CHAPTER 4

A qualitative and quantitative investigation into the Physical Habitat Integrity of the Klip River (Gauteng).

4.1 INTRODUCTION

Rivers always borrow a great part of their character from the terrestrial ecosystem – the catchment – through which they flow. Indeed, if the landscape is in a good condition, then the river is too, and if the landscape is badly treated, then the river flowing through it will magnify and mirror that abuse (Davies & Day, 1998). This is especially true for the prevalent land-use in the surrounding area and the floodplain of a river. Human activities in the catchment, and in the direct vicinity of the watercourse result in habitat characteristics deviating from their natural condition, often to the detriment of the entire aquatic ecosystem.

The biological potential of a section of a river can be limited by the quality of the physical habitat, which forms the template within which biological communities develop. The basic structure of the surrounding physical habitat influences the quality of the water resource and the condition of the resident aquatic community (Barbour *et al.*, 1999; Stoneman & Jones, 2000, Waite & Carpenter, 2000). Water resource managers have, however, over the years encountered problems in understanding and managing non-point pollution, evaluating the complex, cumulative impacts of changing land on stream habitats and biological communities, and assessing the effectiveness of mitigation procedures (Frissel *et al.*, 1986).

For the purpose of aquatic research and management, the emphasis was historically placed mainly on the detection and monitoring of chemical contamination of water resources. The methods applied were insufficient to detect other forms of perturbation (Barbour and Stribling, 1994). To address this shortcoming in water resource management, habitat assessment protocols have been developed to evaluate physical habitat condition, availability, and general integrity. These evaluations are critical to any assessment of ecological integrity (Barbour and Stribling, 1996).

Another issue that renders the assessment of aquatic habitats important is the South African Water Law. The National Water Act (Act No 36 of 1998) states that the National Government is the trustee of the country's water resources. Water resources are a national asset to be utilised in the best interest of all citizens, in a sustainable manner, to guarantee the needs of future generations. The needs of the environment are also guaranteed in the Act, following from the Constitutional right of all to a safe, healthy environment. This means that the government is tasked to ensure that water resources, as well as water users are protected, and the enabling mechanism to do so is the National Water Act. This act requires the registration of all water users to establish where and how much water is being used in the country, as well as the nature and extent of water use in a catchment. Users are required to apply for a permit that entitles them to use water within the terms and conditions of the licence. Resource directed measures (Chapter 3 of the National Water Act) must be taken to ensure sustainable use of this vulnerable resource (DWAF, 2000). In the Water Law, the Reserve is identified as that quality and quantity necessary to protect basic human needs, as well as aquatic ecosystems. The setting of resource quality objectives provides a rigorous numeric or descriptive statement of the requirements of the reserve for that particular water resource, in measurable, enforceable terms (DWAF, 1999). The ecological integrity of a river is generally defined as its ability to support and maintain a balanced, integrated composition of physico-chemical and habitat characteristics, as well as biotic components on a temporal and spatial scale that are comparable to the natural characteristics of the region (Kleynhans, 1996). Habitat integrity assessment is therefore an integral part of any determination of the ecological reserve of a river (DWAF, 1999). It furthermore provides important information of impacts and general characteristics of a river.

In an attempt to investigate the physical habitat integrity, condition and availability, as well as to identify the potential causes for degradation, a comprehensive approach was followed. The Index of Habitat Integrity (IHI), developed by Kleynhans (1996) on the Luvuvhu River, and broadly applied in river classification in South Africa (DWAF, 1999), was used to investigate the habitat of the Klip River on a large scale (Reach). Site-specific habitat assessments were also applied at the time of biological sampling at selected sites within each of the four reaches of the Klip River, as well as a reference site in the Suikerbosrand River. Both quantitative and qualitative methods were applied to describe the habitat structure and surrounding activities at the different sites. The existing habitat evaluation indices were applied to assess the condition and diversity of primary, secondary and tertiary habitat parameters. This resulted in the creation of a comprehensive and integrated picture of the physical habitat integrity status of the Klip River system.

4.2 MATERIALS AND METHODS

4.2.1 Comprehensive qualitative river habitat assessment.

The Index of Habitat Integrity (IHI).

This is based on a qualitative procedure described by Kleynhans (1996) for the assessment of habitat integrity of the Luvuvhu River System. This is also the method proposed by the Department of Water Affairs and Forestry to determine habitat integrity in their Resource Directed Measures procedures (DWAF, 1999). This index investigates the habitat integrity of a river on a large scale (reaches) and assesses both the instream and riparian components of the river.

Collection of data varies from aerial to ground level surveys and is directed towards assessment of modifications of the riparian vegetation and instream channel caused by anthropogenic activities. The Klip River was divided into 5 km segments on a 1: 50 000 topographical map (Figure 4.1). During helicopter surveys in June 1997 and June 1998, continuous video recordings of the total length of the river were made. The beginning and end of each 5 km segment was also indicated on the recordings. The information gathered by the aerial surveys was supplemented by water quality data and observations on the ground, made during biological monitoring.

For each 5 km segment, the severity of the impacts of various modifications, as well as general detail on river characteristics, were recorded. The criteria used in the assessment of habitat integrity of each 5km-river segment included the following:

- Water abstraction
- Flow modification
- Bed modification
- Channel modification

- Water quality modification
- Inundation
- Exotic macrophytes
- Exotic aquatic fauna
- Solid waste disposal
- Indigenous vegetation removal
- Exotic vegetation encroachment and
- Bank erosion.

The above-mentioned criteria were assessed and scored according to their impact (none to critical) on the habitat integrity. Each criterion used carried a relative weight, based on their specific contribution to the total habitat integrity of a system. The impact of a criterion on the habitat integrity, would then be estimated as follows:

$$\text{Impact of criterion on habitat integrity} = \frac{\text{Rating for criterion}}{\text{maximum value (25)}} \times \frac{\text{weight (percentage)}}{1}$$

The estimated impact of all criteria was then summed and expressed as a percentage, and subtracted from 100, to arrive at an assessment of habitat integrity for the instream and riparian components respectively. The final score for the riparian zone and instream components indicate the habitat integrity of that specific segment of the Klip River. The final total scores for the riparian zone and instream components were then used to place the habitat integrity in a specific descriptive habitat integrity category (Table 4.1).

On the basis of gradient and geological similarities, specific segments were grouped to distinguish between the four reaches in the Klip River (Figure 4.1). The first reach (A) consisted of 5km-segments 1 to 3, with an average slope of more than 4 m/km, over a complex geology of quartzite, shale and Ventersdorp Supergroup lavas. Reach B included 5km-segments 4 to 10, with an average slope of 2 to 4 m/km, over dolomite and fluvial sediments. The third reach (C) included 5km-segments 11 to 16 with an average slope of between 1 and 1.5 m/km, over dolomite. Reach D consisted of 5km-segments 17 to 20, with an average slope of less than 1m/km, primarily over dolomite (Figure 4.1).

Table 4.1: Habitat integrity assessment categories used for the Index of Habitat Integrity (Kleynhans 1996).

Category	Description	Score (% of total)
1	Unmodified, natural.	100
2	Largely natural with few modifications. A small change in natural habitats & biota may have taken place but the ecosystem functions are essentially unchanged.	80 to 99
3	Moderately modified. A loss & change of natural habitat & biota have occurred but the basic ecosystem functions are still predominantly unchanged.	60 to 79
4	Largely modified. A large loss of natural habitat, biota and basic ecosystem functions has occurred.	40 to 59
5	The losses of natural habitat, biota and basic ecosystem functions are extensive.	20 to 39
6	Modifications have reached a critical level & the lotic system has been modified completely with an almost complete loss of natural habitat & biota. In worst instances the basic ecosystem functions have been destroyed & the changes are irreversible.	0 to 19

4.2.2 <u>Site-specific habitat assessments.</u>

A few localities were selected within each of the four reaches used in the application of the above-mentioned Index of Habitat Integrity (IHI) (Figure 4.1). The first two biomonitoring localities in the Klip River (localities 1 and 2) fell within the uppermost stream reach (reach A). Localities 3 to 5 were within reach B, while reach C included localities 6 and 7. The most downstream reach of the Klip River (reach D) included localities 8 and 9 (Figure 4.1). At each of these biomonitoring localities, as well as a reference locality within the Suikerbosrand River (locality 10), site-specific habitat assessments were conducted. These assessments included both quantitative methods to describe the available habitats, as well as qualitative methods in which the condition and availability of the physical habitat was assessed on a site-specific scale (not on a reach scale as in case of IHI).

4.2.2.1 Physical Habitat Description

The physical characteristics of the instream channel and riparian habitat of each site was described by using the United States Environment Protection Agency habitat description sheet (USEPA, 1996). Components investigated included: stream characteristics, weather conditions, riparian zone/instream features, riparian vegetation, aquatic vegetation, sediment/substrate, inorganic substrate components and organic substrate components.

In an attempt to gather more quantitative habitat data, a transect method was also applied at each site during the first survey in August 1997. This method involves the following procedures: A rope with one meter marked intervals was place across the river. At each mark (1 meter interval), the velocity, depth, substrate type and flow type was then determined (Gorman and Karr, 1978). This method was repeated within every biotope available at a site, until adequate data was collected. The biotopes were defined as follows:

Backwater: An area alongside, but physically separated from the channel, but connected to it at its downstream end. It may occur over any substrate.

Pool: This biotope is in direct hydraulic contact with upstream and downstream water but has barely perceptible flow.

Glide: A glide exhibits smooth boundary turbulent flow, with clearly perceptible flow, without any surface disturbance. A glide can occur over any substrate.

Run: A run is characterised by a rippled flow type and can occur over any substrate apart from silt.

Riffles: Riffles may have undular standing waves or breaking standing waves and occur over alluvial substrates from gravel to cobble.

Rapids: Rapids have undular standing waves or breaking waves, and occur over fixed substrate such as boulder or bedrock.

Flow-Depth categories were defined as follows:
Slow (<0.3m/s), *shallow* (<0.5m) – Shallow pools and backwaters
Slow-deep (>0.5m) – Deep pools, backwaters and slow glides.
Fast (>0.3m/s), *shallow* – Riffles, rapids and runs.
Fast-deep – Usually rapids and runs and glides.

A sediment sample (depth of 5 cm) was also collected by means of a perspex corer (diameter of 5 cm) in order to identify the organic and inorganic sediment structure and composition. This sample was placed in pre-washed plastic containers and frozen until further analysis. In the laboratory, sediment samples were thawed and dried in an oven at 50 °C for a period of 96 hours. For the determination of the organic-inorganic composition, a sub-sample of ± 2g was used. The organic component was turned into ash by placing the sample in an oven at 500 °C for 6 hours. From each sediment sample, an 80 g sub sample was then placed in an Endecott-mechanical sieve rack consisting of sieves with 0.5 phi intervals (Folk et al., 1957). Sieve grid sizes with mesh ranging from 3200 mm (-1.50 phi) to 0.0313 mm (4,75 phi) were used. Each fraction was weighed to the nearest 0.001 g and used to calculate the average mass percentage and average particle size of the sediment samples. Inorganic substrates were then classified according to the Wentworth grain size classification system:

Boulders-	> 256mm
Cobbles-	64 - 256mm
Gravel-	2 - 64mm
Course sand-	0.25 - 2mm (250 - 2000µm)
Fine sand-	0.0625 - 0.25mm (62.5 - 250µm)
Silt & clay-	< 0.0625mm (< 62.5µm)

4.2.2.2 Qualitative Site-specific Habitat Assessment Indices

A) United States Environment Protection Agency (USEPA) Habitat Assessment Index (HAI).

This matrix applied to assess habitat quality, is based on key physical characteristics of the water body and surrounding land, particularly the catchment of the site under investigation. All of the habitat parameters evaluated are related to overall aquatic life use and are a potential source of limitation to the aquatic biota (Barbour *et al*., 1999. Habitat parameters used in USEPA Habitat Assessment Index (HAI) for low-gradient or glide/pool prevalent streams include the following:

Epifaunal substrate/available cover: Includes the relative quantity and variety of natural structures in the stream, such as cobble (riffles), large rocks, fallen trees, logs and branches, and undercut banks, available as refugia, feeding, or sites for spawning and nursery functions of aquatic macrofauna. A wide variety and/or abundance of submerged structures in the stream provide macroinvertebrates and fish with a large number of niches, thus increasing habitat diversity. As variety and abundance of cover decreases, habitat structure becomes monotonous, diversity decreases, and the potential for recovery following disturbance decreases.

Pool substrate characteristics: Evaluates the type and condition of bottom substrates found in pools. Firmer sediment types (e.g., gravel, sand) and rooted aquatic plants support a wider variety of organisms than a pool substrate dominated by mud or bedrock and no plants. In addition, a stream that has a uniform substrate in its pools will support far fewer types of organisms than a stream that has a variety of substrate types.

Pool variability: Rates the overall mixture of pool types found in streams, according to size and depth. The four basic types of pools are large-shallow, large-deep, small-shallow, and small-deep. A stream with many pool types will support a wide variety of aquatic species. Rivers with low sinuosity (few bends) and monotonous pool characteristics do not have sufficient quantities and types of habitat to support a diverse aquatic community. General guidelines are any pool dimension (i.e., length, width) greater than half the cross-section of the stream for separating large from small and 1 m depth separating shallow and deep.

Channel alteration: Is a measure of large-scale changes in the shape of the stream channel. Many streams in urban and agricultural areas have been straightened, deepened, or diverted into concrete channels, often for flood control or irrigation purposes. Such streams have far fewer natural habitats for fish, macroinvertebrates, and plants than do naturally meandering streams. Channel alteration is present when artificial embankments and other forms of artificial bank stabilization or structures are present; when the stream is very straight for significant distances; when dams and bridges are present; and when other such changes have occurred. Scouring is often associated with channel alteration.

Sediment deposition: Measures the amount of sediment that has accumulated in pools and the changes that have occurred to the stream bottom as a result of deposition. Deposition occurs from large-scale movement of sediment. Sediment deposition may cause the formation of islands, point bars (areas of increased deposition usually at the beginning of a meander that increase in size as the channel is diverted toward the outer bank) or shoals, or result in the filling of runs and pools. Usually deposition is evident in areas that are obstructed by natural or manmade debris and areas where the stream flow decreases, such as bends. High levels of sediment deposition are symptoms of an unstable and continually changing environment that becomes unsuitable for many organisms.

Channel sinuosity: Evaluates the meandering or sinuosity of the stream. A high degree of sinuosity provides for diverse habitat and fauna, and the stream is better able to handle surges when the stream fluctuates as a result of storms. The absorption of this energy by bends protects the stream from excessive erosion and flooding and provides refugia for benthic invertebrates and fish during storm events.

Channel flow status: The degree to which the channel is filled with water. The flow status will change as the channel enlarges (e.g. aggrading stream beds with actively widening channels) or as flow decreases as a result of dams and other obstructions, diversions for irrigation, or drought. When water does not cover much of the streambed, the amount of suitable substrate for aquatic organisms is limited. Channel flow is especially useful for interpreting biological condition under abnormal or lowered flow conditions. This parameter becomes important when more than one biological index period is used for surveys or the timing of sampling is inconsistent among sites or annual periodicity.

Bank vegetative protection: Measures the amount of vegetative protection afforded to the stream bank and the near-stream portion of the riparian zone. The root systems of plants growing on stream banks help hold soil in place, thereby reducing the amount of erosion that is likely to occur. This parameter supplies information on the ability of the bank to resist erosion as well as some additional information on the uptake of nutrients by the plants, the control of instream scouring, and stream shading. Banks that have full, natural plant growth are better for fish and macroinvertebrates than are banks without vegetative protection or those shored up with concrete. In areas of high grazing pressure from livestock or where residential and urban development activities disrupt the riparian zone, the growth of a natural plant community is impeded and can extend to the bank vegetative protection zone. Each bank is evaluated separately and the cumulative score (right and left) is used for this parameter.

Bank stability: Measures whether the stream banks are eroded (or have the potential for erosion). Steep banks are more likely to collapse and suffer from erosion than are gently sloping banks, and are therefore considered to be unstable. Signs of erosion include crumbling, unvegetated banks, exposed tree roots, and exposed soil. Eroded banks indicate a problem of sediment movement and deposition, and suggest a scarcity of cover and organic input to streams. Each bank is evaluated separately and the cumulative score (right and left) is used for this parameter.

Riparian vegetative zone width: Measures the width of natural vegetation from the edge of the stream bank out through the riparian zone. The vegetative zone serves as a buffer to pollutants entering a stream from runoff, controls erosion, and provides habitat and nutrient input into the stream. A relatively undisturbed riparian zone supports a robust stream system; narrow riparian zones occur when roads, parking lots, fields, lawns, bare soil, rocks, or buildings are near the stream bank. Residential developments, urban centers, golf courses are the common causes of anthropogenic degradation of the riparian zone. For variable size streams, the specified width of a desirable riparian zone may also be variable and may be best determined by some multiple of stream width (e.g., 4 x wetted stream width). Each bank is evaluated separately and the cumulative score (right and left) is used for this parameter (Barbour *et al.*, 1999).

Each of the above mentioned criteria is assessed, and according to its condition, rated in one of the following classes, namely: optimal/excellent, suboptimal/good, marginal/fair or poor (Appendix 4.1). For each criterion, a score is given within the selected class. The sum of these scores gives a final score for this index, and can be used when drawing comparisons with other sites, and more specifically, to the baseline or reference condition in order to indicate its physical habitat condition. Quality class ranges were determined for this index in an attempt to use the final score or percentage to classify the physical habitats of a site. Quality class ranges were calculated as follows: If all parameters assessed at a site attained the highest possible score within the poor class (4 or 5), a final HAI score of 24% will be attained. Final Habitat Assessment Index scores ranging between 0 and 24 % were therefore classified as poor (Table 4.2). Similar scenarios were used to determine the ranges for the other quality classess (Table 4.2).

Table 4.2: The different quality classes assigned to HAI percentage scores.

HAI percentage range	Quality class
0 - 24%	Poor
25 - 50%	Fair
51 - 77%	Good
78 - 100%	Excellent

B) Habitat Assessment Matrix (HAM).

This index has been adopted from Plafkin *et al*. (1989) by D. J. Roux, and is aimed at the evaluation of conservation status of a stream (Thirion *et al*, 1995). Habitat parameters investigated in this index include the following: bottom substrate/available cover, embeddedness, biotope diversity categories, bottom area affected by scouring and deposition, pool/riffle & run/bend ratios, bank erosion potential, bank vegetative stability and streamside cover (Appendix 4.2). Each of the above-mentioned parameters is assessed and a score is appointed within one of the following classes, namely Excellent, Good, Fair or Poor. The sum of the scores would indicate a possible score out of 135. The same method as described for the HAI was used to determine the ranges for each HAM quality class (Table 4.3).

Table 4.3: The different quality classes assigned to HAM index percentages.

HAM percentage range	Quality class
0 - 22%	Poor
23 - 49%	Fair
50 - 76%	Good
77 - 100%	Excellent

C) Qualitative Habitat Evaluation Index (QHEI).

The Qualitative Habitat Evaluation Index (Davis and Simon, 1995) is used by the Ohio-Environmental Protection Agency and is based on a qualitative visual evaluation of the following physical habitat criteria, namely: Substrate quality, Instream cover, Channel quality, Riparian quality/Bank erosion and Local stream gradient. Various attributes of these criteria are assessed and scored accordingly (Appendix 4.3). The sum of the different criteria investigated would indicate the condition of the physical habitat at a site.

4.2.3 Statistical analysis

Statistical analysis of the data was performed by STATCON, a statistical consultation service of the Rand Afrikaans University. In an attempt to determine if there was any statistically significant ($p<0.05$) differences between localities over the study period, an independent samples test was used. The Levene's test was firstly used to determine equality of variances of the different variables, and then an independent t-test for equality of means was used to determine significant differences ($p<0.05$). The Pearson's correlation coefficient (r) was used to determine if there was any correlation between different variables (Zar, 1978).

4.3 RESULTS

4.3.1 Index of Habitat Integrity (IHI) – Reach-scale habitat assessment.

The IHI was applied to the July 1998 data, as it would give a perspective of the most recent habitat integrity status of the Klip River system. The flow velocity was slow to moderate in the first reach, but increased through reach B to become fast in the lower part of reach B, and throughout reach C and D (Table 4.4). The most dominant biotope included runs and glides, with rapids being relatively common in reach C. Reach A included some wetlands, while reach B consisted almost exclusively of wetland habitats. The amount of water abstraction pumps increased downstream (Table 4.4).

Table 4.4: General information on selected aspects of the reaches in the Klip River.

Criterion	Reach A	Reach B	Reach C	Reach D
Average slope (m/km)	> 4	2 to 4	1 to 2	< 1
Flow velocity	Slow to moderate	Moderate to strong	Strong	Strong
Riffles	Few	Few	None	None
Rapids	Few	Few	Moderate	Few
Runs/glides	Few	Common	Common	Exclusive
Pools	Moderate	Few	Few	Few
Wetlands	Moderate	Extensive	None	None
Weirs/impoundments	Few	Few	Few	Few
Pumps	None	Few	Moderate	Moderate
Roads/Bridges	Common	Common	Common	Common

Index of Habitat Integrity (IHI) scores calculated for each 5-kilometer segment indicated that, in general, there was a gradual downstream deterioration in the habitat integrity status of both the instream and riparian components (Figure 4.2). Instream habitat integrity was good in reach A and fell within descriptive category 2 (Table 4.1). Integrity decreased sharply from segment 4 (89%) to 5 (58%), after which a gradual deterioration occurred towards segment 14 (30%). The instream habitat integrity improved slightly towards segment 16, but stayed relatively similar throughout reach D (segments 17 to 20). Instream habitat integrity of reach B fell, on average, into descriptive category 4, with reach C falling into category 5 and reach D into category 4.

Riparian zone habitat integrity improved in reach A from a value of 54% at segment 1 to 74% at segment 2 and 71% at segment 3 (Figure 4.2). Thus the riparian zone habitat integrity fell mainly into category 3 (Table 4.1). There was also an increase towards segment 4 in reach B but thereafter it deteriorated significantly toward segment 6 (29%). There was a gradual improvement towards segment 9 (72%), after which it deteriorated significantly again, to a very low integrity status of 9% at segment 15 (Figure 4.2). The riparian integrity status then gradually increased towards segment 20 (51%). The riparian zone habitat integrity of reach B ranged between descriptive categories 3 and 5. At reach C, it ranged between categories 4 and 6. Riparian zone integrity of reach D was on average in category 4. The habitat integrity status for both the instream and riparian components of the Klip River was the highest in reach A, and the lowest in reach C (Figure 4.2).

Anthropogenic activities identified to be responsible for serious to critical instream habitat integrity deterioration in the Klip River included flow modification and inundation (Table 4.5 to 4.7). Indigenous vegetation removal, exotic vegetation encroachment and bank erosion were identified as altering the riparian zone habitat integrity seriously to critically. Bed and channel modifications, as well as poor water quality, generally had a moderate negative impact on the instream habitat integrity of the system (Table 4.5 to 4.7).

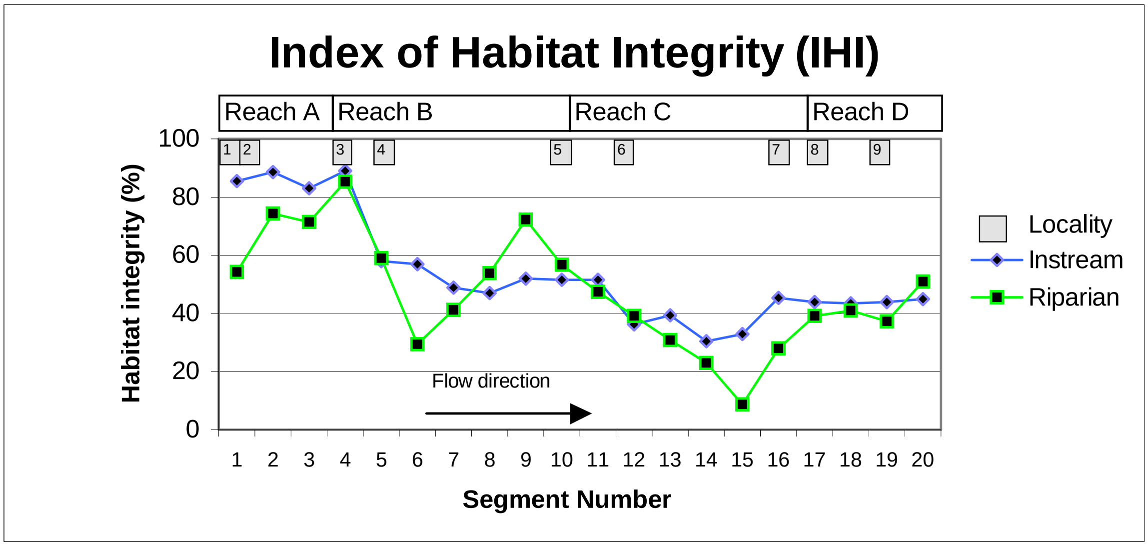

Figure 4.2: The instream and riparian zone integrity of the Klip River during June 1998, according to 5km segments, also indicating reaches and the monitoring localities distribution.

Table 4.5: IHI-scores assigned to, and the relative impact of, the different criteria on the instream and riparian features of each five-kilometer segment (None=0, Small=1-5, Moderate =6 to 10 , Large=11-15, Serious=16-20 and Critical=21-25).

		Reach A			**Reach B**							**Reach C**						**Reach D**			
	SEGMENT NO	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
	BIOMONITORING LOCALITY	**1,2**			**3**	**4**					**5**		**6**			**7**		**8**		**9**	
INSTREAM	**WATER ABSTRACTION**	0	0	0	0	2	1	7	2	2	2	3	1	9	5	4	3	3	3	3	2
	FLOW MODIFICATION	3	5	3	3	17	20	21	21	22	22	22	23	22	22	24	23	22	23	23	23
	BED MODIFICATION	7	5	3	3	8	8	4	8	8	10	10	12	10	18	13	8	8	8	8	8
	CHANNEL MODIFICATION	2	1	4	4	6	13	13	12	4	10	2	13	10	2	13	11	12	12	13	12
	WATER QUALITY	9	9	12	9	8	8	8	8	8	8	8	15	15	17	14	7	8	8	8	7
	INUNDATION	2	0	0	2	16	14	18	21	22	18	22	21	22	24	23	22	23	23	23	23
	EXOTIC MACROPHYTES	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0
	EXOTIC FAUNA	0	0	0	0	3	1	1	1	1	1	1	3	3	12	4	4	7	7	4	4
	RUBBISH DUMPING	10	3	3	0	8	0	0	0	0	2	0	1	1	4	4	2	2	2	2	2
RIPARIAN	**VEGETATION REMOVAL**	14	13	13	5	12	20	20	17	5	15	15	20	16	23	23	19	19	12	14	13
	EXOTIC VEGETATION	20	9	5	8	9	10	14	2	4	5	15	15	18	22	22	19	15	15	16	13
	BANK EROSION	9	5	10	7	11	14	12	14	14	15	12	14	17	8	19	18	15	19	18	11
	CHANNEL MODIFICATION	2	1	4	4	8	13	3	2	2	2	2	3	2	2	5	3	2	3	2	3
	WATER ABSTRACTION	0	0	0	0	2	1	2	2	2	2	3	1	9	5	4	3	3	3	3	2
	INUNDATION	2	0	4	2	2	14	2	3	2	4	4	2	3	17	4	4	3	4	3	4
	FLOW MODIFICATION	0	5	3	3	5	4	4	3	4	4	3	5	3	3	17	8	3	3	4	3
	WATER QUALITY	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 4.6: Summarised impacts of various modifications on the instream habitat integrity of the different reaches of the Klip River.

Criterion	Remarks	General impact rating
Water Abstraction	Reach A: No evidence of this impact	None
	Reach B: Irrigation not of concern to water quantity but causing unnatural fluctuations.	None to moderate
	Reach C: Irrigation not of concern to water quantity but causing unnatural fluctuations.	Small to moderate
	Reach D: Irrigation not of concern to water quantity but causing unnatural fluctuations.	Small
Flow modification	Reach A: Two dams upstream, urban runoff & mine seepages.	Small
	Reach B: WWTW effluent & urban runoff increases flow extensively, reducing natural habitat diversity and seasonality.	Small to Critical
	Reach C: WWTW effluent & the contribution from the Rietspruit increases flow extensively, flooding natural habitats, increasing bank erosion.	Critical
	Reach D: Unnatural high flow due to upstream contributions	Critical
Bed modification	Reach A: Siltation primarily due to mining impacts.	Small to moderate
	Reach B: Increased flow causes scouring, organic pollution increases algal growth on the substrates.	Small to moderate
	Reach C: Increased flow causes scouring, organic pollution increases algal growth on the substrate & high level of organic sedimentation in weir.	Moderate to serious
	Reach D: Increased flow causes scouring, organic pollution increases algal growth on the substrates.	Moderate
Channel modification	Reach A: Road and bridge constructions.	Small
	Reach B & C: Road & bridge construction & scouring due to high flows.	Small to large
	Reach D: Road, bridge & recreational area construction & scouring due to high flows.	Large
Water quality	Reach A: Occasional high turbidity causing siltation & organic pollution increasing algal growth.	Moderate to large
	Reach B: Nutrient enrichment & organic pollution increasing algal growth.	Moderate
	Reach C: Organic & inorganic suspended solids impact on substrates in weirs & impoundments. Organic pollution increases algal growth.	Moderate to serious
	Reach D: Nutrient enrichment & organic pollution increasing algal growth.	Moderate
Inundation	Reach A: Small impoundments.	None to small
	Reach B: Unnatural high water levels inundating habitats such as rapids/riffles, thus decreasing habitat diversity.	Small to critical
	Reach C & D: Unnatural high water levels inundating habitats such as rapids/riffles, thus decreasing habitat diversity.	Critical
Exotic macrophytes	Reach A: No evidence of its presence.	None
	Reach B: High water level removes most instream vegetation while wetlands dominated by indigenous *Phragmites spp*.	None
	Reach C: High water level removes most instream vegetation. Some exotics in weir.	Small
	Reach D: High water level removes most instream vegetation.	None
Exotic fauna	Reach A: None recorded for this reach.	None
	Reach B: Presence of *Cyprinus carpio* slightly impacting on riverbed.	None to small
	Reach C: Presence of *Cyprinus carpio* slightly impacting on riverbed. Moderate disturbance of organic substrate in weir, decreasing oxygen content.	Small to large
	Reach D: Presence of *Cyprinus carpio* slightly impacting on riverbed.	Small to moderate
Solid waste disposal	Reach A: Originating from urban areas & informal housing on banks.	Small to moderate
	Reach B: Some dumping of solid wastes in river at some sites.	None to moderate
	Reach C: Some dumping of solid wastes in river at some sites.	None to small
	Reach D: Some dumping of solid wastes in river at some sites.	Small

Table 4.7: Impact of various modifications on the riparian zone habitat integrity of the different reaches of the Klip River.

Criterion	Remarks	General impact rating
Indigenous vegetation removal	Reach A: Formal & informal housing, roads, pipelines, excavations & some cultivated lands in riparian zone. Solid wastes disposal (SWD) also impact on this criterion	Large
	Reach B: Cultivated lands, golf courses, SWD, excavations, roads & pipelines in the riparian zone.	Small to serious.
	Reach C: Cultivated lands & riparian owners, a golf course, together with SWD affects the riparian zone negatively.	Large to critical
	Reach D: Cultivated lands & riparian owners, a golf course, together with SWD affects the riparian zone negatively.	Large to serious
Exotic vegetation encroachment	Reach A: Extensive encroachment by Black wattles & some Bluegum trees.	Small to serious
	Reach B: Encroachment of riparian zone by Bluegum, Poplar & Weeping willow trees.	Small to large
	Reach C: Encroachment of riparian zone by Bluegum, Poplar & Weeping willow trees.	Large to critical
	Reach D: Encroachment of riparian zone by Bluegum, Poplar & Weeping willow trees.	Large to serious
Bank erosion	Reach A: Excavations, roads & cultivated lands increase bank erosion potential.	Small to moderate.
	Reach B: Roads, cultivated lands and high flow increase bank erosion.	Moderate to large
	Reach C & D: Roads, cultivated lands and high flow increase bank erosion.	Moderate to serious
Channel modification	Reach A: Road and bridge constructions.	Small
	Reach B: Road & bridge construction & scouring due to high flows.	Small to large
	Reach C & D: Road & bridge construction & scouring due to high flows.	Small
Water abstraction	Reach A: No discernable impact	None
	Reach B & C: Unnatural fluctuations might impact slightly on riparian zone, construction of pump stations impact on zone.	None to moderate
	Reach D: Unnatural fluctuations might impact slightly on riparian zone, construction of pump stations impact on zone.	Small
Inundation	Reach A: Few impoundments.	Small
	Reach B: Some flooding due to weirs & impoundments.	Small to large
	Reach C: Some flooding due to weirs & impoundments.	Small to serious
	Reach D: Some flooding due to weirs & impoundments.	Small
Flow modification	Reach A: Upstream dams slight impact on zone.	None to small
	Reach B: Increased flows not over banks, increased scouring slightly impact on riparian zone.	Small
	Reach C: Increased flows not over banks, increased scouring slightly impact on riparian zone.	Small to serious
	Reach D: Increased flows not over banks, increased scouring slightly impact on riparian zone.	Small
Water quality	Reach A, B, C, & D: No discernable impact	None

4.3.2 Site-specific habitat assessments

4.3.2.1 Physical habitat description

The site-specific physical habitat description is based on seasonal observations over the study period of two years (August 1997 to May 1999).

REACH A

Locality 1

Perennial flow occurred at this site with water temperatures that can generally be classified as cold (<22°C). The predominant surrounding land-use at this site included natural veld, gold mining, informal and formal settlements. These were also the most probable sources of point and diffuse pollution impacting on this site. Exotic black wattle trees (*Acacia mearnsii*) were the dominant riparian vegetation type, and the canopy cover was only partly open. The only form of channelisation at this site was where a bridge was constructed across the river. In general, there was little or no aquatic vegetation present (Appendix 4.5).

The stream width ranged between 1 and 3 meters, with a depth of between 0.01 and 2.8 meters. The most dominant inorganic substrate types were sand and cobbles, with bedrock, boulders, gravel, silt and clay also present. The substrate at locality 1 consisted mainly of coarse sand (64.1%), with some granules (34.1%) and very little fine sand (1.3%) and silt (0.1%) (Table 4.8). The sediment was slightly more inorganic (55%) than organic (45%) (Table 4.8). The most dominant biotope at this site was slow runs, with small riffles and rapids, and moderately deep pools also present (Appendix 4.4).

Locality 2

Sampling of locality 2 was conducted over an area of approximately 60 meters (Appendix 4.6). This site was primarily surrounded by natural grassland. Local water erosion potential ranged from none to moderate during the study period. A large number of boulders, probably brought about by gold mining activities and the construction of a high voltage power line, covered the banks and bottom of the river at this site. The stream width ranged between 2 and 4 meters with a depth of 0.025 to 1.6 meters. The influence of gold mining activities in this area was obvious, with fine yellowish silt and water being observed frequently. There was no evidence of channelisation or damming in the direct vicinity of the site. The water surface was almost completely shaded by exotic black wattle trees (*Acacia mearnsii*), which were the dominant and most obvious riparian vegetation, while grass was also present in some areas. Aquatic vegetation consisted almost exclusively of rooted emergent plants.

Table 4.8: Organic and inorganic sediment composition, as well as inorganic size classes determined for the selected sites during August 1997.

Locality	**Composition (%)**		**Inorganic particle size-class composition (%)**			
	Organic	**Inorganic**	**Granules**	**Coarse sand**	**Fine sand**	**Silt & clay**
1	45.30	54.70	34.10	64.58	1.25	0.07
2	24.11	75.89	4.21	62.11	32.11	1.57
3	18.21	81.79	6.04	88.03	5.16	0.77
4	33.36	66.64	13.50	76.07	9.44	0.99
5	1.72	98.28	2.36	91.16	5.91	0.57
6	8.34	91.66	13.59	81.41	4.92	0.08
7	4.36	95.64	3.46	84.54	10.54	1.46
8	5.00	95.00	11.12	59.91	24.07	4.90
9	4.69	95.31	1.95	83.71	13.36	0.98
10	3.75	96.25	13.12	82.98	3.69	0.21

The dominant instream substrate was large boulders, while some cobbles and gravel occurred sparsely. The pool substrates were mostly covered completely by fine yellow silt. A sediment core sample at this site consisted of 62.1% course sand, 32.1% fine sand, 4.2% granules and 1.6& silt and clay (Table 4.8). The sediment was primarily inorganic (76%) (Table 4.8). The primary biotope observed at this site was rapids, while some glides and pools were also present. The river was dominated by two flow-depth classes at this site, namely the fast-shallow and fast-deep categories (Appendix 4.4).

REACH B

Locality 3

Sampling and description of this site was done over a distance of approximately 150 meters. This locality was situated within the Lenasia Country Club. The predominant surrounding land-use at this site was a golf course (Appendix 4.7). There was no obvious evidence of local water erosion in the direct vicinity of the site. Non-point sources of pollution, in the form of informal and formal settlement runoff, entered the river directly upstream. The width of the stream usually ranged from three to ten meters, with a depth of 0.05 to 1.1 meters.

The water surface was only partly shaded by vegetation. The river itself was not channelised in the direct vicinity of the sampling site, but the placement of stones in the river created a small pool from which water was channelised into a dam for the irrigation of the golf course. The dominant riparian vegetation consisted of grasses, although a few exotic Bluegum trees (*Eucalyptus sp*.) also grew beside the river. Rooted emergent vegetation in the form of reeds (*Phragmites sp.)* and bulrushes (*Typha capensis*) were the dominant aquatic vegetation at this site. Boulders, cobbles, sand and mud were the main inorganic substrates present, while organic substrate in the form of detritus was also evident. The inorganic sediment composition consisted of 88% coarse sand, 6% granules, 5.2% fine sand and 0.8% silt and clay (Table 4.8). The inorganic composition of the sediment made up for 93% of the total (Table 4.8). There was a good diversity of biotopes at this site, which included rapids, runs, glides, chutes and riffles. All four flow-depth classes, namely fast-shallow, fast-deep, slow-shallow and slow-deep were observed at this site during the time of sampling. The most common classes present were slow-deep and fast-shallow (Appendix 4.4).

Locality 4

This site was described over a distance of approximately 200 meters, within which the sampling was done. The predominant surrounding land-use consisted of natural fields, with the Olifantsvlei Wastewater Treatment Works (WWTW) effluent entering the Klip River at this site (Appendix 4.8). A small weir at the upstream end of this sampling site created a dam and wetland area. There was no evidence of water erosion potential in the direct vicinity of the site. Non-point sources of pollution in this area of the river include runoff from informal and formal settlements. The Klipspruit joins the Klip River approximately 200 meters upstream of locality 4. The width of the channel varied between four and twenty meters, with depths of 0.07 to 1.2 meters recorded.

The water surface was only partly shaded, mainly by primarily exotic Willow trees (*Salix babilonica*). The dominant riparian vegetation consisted of grasses, while rooted emergent (*Phragmites sp*. and *Typha capensis*) and attached algae were the dominant aquatic vegetation types present. Inorganic substrate components were boulders and cobbles, while gravel, sand, silt and clay were also present. Organic substrate in the form of detritus was also generally evident at this site. Coarse sand (76.1%) was the primary inorganic component in the sediment, while some granules (13.5%), fine sand (9.4%), silt and clay (1%) were also present. The inorganic component of the sediment constituted sixty-seven percent of the total (Table 4.8). The primary biotopes observed were pools, runs, glides and rapids. Slow-deep and fast-shallow flow-depth classes dominated this site, although slow-shallow and fast-deep areas were also present (Appendix 4.4).

Locality 5

Monitoring of this site was usually conducted over a distance of approximately two hundred meters. The predominant surrounding land-use consisted of natural field, pasture and agricultural activities (Appendix 4.9). The keeping of livestock and growing of crops created potential sources for diffuse pollution. The width of the channel ranged from six to twenty meters, with depths of 0.04 to 2.1 meters recorded.

The riparian vegetation consisted almost exclusively of grasses, and the lack of trees meant very little available canopy cover at this site. Rooted emergent vegetation in the form of *Phragmites sp*. formed the most obvious and dominant aquatic vegetation. Upstream of this site lies an extensive *Phragmites sp.* dominated wetland area that stretches for several kilometers. The dominant substrate at this site was boulders and cobbles, while some sand banks also occurred. The banks were very steep and consisted of clay. A sediment core sample consisted primarily of coarse sand (91.2%), with some fine sand (5.9%), granules (2.4%) and silt and clay (0.6%) (Table 4.8). The total organic component constituted 98% of the sediment sample (Table 4.8). The rapid and riffle areas were connected by a relatively fast flowing run. Two flow-depth classes, namely fast-shallow and fast-deep categories, dominated this site. Some slow-deep areas were also present on the side of the main channel, and in a side channel at the site (Appendix 4.4).

REACH C

Locality 6

This site was selected directly downstream of the confluence of the Rietspruit with the Klip River. The Rietspruit is known to be impacted by gold mining activities, formal and informal settlements, agricultural activities and even raw sewage, originating from dysfunctional wastewater treatment works. Sampling at this site was conducted over an area of approximately three hundred meters. The predominant surrounding land-use consisted of natural fields and agricultural activities (Appendix 4.10). Maize fields in close proximity to the river (50 meters) increased the potential for water erosion at this site. Agricultural activities upstream were also the most obvious source of potential diffuse pollution impacting on this site. The channel was generally between six and fifteen meters wide with depths of between 0.01 and 2.6 meters recorded.

The dominant riparian vegetation consisted mainly of grasses, while very little aquatic vegetation was present. The only form of aquatic vegetation was in the form of small stands of reeds and other rooted emergent vegetation. The substrate consisted primarily of cobbles, boulders, sand and clay, while some concrete slabs dominated the substrate in the area of bridge abutments. Coarse sand (81.4%) was the primary constituent of the sediment, with some granules (13.6%), fine sand (4.9%) and silt and clay (0.1%) also present (Table 4.8). The sediment at this locality was mostly inorganic (92%) (Table 4.8). The banks were sandy and very steep with many eroded areas along this stretch of the river. Rapid and riffle areas, primarily created due to the construction of a bridge, were connected to an extensive glide area by a short, fast-flowing run. All flow-depth classes were present, although the fast-deep and fast-shallow areas dominated the site (Appendix 4.4).

Locality 7

This site was situated directly downstream of a large weir (approximately 4 meters high and 50 meters wide) in the Henley-on-Klip area. A stretch of approximately eighty meters of rapid and riffles were sampled directly below the weir. An area of run and glide biotopes, of approximately two hundred meters, were sampled one kilometer further downstream (Appendix 4.11). The predominant surrounding land-use is residential areas, together with some natural grassland. Agricultural activities such as maize and vegetable fields, livestock farming and domestic runoff were the most obvious potential diffuse sources of pollution in this area. The main channel width ranged between ten and twenty meters, while a small secondary channel was approximately one meter wide. The depth of the water at this site ranged between 0.009 to 2.1 meters.

The riparian zone was dominated by grasses, with some exotic Weeping willow and Poplar trees also present. Very little or no aquatic vegetation occurred at this site. The dominant substrate type at this site included boulders and sand, while some cobbles, gravel and silt were also present. A sediment core sample consisted of coarse sand (84.5%), fine sand (10.5%), granules (3.5%) and silt and clay (1.5%) (Table 4.8). The inorganic component of the sediment constituted ninety six percent of the total (Table 4.8). An extensive, fast rapid (approximately 30 x 90 meters) occurred below the weir overflow, while some riffles were present on the side of the main channel and in the secondary channel. The rest of the site consisted of a run and glide area. The flow-depth classes were generally dominated by fast-shallow, fast-deep and slow-deep (Appendix 4.4).

REACH D

Locality 8

This site fell within a two hundred meter stretch of river flowing through the Rothdene caravan park. The predominant surrounding land-use consisted of natural fields, pasture and agriculture, residential and recreational areas (Appendix 4.12). Water erosion potential was moderate, due to the keeping of livestock and agricultural activities close to the river. Raw sewage entering the river from overflowing manholes was witnessed at this site during the sampling period. Diffuse sources of pollution in the direct vicinity of the site included agricultural activities (maize fields) and domestic runoff. The width of the channel ranged between ten and fifteen meters, with depths of 0.02 to 1.6 meters recorded.

Trees dominated the riparian vegetation on the left bank. The right bank was, however, cleared for recreational use, and consisted primarily of grasses. Some shrubs were also present in the riparian zone. Aquatic vegetation occurred in the form of rooted emergent reeds and attached algae. The dominant substrate types were boulders and sand, while some gravel and clay also occurred. A core sediment sample indicated that the inorganic component (95% of total) consisted of coarse sand (59.9%), fine sand (24.1%), granules (11.1%) and silt and clay (4.9%) (Table 4.8).

An attempt was made to dam the river in this area by the piling of large boulders across the river. This created an area with artificial rapids and some chutes. The reason for the damming is probably related to the recreational activities such as canoeing and fishing that takes place in this area. The rest of the site consists of a fast run connecting the rapid to an extensive glide area. The flow-depth classes are dominated by fast-deep and fast-shallow categories, with some slow-deep habitats also present (Appendix 4.4).

Locality 9

This site is situated approximately two kilometers from the confluence of the Klip and Vaal Rivers. Sampling was conducted over a reach of approximately three hundred meters. The predominant surrounding land-use at this site was natural grassland, as the left bank is included in a nature walking-trail (Appendix 4.13). Human activities on the right bank included a few informal houses as well as a school. At the end of the study period, an area of approximately one hectare just outside the riparian zone of the left bank, was cleared from natural vegetation, and agricultural activities then followed. This increased the potential for local water erosion at this site. The river channel was generally between five and ten meters wide, with depths of 0.3 to 2.4 meters recorded.

The canopy cover shaded the water surface only partly. Again, grasses were the dominant riparian vegetation present, with exotic Weeping willows and Poplar trees encroaching in most of the riparian zone. There was generally very little aquatic vegetation observed at this site. The dominant inorganic substrate type at this site was sand, with some boulders, silt and clay also present. The inorganic sediment component made up 95% of the total, and consisted of coarse sand (83.7%), fine sand (13.4%), granules (2%) and silt and clay (1%) (Table 4.8). The primary biotope present was fast-deep runs, with some glides and pools in the shallower and slower flowing areas. This site was dominated by the fast-deep flow-depth class, and no rapid/riffle areas were present. This lowered the habitat diversity at this site a great deal (Appendix 4.4)

Suikerbosrand River: Middle catchment

Locality 10 (Reference Site)

This site consisted of a one hundred and fifty-meter reach in the Suikerbosrand River. This river is within relative close proximity to the Klip River, but the human activities in its catchment are thought to be relatively minor, in comparison to the human activities in Klip River Catchment. The predominant surrounding land-use consisted of natural grasslands and cultivated maize fields (Appendix 4.14). The most obvious negative human impact at this site was reduced flows due to the construction of a dam upstream of the site. The negative impact of the flow modification became especially evident towards the end of the study. Local water erosion potential was generally low in the direct vicinity of the site. The stream width ranged from one to twenty-meters, with depths of between 0.07 and 2.1 meters recorded.

Only small areas of the water surface were covered by vegetation. The dominant riparian vegetation was grass, while some trees and shrubs also occurred. Aquatic vegetation was common in the form of rooted emergent and floating plants. There was a great diversity of inorganic substrates at this site, but boulders constituted the most dominant substrate type. Other substrates included cobbles, gravel and sand. The inorganic component (96% of total) of a core sediment sample consisted of coarse sand (83%), granules (13.1%), fine sand (3.7%) and silt and clay (0.2%) (Table 4.8). There was also a good general diversity of physical biotopes in the form of runs, rapids, riffles, backwaters and a large natural pool area. The predominant flow-depth classes at this site were fast-shallow and slow-deep, with some slow-shallow areas also present (Appendix 4.4).

4.3.2.2 Qualitative habitat assessment indices

Comparison of different site-specific qualitative indices used.

In this study, three different site-specific qualitative habitat assessment indices were applied. This was done in an attempt to investigate variation between different indices, and to get a more comprehensive view of the habitat condition at each site. The indices used were: the United States Environmental Protection Agency Habitat Assessment Index

(HAI) for low gradient streams, the Habitat Assessment Matrix (HAM), and the Qualitative Habitat Evaluation Index (QHEI). It was observed that there was some variation between the scores of the different indices used at any particular site. HAI scores differed statistically significantly ($p<0.05$) from HAM scores 50% of the time, and from QHEI 80% of the time. HAM scores also differed statistically significantly from QHEI 60% of the time (Table 4.9). There was, however, a strong positive correlation between the different indices applied (Table 4.9).

Table 4.9: Habitat assessment index scores differing statistically significantly ($p<0.05$) over the study period (shaded blocks), and Pearson's correlation coefficients (r) between different index scores.

INDICES	**LOCALITY**											
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**%***	**r**
HAM - HAI	▨		▨	▨			▨		▨		50	0.71
HAM - QHEI	▨	▨			▨	▨		▨	▨		60	0.78
HAI - QHEI	▨	▨	▨	▨	▨	▨	▨	▨			80	0.70

*percentage significant differences.

HAI and HAM index scores, as well as the different variables/criteria determining the scores, displayed strong correlation with some chemical and biological variables/criteria of the aquatic ecosystem.

HAI and/or HAM index scores had a relatively strong correlation with the following fish attributes (see chapter 6 and 7 for description of fish attributes):

- Number of sensitive and moderately sensitive species(r=0.58) and individuals (r=0.50).
- Relative abundance of tolerant and moderately tolerant species (r=-0.61).
- Number of species sensitive to siltation (r=0.55)

The HAI and/or HAM scores also correlated strongly with the following macro-invertebrate attributes (see chapter 5 for description of macro-invertebrate attributes):

- SASS4 biological index scores (r=0.58).
- Number of macroinvertebrate families (r=0.62).

Many variables determining the HAI and HAM index scores also correlated strongly with various fish and invertebrate variables.

Spatial variation in physical habitat condition

Median HAI scores in the Klip River ranged from 43±3% (locality 1), to 64±2% (locality 4). The median HAI score calculated for the reference site in the Suikerbosrand River (locality 10) was 74±5%. The lowest median HAM score for the Klip River was calculated for locality 9 (37±6%), and the highest score for locality 4 (71±2%). The median HAM score for locality 10 was again 74±6%. The higher QHEI scores ranged from 55±8% (locality 9) to 73±5% (locality 4) in the Klip River. The median QHEI score for locality 10 was again 74±5% (Table 4.10 and Figure 4.3).

Table 4.10: Habitat assessment index statistics of the different localities investigated (Poor, Fair, Good, Excellent).

Locality	HAI (%)		HAM (%)		QHEI (%)	
	Median±SD	**Range**	**Median±SD**	**Range**	**Median±SD**	**Range**
1	43±3 ⇓	39-49	48±3 ⇓	44-53	59±6 ⇓	43-62
2	↑ 47±4 ⇓	43-54	↑ 55±10 ⇓	34-60	57±8 ⇓	49-71
3	↑ 63±3 ⇓	59-67	69±4 ⇓	61-73	↑ 67±5 ⇓	59-76
4	64±2 ⇓	62-68	71±2	69-73	73±5	64-82
5	63±5 ⇓	59-75	↓ 64±5 ⇓	56-71	72±3	67-77
6	↓ 47±4 ⇓	41-51	↓ 48±7 ⇓	41-59	↓ 61±4 ⇓	54-66
7	↑ 59±4 ⇓	52-63	↑ 67±6 ⇓	60-74	↑ 67±4 ⇓	59-71
8	58±6 ⇓	52-71	↓ 56±6 ⇓	53-70	70±6 ⇓	59-79
9	60±5 ⇓	49-63	↓ 37±6 ⇓	28-47	↓ 55±8 ⇓	46-70
10	74±5	69-83	74±6	70-85	74±5	68-83

↑ - Statistically significant (p<0.05) increase from upstream locality
↓ - Statistically significant (p<0.05) decrease from upstream locality
⇓ - Statistically significant (p<0.05) lower than reference site (locality 10)

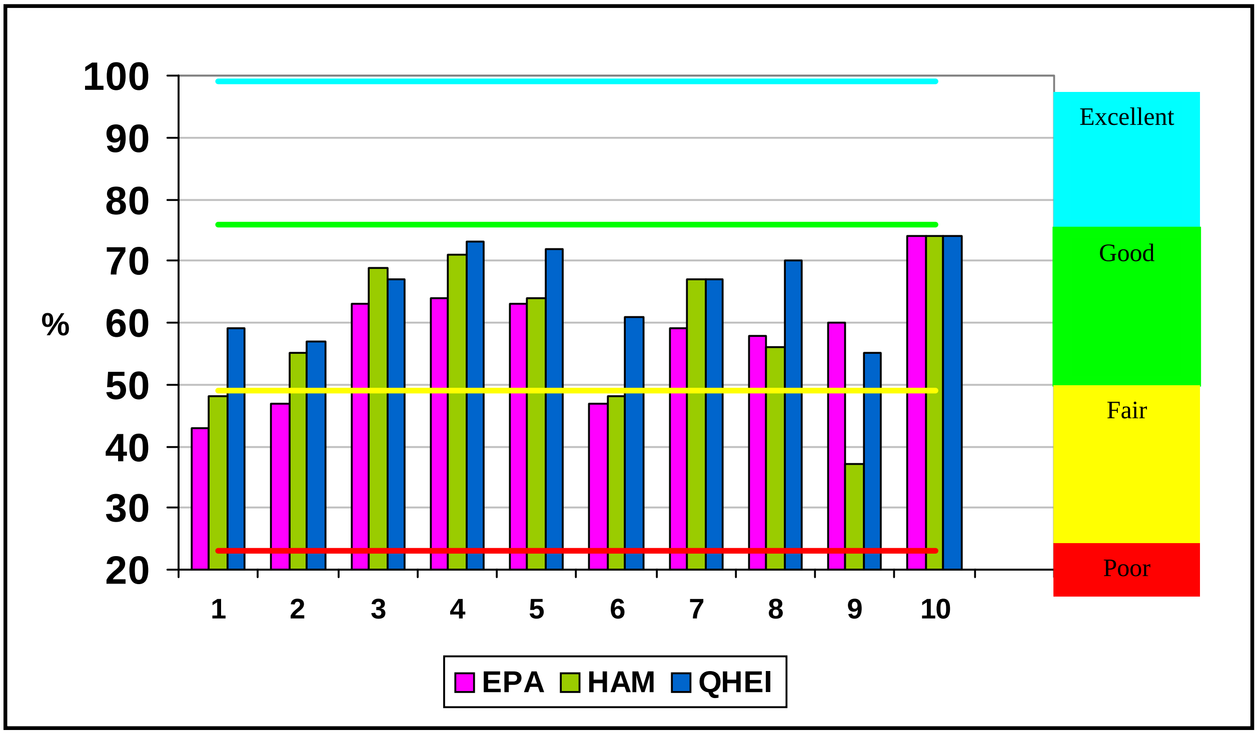

Figure 4.3: Spatial variations in the median HAI and HAM index percentages of the selected sites under investigation.

Most of the habitat variables investigated in the Klip River fell within the good quality classes (Table 4.11). Habitat variables of concern (poor quality class) included low pool variability at localities 1 and 2, largely modified riparian zones at locality 3, very low biotope diversity and pool/riffle and run/bend ratios at locality 9, and poor bank vegetative stability at locality 6 (Table 4.11).

Habitat variables investigated at localities 1 and 2 generally fell within the fair quality class. They indicated the following: low quantity and variety of natural structures to accommodate biota (only at locality 1); fairly uniform bottom substrates, relatively large amounts of sediment deposition and resultant embeddeddnes of substrates, low level of channel sinuosity and a low water level in the channel; lack of vegetative cover on stream banks, eroded stream banks (only at locality 1) and a narrow riparian zone, impacted by human activities (only at locality 2). Other variables falling into the fair category were: low channel sinuosity at localities 6, 7 and 8; low channel sinuosity and/or pool/riffle run/bend ratios at localities 3, 4, 6, 7 and 8; fairly poor bank vegetative protection and stability with great erosion potential at localities 5, 6, 8 and 9; and a narrow or highly impacted riparian zone at localities 4, 6, 7 and 8 (Table 4.11). The lower areas of locality 9 were greatly affected by scouring and deposition, and there was also a general lack of stable bottom substrates and cover.

Excellent habitat features in the Klip River included normal stream patterns without channelisation at localities 2, 8 and 9, high biotope diversity at localities 3 and 5, little scouring and deposition at locality 4, stable banks covered effectively by vegetation at localities 3 and 4 and a streamside cover of shrubs and trees at locality 7 (Table 4.11).

The greatest habitat variables of concern at the reference site (locality 10) were an unnatural low channel flow status (HAI) and fair streamside cover (HAM). At the reference site, fifty percent of the habitat variables assessed by the HAI-index site fell within the excellent class and forty percent within the good class (Table 4.11).

Table 4.11: Spatial variations in different habitat parameters (median±SD) for the HAI and HAM indices (Poor, Fair, Good, Excellent).

	LOCALITY									
	1	2	3	4	5	6	7	8	9	10
HAI										
Epifaunal substrate / Available cover	10±2	11±3	↑ 14±1	15±1	15±2	↓ 11±2	↑ 15±2	15±3	13±2	16±2
Pool substrate characterization	7±1	6±3	↑ 13±2	14±2	15±2	↓ 11±2	11±2	11±2	11±2	16±1
Pool variability	5±1	5±1	↑ 11±2	↑ 14±1	14±4	12±1	12±3	14±1	14±1	15±1
Channel alteration	12±0	16±0	12±0	12±0	↑ 15±0	↓ 12±1	↑ 14±1	↑ 17±1	↓ 16±0	19±0
Sediment deposition	9±2	6±4	↑ 15±2	14±2	15±3	15±2	15±3	13±3	13±4	15±2
Channel sinuosity	6±0	9±0	13±0	11±0	12±0	9±0	10±0	9±0	14±0	16±0
Channel flow status	9±2	8±1	↑ 11±2	10±2	12±3	↓ 9±3	10±3	11±2	12±3	7±4
Bank vegetative protection	6±3	↑ 10±2	↑ 17±2	16±2	↓ 11±2	↓ 4±2	↑ 11±3	10±2	↓ 7±3	13±3
Bank stability	9±2	↑ 12±2	↑ 18±2	17±2	↓ 11±3	↓ 6±2	↑ 13±2	10±3	9±3	14±2
Riparian vegetative zone width	14±2	↓ 10±2	↓ 3±2	↑ 7±3	↑ 13±4	↓ 5±2	9±2	10±2	12±3	17±2
HAM										
Bottom substrate / Available cover	9±2	↑ 11±2	15±2	15±1	15±2	↓ 11±2	↑ 15±2	11±3	9±0	17±1
Embeddedness	10±3	9±4	↑ 12±3	15±2	13±3	12±2	15±3	13±4	12±1	16±3
Biotope diversity categories	12±1	↓ 9±3	↑ 16±2	15±2	16±2	↓ 10±3	↑ 15±2	13±2	↓ 0±0	17±1
Velocity / depth categories	8±1	8±2	↑ 11±1	11±1	10±2	7±3	↑ 11±1	↑ 10±1	↓ 8±2	11±2
Bottom area affected by scouring & deposition	8±3	8±3	↑ 11±2	12±2	11±2	8±2	11±3	11±2	7±3	12±1
Pool/riffle & run/bend ratios	6±0	6±1	7±2	8±2	↑ 11±1	↓ 7±1	↑ 8±2	↓ 7±1	↓ 3±1	8±1
Bank erosion potential	4±1	6±1	↑ 9±0	9±1	↓ 5±2	↓ 3±1	↑ 6±2	4±2	3±1	8±1
Bank vegetative stability	5±1	6±2	↑ 9±0	9±0	↓ 6±1	↓ 2±2	↑ 7±2	5±1	4±1	8±2
Streamside cover	6±2	6±2	5±0	5±1	5±1	↓ 3±1	↑ 9±2	↓ 5±2	6±2	5±1

↑ - Statistical significant (p<0.05) increase from upstream locality
↓ - Statistical significant (p<0.05) decrease from upstream locality

Temporal variation in physical habitat condition

All the habitat assessment indices indicated a slight variation in scores between different surveys. At most sites in the Klip River, there were, however, no definite trends indicating degradation or improvement over the study period. The Pearson correlation coefficient indicated similar trends for HAI and HAM indices only 50 % of the time. Both indices indicated slight temporal habitat degradation at localities 7 and 9, slight improvement at locality 3 and a more evident improvement (r= 0.4 and 0,69) at locality 2. Both indices indicated that the habitat condition at locality 10 (reference site) deteriorated significantly (r=-0.57 & -0.69) over the study period (Table 4.12 & Figure 4.4).

Table 4.12: Temporal variations in HAI and HAM habitat assessments (Poor, Fair, Good and Excellent) and Pearson correlation coefficient (positive/negative).

	LOCALITY	Aug-97	Nov-97	Feb-98	May-98	Aug-98	Nov-98	Feb-99	May-99	R
HAI – Index	1	41	45	40	44	39	44	49	43	0.40
	2	n/a	46	43	54	45	52	47	51	0.40
	3	67	63	60	59	60	63	66	66	0.17
	4	62	68	64	66	63	65	64	63	-0.14
	5	62	60	62	75	59	63	65	69	0.35
	6	47	46	41	50	47	41	51	49	0.30
	7	60	59	52	62	55	63	59	55	-0.07
	8	63	52	54	54	59	58	71	59	0.40
	9	62	59	56	58	61	49	60	63	-0.04
	10	83	71	77	72	78	76	72	69	-0.57
HAM - Index	1	50	51	47	53	44	49	44	47	-0.53
	2	n/a	34	40	60	41	55	55	56	0.69
	3	69	70	61	71	63	70	73	69	0.24
	4	72	73	69	69	70	69	72	73	0.05
	5	70	64	61	71	61	64	56	69	-0.27
	6	56	55	42	47	41	41	59	49	-0.15
	7	70	74	60	61	63	74	71	62	-0.13
	8	62	64	54	54	53	53	70	58	-0.01
	9	47	43	28	38	34	33	36	40	-0.36
	10	85	76	84	70	70	74	73	71	-0.69

n/a – Not available r – Pearson's correlation coefficient

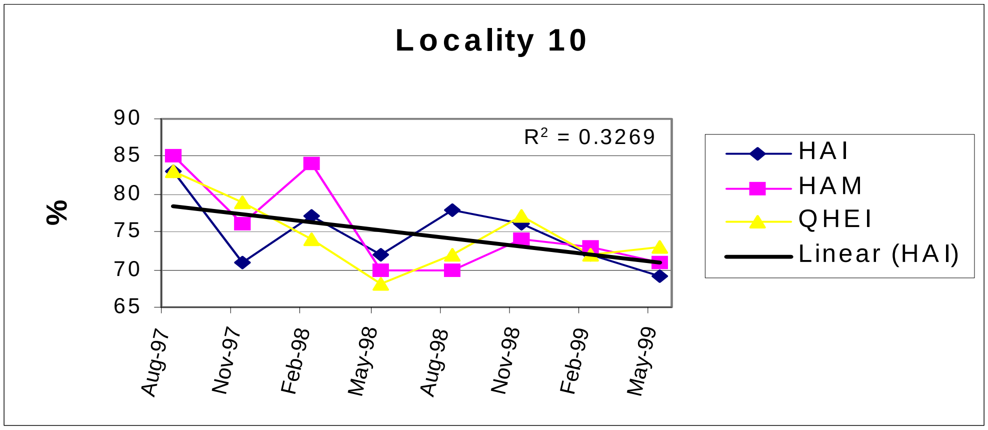

Figure 4.4: Temporal variation in the habitat condition at locality 10 in the Suikerbosrand River and linear trend (R^2) for HAI.

There were generally no definite trends between habitat condition and season. In most cases seasonal variation at a site occurred within the same quality class. Exceptions were localities 1, 2, 6 and 9, that varied between the fair and good classes, as well as locality 10, varying between the good and excellent classes (Table 4.12).

4.4 DISCUSSION

Habitat assessment indices

The use of the Index of Habitat Integrity, as applied during this study, provides a wide, general perspective on the changes that took place, and the potential anthropogenic causes responsible for these changes. This method is described as being suitable for a first conceptual approach in the assessment of modifications on a macro habitat scale (Kleynhans, 1996). The results from the IHI therefore provided a broad overview of the habitat integrity of the Klip River, assessed in four different reaches. Kleynhans (1996) furthermore states that for habitat integrity assessment required on a finer scale, other site-specific methods such as the habitat quality index (Plafkin *et al*., 1989) should also be taken into account. In this study, three site specific habitat assessments, namely the USEPA habitat assessment index for low gradients streams (HAI), the Habitat Assessment Matrix (HAM) and the qualitative habitat evaluation index (QHEI) were applied to obtain more detailed results of habitat integrity at selected sites within each river reach. These indices gave an indication of the habitat's general condition and its potential to sustain healthy biotic communities. The difference between site-specific habitat assessment scores for different indices (HAI, HAM and QHEI) is attributed to the difference in parameters used by the indices. Although there were, in many cases, significant differences in scores attained by different indices, they all indicated similar trends in spatial habitat variation, as shown by the strong correlation between the different index scores. The application of any one of the selected indices would therefore be sufficient to indicate the condition of the physical habitat at a sampling site. The application of more than one index, however, would result in a more comprehensive evaluation of habitat condition, and a higher probability of identifying problematic (lacking) habitat components.

A few advantages (+) and disadvantages (-) of the different indices as identified during this study are indicated as follows:

HAI

+ This index investigates more variables than the HAM, and the score can therefore be assumed to give a more comprehensive habitat assessment.

- The "Riparian Vegetation Criterion" score is based on the width of the riparian zone, and increases with an increase in width. In the catchment under investigation, the width of the visible riparian vegetation is very narrow, even under undisturbed conditions.

- Some parameters need to be adapted for specific river systems (eg. Riparian zone width).

HAM

+ It is the most widely used habitat condition index in South Africa (together with SASS).

- No differentiation is made between indigenous and exotic vegetation.

QHEI

+ The criteria assessed are separated (e.g. substrate, instream cover, etc) and the assessment can therefore be focused on the specific areas.

- It is difficult to assign quality classes to the different parameters assessed.

Due to the ability to assign specific quality classes to HAI and HAM index scores, as well as the criteria determining the scores (e.g. pool variability, bank erosion potential), the discussion of site-specific habitat condition is primarily based on the results of these two indices. The application of the large scale IHI assessment, together with site-specific indices (HAM en HAI), proved to be valuable in the evaluation of the physical habitat of the Klip River. These indices furthermore identified the potential sources responsible for habitat degradation, which could be valuable if management strategies are to be designed and implemented to improve the physical habitat integrity of this river in future. It is proposed that the HAI be used in future to assess the general condition of physical habitat features at a site, while the IHI should be applied to identify the relative impact that different human activities may have on the physical habitat integrity. Although the confidence would be lower, the IHI should also be adopted for site-specific habitat integrity assessments.

Instream and Riparian Habitat Integrity

REFERENCE SITE – Suikerbosrand River

The physical habitat condition and potential at the reference site (locality 10) in the Suikerbosrand River, as measured by the HAI and HAM site-specific habitat assessment indices, was good. Although this site is not pristine, there are far fewer human activities in the vicinity, and upstream from the site, when compared to the Klip River sites. The main human activities observed in the vicinity of this site were agriculture in the form of maize crops, and livestock grazing. Flow modification, by a dam upstream of the site (Balfour), was the most concerning of anthropogenic activities altering the instream physical habitat of this site. A factor of major concern was the deterioration of the habitat condition at this site from August 1997 to May 1999. All indices indicated a strong decrease in scores over this time period. The deterioration can primarily be attributed to the decrease in flow due to the construction of the upstream dam. Other factors impacting on this site was the erosion from cultivated lands, and also the banks of the river. This resulted in the covering of substrates with fine sediment in some areas of the site. Although the habitat integrity of this site was somewhat degraded, it was still significantly higher than those at most sites in the Klip River. It therefore justifies the use of this site in the determination of expected or reference conditions for the physical habitat of Klip River Catchment in general.

REACH A – Klip River

The primary human activities, identified to be responsible for physical habitat integrity deterioration in this reach, were urban development, informal settlements, mining and industrial activities. Based on the Index of Habitat Integrity (IHI), the *riparian zone* habitat integrity of reach A ranged between descriptive categories 3 and 4. This would indicate that the human induced impacts in this reach have caused the habitat integrity to be largely or moderately modified from its natural condition. The most evident degradation in the riparian zone of this reach was the encroachment by exotic Black wattles (*Acacia mearnsii*) trees. An effort should be made to clear this area from exotic invader species, to improve riparian zone habitat integrity. Human activities such as informal housing, solid waste disposal and indigenous vegetation removal furthermore contributed to the lack of indigenous vegetation in the riparian zone of reach A. The root systems of plants growing on stream banks and in riparian zones helps to hold soil in place, thereby reducing the amount of erosion that is likely to occur (Barbour *et al*., 1999). Unstable banks, with some erosion scars present in reach A reflected the negative impact of indigenous vegetation removal on habitat integrity. Indigenous vegetation removal results in increased erosion, which results in high turbidity and sedimentation of pool substrates. This in turn would reduce the potential of the river to provide habitats for biota.

Another impact that the extensive growth of exotic trees has on the habitat integrity of a river is its limitation to the natural growth of aquatic, bank and riparian vegetation. Shading affects the growth of natural vegetation, and it also affects the whole of an aquatic plant, while aspects such as turbidity affects only those parts of the plant which are in the water (Haslam, 1987). This explains the general lack of aquatic and bank vegetation in reach A, where the exotic trees shade most of the river. Banks that have full, natural plant growth are better for fish and macroinvertebrates than are banks without vegetative protection (Barbour *et al*., 1999). Eradication of these exotic trees could therefore increase the possibility for aquatic vegetation to re-colonize this site. This will also increase the possibility of recolonization of aquatic biota, water quality permitting.

The *instream habitat integrity* of reach A was generally good, and fell within descriptive category 2. This would suggest that the *instream habitat integrity* of this reach is largely natural, with few modifications. It therefore seems that the human activities in the upper reaches of the Klip River had a small impact on the instream habitat integrity of reach A. The rapid increase of informal settlements in this area could, however, cause this to change drastically in the near future. The most obvious concern in this area, relating to instream habitats, was sedimentation of pool substrates. Increased bank and catchment erosion, together with mine dumps upstream from this site, contributed to fine silt that covered the pool substrates. Furthermore, two upstream dams were responsible for a reduction in flow, which could have aggravated the potential for fine sediment to become suspended and to cover substrates in this reach. Generally, as rocks become embedded, the surface area available to macroinvertebrates and fish (for shelter, spawning, and egg incubation) is decreased (Barbour *et al.*, 1999). It can therefore be expected that the embedding of pool substrates in this area of the Klip River could be a physical constraint, limiting the natural occurrence of biota. The decreased amount of water furthermore also lowered the habitat diversity, forming mainly slow flowing habitat types and causing low pool variability. Rivers with low sinuosity (few bends) and monotonous pool characteristics do not have sufficient quantities and types of habitat to support a diverse aquatic community (Barbour *et al.*, 1999). This reach, being close to the origin of the river, can however be expected to have lower habitat diversity and pool variability than the lower reaches with higher flow. Channel width, drainage order and depth are all measures of size of a stream, and so they usually all increase downstream (Haslam, 1978).

Site-specific habitat evaluations within reach A (localities 1 and 2), indicated that fair to good habitat conditions and potential prevailed during the study period. Index scores indicated a general downstream increase, which could be related to a decrease in human activity along this reach. The middle section of reach A (in the vicinity of locality 2, has great aesthetic value for the local community, and baptism in the river was often observed during the study. A large area surrounding this section is still relatively natural, without any form of housing. Illegal solid waste disposal at large scale is, however, rapidly degrading the natural character of the surrounding landscapes. If the correct steps are taken soon, this area might be the most valuable and most natural area to conserve in the upper Klip River system. There was also an improvement in habitat condition at locality 2, over the study period. This could possibly be attributed to reduced impacts by gold mining activities in the area, which were also reflected by the water quality of this site (Chapter 3).

REACH B – Klip River

Based on the site-specific habitat assessment scores (IHA and HAM), the habitat conditions and potential for biota were generally good at all the sites within reach B. This would be an indication that the physical habitat within the reach should be adequate to sustain viable biotic populations, water quality permitting. Based on the IHI, the riparian zone habitat integrity within this reach deteriorated from category 2 (largely natural) to category 5 (extensive modification) and then improved again to category 3 (moderately modified). The primary cause responsible for riparian degradation was, again, residential development in the form of construction (housing, etc.) and recreation (golf courses, etc.), as well as informal settlements in the riparian zone. From this reach, agricultural activities downstream also contributed greatly to reduced riparian zone integrity. All of these activities were responsible for indigenous vegetation removal. Agricultural activities responsible for habitat degradation included the impact of cultivated lands, reducing natural vegetation and increasing erosion potential, a scenario also observed in the Luvuvhu River (Kleynhans, 1996). Water abstraction pumps and associated structures, erected in the riparian zone for irrigation purposes, were furthermore responsible for habitat degradation through indigenous vegetation removal. Human activities such as angling, spiritual traditions and cattle grazing have also contributed to the removal of indigenous vegetation from the riparian zone in some sections of reach B. The vegetative riparian zone serves as a buffer to pollutants entering a stream from runoff, controls erosion, and provides habitat and nutrient input into the stream (Barbour *et al*., 1999). Undisturbed riparian zones support a healthy stream system, but rivers with depleted riparian zones, such as the Klip River, are indicative of habitat deterioration with reduced integrity.

Instream habitat integrity deteriorated in reach B, and ranged from category 2 (largely natural) to category 4 (largely modified). The most profound human impact altering the *instream habitat integrity* from reach B downstream was flow modification. Flow modification by the dams upstream of reach A, together with abstraction for irrigation, contributed to decreased water levels in the upstream section of reach B. Increased flows were, however, observed to be of greater concern in the Klip River than reduced flows. The two primary sources responsible for increased flows were effluent from wastewater treatment works (WWTW), and urban runoff. Effluent from several wastewater treatment works and urban runoff contribute to the unnaturally high flows in this river reach. Although unnatural, it increased the habitat diversity and reduced settling of suspended solids and thus sedimentation, especially in the rapid areas. The increased flow was, however, more detrimental to the habitat integrity of the system. The most evident impacts of the increased flows were inundation, and loss of shallow and slow habitats, decreasing the natural habitat diversity. This will lower the ability of the river to sustain naturally diverse biotic assemblages, as a river with high habitat diversity will be able to sustain a more diverse biotic assemblage (Gore & Judy, 1981; Barbour *et al.*, 1999). The increased flows furthermore decreased bank stability and increased erosion potential, scouring and deposition. Another impact that could be primarily attributed to the impact of the WWTW effluents is nutrient enrichment. The enrichment of the river water with nutrients caused excessive growth of algae, covering substrates, and therefore reducing instream habitat integrity.

One of the first human impacts on the habitat integrity of the Klip River system was probably water abstraction. Even in the early 1900's the Rand Water Board, as it was then known, extracted water from the Klip River. This caused ructions between riparian landowners irrigating cultivated lands from the river. It can therefore be assumed that agricultural and housing activities were already impacting on the riparian zone at that early stage (KKVO, 1910). The present unnaturally high water level, mainly due to the WWTW effluents, buffers the current water extraction effect. Presently, the only impact of water abstraction on habitat integrity is the creation of short-term fluctuations and the destruction of riparian vegetation due to pump station construction. Furthermore, the historic impact of indigenous vegetation removal for agricultural purposes is today still a major cause for habitat deterioration in the Klip River system. Drinking areas for cattle are often responsible for increased bank erosion and bottom substrate disturbances, especially in the middle and lower sections of the river. Farmers and other water users should be advised to better manage abstraction points and cattle drinking areas, to limit the impact on the riparian zone.

A great part of reach B is covered by wetlands, one of the most valuable habitat features of the Klip River. These wetlands perform vital functions in flood-control and also in serving as natural filters for the system. They can trap sediment, nutrients, pollutants and even pathogenic bacteria (Davies & Day, 1998; Rand Water, 1998). Furthermore, these wetlands provide vital habitat, food and shelter for a variety of aquatic and terrestrial biota. Hundreds of waterfowl have been observed in the wetlands during the study period, emphasizing their importance even more. Riparian and instream vegetation is part of the natural ecosystem of the river, and if the one is to be preserved, the other must be also. The benefits of vegetation are that they anchor in, and stabilize channel banks, provide shelter, a substrate, and sometimes food, for invertebrates. Vegetation is also important to provide shelter for fish, to protect some fish species while spawning, and to provide a feeding surface with algae and invertebrates. The increased channel flow status and lack of seasonal variability decreases the ability of natural vegetation to occur unstressed in this section of the Klip River. Aquatic vegetation is a sensitive indicator of the condition in which they live, and water movement is one of the most important factors influencing them. Flow affects plants directly and indirectly through its effects on the channel bed. Habitats with fast flow, such as the Klip River, have continuous scouring which prevents particles from accumulating in the path of the main current, but since the flow is steady, the bed is usually stable (Haslam, 1978). Vegetation and flow are normally in equilibrium, the plant species present in any one reach, being those which can, in the long run, tolerate both the normal flows and the storm flows of that reach (Haslam, 1978). Aquatic vegetation is damaged, broken and uprooted by natural processes such as storm flows (Haslam, 1978). Due to the unnaturally high flow all year round in the Klip River, this effect is enhanced and is altering the natural vegetation to a great extent. Furthermore, reduced vegetation leads to increased erosion with obvious negative effects on the water quality (increase turbidity), streambed quality (sedimentation) and the general physical characteristics of the river (bank slopes).

REACH C & D – Klip River

Human activities along the Klip River were relatively similar throughout reaches C and D. However, based on the IHI, reach C had the lowest instream and riparian zone habitat integrity of the entire Klip River, ranging between the largely to critically modified categories. Both the instream and riparian zone integrity of reach D were also largely modified from their natural condition.

The most profound impact responsible for *riparian zone habitat* degradation in the lower reaches of the Klip River was the removal of indigenous vegetation and the resulting encroachment by exotics. Riparian owners cleared the riparian zones in large areas of reach C and D. This was done for the purpose of recreational activities and land cultivation, often up to the riverbanks. According to Waite and Carpenter (2000) low gradient streams with poor riparian conditions, especially in agricultural areas, can be expected to have increased water temperature, nutrients and fine grain sediments. This phenomenon was also observed in the Klip River sections with decreased riparian zone integrity. Solid waste disposal, accompanying the uncontrolled presence of humans, resulted in a further decrease in riparian habitat integrity. Riparian landowners and humans utilizing these areas should be managed to reduce riparian zone destruction, and to limit solid waste disposal.

In both reaches C and D, the unnaturally high water level, due to WWTW-effluents, urban runoff, as well as the contribution of the Rietspruit, was the most concerning influence on *instream habitat integrity*. The impacts were similar to those caused by increased flow in reach B, but intensified downstream as water volume increased. It again resulted in flooding of natural habitats, thereby decreasing instream habitat diversity. It also had a moderate to serious impact on the riverbed and banks due to extensive scouring in both reaches C and D. Nutrient enrichment again caused increased algal growth, which covered substrates. At times, high volumes of suspended solids were also released by dysfunctional WWTW. The sedimentation of these suspended solids in the weirs caused decreased oxygen levels, which has even been observed to cause fish kills in this river system. The exotic fish *Cyprinus carpio,* known to be responsible for disturbing the substrates especially in weirs, was present in this reach, and could have contributed further to increasing turbidity and biological oxygen demand in this reach.

Site-specific habitat assessment indices indicated a profound deterioration in habitat condition from locality 5 (Reach B) to 6 (Reach C), where both HAM and HAI indices indicated fair conditions. This phenomenon can primarily be attributed to the further modification of flow by the contribution of water from the Rietspruit tributary. The Rietspruit also drains a highly developed area, and its water comes primarily from WWTW' effluents, urban-runoff and mining activities. Due to the high volume of water, extremely high flow, with very little seasonal variation occurred all year round. This contributed largely to the high level of bank erosion (Plate 5.1) in the lower part of the Klip

River. This decreased vegetative protection on the banks rendered conditions of high erosion potential.

The observed gradual downstream deterioration in habitat integrity along the Klip River, as indicated by the Index of Habitat Integrity (IHI), can be expected as the downstream sections of the river carry the cumulative effects of all upstream stressors (Davies & Day, 1998). Based on the habitat assessment protocols applied, it is obvious that the physical habitat of the Klip River system is presently being negatively impacted by various anthropogenic activities. The importance of habitat condition and availability to sustain viable populations of aquatic biota in a river, has previously been stressed by various authors (Gorman and Karr, 1978; Korman and Higgins, 1997; Stoneman and Jones, 2000). It can therefore be expected that the present condition of the Klip River's physical habitat act as a major constraint to biotic assemblages.

4.5 CONCLUSIONS

The Index of Habitat Integrity (IHI), as applied during this study, provided a wide, general perspective on the changes that took place and the potential causes responsible for these changes in the Klip River system. Descriptions of the different descriptive integrity categories used by Kleynhans (1996) on the Luvuvhu River coincided with the scenarios observed in the current study and could therefore be applied directly to the Klip River. The USEPA habitat assessment index (HAI) and Habitat assessment matrix (HAM) proved to be the most valuable indices for site-specific habitat assessments. Of the two, the HAI is proposed for future use, and should be adapted for application to each river system.

The impact of the large human population and their associated activities in the Klip River catchment is reflected by the physical habitat condition, availability and integrity. Many instream and riparian zone habitat features were negatively impacted by these anthropogenic activities. Habitat variables of major concern and their probable sources in the Klip River catchment included the following:

- Flow modification due primarily to WWTW effluents and storm water runoff from urban areas.
- Decrease in habitat diversity due to increased flows.

- Bank erosion due to increased flows and vegetation removal.
- Exotic vegetation encroachment
- Indigenous vegetation removal.
- Bed modification due to scouring, solid waste disposal and increased algal growth on substrates, due to nutrient enrichment.
- Instream habitat destruction (vegetation) and decrease in biotope diversity due to flow modification.

(Refer to Chapter 8, figure 8.1, for a diagrammatic presentation of habitat degradation observed in the Klip River).

Based on the habitat assessment protocols applied, it is obvious that the physical habitat of the Klip River system is presently being negatively impacted by various anthropogenic activities. It can be expected that the present condition of the Klip River's physical habitat acts as a constraint to biotic assemblages.

It is advised that actions should be taken by the appropriate authorities to prevent further degradation of the instream and riparian zone integrity of the Klip River. Angling should be limited to specified areas cleared for this purpose and access roads should be provided. The managers of recreational areas, such as golf clubs, should be advised to conserve the natural vegetation alongside the rivers that traverse these areas. Areas of importance, for both the ecosystem and humans, should be identified and more intensive management applied for the conservation of these sections of the river. Appropriate areas along the Klip River should be declared nature reserves to enable the aquatic system to function as undisturbed as possible, at least within some sections of the river. This would create refuge areas for fish and also water birds, which have been observed in great numbers in the wetland sections of this river system. Farmers and other water users should be advised to better manage abstraction points, and cattle drinking areas to limit the impact on the riparian zone. Informal settlements should not be allowed within close proximity of the river, as this could be detrimental to both them and to the aquatic system. Exotic vegetation should be removed, especially in the upper section of the Klip River where invasion is the most serious.

4.6 REFERENCES

BARBOUR MT and STRIBLING JB (1994) A technique for assessing stream habitat structure. Pp. 156-178, In: *Proceedings of the conference "Riparian Ecosystems of the Humid U.S. Management, functions, and Values*". National Association of Conservation Districts. Washington, DC, United States of America.

BARBOUR MT and STRIBLING JB (1996) *A workshop on the Technique for Assessing Stream Habitat Structure for Non-point source Evaluations.* http://www.epa.gov/OWOW/watershed/Proceed/barbour.html

BARBOUR MT, GERRITSEN J, SNYDER BD and STRIBLING JB (1999) *Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates and Fish, Second Edition.* EPA 841-B-99-002. U.S. Environmental Protection Agency; Office of Water; Washington, D.C. United States of America.

DAVIS WS and SIMON TP (1995) *Biological Assessment and Criteria: Tools for water resource planning and decision making.* CRC Press, Inc. United States of America.

DAVIES B and DAY J (1998) *Vanishing Waters*. University of Cape Town Press, Cape Town, South Africa. 487pp.

DEPARTMENT OF WATER AFFAIRS AND FORESTRY (DWAF) (2000) *National Water Act News, March 2000*. http://www-dwaf.pwv.gov.za.

DEPARTMENT OF WATER AFFAIRS AND FORESTRY (DWAF) (1999) *Resource Directed Measures for Protection of Water Resources.* Volume 2: Integrated Manual, Version 1.0. Pretoria, South Africa.

FOLK R and WARD W (1957) Brazos River bar: A study in significance in grain size parameters. *J. Sedim. Petrol*. **27** 3-26.

FRISSEL CA, LISS WL, WARREN CE and HURLEY MV (1986) A hierarchial framework for stream habitat classification, viewing streams in a watershed context. *Environmental Management* **10**(2) 199-214.

GORE JA and JUDY RD (Jr.) (1981) Predictive models of benthic macroinvertebrate density for use in instream flow studies and regulated flow management. *Canadian Journal of Fisheries and Aquatic Sciences* **38** 1363-1370.

GORMAN OT and KARR JR (1978) Habitat structure and stream fish communities. *Ecology* **59**(3) 507-515.

HASLAM S M (1978) *River Plants*. Cambridge University Press, London. United Kingdom. 396pp.

KORMAN J and HIGGINS PS (1997) Utility of escapement time series data for monitoring the response of salmon populations to habitat alteration. *Can. J. Fish. Aquat. Sci*. **54** 2058-2067.

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

KLIPRIVIER KOMMISSIE VAN ONDERZOEK (KKVO) (1910) *Rapport van de Kliprivier Komminssie van Onderzoek*. Goevernementsdrukker, Pretoria. South Africa. 79 pp.

PLAFKIN JL, BARBOUR MT, PORTER KD, GROSS SK and HUGHES RM (1989) *Rapid Bioassessment Protocols for Use in Streams and Rivers: Benthic Macroinvertebrates and Fish.* U.S. Environmental Protection Agency Report No. EPA/440/4-89-001. Assessment and Watershed Division, Washington, DC 20460. United States of America.

RAND WATER (1998) *The Socio-Economic Value of Wetlands in Highly Industrialised Catchments: Development of a Programme for the Klip River Catchment*. Vol. 2 no. 1. 64 pp. Rietvlei, Johannesburg, South Africa.

ROUX DJ (1997) *National Aquatic Ecosystem Biomonitoring Programme: Overview of the design process and guidelines for implementation*. NAEBP Report Series No. 6. Institute for Water Quality Studies, Department of Water Affairs and Forestry, Pretoria, South Africa.

STONEMAN CL and JONES ML (2000) The influence of habitat features on the biomass and distribution of three species of Southern Ontario stream salmonines. *Trans. Am. Fish. Soc*. **129** 639-657.

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

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY (USEPA) (1996) *Revision to Rapid Bioassessment Protocols for use in Streams and Rivers: Periphyton, Benthic Macro invertebrates and fish*. USEPA Internet Web Page: http://epa.gov/owow/monitoring/rbp.

WAITE IR, CARPENTER KD (2000) Associations among Fish Assemblage Structures and Environmental Variables in Willamette Basin Streams, Oregon. *Trans. Am. Fish. Soc*. **129** 754-770.

ZAR J (1978) *Biostatistical Analysis*. Prentice-Hall Publishers. Englewood Cliffs, United States of America. 718pp.