense over approximately 60% of the area with terrestrial species such as *Gymnosporia buxifolia* and *Coddia ruddis* occurring alongside riparian species. The height of the forest canopy is about with 10m with key species consisting of *Erythrina caffra*, *Podocarpus falcatus* and *Ficus sur*.

Understorey and pioneer species such as *Halleria lucida*, *Grewia occidentalis* and *Trimeria* are common. In general species composition is altered, although the extent of vegetation cover is still high. There is also evidence of recruitment of juvenile indigenous species. The river is intersected by a cattle crossing which has been cleared of trees and which has caused erosion on both river banks. It appears as if clearing on the right bank downstream of the crossing has taken place for previous agricultural activities, as is evidenced by the distinct differences and loss of graduation of vegetation through the boundaries of the different riparian and terrestrial plant communities. An artificial wetland has formed on the right bank due to new contours created by ploughing practises and is characterised by species such as *Zantedescia*, *Gunnera perpensa*, *Phalaris* and *Mariscus*. Alien species such as Black wattle, Syringa and Sesbania are present.

Children from a nearby school also utilise the river for drinking water and play in the area. Plant materials are utilised for wood and medicinal purposes. Although this site scores an A in the RIP index, it scores a **C** gut score and RVI and IRVI indices. This indicates that the riparian vegetation in the area has been moderately modified, but the basic ecosystem functions are still primarily unchanged. Actions for improvement of this section of the river should perhaps centre on control of alien species, the monitoring of agricultural practises and education of the local residents in the sustainable use of plants in this area.

5.3.4 Site 9: Buffalo River at Buffalo Pass

Site 9 is located at the lower reaches of the Buffalo River, above and relatively close to the ebb and flow, and below the Bridle Drift Dam. It has the Umtiza Nature Reserve on its right bank and public space on the left. Vegetation in this area consists of a mix between coastal forest and valley thicket. It is also known as Umtiza Valley thicket, after the rare and endemic *Umtiza listeriana* tree known to grow only in this (and one other) locality in the Eastern Cape. The Umtiza Nature Reserve and valley opposite are dissected by a provincial road and border on the lower income residential areas of Scenery Park, within the Buffalo City Municipality management area. Valley sides are steep for much of the left bank while less so on the right, and observations were recorded from the upper bridge and the remains of an old weir in the channel. Under pristine conditions this area should consist of intact closed canopy indigenous Valley Thicket and Coastal forest.

Due to disturbances from previous bridge construction practises and the previous use of the north end of the reserve as a picnic area, there is substantial encroachment of invasive exotic weed species. Balloon vine, *Ricinis communis*, *Cestrum laevigatum* and *Melia azederach* predominate, but sections of *Pereskia aculeata* stand out as areas of immediate concern. Since the river also acts as a conduit for dispersal of seed, ongoing weed control would also be required upriver of this site. Despite the presence of exotic weeds, structural intactness in terms of vertical composition is still quite good in those areas where weed infestation is less severe. There is also evidence of recruitment of indigenous riparian species. Other disturbances are poaching (communication with reserve manager) and removal of plant material from the forest. Vegetation cover is almost 100% but a large part of this consists of invasive alien species. Key species include *Celtis africana*, *Harpephyllum caffra* and *Ficus* *sur*. In-channel vegetation is well established on islands amid the primarily boulder and cobble substrate, and consists of species such as *Mariscus*, *Cyperus textilis* and *Phalaris* sp. which thrive in the nutrient rich water. Future invasion of the river bed by reeds and sedges (which are present as indicated on the species list) is a potential problem should flow regulation from dams reduce flow below critical levels. This site had a gut score of C but a IRVI score of **D**. Loss of natural habitat and biota and therefore loss of some basic ecosystem functions has occurred. The presence of *Pereskia aculeata* in this area was noted and the local branch of WFW was notified of its presence.

It is recommended that steps are taken to curb the invasion of alien species and prevent further disturbances to the area. Protection of the buffer zone of the reserve on steep slopes of the east bank of the river, by limiting development and disturbance, would aid Nature Conservation in the protection of the Umtiza Forest Nature Reserve, which forms a significant part of the riparian zone of the Buffalo River in this area.

5.4 DISCUSSION AND CONCLUSION

The application of the three indices RVI, RIPARI-MAN and IRVI on riparian vegetation at four sites along the Buffalo River, yielded information on the current status of the riparian vegetation at those sites. With regard to the effectiveness of the various indices the following is concluded.

Although the RVI provided relevant information, it did not meet its time requirements and was also relatively complex to apply in the field. From examination of information in Tables 5.1 and 5.5, the value of the results from RIP appear questionable when applied to the Ecological Reserve assessment classes in their current manner. The development of IRVI from a combination of the RVI and RIP indices, as well as other relevant inputs, resulted in an index that produced outcomes compatible with the six Ecological Reserve assessment classes. It also proved to be less time-consuming to apply than the prior RVI index and produced a wider variety of information on the riparian zone. Although IRVI was relatively cumbersome in terms of number of pages to handle in the field, it was acknowledged that work on the layout could reduce the number of pages to 3.

It is recommended that a field manual be prepared for use with IRVI. The complexity of the field manual will be relative to the level of skill and knowledge of riparian vegetation possessed by the end-user. The field manual would potentially include instruction on application of IRVI and the nature of riparian systems, as well as separate identification guides for vegetation specific to the area being assessed.

Additional recommendations for inclusion on the data sheets include the following:

- Small diagrams for type of bank instability and channel instability be included in the data sheets.
- Possibly restructure wording on options for alteration of streambank morphology.
- Include place on each page for general information such as the date, name of assessor and name of the river and reach.

The inclusion of the formula for calculation of the final score, although theoretically not necessary since the data goes into the database for calculation, is important to allow the assessor immediate access to results. This feedback aids in the improvement of quality of assessment skills.

The summary of status of riparian vegetation at each of the four survey sites is as follows.

Riparian vegetation along the Buffalo River encompasses a number of vegetation types within the Forest, Savanna and Thicket biomes. In the upper catchment Afromontane forest, particularly the Amatole Afromontane forest, predominates. (Some Afromontane grassland may also exist but this did not occur in any of the chosen sites of study.) Due to protection within state forests, riparian vegetation here is still performing most of the necessary ecological functions even though it is not entirely intact in terms of species composition. The presence of alien species even within this protected zone is an indication of the extent of the problem throughout the length of the Buffalo River.

In the middle reaches the Eastern Thorn Bushveld and Valley Thicket appear to be the dominant vegetation type, although due to agricultural practises it seems that much of this is disturbed. The functioning of riparian vegetation in these areas is severely compromised and river banks are unstable due to lack of acceptable vegetation cover. Infestation of alien plants is high. Intervention will be required in these areas, perhaps in the form of increased efforts by the land care program, in order to rehabilitate failed ecosystem functioning. Lower reaches are dominated by Valley Thicket and Coastal Forest vegetation types. While most ecosystem functions are still intact, the dense infestation of exotic invasive species in the riparian zone is of concern in the areas in and around the Umtiza Valley, and special effort should be made to control this spread of exotics. Conservation of the Umtiza tree habitat and control of erosion on the steep valley slopes by controlling development in this area, should perhaps be the primary management concerns in this area. Pressures from the surrounding communities may possibly be alleviated through social development and environmental awareness programmes.

CHAPTER 6

GEOMORPHOLOGICAL CLASSIFICATION AND ASSESSMENT

6.1 INTRODUCTION

Geomorphology has two main roles to play in the context of river management. Firstly, geomorphology forms the physical template upon which ecosystems exist and function. As such, it forms the spatial framework that will guide managers in their goal setting and decision-making. Secondly, geomorphology is itself one of the highly interrelated components within a river system and can therefore change over time. Thus, the geomorphological status or health of a river system needs to be ascertained as part of the assessment of the general health of the river (or river section) being studied.

With regards to the first role of geomorphology, namely geomorphology as a spatial framework, the longitudinal zone (i.e. the third tier in the hierarchical classification model for South African rivers) is defined as *a sector of the river longitudinal profile which has a distinct valley floor and valley slope* (Rowntree and Wadeson, 1999; Rowntree et al., 2000). The levels of the hierarchy (from coarser to finer spatial and temporal scales) are as follows:

1. catchment
2. segment
3. zone
4. reach
5. morphological unit
6. hydraulic biotope

It is the third level of the hierarchy that is most important in the context of the NRHP. The zone will provide the template for processes acting at the reach scale. The reach, in turn, will exhibit a particular channel pattern and morphology in response to a suite of physical, hydrological and hydraulic controls (Rowntree and Wadeson, 1999). It is thus important to ascertain what longitudinal zone a site falls into.

The second role of geomorphology, i.e. the development of a Geomorphological Index for River Health, is ongoing (Rowntree and Ziervogel, 1999). The accuracy, applicability and reliability of such an index will largely depend upon the availability and synthesis of a comprehensive collection of field data for various river sites across the country. To this end, a geomorphological database for South Africa is currently being established as part of a WRC-funded project that will be completed by mid-2004. This project aims to establish a recognized method by which the geomorphological reference condition of a site can be ascertained. Once this method is in place, it will facilitate the further development of the Geomorphological Index and hence the more accurate assessment of the PGS of a site. The collection of geomorphological information for the Buffalo River was conducted as part of this WRC-funded project.

The importance of the geomorphological condition of river sites has only recently been officially acknowledged within river health studies. The method followed in South Africa's NRHP with regard to understanding the present state of a river site is to establish *reference* *sites* which are then used as benchmarks against which the condition of *non-reference* sites is gauged (Dallas, 2000). At present, there is not yet a definition for the Present Geomorphological State (PGS) of a river site. This is largely because there is not yet a recognised method by which to identify a Geomorphological Reference Condition (GRC). This gap in knowledge is currently being addressed within the current WRC project. However, in the interim, a method has been derived by which a qualitative assessment of the PGS of a river site can be gauged (see explanation in Section 6.2). It is this method that will be reported on in this document.

6.2 MATERIALS AND METHODS

In order to complete an initial, detailed baseline survey by which to classify a river reach in terms of its geomorphology (see Rowntree and Wadeson, 1999; Rowntree et al., 2000), and to ascertain its geomorphological health status, both desktop and field data are required (Rowntree and Ziervogel, 1999).

6.2.1 Desktop data

Necessary desktop data include site location, altitude, channel gradient and quaternary catchment code. These data ultimately enable one to calculate expected stream power of the Mean Annual Flood (MAF), as well as to place the site within a particular ecoregion, rainfall region or geomorphological province. This information is useful in guiding the geomorphologist as to what characteristics could reasonably be expected at a site.

In addition to obtaining these data for each river site, it is useful to plot a longitudinal profile for the river channel in order to view each site in the context of the entire channel length. The longitudinal profile for the Buffalo River (Figure 6.1) was plotted by digitising the river channel in ArcView and then converting values obtained to spreadsheet format and constructing a profile in Microsoft Excel.

The methods by which necessary desktop data for each site were obtained are as follows:

- location — position (latitude and longitude) can be deduced from a 1:50 000 topographic map, but in this case was obtained by using a GPS in the field
- altitude — obtained from 1:50 000 topographic maps
- channel gradient and long. profile — calculated by measuring the vertical change and dividing this by the horizontal distance between two points. This was done using the ArcView GIS package. The final profile was plotted using Microsoft Excel
- quaternary catchment code — obtained from the WR90 database

6.2.2 Field data

Over a period of years, a standardised form has been developed (by Prof. K.M. Rowntree of Rhodes University as well as Dr. R.A. Wadeson, a consulting fluvial geomorphologist) to guide the collection of geomorphological field data. An example of the form is included in this document as Appendix 4. An explanation of the field data collection purposes and methods is available in Rowntree and Wadeson (2000), though this explanatory document is due to be updated. On the whole, the field form is self-explanatory, and the materials required are limited to a measuring tape and a staff. At this stage, expert judgement is key to the geomorphological assessment process.

At each of the selected sites, the primary responsibility of the team's geomorphologist is to spend time walking as much of the stream channel as possible, both upstream and downstream of the site, in order to gain a balanced and holistic impression of the characteristics and geomorphological “health status" of the river channel. The field form is then completed and facilitates the focused observation of characteristics such as channel morphology, channel type, bed material, channel width, bank stability, habitat diversity and flow conditions at the time of the survey.

In addition to sections relating to the observation and recording of channel characteristics, the field form includes a section relating to human impact. The current field form therefore does allow a qualitative assessment of the likely effect of human activity on the geomorphology of a site in the form of a channel impact matrix (see Section 5 of the field form in Appendix 4).

The channel impact matrix is a tool by which one can qualitatively gauge the geomorphological health of a river site. The final impact rating (between A and F) is assigned to a site after the expected effects of all the impacts noted at the site have been roughly averaged. The definitions of the values A to F are presented in Table 6.1.

Table 6.1 Meanings of impact class values A to F (Rowntree, 2003).

CLASS	GEOMORPHOLOGICAL CHANGE	ANTHROPOGENIC INDICATORS
A: unmodified natural	No changes, erosion and deposition within reach are in balance.	No human impacts identified in the catchment.
B: largely natural	Short-term changes that can be reset within the frequency of the 'bankfull' flood.	Human impacts identified, but no clear evidence of channel response.
C: moderately modified	Slow trajectory of change, can be reset within five to ten 'bank full' events by restoring natural flow / sediment regime and bank stability.	Significant human impacts, changes to bed structure evident, localised bank erosion and channel widening, or deposition and narrowing. Changes reversible in the short term.
D: largely modified	Well into the trajectory of change, may be difficult to restore natural conditions; river adjusting its form to the current sediment load and flow regime.	Major human impacts resulting in significant long term changes to channel geometry, pattern or reach type that may be irreversible.
E: seriously modified	Engineering intervention required for rehabilitation.	Channel structure largely engineered, but bed perimeter includes some natural materials that can be worked by fluvial processes (includes gabions, engineered bank stabilisation, channel straightening or re-alignment, bulldozing.
F: critically modified	Major engineering intervention required for rehabilitation.	Totally engineered channel, no natural material in the channel perimeter.

6.3 RESULTS

6.3.1 Longitudinal profile and zonation

Geomorphological zonation of sites on main channel

The longitudinal profile for the main Buffalo river channel is presented in Figure 6.1. The accompanying table of values which were used to zone the channel are presented in Table 6.2. The process by which zonation was undertaken is outlined in Rowntree et al. (2000). Seven reasonably distinct zones have been identified along the main channel (Rowntree et al., 2000) and three of these were sampled in this study. Asterisks (*) indicate the number of RHP sites situated within these zones. The dominant bed material and morphology expected in each of these zones is presented in Table 6.2.

Table 6.2 Geomorphological zonation of river channels (Rowntree et al., 2000).

A. Zonation associated with a 'normal' profile		
1. Source zone	Not specified	Low gradient, upland plateau or upland basin able to store water. Spongy or peaty hydromorphic soils.
2. Mountain headwater stream	0.1 – 0.7	A very steep gradient stream dominated by vertical flow over bedrock with waterfalls and plunge pools. Normally first or second order. Reach types include bedrock full and cascades.
3. Mountain stream	0.01 – 0.1	Steep gradient stream dominated by bedrock and boulders, locally cobble or coarse gravels in pools. Reach types include cascades, bedrock fall, step-pool, plane bed, pool-rapid or pool riffle. Approximate equal distribution of 'vertical and 'horizontal' flow components.
4. Foothills (cobble bed)	0.005 – 0.01	Moderately steep, cobble-bed or mixed bedrock-cobble bed channel, with plane bed, pool-riffle or pool-rapid reach types. Length of pools and riffles/rapids similar. Narrow flood plain of sand, gravel o cobble often present.
5. Foothills (gravel bed)	0.001 – 0.005	Lower gradient mixed bed alluvial channel with sand and gravel dominating the bed, locally may be bedrock controlled. Reach types typically include pool-riffle or pool-rapid, sand bars common in pools. Pools of significantly greater extent than rapids or riffles. Flood plain often present.
6. Lowland sand bed or lowland floodplain	0.0001 – 0.001	Low gradient alluvial sand bed channel, typically regime reach type. Often confined, but fully developed meandering pattern within a distinct flood plain develops in unconfined reaches where there is an increased silt content in bed or banks.
B. Additional zones associated with a rejuvenated profile		
7. Rejuvenated bedrock fall/cascades	0.01 – 0.5	Moderate to steep gradient, often confined channel (gorge) resulting from uplift in the middle to lower reaches of the long profile, limited lateral development of alluvial features, reach types include bedrock fall, cascades and pool-rapid.
8. Rejuvenated foothills	0.001 – 0.01	Steepened section within middle reaches of the river caused by uplift, often within or downstream of gorge, characteristics similar to foothills (gravel cobble bed rivers with pool-riffle/pool-rapid morphology) but of a higher order. A compound channel is often present with an active channel contained within a macro channel activated only during infrequent flood events. A flood plain may be present between the active and macro-channel.
9. Upland flood plain	9.0.0001 – 0.001	An upland low gradient channel, often associated with uplifted plateau areas as occur beneath the eastern escarpment.

The zones identified along the Buffalo river are as follows:

- 1160 – 620 m.a.s.l. - Mountain Headwaters
- 620 – 480 m.a.s.l. - Mountain Stream (*)
- 480 – 280 m.a.s.l. - Foothill Gravel Bed/Foothill Cobble Bed (***)
- 280 – 240 m.a.s.l. - Mountain Stream
- 240 – 120 m.a.s.l. - Foothill Gravel Bed/Foothill Cobble Bed
- 120 – 40 m.a.s.l. - Mountain Stream
- 40 – 0 m.a.s.l. - Foothill Gravel Bed/Foothill Cobble Bed (*)

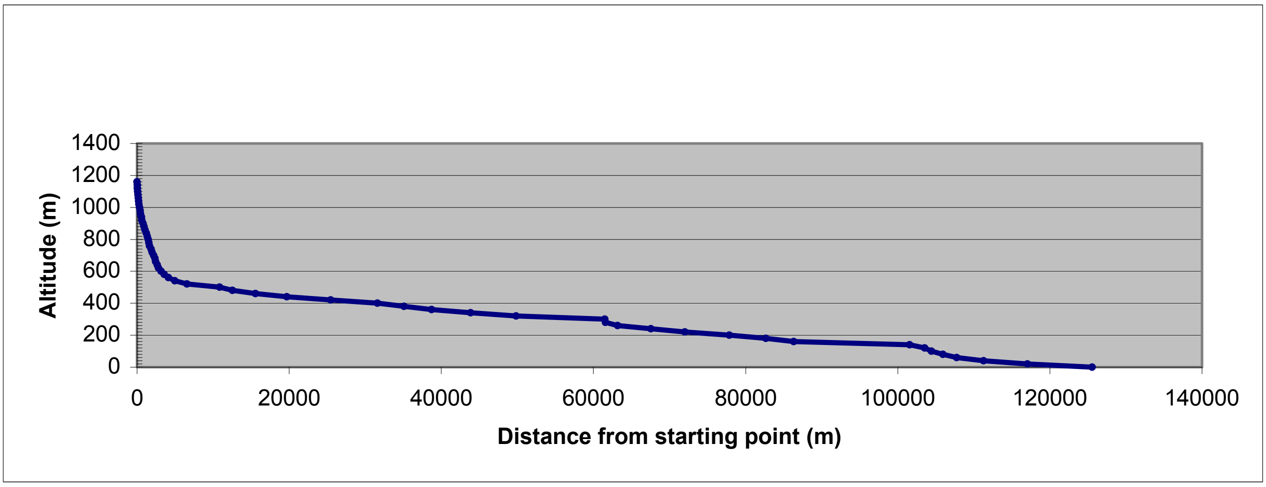

Figure 6.1 Longitudinal profile of the Buffalo River.

6.3.2 Desktop and field findings

Results of desktop and field studies will be presented in a combined format for each site.

Summary of geomorphological characteristics and impacts found at sites on the main channel

Site 1 : Buffalo River above Maden Dam

Latitude	32º 43' 21" S
Longitude	27º 17' 46" E
Altitude range	620 – 600 m.a.s.l. (Mountain Stream Zone)
Quaternary catchment	R20A
Lithology (WR90)	Intercalated arenaceous and argillaceous strata.
Site summary	This is an alluvial channel section with moderately packed and moderately embedded bed material consisting predominantly of boulders, but including some cobble. The reach is classified as pool-rapid. Bank stability on the left and right is considered to be high, though slight fluvial and sub-aerial bank erosion was noted on both banks. Impacts noted in the reach include a gauging weir, infrequent causeways and a few sediment sources related to human activity. In terms of vegetation, there is no clear riparian zone evident. There is indigenous forest on both banks which gives good canopy cover and stabilizes the bank

	with a deep rooting system. There is evidence of previous bank undercutting and slumping on bends. It has been noted by Rowntree (Rhodes University, pers comm., 2004) that one feature that can be noted from this zone of the river is that there are a number of relict cut-off meanders or secondary channels and evidence of channel straightening and incision. About 500 to 1000m above the weir the channel has a naturally divided form. If one of these channels is lost, the main channel has to accommodate more water, resulting in bank erosion etc.. Whether these changes are natural or due to human disturbance is not clear, but one side channel has been blocked by pipes washed down from a causeway
Impact class	B

Site 2 : Buffalo River at Horseshoe Bend

Latitude	32º 49' 21" S
Longitude	27º 22' 49" E
Altitude range	420 – 400 m.a.s.l. (Foothill Gravel Bed/Foothill Cobble Bed Zone)
Quaternary catchment	R20B
Lithology (WR90)	Intercalated arenaceous and argillaceous strata.
Site summary	This site is located on a mixed channel section which has been classified as having a pool-rapid morphology. The dominant bed materials are bedrock and cobble (which is moderately packed and embedded). Impacts noted along this reach include sediment extraction (though this is deemed to have a low impact), an upstream dam, infrequent causeways, dense alien vegetation and moderate sediment sources related to human activity. Bank stability is identified as being low on the left hand bank, but moderate on the right hand bank. This is due to the fact that the site is located on a sharp river bend, though it seems that alien vegetation present on the bank is accelerating the processes of undercutting and slumping. Multiple terraces were noted on the right hand bank.
Impact class	C

Site 7 : Buffalo River above Zwelitsha (below King Williams Town)

Latitude	32º 55' 14.2" S
Longitude	27º 29' 18.0" E
Altitude range	340 – 320 m.a.s.l. (Foothill Gravel Bed/Foothill Cobble Bed Zone)
Quaternary catchment	R20D
Lithology (WR90)	Intercalated arenaceous and argillaceous strata.
Site summary	This site is located in a mixed channel reach with bedrock and boulders as predominant bed materials, and displaying pool-rapid morphology. Bed material is moderately packed and not embedded. Impacts identified include a small amount of sediment extraction, an upstream dam, infrequent causeways, bridges with in-channel supports, moderate invasion by alien vegetation, recent indigenous vegetation clearance from the

	riparian zone and extensive sediment sources related to human activity. Bank stability is moderate on both the left and right hand banks, except where bank stability is reduced locally as a result of the bridge and gully headcuts.
Impact class	C/D

Site 8 : Buffalo River downstream of Zwelitsha

Latitude	32º 55' 54.4" S
Longitude	27º 26' 22.1" E
Altitude range	340 – 320 m.a.s.l. (Foothill Gravel Bed/Foothill Cobble Bed Zone)
Quaternary catchment	R20D
Lithology (WR90)	Intercalated arenaceous and argillaceous strata.
Site summary	The site is located on a mixed, pool-riffle section with bedrock and boulders as the predominant bed materials. Impacts noted on this reach include an upstream dam, infrequent causeways, bridges with in-channel supports, negligible geomorphological impacts due to alien vegetation and moderate sediment sources related to human activity. All of these have the potential to alter natural sediment and flow regimes. Bank stability is high on both banks, though bank stability was assessed roughly 150m from the dedicated RHP site due to high and unrepresentative levels of erosion at the RHP site. This erosion was highly localized due to the bridge construction and subsequent gully formation.
Impact class	C/D

Site 9 : Buffalo River at Buffalo Pass

Latitude	33º 00' 31.6" S
Longitude	27º 29' 32.6" E
Altitude range	20 – 0 m.a.s.l. (Foothill Gravel Bed/Foothill Cobble Bed Zone)
Quaternary catchment	R20G
Lithology (WR90)	Intercalated arenaceous and argillaceous strata.
Site summary	This site is located on an alluvial pool-rapid section with tightly packed boulders as the dominant bed material. Impacts noted include an upstream dam, infrequent causeways, a bridge with in-channel supports, negligible geomorphological impacts due to invasion by alien vegetation and few sediment sources related to human activity. A low water bridge at the site has been partially washed away which has resulted in the formation of a deep pool behind the remnants of the bridge. Bank stability is high on both banks. Overall, this is a geomorphologically stable site.
Impact class	C

Summary of geomorphological characteristics and impacts found at sites on tributaries and adjacent streams

Site 3 : Mgqakwebe tributary at Pirie Mission Station

Latitude	32º 47' 17" S
Longitude	27º 14' 59" E
Quaternary catchment	R20B
Lithology (WR90)	Intercalated arenaceous and argillaceous strata.
Site summary	This site is located on an alluvial channel reach with moderately packed and moderately embedded cobble as the dominant bed material. The reach morphology is classified as being pool-riffle. Impacts noted at the site are alien vegetation, though this has a negligible geomorphological impact, as well as moderate sediment sources related to human activity. Both banks are moderately stable, but are being slowly undercut as a result of fluvial action. An interesting phenomenon at the site is a wetland which has formed in a natural depression on the right hand bank.
Impact class	B

Site 4 : Ngqokweni tributary

Latitude	32º 54' 59" S
Longitude	27º 22' 45" E
Quaternary catchment	R20D
Lithology (WR90)	Intercalated arenaceous and argillaceous strata.
Site summary	This site is located on a bedrock reach. It displays cascade morphology. Overall, bank stability is classified as moderate due to the fact that bedrock cliffs alternate with less stable bank sections which consist of a layer of sand over bedrock. Impacts noted include a gauging weir (though the impact of this is probably negligible), infrequent causeways, recent indigenous vegetation clearance from the riparian zone (largely due to firewood collection) and moderate sediment sources related to human activity.
Impact class	C

Site 5 : Yellowoods River 1 (at Leonsdale Bridge)

Latitude	32º 48' 30" S
Longitude	27º 22' 45" E
Quaternary catchment	R20B
Lithology (WR90)	Intercalated arenaceous and argillaceous strata.
Site summary	This site is located on a mixed channel reach with bedrock and cobble (which is loosely packed and moderately embedded) as the predominant bed materials. The reach type has been classified as pool-riffle. Impacts noted at this site include sediment extraction, bridges (though these have side supports only), negligible geomorphological impacts due to invasive alien vegetation and extensive sediment sources related to human activity. The stability of both banks is low to moderate due to extensive gullying, as well as undercutting and slumping

	of banks. Geomorphologically, the site is highly disturbed, mainly as a result of sand mining and overgrazing. There is a marked difference between the area upstream of the bridge and the area surrounding the bridge.
Impact class	C/D

Site 6 : Yellowoods River 2

Latitude	32º 55' 14.2" S
Longitude	27º 29' 18.0" E
Quaternary catchment	R20E
Lithology (WR90)	Intercalated arenaceous and argillaceous strata.
Site summary	This site is located on a mixed reach with bedrock and boulders (which are added to the channel directly from the abutting hillslope) as the dominant bed materials. The reach type has been classified as "pool - rapid". Stability of the left hand bank, which is dominated by bedrock, is high, whilst the right hand bank is moderately stable. There is more erosion occurring on the right hand bank than on the left hand bank. Impacts noted at the site include a few storage weirs, negligible geomorphological impact due to invasion by alien vegetation and a few sediment sources related to human activity.
Impact class	C/D

Site 10 : Nahoon River (upstream of Nahoon Dam)

Latitude	32º 51' 1" S
Longitude	27º 45' 55" E
Quaternary catchment	R30E
Lithology (WR90)	Intercalated arenaceous and argillaceous strata.
Site summary	This site is located on a mixed, pool-rapid reach. Bedrock and boulders were identified as the pre-dominant bed materials. The stability of both banks is low, largely as a result of gully erosion. A bridge located at the site also has a noteworthy local impact on bank stability. Impacts noted include localized gabions, infrequent causeways, the bridge (which has in-channel supports), recent indigenous vegetation clearance from the riparian zone and moderate sediment sources related to human activity.
Impact class	C

Site 11 : Shangani tributary (flows through Mdantsane into Bridle Drift Dam)

Latitude	32º 58' 11.1" S
Longitude	27º 42' 37.3" E
Quaternary catchment	R20F
Lithology (WR90)	Intercalated arenaceous and argillaceous strata.
Site summary	This site is located on a mixed, pool-rapid channel section with bedrock and gravel as the dominant bed materials. The stability of both banks is high, though there is severe localized erosion at one point on the left hand bank due to a previous waste disposal site at this point. Impacts noted include infrequent causeways,

	bridges with in-channel supports, moderate geomorphological impact due to invasive alien vegetation and moderate sediment sources related to human activity. It must be said that this is not a good site for the purposes of a geomorphological survey. The site is located very close to a bridge, a tunnel and a large dam, and accessibility is limited due to security issues.
Impact class	C/D

Site 12 : KwaNxamkwana tributary downstream of Potsdam town (approximately 500m from the confluence with the main stream)

Latitude	32º 59' 6.7" S
Longitude	27º 38' 19.5" E
Quaternary catchment	R20F
Lithology (WR90)	Intercalated arenaceous and argillaceous strata.
Site summary	This site is located on a mixed reach section with bedrock and cobble as the dominant bed materials. The reach displays both pool-rapid morphology (where bedrock dominates) as well as pool-riffle morphology (where cobble dominates). Bank stability is high on the right hand bank which is dominated by bedrock, and moderate on the left hand bank. Bank stability decreases closer to the confluence. Impacts noted at the site include invasion by alien vegetation (though this is thought to be geomorphologically insignificant), as well as recent indigenous vegetation clearance from the riparian zone and moderate sediment sources related to human activity.
Impact class	B

6.4 DISCUSSION AND CONCLUSION

Detailed geomorphological surveys were conducted at all of the sites selected during a field trip in October 2002. It is recommended by Rowntree and Ziervogel (1999) that detailed surveys for the purposes of classification and assessment of channel stability be carried out once in the initial stages of a monitoring project. Thereafter, this type of survey need only be conducted after a major hydrological event (e.g. a 10 year flood) or after a major upstream disturbance has occurred. It is further recommended that less detailed monitoring surveys should be carried out once a year during low flows.

The Buffalo River catchment is highly utilized with many demands being placed on it from various sectors of the population. In terms of geomorphological status (PGS), the majority of the sites were awarded an impact status of C (see Table 6.1). This indicates significant human impact, evident changes to bed structure, localised bank erosion and channel widening, or deposition and narrowing. However, it is felt that at many of the sites this may be too high a rating (pers comm., Rowntree, Rhodes University,) and that the condition is more than likely tending towards an impact rating of D (major human impacts resulting in significant long term changes to channel geometry, pattern or reach type that may be irreversible). This is largely as a result of the major impoundments in the catchment which have permanently and significantly altered the river's natural flow regime. This will have serious implications for habitat integrity and thus community structure.

It would be advantageous to undertake regular geomorphological monitoring surveys (once a year) to ascertain whether the river channel is on a trajectory of change and, if so, what direction this trajectory is taking (Rowntree and Ziervogel, 1999). However for the time being, the overall geomorphological health of the system could probably be best described as mediocre, verging on poor in places.

CHAPTER 7

WATER QUALITY

7.1 INTRODUCTION

Water quality is a term describing the physical, chemical, microbial and radiological properties of water. It is an important attribute of rivers affecting the biotic community, and subsequent health, of the aquatic ecosystem (Dallas and Day, 1993; Palmer et al., in prep-a). Water quality varies naturally as a result of the combined influences of climate, geomorphology, geology, soils and the aquatic and terrestrial biota living in a particular catchment (Davies and Day, 1998), but water quality can also vary as a result of anthropogenic influences. Aquatic organisms live in limited water quality ranges and these requirements are determined by the evolutionary history of the organisms and any adaptations that they may have undergone to living in particular water quality conditions (Dallas and Day, 1993; Davies and Day, 1998). Aquatic organisms provide an essential cleansing service in aquatic ecosystems, removing nutrient-rich organic waste and breaking down complex organic matter, and in order to ensure their continued survival in ecosystems it is therefore necessary to provide their particular water quality requirements (Davies and Day, 1998). Water quality data, therefore, are an essential component of any assessment of present ecological state of aquatic resources and this chapter provides a summary of recent water chemistry in the Buffalo River.

There has been concern over water quality of the Buffalo River, particularly downstream of King Williams Town (O'Keeffe et al., 1996). The main sources of water quality impairment in this part of the Buffalo River catchment have been identified as the Sewage Treatment Works in King Williams Town and Zwelitsha, return flows from industrial irrigation schemes, return flows from other agricultural irrigation schemes and spillages from the urban area of Mdantsane. The study identified salinity, nutrients and faecal bacteria as the major water quality variables of concern, but other water quality variables were also found to exceed the DWAF water quality guidelines available at the time of the study (O'Keeffe et al., 1996). Many variables were identified, e.g. heavy metals, for which no data existed at the time of the study.

The approach used for this study was to follow the method for undertaking a Present Ecological State assessment as for an Ecological Reserve (Ecological Water Requirements: Rivers) study. Salinity (measured as Total Dissolved Salts and Electrical Conductivity) and faecal bacteria were excluded from this approach.

7.2 MATERIALS AND METHODS

In this study, only Department of Water Affairs and Forestry (DWAF) water quality monitoring points were considered, and only data from weirs in rivers were considered (i.e. no water quality data from the dams or pipelines leading from dams to purification works were considered).

Although algal blooms, as a result of nutrient enrichment, have been reported in the dams in the Buffalo River catchment (O'Keeffe et al., 1996), water quality of the dams was not included as part of the state of the river assessment. In addition, although faecal bacteria have previously been identified as a variable of concern for this catchment (O'Keeffe et al., 1996), it was not included in the current assessment, as the focus was on ecological water quality.

The monitoring points used are listed in Table 7.1 along with their position relative to the biomonitoring sites sampled. Although the monitoring point R2H002 (upstream of Site 9) appears to have a reasonable data record, there are in fact only 17 records over that time period, with no discernable pattern. Due to the apparent ad hoc nature of sampling at this site, it was excluded from any further analysis.

Table 7.1 DWAF water quality monitoring points, listed from upstream to downstream sites.

DWAF WEIR NUMBER	CO-ORDINATES	POSITION RELATIVE TO MONITORING POINTS	DATA RECORD
R2H001Q01	32.7319S 27.29361E	Buffalo River, in Pirie forest reserve. Site 1.	1971 – 2003
R2H005Q01	32.8753S 27.37306E	Buffalo River upstream of King Williams Town, downstream of Site 2.	1977 – 2003
R2H010Q01	32.9406S 27.46139E	Buffalo River immediately upstream of Site 8.	1972 – 2003
R2H027Q01	32.9936S 27.61667E	On Buffalo River, at Mhlabati Needs Camp. Immediately upstream of tributary input from Site 12.	1994 – 2003
R2H002Q01	32.9964S 27.79667E	Buffalo River, upstream of Site 9.	1972 – 1995

The method used to analyse the present state of the water quality of the Buffalo River is that used for Ecological Water Requirements (Rivers) assessments (Palmer et al., in prep.). Although these methods have not yet been peer reviewed, they are currently the only methods available for undertaking a Present Ecological State assessment for water quality. Only data from 1999 onwards were used in the assessment and the assessment was undertaken relative to the default benchmark boundary values provided in the method, which may result in a more conservative assessment of the water quality. Only variables for which there were data available at a minimum of one of the monitoring points were included in the assessment. Although turbidity data were available at two of the monitoring points, there is currently no assessment method available for this variable. Temperature data were available at two of the monitoring sites, but as no Reference Condition data were available, an assessment could not be undertaken.

7.3 RESULTS

Results for the Present Ecological State assessment for water quality of the Buffalo River are shown in Table 7.2. The most upstream monitoring point (R2H001, at Site 1) showed the most unimpacted assessment relative to the default benchmark boundary tables, with only Soluble Reactive Phosphate (SRP) having higher than natural concentrations of PO_4-P. The overall site classification remained in the Natural category. However, at monitoring points further downstream in the catchment, water quality impairment is evident. At each of these sites, increased concentrations of nutrients and inorganic salts have resulted in reduced water quality. In addition, data were available to assess (limited) toxic substances, and particularly aluminium appears to be a water quality variable of concern. Aluminium is present in high concentrations upstream of King Williams Town (R2H005), although there is no obvious source of this metal and this result should be interpreted with caution.

Monitoring point R2H010 is downstream of King Williams Town and Zwelistha and the overall site assessment for water quality puts this site in a Fair category, the lowest for the Buffalo River catchment (Table 7.2). The monitoring site further downstream (R2H027) indicates that improvement in water quality has taken place (improvement in class from Fair to Good - Fair). However, the interpretation of downstream improvement in water quality should be made with care as this monitoring site is upstream of any input from Mdantsane. Spillages from the urban sprawl of Mdantsane to the Buffalo River have previously been identified as a source of water quality impairment in the river, and further investigations will have to be undertaken (e.g. reinstituting regular monitoring).

Table 7.2 Present Ecological State assessment of selected water quality variables of the Buffalo River (ND indicates that no data were available for the water quality variable and an assessement could not be undertaken) (SRP: Soluble Reactive Phosphate; TN: Total Inorganic Nitrogen).

WATER QUALITY VARIABLE	R2H001 (Site 1)	R2H005 (Site 2)	R2H010 (Site 8)	R2H027 (upstream Bridledrift Dam)
Inorganic salts				
$MgSO_4$	Natural	Fair - Poor	Poor	Fair - Poor
Na_2SO_4	Natural	Natural	Natural	Natural
$MgCl_2$	Natural	Poor	Poor	Fair - Poor
$CaCl_2$	Natural	Fair	Fair - Poor	Fair
NaCl	Natural	Natural	Natural	Good
$CaSO_4$	Natural	Natural	Natural	Natural
Nutrients				
SRP	Good	Fair	Poor	Fair
TIN	Natural	Good	Fair	Good
System Variable				
pH	Natural	Natural - Good	Natural - Good	Natural - Good
Toxic substances				
NH_3	Natural	Natural - Good	Good	Natural
F	Natural	Natural	Natural	Natural
Al	ND	Poor	Poor	Poor
OVERALL ASSESSMENT	Natural	Good - Fair	Fair	Good - Fair

The method for calculating inorganic salt concentrations from the DWAF ion data has been shown to be not entirely accurate (Jooste, Resource Quality Service, pers. comm.). Although a new method is currently under development, it was not yet available for use in this study, and the resultant inorganic salt categories should be interpreted with caution. The trend shown by the inorganic salts, i.e. water quality impairment, is as a result of increased concentrations of $MgSO_4$, $MgCl_2$ and $CaCl_2$. Although this suggests that there may be salinisation occurring in the catchment, this result should be interpreted with care. Table 7.3 lists the median Total Dissolved Salts (TDS) and Electrical Conductivity (EC) for the same monitoring points. They clearly show a downstream increase in salinity (increased TDS concentrations and EC readings). Although the trend reflects the tendency for a natural increase in TDS and EC, it is obvious that the trend shown here is exacerbated by anthropogenic input, as the readings immediately downstream of King Williams Town and Zwelitsha are the highest with some downstream improvement in water quality evident at R2H027.

Table 7.3 Median Total Dissolved Salt (TDS; mg/ℓ) concentrations and median Electrical Conductivity (EC; mS/m) for data from DWAF monitoring points from 1999 to the most recently available data.

MONITORING POINT	TDS (mg/ℓ)	EC (mS/m)
R2H001	53	8.4
R2H005	315	47
R2H010	483	75
R2H027	312	51

7.4 DISCUSSION AND CONCLUSION

The results presented in this assessment support the findings of the earlier study by O'Keeffe et al. (1996) who identified nutrients to be of concern in the middle reaches of the Buffalo River catchment. The previous study also reported that there were no long-term trends indicating increasing salinity levels, although there were temporary increases during drought (O'Keeffe et al., 1996). Although it was beyond the scope of this study, it would be useful for resource management of the Buffalo River to examine whether this is still the case. There is a noticeable downstream pattern in TDS and EC, which appears to be associated with urban settlements. These have increased in size considerably since the last study, and may have resulted in increased salinity levels in the Buffalo River. However, it will be necessary to reinstitute regular monitoring at R2H002Q01 in order to adequately assess the impacts of input from Mdantsane.

In addition, there are a number of variables (e.g. heavy metals, pesticides) which are currently not being monitored. In order to adequately assess the Present Ecological State for these variables, it will be necessary to institute appropriate monitoring programmes.

CHAPTER 8

FINAL DISCUSSION, CONCLUSION AND RECOMMENDATIONS

Each chapter has dealt with recommendations regarding the monitoring of each individual variable. Chapter 8 therefore serves to graphically demonstrate an overview of the state of the Buffalo River (Figure 8.1), per site and per indicator. Colours used in Figure 8.1 denote the following: Natural – blue, Good – green, Fair – yellow, Poor – red.

The overview state of the biological indicators is shown in Table 8.1.

Table 8.1 An overview of state of health of biological indicators (i.e. fish, macroinvertebrates, riparian vegetation) per site.

SITE NUMBER	DESCRIPTION OF LOCATION	DESCRIPTION OF STATE OF HEALTH OF BIOLOGICAL INDICATORS
1	Buffalo River above Maden Dam	Good (RVI) to Fair
2	Buffalo River at Horseshoe Bend	Fair to Poor
3	Maqakwebe tributary	Good to Fair
4	Ngqokweni tributary	Fair (no RVI)
5	Yellowwoods River at Leonsdale bridge	Fair (no RVI)
6	Yellowwoods River 2	Fair (to Poor for fish) (no RVI)
7	Buffalo River below King Williams Town, and above Zwelitsha	Poor (no RVI)
8	Buffalo River below Zwelitsha	Poor (no RVI)
9	Buffalo River at Buffalo Pass	Good
10	Nahoon River upstream of Nahoon Dam	Poor (no RVI)
11	Shangani Stream draining Mdantsane	Fair to Poor (no RVI)
12	KwaNxamkwane Stream draining Potsdam	Fair to Poor (no RVI)

General recommendations are provided below in point form per indicator. See chapters for more detailed information.

Macroinvertebrates (icon: crab)

- SASS results were a useful indicator of the validity of reference vs. monitoring sites.
- Sites 1 and 10 were considered particularly poor indicators of reference condition.

Fish (icon: fish)

- It is recommended that a fish specialist workshop be conducted in the Eastern Cape (similar to the workshop conducted for the riparian vegetation index development). Development is required on the fish index, particularly due to the low species-richness of Eastern Cape rivers.

- An important point to consider for future fish monitoring is sampling method. Methods used at present satisfy the RHP requirements for time, but do not adequately sample all fish species or habitats.
- Development is also required around the derivation of fish habitat segments, and the assessment of fish health.
- It is recommended that fish monitoring of the Buffalo River be conducted again in 2004 (one intensive survey per site), but after a developmental workshop has been conducted.

Riparian vegetation (icon: tree)

- The IRVI, developed during the project and tested on a few representative sites, should be tested on a wider range of sites in the catchment. Only one survey is required per year.
- The information regarding the new modified index should be passed on to the national team for evaluation.
- Monitoring and management recommendations for each site are presented in Chapter 3.

Geomorphology (icon: stream)

- Monitoring and management recommendations for each site are presented in Chapter 6.
- Due to the poor geomorphological state of most of the Buffalo River catchment, it is recommended that this index by conducted again in 2004 so as to ascertain whether conditions are on a negative trajectory of change.

Water quality (icon: measuring cylinder)

- As this report only assessed water quality conditions of the main stem of the river, a water quality present state assessment must be conducted for selected tributaries of the Buffalo River, e.g. Yellowwoods, Mgqakwebe and Ngqokweni rivers.
- Water quality monitoring must be re-instituted in the lower reaches, i.e. around Site 9.

General

- The development of a *reference condition* (vs. the selection of reference sites) for the Buffalo River catchment should be persued, particularly due to the highly developed nature of this catchment.
- Although Site 1 served as a poor reference site, monitoring should be continued due to the unusually poor results obtained at this site (particularly as it is in a protected area).
- Site 3 should be monitored as a reference site, pending a water quality investigation.
- It is recommended that monitoring be discontinued at Site 4. The stream enters the Buffalo River between Sites 7 and 8 – its impact on the impaired water quality at Site 8 should be investigated.
- Pending a water quality investigation, it may be possible to discontinue monitoring at Site 5 on the Yellowwoods River. However, monitoring the possible ecological impact of the transfer from Wriggleswade Dam on this system may be useful.
- It may not be necessary to continue monitoring at both Sites 7 and 8, unless specific requirements exist. Monitoring at Site 8 only may be adequate for meeting management requirements.
- Monitoring should be continued at Site 9, as this site shows good recovery from the poor condition of upstream sites (e.g. Sites 7 and 8).

- Biological monitoring at Site 10, i.e. the Nahoon River, should be discontinued. This site was assessed as a reference site for the lower reaches of the Buffalo River catchment, but proved to be a poor site (consider as a monitoring site for the Nahoon River catchment).
- It may be possible to discontinue monitoring at both Sites 11 and 12. Both rivers drain large urban and rural settlements, and continued monitoring at Site 11 may be adequate for the lower catchment.

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APPENDIX 1

MACROINVERTEBRATES

THE RIVER HEALTH PROGRAMME

DEPT. OF WATER AFFAIRS & FORESTRY
WATER RESEARCH COMMISSION
DEPT. OF ENVIRONMENTAL AFFAIRS & TOURISM

Date: / /200__

Grid References:
S: ° ' , "
E: ° ' , "

WGS-84 | Cape datum

Site code:……………………

River:……………………………………

Site description:…………………………

Weather Condition:………………………

Temp:……………°C pH:……………

DO:……………mg/l Cond:…………mS/m

Biotopes sampled:

SIC ……………… Time……………minutes
SOOC………………
Bedrock……………
Aquatic veg'n……… Dom. sp……………………
MvegIC………… Dom. sp……………………
MvegOOC……… Dom. sp……………………
Gravel…………… Sand……………
Mud…………………

Hand picking/Visual observation……………

Flow: Low/Medium/High/Flood

Turbidity: Low/Medium/High

Riparian land use:

Disturbance in the river: eg. sandwinning, cattle drinking point, floods etc.

Signs of pollution: eg. smell and colour of water, petroleum, dead fish, etc.

Other observations:

Taxon		S	VG	GSM	TOT
PORIFERA	5				
COELENTERATA	1				
TURBELLARIA	3				
ANNELIDA					
Oligochaeta	1				
Leeches	3				
CRUSTACEA					
Amphipoda	13				
Potamonautidae*	3				
Atyidae	8				
Palaemonidae	10				
HYDRACARINA	8				
PLECOPTERA					
Notonemouridae	14				
Perlidae	12				
EPHEMEROPTERA					
Baetidae 1sp	4				
Baetidae 2 sp	6				
Baetidae > 2 sp	12				
Caenidae	6				
Ephemeridae	15				
Heptageniidae	13				
Leptophlebiidae	9				
Oligoneuridae	15				
Polymitarcyidae	10				
Prosopistomatidae	15				
Teloganodidae SWC	12				
Tricorythidae	9				
ODONATA					
Calopterygidae ST,T	10				
Chlorocyphidae	10				
Chlorolestidae	8				
Coenagrionidae	4				
Lestidae	8				
Platycnemidae	10				
Protoneuridae	8				
Zygoptera juvs.	6				
Aeshnidae	8				
Corduliidae	8				
Gomphidae	6				
Libellulidae	4				
LEPIDOPTERA					
Pyralidae	12				

Taxon		S	VG	GSM	TOT
HEMIPTERA					
Belostomatidae*	3				
Corixidae*	3				
Gerridae*	5				
Hydrometridae*	6				
Naucoridae*	7				
Nepidae*	3				
Notonectidae*	3				
Pleidae*	4				
Veliidae/M...veliidae*	5				
MEGALOPTERA					
Corydalidae	8				
Sialidae	6				
TRICHOPTERA					
Dipseudopsidae	10				
Ecnomidae	8				
Hydropsychidae 1 sp	4				
Hydropsychidae 2 sp	6				
Hydropsychidae > 2 sp	12				
Philopotamidae	10				
Polycentropodidae	12				
Psychomyiidae/Xiphocei	8				
Cased caddis:					
Barbarochthonidae SWC	13				
Calamoceratidae ST	11				
Glossosomatidae SWC	11				
Hydroptilidae	6				
Hydrosalpingidae SWC	15				
Lepidostomatidae	10				
Leptoceridae	6				
Petrothrincidae SWC	11				
Pisuliidae	10				
Sericostomatidae SWC	13				
COLEOPTERA					
Dytiscidae*	5				
Elmidae/Dryopidae*	8				
Gyrinidae*	5				
Haliplidae*	5				
Helodidae	12				
Hydraenidae*	8				
Hydrophilidae*	5				
Limnichidae	10				
Psephenidae	10				

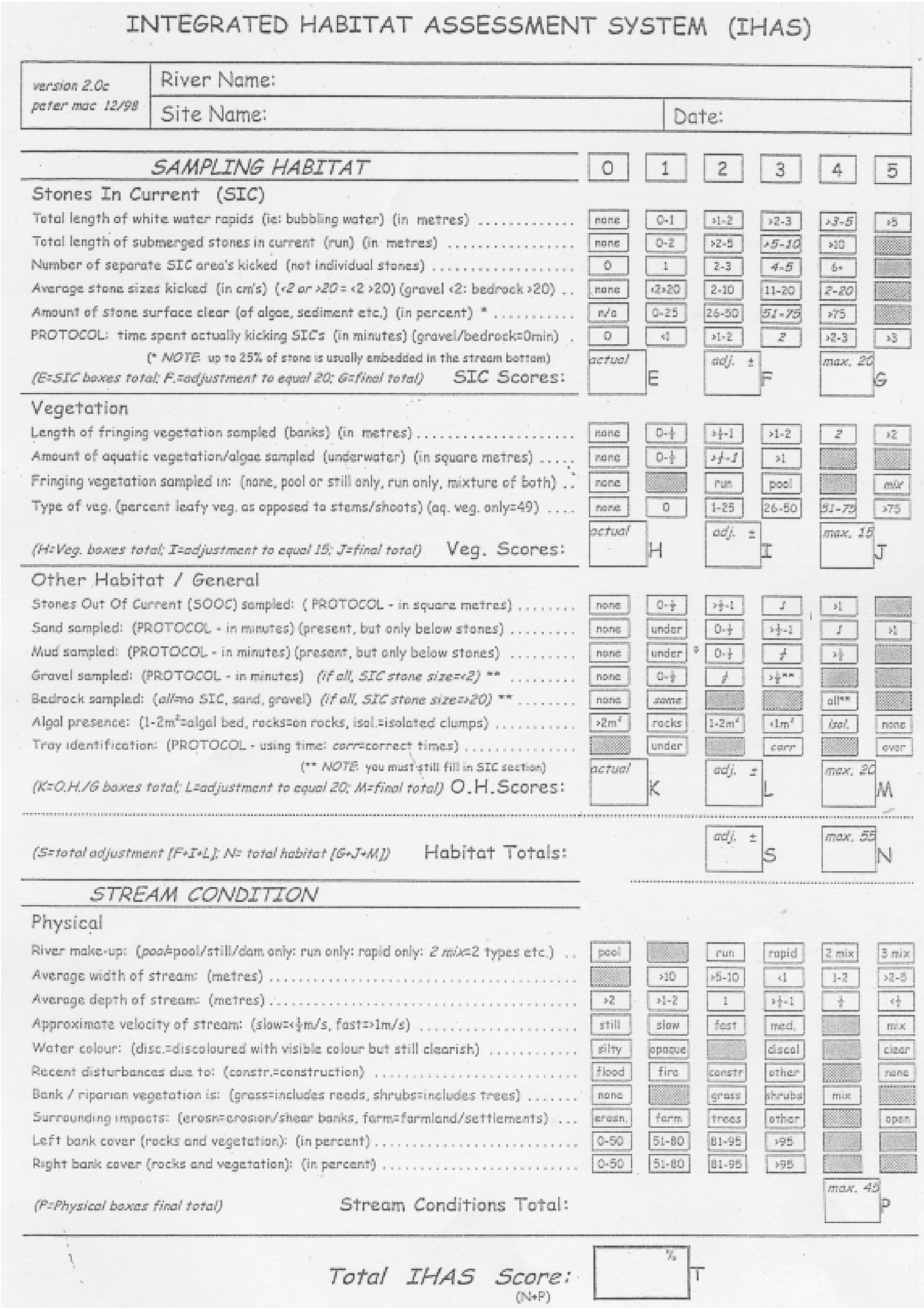
Taxon		S	VG	GSM	TOT
DIPTERA					
Athericidae	10				
Blepharoceridae	15				
Ceratopogonidae	5				
Chironomidae	2				
Culicidae*	1				
Dixidae*	10				
Empididae	6				
Ephydridae	3				
Muscidae	1				
Psychodidae	1				
Simuliidae	5				
Syrphidae*	1				
Tabanidae	5				
Tipulidae	5				
GASTROPODA					
Ancylidae	6				
Bulininae*	3				
Hydrobiidae*	3				
Lymnaeidae*	3				
Physidae*	3				
Planorbinae*	3				
Thiaridae*	3				
Viviparidae* ST	5				
PELECYPODA					
Corbiculidae	5				
Sphaeriidae	3				
Unionidae	6				
Sass score					
No. of taxa					
ASPT					
IHAS					

Other biota:

Comments:

Procedure: Kick stones in current & bedrock for 2 mins, max. 5 mins. Kick SOOC & bedrock +/- 1m2. Sweep vegetation (IC & OOC) for 2m total. Stir & sweep gravel, sand, mud for 30 secs total. * = airbreathers
Hand picking & visual observation for 1 min - record in biotope where found. Tip net contents into tray. Remove leaves, twigs & trash. Check taxa present for 15 mins and stop if no new taxa seen after 5 mins.
Estimate abundances: 1 = 1, A = 2-10, B = 10-100, C = 100-1000, D = >1000 S = Stone and rock; VG = All vegetation; GSM = Gravel, sand, mud SWC = South Western Cape, T = Tropical, ST = Sub-tropical
Rate invertebrate biotope sampled: 1=very poor (i.e. limited diversity), 5=highly suitable (i.e. wide diversity)

Figure 1 The SASS Score sheet.



INTEGRATED HABITAT ASSESSMENT SYSTEM (IHAS)

version 2.0c *peter mac 12/98*	River Name:	
	Site Name:	Date:

SAMPLING HABITAT	0	1	2	3	4	5
Stones In Current (SIC)						
Total length of white water rapids (ie: bubbling water) (in metres)	none	0-1	>1-2	>2-3	>3-5	>5
Total length of submerged stones in current (run) (in metres)	none	0-2	>2-5	>5-10	>10	
Number of separate SIC area's kicked (not individual stones)	0	1	2-3	4-5	6+	
Average stone sizes kicked (in cm's) (*<2 or >20* = <2 >20) (gravel <2: bedrock >20)	none	<2>20	2-10	11-20	2-20	
Amount of stone surface clear (of algae, sediment etc.) (in percent) *	n/a	0-25	26-50	51-75	>75	
PROTOCOL: time spent actually kicking SICs (in minutes) (gravel/bedrock=0min)	0	<1	>1-2	2	>2-3	>3
(* *NOTE*: up to 25% of stone is usually embedded in the stream bottom) *(E=SIC boxes total; F=adjustment to equal 20; G=final total)* SIC Scores:	*actual*	E	*adj.* ±	F	*max. 20*	G
Vegetation						
Length of fringing vegetation sampled (banks) (in metres)	none	0-½	>½-1	>1-2	2	>2
Amount of aquatic vegetation/algae sampled (underwater) (in square metres)	none	0-½	>½-1	>1		
Fringing vegetation sampled in: (none, pool or still only, run only, mixture of both)	none		run	pool		mix
Type of veg. (percent leafy veg. as opposed to stems/shoots) (aq. veg. only=49)	none	0	1-25	26-50	51-75	>75
(H=Veg. boxes total; I=adjustment to equal 15; J=final total) Veg. Scores:	*actual*	H	*adj.* ±	I	*max. 15*	J
Other Habitat / General						
Stones Out Of Current (SOOC) sampled: (PROTOCOL - in square metres)	none	0-½	>½-1	1	>1	
Sand sampled: (PROTOCOL - in minutes) (present, but only below stones)	none	under	0-½	>½-1	1	>1
Mud sampled: (PROTOCOL - in minutes) (present, but only below stones)	none	under	0-½	½	>½	
Gravel sampled: (PROTOCOL - in minutes) *(if all, SIC stone size=<2)* **	none	0-½	½	>½**		
Bedrock sampled: (*all=no SIC, sand, gravel*) *(if all, SIC stone size=>20)* **	none	*some*			all**	
Algal presence: (1-2m²=algal bed, rocks=on rocks, isol.=isolated clumps)	>2m²	rocks	1-2m²	<1m²	*isol.*	none
Tray identification: (PROTOCOL - using time: *corr*=correct times)		under		*corr*		over
(** *NOTE*: you must still fill in SIC section) *(K=O.H./G boxes total; L=adjustment to equal 20; M=final total)* O.H.Scores:	*actual*	K	*adj.* ±	L	*max. 20*	M
(S=total adjustment [F+I+L]; N= total habitat [G+J+M]) Habitat Totals:			*adj.* ±	S	*max. 55*	N
STREAM CONDITION						
Physical						
River make-up: (*pool*=pool/still/dam only: run only: rapid only: *2 mix*=2 types etc.)	pool		run	rapid	2 mix	3 mix
Average width of stream: (metres)		>10	>5-10	<1	1-2	>2-5
Average depth of stream: (metres)	>2	>1-2	1	>½-1	½	<½
Approximate velocity of stream: (slow=<½m/s, fast=>1m/s)	still	slow	fast	med.		mix
Water colour: (disc.=discoloured with visible colour but still clearish)	silty	opaque		discol		clear
Recent disturbances due to: (constr.=construction)	flood	fire	constr	other		none
Bank / riparian vegetation is: (grass=includes reeds, shrubs=includes trees)	none		grass	shrubs	mix	
Surrounding impacts: (erosn=erosion/shear banks, farm=farmland/settlements)	erosn.	farm	trees	other		open
Left bank cover (rocks and vegetation): (in percent)	0-50	51-80	81-95	>95		
Right bank cover (rocks and vegetation): (in percent)	0-50	51-80	81-95	>95		
(P=Physical boxes final total) Stream Conditions Total:					*max. 45*	P

Total IHAS Score: (N+P) | % | T

Figure 2 The IHAS score sheet.

Table 1 Summary of the in-stream macroinvertebrates found during each of the biomonitoring surveys in the Buffalo River (Sites 1, 2, 7, 8 and 9), selected tributaries (Sites 3, 4, 5, 6, 11 and 12) and a single site in the Nahoon River (Site 10) (results for individual biotopes at each site are combined to provide presence / absence summary per site) (S: spring; A: autumn; W: winter).

SITE	**1**			**2**			**3**			**4**			**5**			**6**		
Season	**S**	**A**	**W**	**S**	**A**	**W**	**S**	**A**	**W**	**S**	**A**	**W**	**S**	**A**	**W**	**S**	**A**	**W**
Turbellaria				●		●	●	●			●		●	●	●			●
Annelida																		
Oligochaeta		●	●	●	●			●	●			●	●	●	●	●	●	●
Leeches															●			
Crustacea																		
Potamonautidae	●	●	●		●	●	●	●	●		●	●	●	●	●	●	●	●
Atyidae																		
Hydracarina													●		●			
Plecoptera																		
Perlidae							●	●										
Ephemeroptera																		
Baetidae	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
Caenidae		●	●	●		●	●	●	●	●	●	●	●	●	●	●	●	●
Heptageniidae				●	●		●	●	●									
Leptophlebiidae		●		●	●	●	●	●	●	●		●	●	●	●	●	●	●
Tricorythidae				●	●	●	●	●	●	●		●			●			
Odonata																		
Chlorocyphidae				●			●											
Chlorolestidae									●									
Coenagrionidae			●	●		●	●	●	●	●		●	●	●	●	●	●	●
Lestidae				●										●	●	●		
Platycnemidae						●	●	●	●									
Aeshinidae					●		●	●				●	●	●	●	●		
Gomphidae		●	●	●			●	●					●	●				●
Libellulidae		●	●	●							●			●			●	
Lepidoptera																		
Pyralidae							●									●		
Hemiptera																		
Belostomatidae										●				●				
Corixidae																		
Gerridae		●					●	●			●							
Naucoridae			●	●	●	●				●		●	●	●	●	●	●	●
Nepidae																		
Notonectidae								●		●	●			●	●		●	●
Vellidae				●				●		●								
Trichoptera																		
Hydropsychidae					●	●	●	●	●	●			●	●	●	●	●	●
Philopotamidae								●	●									
Leptoceridae				●			●	●	●	●			●					
Coleoptera																		
Dytiscidae				●		●		●	●	●	●	●	●	●	●	●	●	●
Elmidae				●	●	●	●			●	●		●	●		●		

SITE	1			2			3			4			5			6		
Season	**S**	**A**	**W**	**S**	**A**	**W**	**S**	**A**	**W**	**S**	**A**	**W**	**S**	**A**	**W**	**S**	**A**	**W**
Gyrindae				●			●			●		●	●	●	●		●	
Helodidae						●												
Hydrophilidae				●						●			●			●		●
Psephenidae				●			●	●		●	●	●					●	
Diptera																		
Athericidae	●	●	●		●	●	●	●	●									
Ceratopogonidae			●	●		●	●				●		●	●	●		●	●
Chironomidae	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
Culicidae						●	●		●				●	●	●			
Muscidae																		
Simuliidae	●		●	●		●	●	●	●	●	●	●	●	●	●	●	●	●
Tabanidae				●	●		●							●		●		
Tipulidae	●			●			●	●	●								●	
Gastropoda																		
Ancylidae		●	●	●	●	●		●				●	●	●	●			
Lymnaeidae												●						
Planorbinae				●		●												
Thiaridae																		
Pelecypoda																		
Corbiculidae		●			●	●								●			●	
Sphaeriidae						●				●		●		●	●			●

SITE	7			8			9			10			11			12		
Season	**S**	**A**	**W**	**S**	**A**	**W**	**S**	**A**	**W**	**S**	**A**	**W**	**S**	**A**	**W**	**S**	**A**	**W**
Turbellaria	●	●		●		●	●	●				●				●		
Annelida																		
Oligochaeta	●	●	●	●	●	●	●			●	●	●	●	●	●		●	●
Leeches	●	●	●	●	●				●		●			●				
Crustacea																		
Potamonautidae	●	●			●	●	●	●		●			●	●	●	●		
Atyidae									●									
Hydracarina																		
Plecoptera																		
Perlidae							●		●									
Ephemeroptera																		
Baetidae	●	●		●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
Caenidae	●			●	●		●	●	●	●	●	●				●	●	●
Heptageniidae							●	●	●									
Leptophlebiidae				●			●	●	●			●				●	●	
Tricorythidae	●			●			●											
Odonata																		
Chlorocyphidae								●										
Chlorolestidae																		
Coenagrionidae		●				●	●	●	●	●		●	●	●		●		●
Lestidae																●		
Platycnemidae									●				●					●
Aeshinidae												●					●	●
Gomphidae	●										●	●						●

SITE	**7**			**8**			**9**			**10**			**11**			**12**		
Season	**S**	**A**	**W**	**S**	**A**	**W**	**S**	**A**	**W**	**S**	**A**	**W**	**S**	**A**	**W**	**S**	**A**	**W**
Libellulidae								●			●	●				●		●
Lepidoptera																		
Pyralidae									●									
Hemiptera																		
Belostomatidae					●		●			●							●	
Corixidae																		
Gerridae																		
Naucoridae		●					●		●	●	●	●	●	●		●	●	●
Nepidae																●		
Notonectidae																		●
Vellidae	●					●		●				●	●			●	●	
Trichoptera																		
Hydropsychidae													●	●		●	●	●
Philopotamidae	●	●		●	●	●	●	●	●	●	●							
Leptoceridae								●										
Coleoptera																		
Dytiscidae													●	●		●	●	●
Elmidae									●		●	●				●	●	●
Gyrindae	●			●	●		●				●	●					●	●
Helodidae				●						●								
Hydrophilidae													●	●		●		
Psephenidae									●	●								
Diptera																		
Athericidae																		
Ceratopogonidae																●		●
Chironomidae				●		●		●	●			●	●	●	●	●	●	●
Culicidae	●	●	●	●	●	●	●	●	●	●	●	●	●			●		●
Muscidae			●							●						●		●
Simuliidae												●	●	●	●	●	●	
Tabanidae	●	●		●	●	●			●	●	●			●				
Tipulidae							●										●	
Gastropoda																		
Ancylidae													●	●		●		●
Lymnaeidae	●		●	●	●	●	●	●			●							
Planorbinae							●											
Thiaridae							●											
Pelecypoda																		
Corbiculidae								●									●	
Sphaeriidae	●			●														

APPENDIX 2

FISH

Appendix 2.1 Fish Assemblage Integrity Index sample sheets

SITE CLASSIFICATION AND LOCALITY

Date:	Time:	System:
River:	Stream:	Ecoregion:
Geomorphological Zone:	Geomorphological segment: Fish segment:	Geomorphological Reach:

5 km sector:	Farm:
Altitude:	Stream order:
Coordinates S: Degrees: Minutes: Seconds:	
Coordinates E: Degrees: Minutes: Seconds:	
Site number:	

FLOW CONDITIONS AND WATER QUALITY AT SITE

Approximate width:	General flow (none, low, moderate, strong, fresh, flood):	Water colour:	Turbidity (clear, moderate, turbid):
Water temperature:	Conductivity (mS/m):	pH:	Oxygen (mg/l):
Water quality sample taken? (Y/N):		Remarks:	

FISH VELOCITY-DEPTH CLASSES AND COVER PRESENT AT SITE
(Abundance: 0=absent; 1=rare; 2=sparse; 3=moderate; 4=extensive)

SLOW DEEP:	SLOW SHALLOW:	FAST DEEP:	FAST SHALLOW:
Overhanging vegetation:	Overhanging vegetation:	Overhanging vegetation:	Overhanging vegetation:
Undercut banks & root wads:	Undercut banks & root wads:	Undercut banks & root wads:	Undercut banks & root wads:
Substrate:	Substrate:	Substrate:	Substrate:
Aquatic macrophytes:	Aquatic macrophytes:	Aquatic macrophytes:	Aquatic macrophytes:
Remarks:	Remarks:	Remarks:	Remarks:

INSTREAM USE & SURROUNDING AREA LAND USE
(0=absent; 1=rare; 2=sparse; 3=moderate; 4=extensive/intensive)

Weirs:	Cultivated lands:	Grazing:	Plantations:
Impoundments:	Residential:	Mines:	Industries:
Roads:	Bridges/crossings:	Pumps:	Canals:
Exotic vegetation:	Aquaculture:	Fishing:	Recreation/ Conservation:
Remarks:			

FISH HABITAT INTEGRITY AT SITE: ESTIMATED IMPACT OF MODIFICATIONS

(Severity of impact: 0=none; 1=small; 3=moderate; 5=large)

Water abstraction:	Flow modification:	Bed modification:	Channel modification:
Inundation:	Exotic macrophytes:	Solid waste disposal:	Indigenous vegetation removal:
Exotic vegetation encroachment:	Bank erosion:	Remarks:	

HABITATS SAMPLED AND EFFORT

SAMPLING EFFORT	SLOW DEEP	SLOW SHALLOW	FAST DEEP	FAST SHALLOW
Electro schocker (min)				
Small seine (mesh size, length, depth, efforts)				
Large seine (mesh size, length, depth, efforts)				
Cast net (dimensions, efforts)				
Gill nets (mesh size, length, time)				

REMARKS

FISH CAUGHT (COMBINED/HABITAT/SAMPLING METHOD)

HABITAT:	
SAMPLING METHOD:	
SPECIES	NUMBER (J=juvenile, A=abnormality)

HABITAT:	
SAMPLING METHOD:	
SPECIES	NUMBER (J=juvenile, A=abnormality)

FISH CAUGHT (COMBINED/HABITAT/SAMPLING METHOD)

HABITAT:	
SAMPLING METHOD:	
SPECIES	NUMBER (J=juvenile, A=abnormality)

HABITAT:	
SAMPLING METHOD:	

SPECIES	NUMBER (J=juvenile, A=abnormality)

Appendix 2.2 Conversion from fish assessment categories A-F (FAII and QFAA) to RHP classes Natural-Poor.

Fish Assessment Category	Description of generally expected conditions for integrity classes	FAII and QFAA score (%)	Adjustment of the score (%) for RHP	RHP classes
A	Unmodified, or approximates natural conditions closely.	90-100	90-100	Natural
B	Largely natural with few modifications. A change in community characteristics may have taken place but species richness and presence of intolerant species indicate little modification.	89-90	65-89	Good to Natural Good Good to Fair
C	Moderately modified. A lower than expected species richness and presence of most intolerant species. Some impairment of health may be evident at the lower limit of this class.	60-79		
D	Largely modified. A clearly lower than expected species richness and absence or much lowered presence of intolerant and moderately intolerant species. Impairment of health may become more evident at the lower limit of this class.	40-59	40-64	Fair to Good Fair Fair to Poor
E	Seriously modified. A strikingly lower than expected species richness and general absence of intolerant and moderately intolerant species. Impairment of health may become very evident.	20-39	20-39	Poor to Fair Poor
F	Critically modified. An extremely lower species richness and general absence of intolerant and moderately intolerant species. Only tolerant species may be present with a complete loss of species at the lower limit of the class. Impairment of health generally very evident	0-19	0-19	

Source: Adapted from Kleynhans (1999)

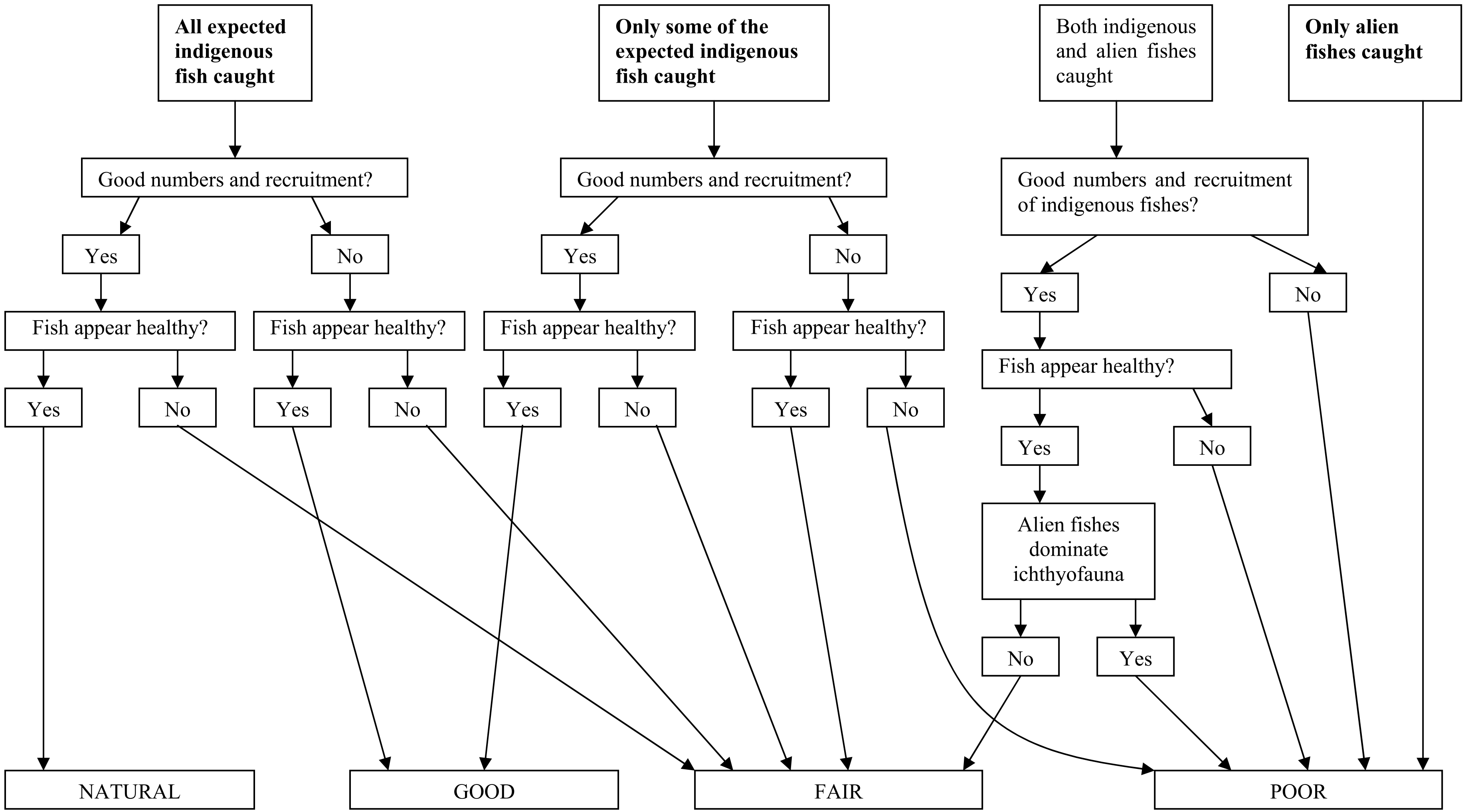
Appendix 2.3 Qualitative Fish Assemblage Assessment Data Sheet

	Resource unit						
Determinant	**Site 1**	**Site 2**	**Site 3**	**Site 4**	**Site 5**	**Site 6**	**Site 7**
Native species richness							
Presence of native intolerant species							
Abundance of native species							
Frequency of occurrence of native							
Health/condition of native & introduced species							
Presence of introduced fish species							
In-stream habitat modification							
TOTAL SCORE	**0**	**0**	**0**	**0**	**0**	**0**	**0**
%	0.0	0.0	0.0	0.0	0.0	0.0	0.0
FISH ASSEMBLAGE CATEGORY	NA	NA	NA	NA	NA	NA	NA

Appendix 2.4 The Qualitative Fish Assemblage Assessment adapted for the Buffalo River. Included are the rules used for scoring sample sites for each determinant.

Determinants	**Assessment criteria**	**Scoring**	**Rule used to choose a score**
Native species richness	None of the expected present	0	None of expected present
	Only few of expected present	1-2	< 50% of expected present
	Majority of expected species present	3-4	50-89% of expected
	All/almost all of expected present	5	> 90%
Presence of native intolerant species	No intolerant species present	0	An Intolerant species was considered to be one with a > 3 intolerance rating from FAII. The rule used to choose a score was as above
	Few intolerant species present	1-2	
	Majority of intolerant species present	3-4	
	All/almost all intolerant species present	5	
Abundance of native species	No fish	0	No fish
	Only few individuals	1-2	0-10 individuals
	Moderate abundance	3-4	10-30 individuals
	Abundance as expected for natural conditions	5	> 30 individuals
Presence of introduced fish species	Predaceous species and/or habitat modifying species with a critical impact on native species	0	Basses, Trouts, Catfishes, and the Bluegill sunfish
	Predaceous species and/or habitat modifying species with a serious impact on native species	1-2	Carp
	Predaceous species and/or habitat modifying species with a moderate impact on native species	3-4	Moggel, Banded tilapia
	Predaceous species and/or habitat modifying species with no impact on native species	5	
Instream habitat modification	Water quality/flow/stream bed substrate, critically modified, no suitable conditions for expected species	0	Based on observation and expert opinion
	Water quality/flow/stream bed substrate, seriously modified, little suitable conditions for expected species	1-2	
	Water quality/flow/stream bed substrate, moderately modified, moderately suitable conditions for expected species	3-4	
	Water quality/flow/stream bed substrate, little or no modification, abundant suitable conditions for expected species	5	

Appendix 2.5 The decision support tree used in aiding the assessment of fish integrity



APPENDIX 3

RIPARIAN VEGETATION

APPENDIX 4

GEOMORPHOLOGY