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DEPARTMENT OF WATER AFFAIRS AND FORESTRY

in association with

UMGENI WATER
Corporate Services Division

MKOMAZI-MGENI TRANSFER SCHEME PRE-FEASIBILITY STUDY

MKOMAZI-MGENI TRANSFER SCHEME

SUPPORTING REPORT No 5

ENVIRONMENTAL

VOLUME 3

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MKOMAZI/MOOI-MGENI TRANSFER SCHEME PRE-FEASIBILITY STUDY

SUPPORTING REPORT NO 5: ENVIRONMENTAL

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SCOTTBURGH

SPECIALIST MEETING PROCEEDINGS

IWR ENVIRONMENTAL

INSTITUTE FOR WATER RESEARCH

COMPILED BY
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EXECUTIVE SUMMARY

Background

The Department of Water Affairs and Forestry together with Umgeni Water has commissioned a pre-feasibility study into posible water transfer schemes from the Mkomazi River to the Mgeni River System. The scheme would augement The Mgeni System, which is already close to its capacity.

In order to undertake this study, the Department of Water Affairs and Forestry and Umgeni Water have appointed Ninham Shand as their lead consultant. Ninham Shand has subcontracted IWR Environmental to undertake the Integrated Environmental Management (IEM) procedures and Instream Flow Requirements (IFR) study and to manage the Estuary Flow Requirements (EFR) study.

This component of the study, which has as its objective the determination of the Instream Flow Requirements (IFR) of the river, forms part of the specialist studies identified as part of the Environmental Impact Assessment, which will be completed at the end of the study.

IFR, which is the flow regime required to maintain the essential ecological functioning of the river, can be equated to the ecological (quantity) protection component of the Reserve of South Africa's new water law.

Methodology

Approximate 20 IFR studies have been undertaken in South Africa using the Building Block Methodology (BBM), since 1991.

In the methodology the following assumptions are made.

- The biota associated with a river can cope with those low-flow conditions that naturally occur in it often, and may be reliant on higher-flow conditions that naturally occur in at it at certain times. This assumption reflects the thinking that the flows that are a normal characteristic of a specific river, no matter how extreme, variable or unpredictable they may be, are ones to which the riverine species characteristic of that river are adapted and on which they may be reliant. On the other hand, flows that are not characteristic of that river will constitute an atypical disturbance to the riverine ecosystem and could fundamentally change its character.
- Identification of what are felt to be the most important components of the natural flow regime and their incorporation as part of the modified flow regime will facilitate maintenance of the natural biota and natural functioning of the river
- Certain kinds of flow influence channel geomorphology more than others. Identifications of such flows and their incorporation into the modified flow regime will aid maintenance of the natural channel structure and diversity of physical biotopes. (King & Louw)

The flows incorporated into the modified flow regime will constitute the IFR for the river. The IFR describes, in space and time, the minimum amount of water that it is felt will facilitate maintenance of the river at some pre-defined desired state.

The recommended flows are identified and their magnitudes, timing and duration decided upon in the BBM specialist meeting. Initially, thought is focussed on the characteristic features of the natural flow regime of the river. The most important of these are usually; degree of perenniality; magnitude of base flows in the dry and wet season; magnitude, timing and duration of floods in the wet season; and small pulses of higher flow, freshes, that occur in the drier months. Attention is then given to which flow features are considered most important for maintaining or achieving the desired state of the river, and thus should not be eradicated during development of the river's water resources. The described parts of each flow component are considered the building blocks which create the IFR, each being included because it is understood to perform a required ecological or geomorphological function. The first building block, or low-flow component, defines the required perenniality or non-perenniality of the river, as well as the timing of wet and dry seasons. Subsequent building blocks add essential higher flows.

Desired Future State

The IFR for a river depends intimately on its Desired Future State (DFS). The DFS can be the same as its present state (ie, the river is in good condition, and must stay in good condition), or it can be aspirational (ie, some improvement in the river's condition is desired). A river with a "high" DFS will have a higher IFR than one which is, for instance, degraded or is not important, and for which no impovement is required.

It is therefore imperative that the DFS for the river is realistic and correct, as the IFR will be set according to the DFS.

The steps undertaken for the Mkomazi study to determine the DFS were the following:

- *Determine the present ecological/environmental state.*
  A habitat integrity analysis was undertaken to determine the present state categories of the river. The results of this are illustrated in Fig 2.3.
- *Determine the ecological/environmental importance of the river*
  Prof J O'Keeffe defined the ecological importance of a river as "a measure of the value of a river for conservation, including natural, socio-economic and cultural aspects". Criteria for evaluating natural aspects includes rarity, special features, resilience/fragility and the degree of modification. The criteria considered were uniqueness, condition, biodiversity, human usage, planning initiatives. The study resulted in attribute scores ranging from 3 to 4,5 on a scale of 6. As all the criteria are ranked at 3 or better, it is apparent that the Mkomazi is a river of some importance.
- *Determine the DFS which would ensure a healthy ecosystem.*
  Due to the importance of the river, it was decided that the river should be treated as a continuum, with one class allocated to the whole river.

The Present State and Desired Future State are described in the following table. Detailed motivations are supplied in Chapter 2.

Component	Present	DFS
Invertebrates	B+	B+
Fish	B+	B+
Vegetation	C/D	C
Geomorphology	C	C
Water Quality	B/C	B
Habitat: Integrity : Instream	B/C	B/C
Habitat Integrity : Riparian	C	C
Social : Flow	B	B
Social : Quality	B-	B
Social : Riparian zone	C/D	C
Importance	B/C	B/C

Process followed during the specialist meeting

The approach during the specialist meeting (IFR workshop) was as follows:

- The highest low flow (base flow) month and lowest low flow month were selected as February and September utilising the hydrological record to make this decision.
- These months were used to set the low flows, and the range of flows that occur during the year was therefore fixed between the highest and lowest low flows.
- The low flow IFR for the rest of the months were extrapolated from the September and February flows following the natural shape of the annual hydrograph. This extrapolation was undertaken by the hydrologists and checked by the ecologists.
- Each specialist provided motivations describing the physical characteristics (eg water level, velocity, depth) and the reasons for requiring these flows. Some of the disciplines provided primary and some secondary motivations. Primary motivations refer to motivations provided by the disciplines that require a certain type of flow which is critical. Secondary motivations refer to motivations provided by disciplines that could maintain the component with less flows, but for which higher flows to satisfy the other components requirements will not be harmful.
- After each flow is agreed on, the flows specified were checked for realism in non-drought years. Normal or average hydrological years were utilised to provide this check.
- During the wet season high flow events were set and motivated. High flows refer to freshes, small, medium and large floods. A fresh refers to a small increase in base flow. The high flows are given in m^3/s and the flow provided refers to an instantaneous peak.

As the hydrology was provided in mean daily averages, the peaks recommended were converted to slightly lower flows to reflect the mean daily average.

* In all cases the duration of the floods were provided in days.
* The shape of the floods was based on the shape of the natural hydrograph.
* The peaks specified include the low (base) flows.
* When the total volume of each flood was calculated, it excluded the low flow volume, which is already included in the total low flow volume.

C A hydrological check of each flood was repeated..

The same procedure was followed for drought years.

IFR results

The results of the 4 IFR sites (the points in the river for which the IFRs are determined) are summarised as follows

	IFR 1		IFR 2		IFR 3		IFR 4	
	X 10^6 m^3	% OF MAR	X 10^6 m^3	% OF MAR	X 10^6 m^3	% OF MAR	X 10^6 m^3	% OF MAR
MAINT LOW FLOWS REFINEMENT (1998)	148.37	21.5	187.79	21	221.1 216.1	22 21.5	235.3 229	22.1 21.52
MAINT HIGH FLOWS REFINEMENT (1998)	69.2	10	88.56	9.7	97.79 120.7	9.7 12.02	104.96 128	10 12
TOTAL REFINEMENT (1998)	***217.57***	***31.5***	***276.35***	***30.7***	***318.89 336.8***	***31.7 33.52***	***340.26 357***	***32.1 33.5***
DROUGHT LOW REFINEMENT (1998)	67.8	9.8	89.66	9.9	100.4 73.26	10 7.3	107 77.54	10.1 7.29
DROUGHT HIGH REFINEMENT (1998)	14.13	2	16.12	1.8	13.75 31.11	1.4 3.1	17.83 32.99	1.7 3.1
TOTAL REFINEMENT (1998)	***81.93***	***11.8***	***105.78***	***11.7***	***114.2 104.37***	***11.4 10.4***	***124.83 110.53***	***11.9 10.39***

Confidence in IFR results

The confidence in the IFR results was motivated by each specialist and the combined results indicated that the confidence in the results was in the *medium* range . It was noted in general that the most important reason for low confidence experienced for this IFR study was the lack of low flows observed during the study period.

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CHAPTER 1 : INTRODUCTION

The Department of Water Affairs and Forestry together with Umgeni Water has commissioned a pre-feasibility study into possible water transfer schemes from the Mkomazi River to the Mgeni River System. The scheme would augement the Mgeni System, which is already close to its capacity.

In order to undertake this study, the Department of Water Affairs and Forestry and Umgeni Water have appointed Ninham Shand as their lead consultan. Ninham Shand has subcontracted IWR Environmental to undertake the Integrated Environmental Management (IEM) procedures and Instream Flow Requirements (IFR) study and to manage the Estuary Flow Requirements (EFR) study.

1.1 INTEGRATED ENVIRONMENTAL MANAGEMENT (IEM)

As part of the Mkomazi Pre-Feasibility Study, an IEM process is being applied to determine the acceptability of the proposed development and to recommend preferred options.

IEM is a process that ensures that environmental considerations are efficiently and adequately taken into account at all stages of the development process. The aims of IEM are summarised as follows:

- Collect and synthesise relevant data
- **Identify potential environmental impacts**
- **Minimise potential negative impacts**
- **Maximise potential positive impacts**
- Liaise with all public groups
- Resolve conflict

This study which has as its objective the determination of the Instream Flow Requirements (IFR) of the river, forms part of the specialist studies identified as part of the Environmental Impact Assessment which will be completed at the end of the study. The study adresses the three issues in bold type above.

IFR which is the flow regime required to maintain the essential ecoogical functioning of the river, can be equated to the ecological (quantity) protection component of the Reserve of South Africa's new water law. This is described more fully in 1.3. following. The terms "IFR" and "Reserve" are used synanymously in the text.

In more detail, the IFR study answers the following:

- How much water is required for the Reserve for a specific management class or desired future state?

- Will the proposed development impact on this requirement?
- If so, can the impact be mitigated by allocating water to the Reserve and releasing it?
- If not, is the proposed development acceptable from all other environmental viewpoints?

Water Affairs applies IEM to the various engineering phases and the IFR study is also linked to these phases. The IFR actions required during the Pre-feasibility phase in which the Mkomazi study falls are:

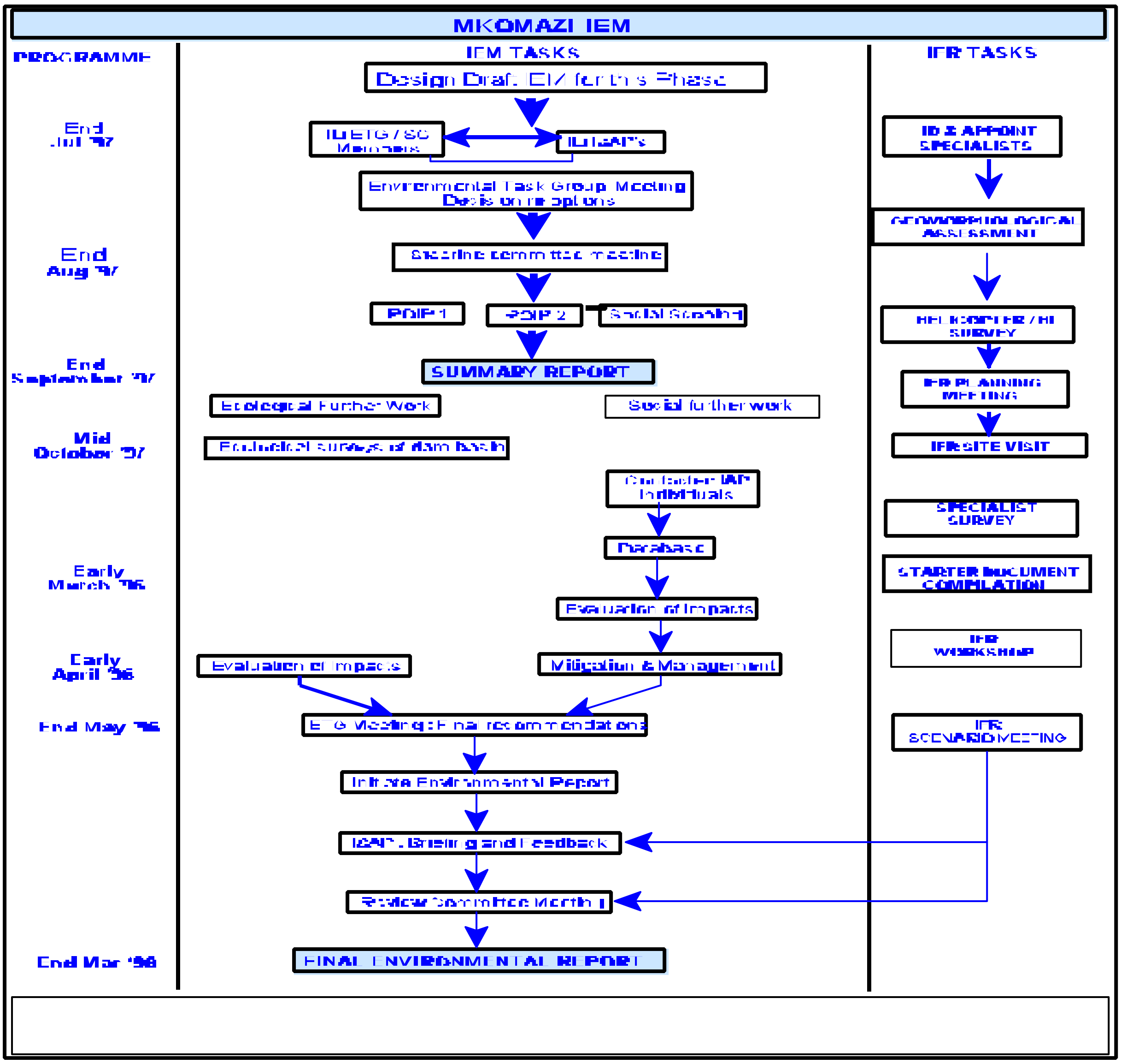
C The identification of IFR sites.

C The base-line surveys required for the IFR specialist meeting (previously known as the IFR workshop).

C An IFR workshop where the IFRs are determined.

The phases of the Mkomazi IEM study, with the concurrent IFR actions are illustrated in Fig 1.1.

Fig 1.1 Mkomazi IEM and IFR actions (Note dates not applicable at present stage)



1.2 INSTREAM FLOW REQUIREMENTS

The demand for water from South Africa's growing population is creating an ever-increasing pressure on the country's water resources, especially its rivers. The urgent need to provide more water services often conflicts with the desire to maintain or improve the ecological condition of the rivers. To provide guidance on the sustainable use of a river's water-resources, the Building Block Methodology (BBM) has been developed for assessing the instream flow requirement for any river. (King & Louw). Development has been carried out jointly over the last five years by the Department of Water Affairs and Forestry and river scientists, and the accent is on identifying a complex of different magnitude flows for maintenance of entire river ecosystems. The BBM caters for the almost universal reality in South Africa of having rapidly to provide scientific guidance on such flows for a river in cases where biological data and understanding of the functioning of the river are limited. However, the methodology works equally well in data-rich situations.

The BBM depends on available knowledge and expert opinion, gleaned from experienced river scientists in a structured 4-day meeting. Limited new data of a specific nature are gathered to facilitate the process. Relevant data on the river are prepared in a way that specialist workshop participants can easily understand and quickly begin to use. Scientists typically involved in the specialist meeting, all with specific roles, are those with specialist knowledge of the river or similar rivers in terms of the fish, aquatic invertebrates, riparian vegetation, river importance, habitat integrity, fluvial geomorphology, local hydraulics, water chemistry and social dependence on the riverine ecosystem. Hydrological and hydraulic modellers provide data inputs and facilitate the workshop process by answering questions and producing additional data as requested. The specialist meeting output, reached by consensus, is a quantitative description in space and time of a flow regime that should facilitate maintenance of the river ecosystem in some predetermined desired future state.

1.3 THE RESERVE

The supreme law of the Republic is the Constitution of the Republic of South Africa (Act No. 108 of 1996). This includes the Bill of Rights, which are all human-centred. The two rights most directly relevant to water are:

- Section 27: the right to sufficient food and water; and
- Section 24: the right to an environment not harmful to health and well being, and to have the environment protected for future generations.

The White Paper on a National Water Policy for South Africa was approved by Cabinet in April 1997, and incorporated the constitutional requirements described above, as "the Reserve".

"The Reserve" has also been codified as a legal requirement within the National Water Bill, B34-98 as introduced in the National Assembly on 3 April 1998. (It is anticipated that the Bill will receive Presidential assent during the second half of 1998).

The fundamental principles of the National Water Bill can be described as follows:
National Government, as Public Trustee of the nation's water resources, is to ensure that water is *protected, used, developed, conserved, managed and controlled* in a sustainable and equitable

manner for the benefit of all persons.

- C Equity of access: to water services; to the use of water; and to the benefits of water use.
- C Sustainable use of water: through measures to protect water resources so as to ensure their indefinite availability for human use.
- C Optimal use of water: to foster wise and efficient use of water by, among other things, conservation measures and an economic pricing system.

The basic premise is that sustainable use of water resources requires that they must be protected.

The priorities in the use of water are the following:

- C The Reserve, i.e. basic human needs and ecosystem protection. These are the only two rights to water, and the Reserve may not be allocated to other users.
- C International obligations
- C All other uses require authorisations

It is therefore necessary to quantify the Reserve before allocating water to other new users. In some areas it is possible that allocations of water to existing users may need to be adjusted to meet the requirements of the Reserve.

Definition of the Reserve:
[B34-98, Section1(xvii)]:
(xvii) "Reserve" means that quantity and quality of water required.

(a) to satisfy basic human needs for all people who are, or who may be, taking water from the relevant water resource; and
(b) to protect aquatic ecosystems in order to secure ecologically sustainable development and use of the relevant water resource.

Resource Protection

The intention of the new law is to protect all water resources which, from the definitions in Section 1, include rivers, springs, natural channels, wetlands, lakes, dams, surface water, estuaries, aquifers or other underground water and includes the bed and banks where relevant. The aim is to protect all components of the whole ecosystem, i.e. water, biota, riparian zones and sediments.

Chapter 3 of the National Water Bill - Protection of Water Resrouces - describes how resource protection will be achieved by:

- the establishment of a system for classifying water resources (resource classification);
- the determination of:
  * the class of significant water resources
  * resource quality objective (water quantity, water quality, habitat and biotic integrity)
  * the Reserve

Resource classification is required because human use causes damage to ecosystems. However, ecosystems are resilient and can tolerate use before they cease to function. The issue is how much use they can tolerate. The class of a resource is an expression of the extent of use which should be permitted, and the level of risk of damage or deterioration to which it should be exposed, to retain its capacity for sustainable utilisation. This is illustrated by the following:

High class _ low risk of damage _ low use

Low class _ high risk of damage _ high use
The Reserve reflects the level of risk.

In summary the Reserve is about resource protection for sustainable use. The Reserve is not about conservation for conservation's sake, nor does it mean that all resources must be pristine.

In the relatively brief history of the determination of the instream flow requirements of South African rivers the most commonly used method has been the Building Block Methodology. To date the BBM has been applied to more than 20 rivers countrywide, and it was the demonstrable fact that such a scientifically-based methodology existed, and was being successfully used to make estimates of instream flow requirements, that was a key factor in the inclusion, in the Water Law Principles, the National Water Policy for South Africa, and the National Water Bill, of the requirement for a statutory allocation of water to the resource itself so as to maintain ecological functioning.

1.4 OVERVIEW OF THE CATCHMENT

The Mkomazi catchment drains an area of 4387 km^2 in KwaZulu-Natal. The Great Escarpment around Sani Pass forms the headwaters of the Mkomazi, and it exits into the Indian Ocean at Umkomaas. The upper catchment geology is relatively simple, with Karoo sequence Elliot and Clarens sandstone being capped by the Drakensberg lavas. The upper-middle catchment is dominated by the Tarkastad mudstones and Dolerite, while the Ecca and Beaufort Group dominate the middle catchment. The lower middle and lower catchment display a complex geology. The catchment lithology here forms part of the Natal structural and metamorphic province, consisting of granites and gneiss. The terrain is faulted, and thus structural control of the channel is considerable. Basement geology means that the upper catchment has steep relief, while the middle and lower-middle catchment can be classified as undulating. Steep relief in the lower catchment is a function of the underlying lithology. (Appendix, Chapter 4.1).

Rainfall distribution is reasonably consistent along the catchment, ranging from nearly 1300mm per annum at the headwaters to 1000 mm p.a. in the middle and 900mm p.a. in the lower reaches of the catchment. The lithology produces clay to clay loam soils, which are only moderately erodible. According to WR90 (after Rooseboom), sediment yield from the catchment is around 155 $t/km^2/yr$ for the upper, middle and lower-middle catchment. The lower catchment produces around 175-189 $t/km^2/yr$. Catchment land use is mainly grazing and commercial forestry (wattle, pines and eucalyptus). Under 'natural conditions', the upper catchment vegetation would be dominated by pure grassveld and temperate and transitional forest and scrub, with false grassveld and coastal tropical forest dominating the middle and lower catchment. Overgrazing and high population densities in the upper-middle and lower parts of the catchment probably produce an increased sediment yield, while commercial forestry plantations have a great capacity for increasing catchment sediment yield and reducing base flows. (Appendix, Chapter 4.1)

1.5 AIM OF THIS REPORT

This report aims to summarise the actions leading to the IFR Specialist meeting and to document the results generated at the specialist meeting. Most of the information generated at the specialist meeting is documented during the specialist meeting by each specialist for inclusion in the report. The purpose of this report is not to explain the conceptual basis of IFR, or the details of the BBM.

A starter document containing all the summaries of the specialist work undertaken for the IFR study was provided prior to the IFR Specialist meeting. These papers within the starter document will be referred to and some main issues summarised in this report. The starter document as provided to the specialists prior to the Specialist meeting forms the Appendix to this document and, except for key information, will not be repeated in this report.

CHAPTER 2 : IFR METHODOLOGY

2.1 BBM

Approximately 20 IFR studies have been undertaken in South Africa using the BBM, since 1991.

In the methodology the following assumptions are made.

- The biota associated with a river can cope with those low-flow conditions that naturally occur in it often, and may be reliant on higher-flow conditions that naturally occur in at it at certain times. This assumption reflects the thinking that the flows that are a normal characteristic of a specific river, no matter how extreme, variable or unpredictable they may be, are ones to which the riverine species characteristic of that river are adapted and on which they may be reliant. On the other hand, flows that are not characteristic of that river will constitute an atypical disturbance to the riverine ecosystem and could fundamentally change its character.
- Identification of what are felt to be the most important components of the natural flow regime and their incorporation as part of the modified flow regime will facilitate maintenance of the natural biota and natural functioning of the river
- Certain kinds of flow influence channel geomorphology more than others. Identifications of such flows and their incorporation into the modified flow regime will aid maintenance of the natural channel structure and diversity of physical biotopes. (King & Louw)

The flows incorporated into the modified flow regime will constitute the instream flow requirement (IFR) for the river. The IFR describes, in space and time, the minimum amount of water that it is felt will facilitate maintenance of the river at some pre-defined desired state.

The recommended flows are identified and their magnitudes, timing and duration decided upon in the BBM specialist meeting. Initially, thought is focussed on the characteristic features of the natural flow regime of the river. The most important of these are usually; degree of perenniality; magnitude of base flows in the dry and wet season; magnitude, timing and duration of floods in the wet season; and small pulses of higher flow, or freshes, that occur in the drier months. Attention is then given to which flow features are considered most important for maintaining or achieving the desired state of the river, and thus should not be eradicated during development of the river's water resources. The described parts of each flow component are considered the building blocks which create the IFR, each being included because it is understood to perform a required ecological or geomorphological function. The first building block, or low-flow component, defines the required perenniality or non-perenniality of the river, as well as the timing of wet and dry seasons. Subsequent building blocks add essential higher flows.

The IFR study is characterised by a series of actions which are interrelated. These actions / sequence of events are illustrated in Fig 2.1 & Fig 2.2. The IFR specialist meeting forms an action within the IFR study.

FIG 2.1 : SEQUENCE OF EVENTS PRIOR TO THE SPECIALIST MEETING

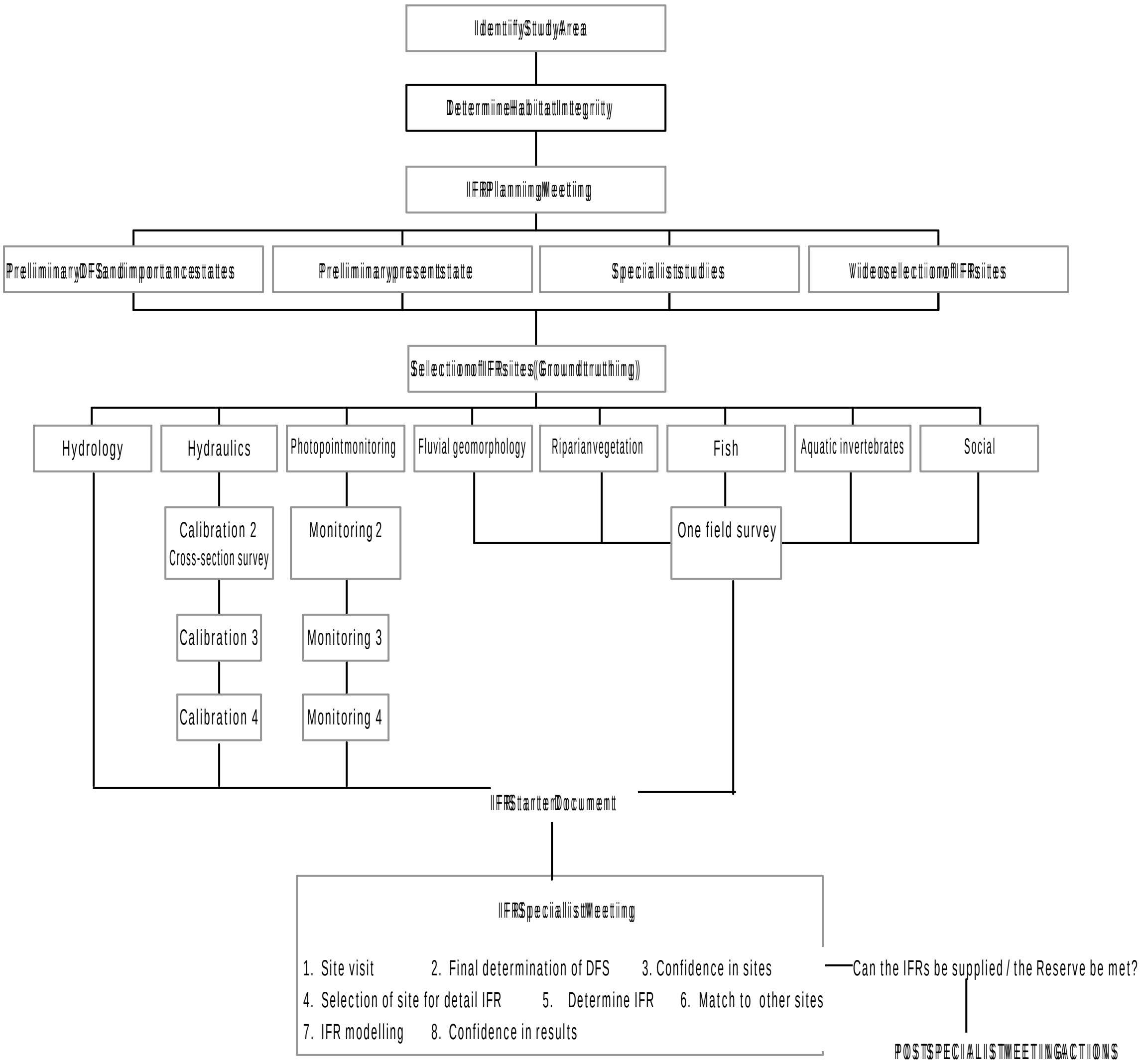
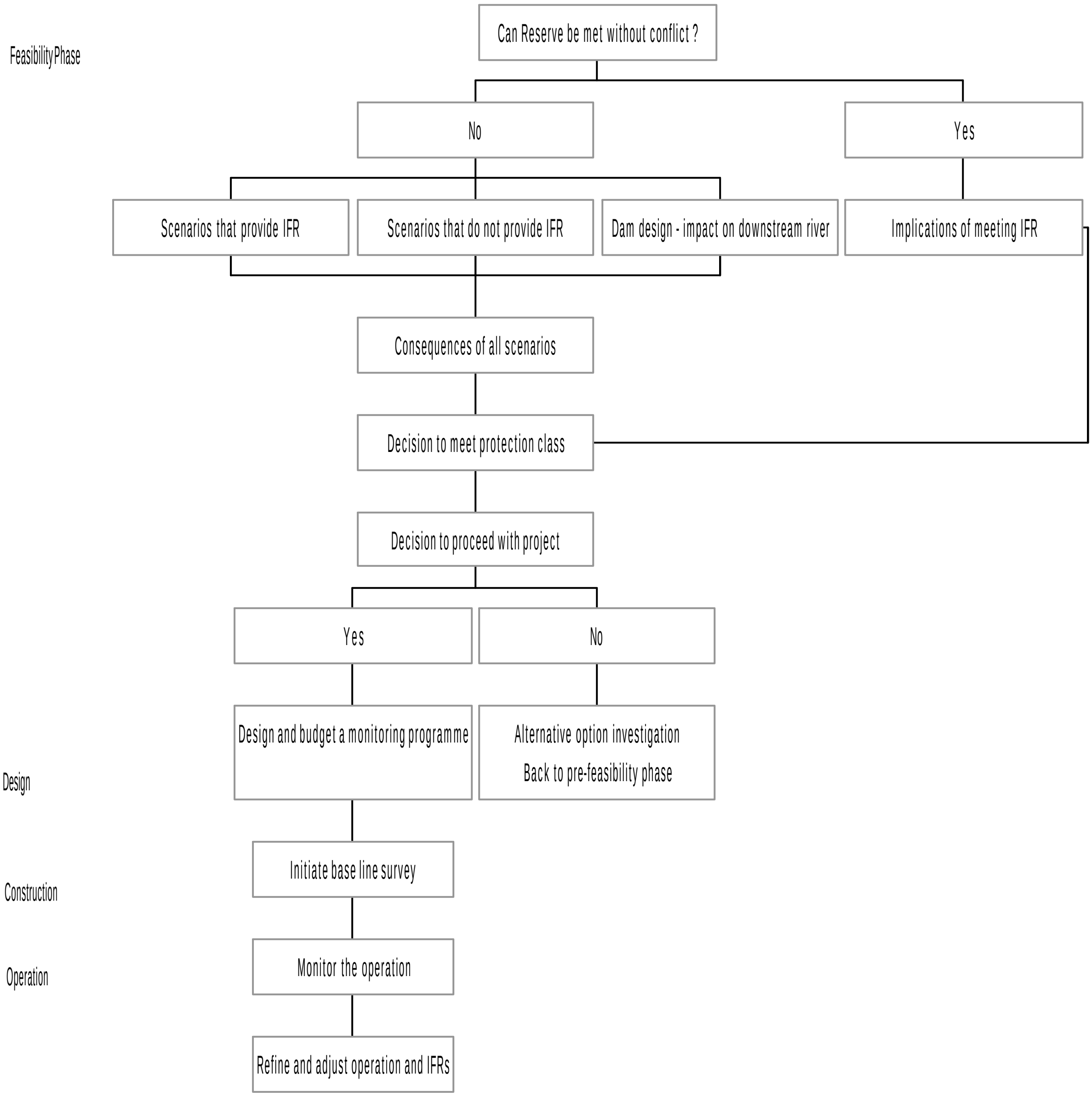


FIG 2.2 :SEQUENCE OF EVENTS AFTER THE SPECIALIST MEETING



2.2 DESIRED FUTURE STATE

The IFR for a river depends intimately on its Desired Future State (DFS). The DFS can be the same as its present state (ie, the river is in good condition, and must stay in good condition), or it can be aspirational (ie, some improvement in the river's condition is desired). A river with a "high" DFS will have a higher IFR than one which is, for instance, degraded or is not important, and for which no impovement is required.

It is therefore imperative that the DFS for the river is realistic and correct, as the IFR will be set according to the DFS.

Note on terminology : "Desired Future State" is no longer accepted terminology and has changed to either " protection class", or preferred, " management class". Please note that these three terms are used symonymously in the text.

2.2.1 Approach to determination of the DFS

During the Water Law Review process, documentation was prepared which suggested that a protection system based on different classes should be established. These protection classes relate to the management objectives or goals for the river and to the DFS. Different classes for each protection class were described in a draft document based on the Habitat Integrity system (Kleynhans). This system was described in a draft document presented as part of the Water Law Review process. In short the process can be described as follows:

- A **present state** class must be allocated to the river reach for which a mangement class is required. The present state is described by allocating a class (see Table 2.1) to the river reach. The present state is described in six classes with A being near pristine and F irreversibly changed. These classes are based on the Habitat Integrity classes (Kleynhans).
- The river importance (social, economic and ecological) is then established and considered when determining the protection class.
- After a process of consultation, a protection class is allocated to the river reach. The protection class is described in classes ranging from A (near pristine) to D (largely modified) (see Table 2.2). Unlike the present state classes, the range of protection classes does not extend to E and F. Rivers which are currently in classes E and F are not considered to represent sustainable systems, and must therefore be protected and managed for improvement. A high protection class relates to a flow that will ensure a high degree of sustainability and a low risk of ecosystem failure. A low protection class will ensure marginal maintenance of sustainability and a high risk of ecosystem failure.

The following quotations from the White Paper on a National Water Policy for South Africa illustrate the principles of this process. These concepts have been codified in provisions and requirements in the National Water Bill.

"*A national resource protection classification system will be introduced. Through a process of consensus-seeking among water users and other stakeholders, the level of protection for a resource will be decided by setting objectives for each aspect of the Reserve (water quality,* *quantity and assurance, habitat structure, and living organisms). The objectives for each aspect of the Reserve will show what degree of change or impact is considered acceptable, and unlikely to damage a water resource beyond repair.*

Resources will be grouped into a number of protection classes, with each class representing a certain level of protection. Where a high level of protection is required, the objectives will be strict, demanding a low risk of damage and the use of great caution. In other cases, the need for short to medium term use may be more pressing and the need for protection lower. Some resources may already need action to restore them to a healthy state, and, in future, no resources should be allowed to become irreversibly degraded."

TABLE 2. 1 : Present state classes based on ecosystem health / ecological integrity status

CLASS	DESCRIPTION
A	! Unmodified, natural; ! The resource base reserve has not been decreased; ! The resource capability has not been exploited
B	! Largely natural with few modification; ! The resource base reserve has been decreased to a small extent; ! A small change in natural habitats and biota may have taken place but the ecosystem functions are essentially unchanged.
C	! Moderately modified; ! The resource base reserve has been decreased to a moderate extent. ! A change of natural habitat and biota have occurred, but the basic ecosystem functions are still predominantly unchanged.
D	! Largely modified; ! The resource base reserve has been decreased to a large extent. ! Large changes in natural habitat, biota and basic ecosystem functions have occurred.
E	! Seriously modified; ! The resource base reserve has been seriously decreased and regularly exceeds the resource base; ! The loss of natural habitat, biota and basic ecosystem functions is extensive.
F	! Critically modified; ! The resource base reserve has been critically decreased and permanently exceeds the resource base; ! Modifications have reached a critical level and the resource has been modified completely with an almost total loss of natural habitat and biota. In the worst instances the basic ecosystem functions have been destroyed and the changes are irreversible.

TABLE 2.2 : Desired future state classes based on ecosystem health / ecological integrity status

CLASS	DESCRIPTION
A	! Unmodified, natural - the natural abiotic template should not be modified; ! The characteristics of the resource should be completely determined by unmodified natural disturbance regimes; ! There should be no human induced risks to the abiotic and biotic maintenance of the resource. ! The supply capability of the resource will not be utilised.
B	! Largely natural with few modification - only a small risk of modifying the natural abiotic template and exceeding the resource base should be allowed. ! Although the risk to the well-being and survival of especially intolerant biota (depending on the nature of the disturbance) at a very limited number of localities may be slightly higher than expected under natural conditions, the resilience and adaptability of biota must not be compromised. ! The impact of acute disturbances must be totally mitigated by the presence of sufficient refuge areas.
C	! Moderately modified - a moderate risk of modifying the abiotic template and exceeding the resource base may be allowed. Risks to the well-being and survival of intolerant biota (depending on the nature of the disturbance) may generally be increased with some reduction of resilience and adaptability at a small number of localities. However, the impact of local and acute disturbances must at least partly be mitigated by the presence of sufficient refuge areas.
D	! Largely modified - a large risk of modifying the abiotic template and exceeding the resource base may be allowed. Risks to the well-being and survival of intolerant biota (depending on the nature of the disturbance) may be allowed to generally increase substantially with resulting low abundances and frequency of occurrence, and a reduction of resilience and adaptability at a large number of localities. However, the associated increase in the abundance of tolerant species must not be allowed to assume pest proportions. The impact of local and acute disturbances must at least to some extent be mitigated by the presence of adequate refuge areas.;

2.2.3. Results of the Mkomazi DFS

The steps undertaken for the Mkomazi study to determine the DFS were the following:

C *Determine the present ecological/environmental state.*
A habitat integrity analysis was undertaken to determine the present state categories of the river. The results of this are illustrated in Fig 2.3. During a site visit by the multi-disciplinary IFR specialist team, a preliminary estimate of the present and DFS classes of the river were obtained.

C *Determine the ecological/environmental importance of the river*
Prof J O'Keeffe defined the ecological importance of a river as "a measure of the value of a river for conservation, including natural, socio-economic and cultural aspects". Criteria for evaluating natural aspects includes rarity, special features, resilience/fragility and the degree of modification. The information on which the assessment was based was derived from:

- other investigations which are part of the same IFR study;

*	expert knowledge and interviews with specialists; and
*	consideration of catchment-wide management initiatives.

The criteria considered were uniqueness, condition, biodiversity, human usage, planning initiatives. The detail is described in Appendix 1, the starter document. The study resulted in attribute scores ranging from 3 to 4,5. As all the criteria are ranked at 3 or better, it is apparent that the Mkomazi is a river of some importance. (Alletson)

C *Determine the DFS which would ensure a healthy ecosystem.*
Due to the importance of the river, it was decided that the river should be treated as a continuum, with one class allocated to the whole river. It is acknowledged that the downstream section of the river is degraded and has the potential to become more degraded. However, the conditions of the estuary is linked to the condition of this section of the river. Relative ease of access has resulted in increasing social use of the lower river reaches and a high importance was attributed to it. Accordingly, a lower protection class for this section could not be contemplated.

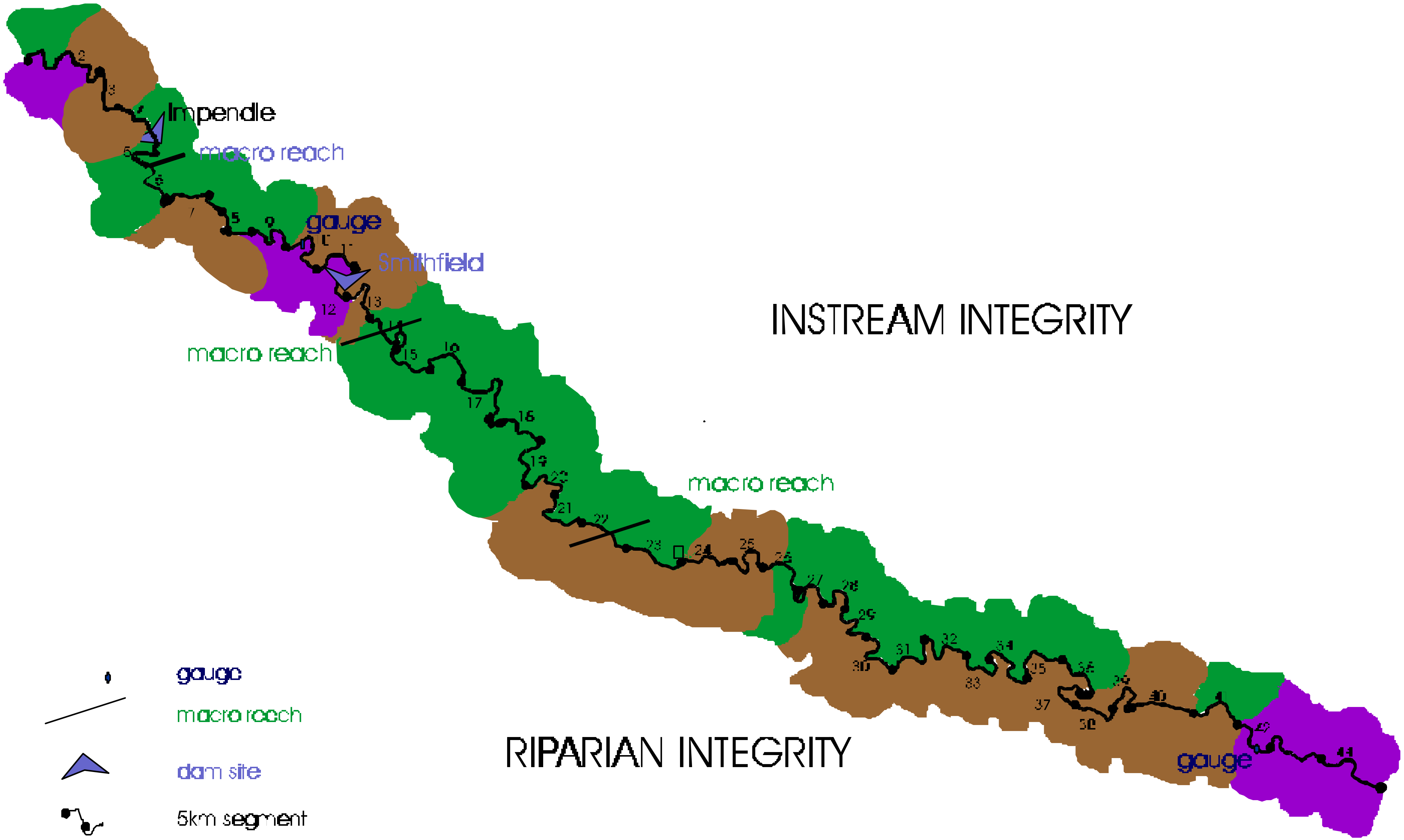
Within the overall class for the river a present class and protection class were allocated to each IFR (discipline) component, and a motivation for the protection class provided. Specific objectives when setting the IFRs to achieve the protection class were also provided. These are described in Table 2.3 following:

TABLE 2.3 :The DFS classes for the Mkomazi River

Component	Present	DFS	MOTIVATION	OBJECTIVES
Invertebrates	B+	B+	High diversity with no domination. Several undescribed species. Several unstudied species which are abundant & important. Functional composition of invertebrates provides a river water purification capacity resilience due to diversity.	Maintain diversity of annual flow regimes to ensure that no species dominate. Scouring floods to reset system. Maintain high diversity of hydropneustic species especially filter feeding caddis and blackfly. Predatory insects (eg Plecoptera) must be well represented. Minimise changes to the natural thermal and sediment regimes. Invert community different than eg Tugela system fairly unique and thus needs to be maintained.
Fish	B+	B+	To protect abundance and distribution of *Amphilius natalensis* at the southern limit of its natural distribution range. To avoid species loss in a system with low natural species diversity.	Maintain pool habitats for large fish species, dense population. Maintain natural fish migrations. Facilitate breeding of riffle-dependent and gravel-dependent species (*Amphilius* and *Barbus natalensis*) - i.e. maintain silt free cobble and gravel beds at breeding sites. Maintain seasonal inundation of marginal vegetation as egg-laying sites (catfish) Maintain backwater nursery areas for juvenile fish. Retain seasonal variability of flow combination of floods and low flows.
Vegetation	C/D	C	The combination of the phreatic and hygrophilous vegetation and the grazing lawns define the components of the riparian vegetation. The maintenance of these three components ensure that the C status is maintained and that degradation towards a D does not happen.	Maintain hygrophilous vegetation especially *Arundinella* + *Persicaria* Maintain phreatic spp. *Combretum erythrophyllum*, *Ficus sur* + *Schizigium cordatum* + *Eugenia* and *Maytenus* on boulder beds Scour out exotics with flood events especially *Acacia delbata* and *Acacia mearnsii*, *Cassia didymobotrya* + *Sesbania punicea* Maintain grazing lawns of *Cynodon dactylon* (through water levels and scouring) Maintain *Phragmites* at reasonable population levels - do not have excessive choking (flood events)
Geomorphology	C	C	Present class: Hydrological regime natural Increased sediment input from catchment Degraded riparian zone decreased bank stability. Protection class: Minimum potential to improve catchment conditions, also difficult to improve riparian conditions	Maintain hydro-sedimentological dynamics : maintain medium sized floods, relatively high frequency. Minimise encroachment into channel of lateral bars etc, minimise development of mid-channel bars. Maintain present alluvial features using constructive flows Maintain (or improve) riparian vegetation Scoure algal silts

Water Quality	B/C	B	The upper section IFR 1 has Water Quality Index (WQI) classes A to C over 23 months (8 x A, 11 x B, 4 x C). The lower section IFR 4, has WQI classes A to D over 25 months (3 x A, 12 x B, 8 x C, 3 x D). Weighting each with A=5, B=4, C=3, D=2, E=1, IFR 1 = 4.2, just above B class, IFR 4 = 3.6 midway between B-C classes. The objectives would be to at least maintain and probably improve water quality, ie: IFR 1 to move to class A most of the time, IFR 4 to move to class B for most of the time. Future water quality should be maintained below the 95th percentile values for all determinands, and for temperature between the 5th and 95th percentile values for summer and winter. The above WQI classes more or less equate to the ecosystem health / integrity classes.	1. To reduce turbidity and suspended solids, reduce soil erosion by: a) preventing overgrazing, b) preventing poor cropping practices, c) controlling future land use activities. 2. To reduce bacterial contamination: a) keep cattle out of the rivers, provide off-stream watering, b) control sanitation practices. 3. Develop and implement a catchment management plan. 4. Maintain moderate flows. High flows leads to high turbidity and high bacterial counts, while very low flows during droughts lead to stagnant, poor quality water due to lack of dilution of natural pollution occurring. Dilution through dam releases should be beneficial
Habitat: Integrity: Instream	B/C	B/C	See Appendix E	Reasoning part of Appendix E
Habitat Integrity : Riparian	C	C	Reasoning part of Appendix E	Reasoning part of Appendix E
Social : Flow	B	B	The river is presently sustaining the social demands on it and should be maintained. .	To ensure that the flow of the river will continue to support the current patterns of utilisation
Social : Quality	B-	B		To ensure that the quality of the water is good enough to support the fundamental components of some aspects of utilisation
Social : Riparian zone	C/D	C		To manage utilisation patterns in a negotiated manner that is as sustainable as possible (Note - management regime and integrated catchment management objectives negotiated with stakeholders)
Importance	B/C	B/C	Reasoning in Appendix F	Keep the river in at least its present conditions because it has high importance scores. Maintain present biodiversity. Establish SASS or other scores and use these as management objectives or performance criteria. Encourage catchment wide planning. Use side channel (tributaries) as means of mitigating main channel impacts.

FIG 2.3 : HABITAT INTEGRITY (PRESENT STATE) CLASSES FOR THE MKOMAZI RIVER



3.1 ZONATION

Four macro reaches have been identified for the Mkomazi below the upper dam site (Fig 3.1). These reaches were identified from an analysis of channel gradients taken from the 1:50 000 topographic sheets. Because of the complex nature of the local geology, plus rejuvenation due to tectonic uplift and sea-level change, within each macro-reach there are a number of reaches which probably represent distinct channel types separated by marked gradient changes.

Table 3.1 describes the main features of each macro-reach with observed and inferred channel morphology. Characteristic channel gradients are detailed for each reach, together with the number of such reaches and their total length. (See Fig 3.1 showing a long-profile with macro-reaches)

Fig 3.1 : Longitudinal Profile

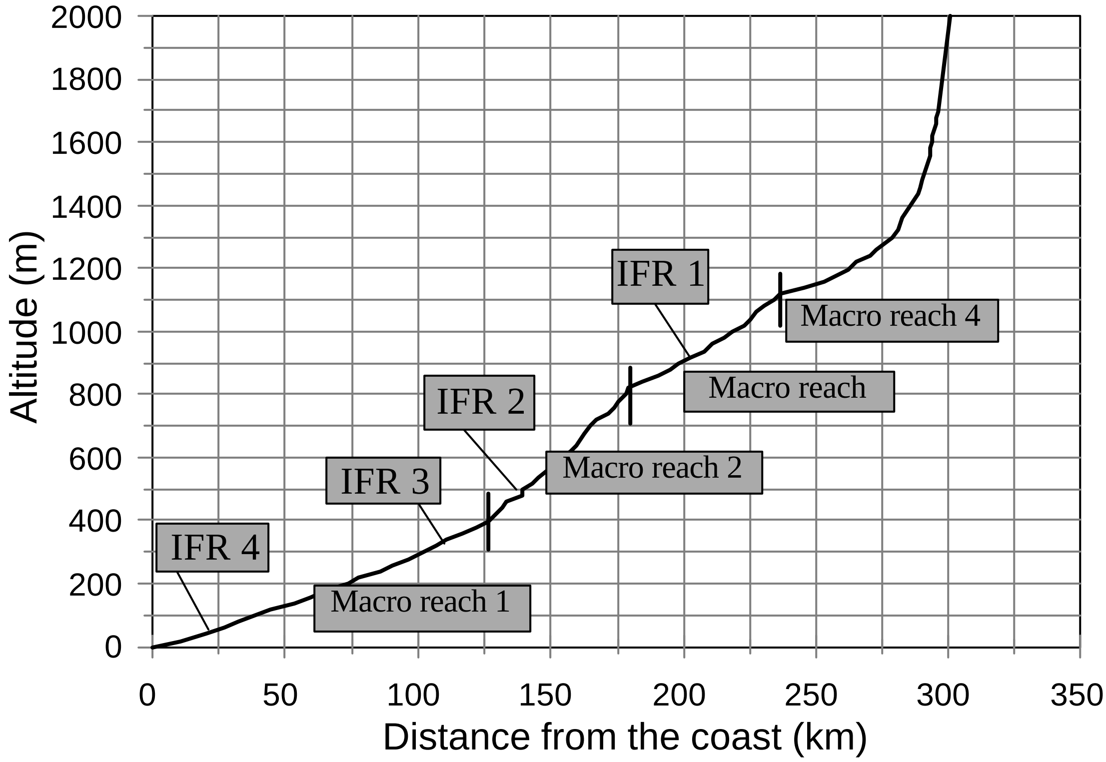


Table 3.1 : Characteristics of macro-reaches

Macro -reach	General characteristics	gradient class	F	total length (km)
1	Elevation : 0-400m. Confined to semi-confined valley, hilly topography in intrusive granites with some sedimentaries in the upper reaches; many small 1st and 2nd order tributaries. Valley bushveld dominating in valleys. Very high rural population density. Cultivation on terraces and fans on valley footslopes. Anabranching channels common, sandy foothill zone with mixed alluvial-bedrock channel, pool-riffle morphology, sand or gravel bars. Local steepening to include pool rapid sections.	0.0019 - 0.0024 0.0028 - 0.0029 0.0032 - 0.0036 0.0041 - 0.0045 0.0053 - 0.0060	4 3 7 4 2	37.712 21.077 41.998 18.130 7.068
2	Elevation : 400 - 820m Confined to semi-confined valley, cultivation on valley floors in unconfined sections. Sedimentary rocks (shales and mudstones) with extensive dolerite intrusions. Forested slopes (valley bushveld). Commercial farming. Single channel with well-developed lateral bars, above 680m valley becomes steep-sided and gorge-like, with an anabranching channel within an alluvial bed. Rejuvenated foothills and rejuvenated cascade zones with mixed pool-riffle or pool-rapid morphologies in lower gradient sections, bedrock or boulder/large cobble-dominated channels in steeper sections, rapids, cascades and bedrock controlled pools common.	0.0035 0.0047 0.0057 - 0.0066 0.0077 - 0.0091 0.0111 - 0.0143 0.0216 - 0.1290	1 2 4 7 5 2	5.726 8.585 12.942 16.651 7.739 1.082
3	Elevation : 820-1020m Confined to semi-confined valley within hilly topography, sedimentary rocks (shales and mudstones) with dolerite intrusions. Moderate population density with extensive cultivation, especially within the Luhane catchment. Irregular channels with infrequent islands, cobble bed foothills zone with gravel/cobble bed river, pool-riffle or pool-rapid morphology, locally bedrock-controlled. Narrow flood plain of sand and/or gravel may be present.	0.0035 - 0.0037 0.0045 - 0.0049 0.0053 - 0.0060	3 3 4	16.747 12.753 14.130
4	Confined valley in sedimentary rocks (sandstones) with dolerite intrusions. Low population density. Cobble bed foothills to mountain stream zone, with cobble and boulder bed channel characterised by plain beds, step pool morphology, rapids and pools. Flood plain generally absent, but lateral depositional bench features may occur.	0.0049 0.0072 0.0081 - 0.0090	1 1 3	4.108 2.769 6.979

F - frequency, number of reaches within this gradient class.

3.2 IFR SITES

Refer to the detailed explanation of selecting sites in the Appendix (starter document).

3.2.1. Purpose of IFR Sites

In order to determine the IFRs of a river system, it is necessary to determine the flow requirements at a number of points within the system.

More than one IFR site is usually selected within the system, for a number of reasons:

- Tributaries entering the system may introduce different channel, bank and/or habitat conditions which may need to be considered separately.
- The DFS of particular reaches of the river may differ from the rest and may therefore require specific IFR.
- A river system displays biological diversity along its length, and consequently, a single IFR point is unlikely to adequately reflect this range of diversity.
- Various hydrological stage points are required within the system to cater for the inflows of tributaries and losses down the length of the system.

A range of hydrological, hydraulic, geomorphological and ecological data is collected at each IFR site. This information is then utilised during the IFR specialist meeting to determine the IFR for the system.

3.2.2 Selection of IFR Sites

The selection of IFR sites is guided by a number of considerations such as:

- The locality of gauging weirs with good quality hydrological data.
- The locality of the proposed developments.
- The locality and characteristics of tributaries.
- The habitat integrity/conservation status of the different river reaches.
- The reaches where social communities depend on a healthy river ecosystem.
- The suitability of the sites for follow-up monitoring.
- The habitat diversity for aquatic organisms, marginal and riparian vegetation.
- The suitability of the sites for accurate hydraulic modelling throughout the range of possible flows, especially low flows.
- Accessibility of the sites.
- An area or site that could be critical for ecosystem functioning. This is often a riffle which will stop flowing during periods of low or no flow. Unnatural cessation of flow constitutes a break in the functioning of the river. Those biota dependant on this habitat and/or on continuity of flow will be adversely affected. Pools are not considered as critical since they are still able to function as an ecosystem, or at least maintain life, during periods of no flow.
- The locality of geomorphological reaches and representative reaches within the geomorphological reaches.

When selecting IFR sites, a decision-making process is followed which consists of the following steps:

- Selection of IFR study area;
- Selecting river stretches in which IFR sites should be situated (see fig 3.2):
  - Impendle Dam site to the end of the first geomorphological macro-reach.
  - From the above border to the end of the next geomorphological macro reach.
  - From the above border to upstream of the estuary. Due to the length of this stretch, it was decided to select two equally spaced sites in it.
- Helicopter flight to select IFR sites;
- Use of the river video for the identification of possible IFR sites;
- Ground truthing - final selection of sites; and
- Placing of cross-sections.

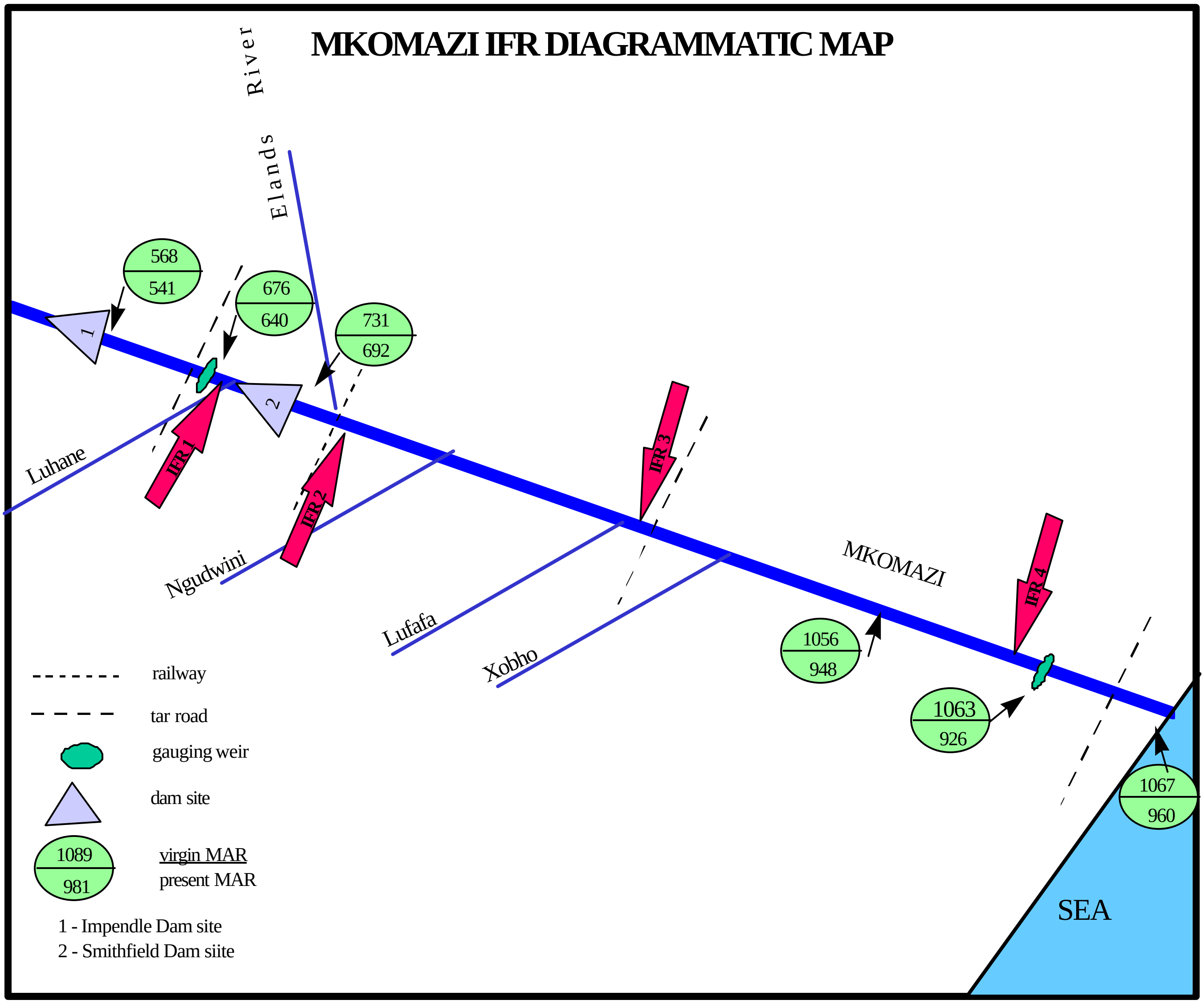


FIG 3.2 : LOCALITY MAP

3.2.3 IFR sites : Locality, Advantages and Disadvantages

IFR 1 : LUNDY'S HILL

Coordinates : S 29E 44,603 E 29E54,688
Locality : Situated about 1 km downstream of the Camden gauge, just downstream of the arch gravel road bridge next to the tar road bridge.

Components	**Advantages**	**Disadvantages**
General	Accessible by any vehicle. No flow measurements required in the main stream as the gauge could be utilised. View for fixed photo-point monitoring excellent.	A small stream comes in between the gauge and the site which needs to be measured.
Invertebrates	Some moveable stones in current in the island, and also some vegetation.	Diversity of habitat fairly poor and dominated by fast moving water and bedrock. Pools, proper stones out of current, mud banks and softer submerged vegetation (sedge bases only available) are not present. (Pools on the bedrock on the left bank, that are fed by seepage and by flood waters, were not sampled as they appeared to be independent of instream flows. They would nevertheless be altered during times of high flow.)
Fish	Habitat diversity better on right bank than on left.	Habitat diversity is less than at the site upstream of the bridge. Sampling will need to be spread out to encompass best options.
Riparian vegetation	Both banks have good vegetation cover LHB best with well defined riparian zone and *C. erythrophyllum* in a flood channel situation typical of vegetation in that reach of the river.	RHB comprised of high mudstone banks, vegetation is therefore not all riparian, some is dry terrestrial. High flood and annual flood levels are difficult to determine by vegetation characteristics due to unexplained *C. erythrophyllum* distribution at a very high level. Grazing a serious problem.
Geomorphology	Representation of macro-reach satisfactory. Well-defined bank morphology. Good range of instream morphological assemblages. Good hydraulic habitat diversity. Pools allow assessment of aggradation potential.	None
Hydraulics	The location of upstream gauging weir (1km) that will be used to accurately measure discharge.	Small tributary entering the river between the site and gauging weir. Influence of bedrock likely to result in non-zero flow depths at the cessation of flow, particularly at the upstream (A) and downstream (C) cross-sections that run through pools. Non-horizontal flow levels within the middle cross-section (B) positioned through a rapid. Non-uniform flow conditions at the site.

IFR 2 : HELLA HELLA

Coordinates : S 29E55,260 E 30E 05,069
Locality : Located approximately 1,5 km downstream of the Hella Hella bridge.

Components	Advantages	Disadvantages
General	Site accessible with high clearance vehicle. Clear view for fixed photo-point monitoring. Site representative of the undisturbed gorge wilderness area. Bridge near by for flow measurements during high flows.	No gauge. Hand flow measurements (difficult during medium flows due to the depth of the pool) are required.
Invertebrates	The base of the riffle contains more, but only a few, loose stones in current. Also the bar near the middle of the river had more loose cobbles. Abundant reeds on the riparian zone, well inundated.	Habitat diversity fairly poor. Dominated by high velocities. Very few moveable stones.
Fish	Fairly good habitat diversity	Narrowness of river bed makes it difficult to sample at moderate and high flows. Other nearby sites will need to be sampled to supplement data.
Riparian vegetation	*S. guinieense* individuals on LHB which could be used for IFR determination	Riparian zone depleted of vegetation. Few remnant indicator species remaining which can be used. Mostly terrestrial and exotic species. Access to RHB not possible at time of site visit. RHB riparian zone poor. Grazing a serious problem.
Geomorphology	Well defined bank morphology. Satisfactory range of instream morphologies. Satisfactory diversity of hydraulic habitat.	Not representative of anabranching channel systems which are very common within this macro-reach. Channel steeper and narrower than average.
Hydraulics	The location of a reasonable measuring site upstream of section A.	Potential for non-horizontal water profiles at low flows at the downstream cross-section (A), which runs through a boulder rapid. Difficulty of obtaining accurate measurements of stage due to wave action along the banks at intermediate and high flows.

IFR 3 : ST JOSEPHINE'S BRIDGE

Coordinates : S 30E 00,492 E 30E 14,342
Locality : Approximately 500 m upstream of the bridge.

Components	Advantages	Disadvantages
General	Site accessible with high clearance vehicle. Photo-point monitoring opportunities good - clear view of the site both upstream and downstream.	Disturbed site. Need a boat to gauge during low flows. Limited habitat variability
Invertebrates	Riffle present	Of all the sites, the most limited in habitat diversity, basically a uniform riffle with a pool above.
Fish	Site not seen. Area has varied habitat diversity.	Site not seen : Rocks where previously sampled were slimy and slippery, making shocking difficult.
Riparian vegetation	*C. erythrophyllum* individual on LHB possibly could be used . *Ficus sur* on RHB could possibly be used.	Riparian zone depleted of vegetation. Mostly exotic and terrestrial species present. Access to RHB not possible during site visit. Grazing a serious problem.
Geomorphology	Reasonably representative of longer reach. Cross-section across riffle has clear bank morphology on the RHB. Upstream pool should allow assessment of aggradation potential.	No obvious disadvantages
Hydraulics	The location of a reasonable measuring site in the pool upstream of the section	Potential for non-horizontal water profiles at low flows for the cross-section which runs through a boulder rapid. Non-uniform flow conditions at the site. Difficulty of obtaining accurate measurements of stage due to wave action along the banks at intermediate and high flows.

IFR 4 : MFUME

Coordinates: S 30E07,575 E 30E40,122
Locality: Site situated about 10 km upstream of the Good Enough Weir.

Components	**Advantages**	**Disadvantages**
General	Near a good gauging weir - no flow measurements required. Photo-point monitoring view good. Access good for normal vehicle.	Area disturbed. Sandy river bed which will have subsurface flows present and for which it is difficult to determine habitat requirements.
Invertebrates	Good habitat, especially along the edges, (backwaters etc). Range of flow velocities.	Dominated bedrock and sand with few stones in current anticipated (not sampled)
Fish	Site not seen : Sandy habitat may favour fresh water gobies but not a large diversity of species.	Siltation probably results in limited habitat diversity.
Riparian vegetation	*Millettia grandis* present on LHB, could be used for bank recharge .	Riparian zone depleted of vegetation . Access to RHB not possible during site visit. Mainly exotic species present. Grazing a serious problem. Highly disturbed riparian zone.
Geomorphology	Reasonable representation of lower reaches of macro reach Satisfactory definition of bank morphology.	Dominance of bedrock in active channel banks may hinder interpretations of water levels in terms of channel forming discharges.
Hydraulics	The location of a downstream gauging weir (6km) that will be used to accurately measure discharge.	Non-horizontal stages within the channel for the braided site at low flows. The potential for change in channel geometry given the alluvial nature of the site.

3.3 EVALUATION OF IFR SITES

Four IFR sites were selected during the IFR process. During the IFR specialist meeting, approximately eight hours are required to set the maintenance and drought IFRs for each site. Therefore, four sites cannot be investigated in detail during the specialist meeting and the best two IFR sites are selected for detailed IFR determination. These recommendations are then hydrologically extrapolated to the other two IFR sites and then checked by means of the suitability of the hydraulic parameters for the required ecosystem functioning.

Each site is evaluated from the different specialist viewpoints and the sites that have the most potential to result in high quality IFRs are specified. The advantages and disadvantages of the sites for the biological and biophyscial components reflects the evaluation of the confidence in IFR sites.

Table 3.2 : Evaluation of IFR sites

NONE = 0 *LOW = 1* *LOW - MEDIUM = 2* *MEDIUM =3*
MEDIUM - HIGH = 4 *HIGH = 5* *L = LOW FLOWS* *H = HIGH FLOWS*
Hydraul = Hydraulics Hydrol = Hydrology Rip Veg = Riparian Vegetation Inverts = Invertebrates
Geom = Geomorphology L = low flows H = high flows

IFR SITES		IFR COMPONENT							
		HYDRAUL	HYDROL	FISH	RIP VEG	GEOM	AQUATIC INVERTS	WATER QUALITY	PHOTO
1	L	2	4	4	3-4	-	3	3	4
	H	4	3	3	2-3	3		4	
2	L	1	4	4	3-4	-	4	3	3
	H	5	3	4	3-4	3		4	
3	L	1	4	3	1-2	-	2	3	2
	H	5	3	3	2-3	3		4	
4	L	2	4	5	2-3	-	5	3	4
	H	5	3	4	3-4	3		4	

Motivation for hydraulic evaluations:
IFR 1 Low flows : Lowest flow observed was 5.8 m^3/s therefore any flows lower than 5 m^3/s will have low confidence. Flow depths at cross-section 1A and 1C will not be zero at no flows.
IFR 2 Low flows : Same problem as the above - lowest observed flow 9,6 m^3/s. Flow depths at cross-section 2A will not be zero at no flows

The sites selected for IFR determination during the IFR specialist meeting were Site 2 and 4. The specialist had the most confidence in these overall confidence in these sites. IFR 3 was definitely the poorest overall, especially with regards to the hydraulics.

CHAPTER 4 : DATA USED FOR IFR DETERMINATION

4.1 BIOPHYSICAL INFORMATION

4.1.1 Fish (Coke, Appendix L)

The Mkomazi river supports a moderate diversity of fish species, with many of these being limited to the lower reaches near the coast where the impact of a dam in the middle reaches would probably be minimal. *Amphilius natalensis* is the only riffle-dependent species present, but riffle habitats are likely to remain available even if river flows become reduced. The impact of a dam on the migrations of scaly, sharptooth catfish and eels could be considerable and therefore the provision of a fishway, or at least an eelway, is considered essential. The release of summer spate flows from the dam would probably stimulate successful breeding by the flood-dependent species.

4.1.2 Aquatic invertebrates (de Moor, Appendix M)

The Mkomazi and Mkomazana show an exceptional diversity of aquatic insects dominated by hydropneustic groups. Both rivers are swift flowing with mostly stony reaches and there are diverse communities of filter feeding Hydropsychidae and Simuliidae as well as Elmidae and baetid mayflies. This rich diversity of species with low numbers of individuals for each species indicates a healthy, rich heterogeneous environment with a wide range of ecological conditions, which has also ensured that pest species have not become abundant and problematic in the Mkomazi River.

Comparing the species composition of the Mkomazi/Mokomazana Rivers with that of the Mooi River, a tributary of the Tugela River, it is notable that the species of Hydropsychidae are very different with only two of the twelve species from the Mkomazana and Mkomazi Rivers also being found in the Mooi River. There are also more species of Leptoceridae in the Mkomazana and Mkomazi Rivers with several species of Oecetis , Triaenodes and Trichosetodes which are absent from the Mooi River. *Simulium wellmani* and *S. letabum* are also absent from the Mooi River.

A measure of the abundance and diversity of aquatic macroinvertebrates in a river provides information on the status or "environmental health" of that system. Because different species of invertebrates have varying aquatic life-cycle durations, the community structure of aquatic invertebrates can provide a time-integrated measure of the prevailing conditions. The presence or absence and relative abundance of macroinvertebrate species can be used to assess disturbance events which occurred prior to sampling. Water chemical samples which give an instantaneous record of prevailing conditions do not provide such information. Because of their small size and relatively sedentary nature aquatic macroinvertebrates are vulnerable to ecological disturbances, unlike fish which can move away from unfavourable areas and return again once this has passed. The macroinvertebrate species need time to recolonise sections of river and various species do this at differential rates. For this reason certain species may be eliminated from sections of river for a considerable time as a result of ecological disturbances. Species composition of macroinvertebrate communities therefore also provide information as to how long ago a disturbance event occurred. In certain instances the form of the disturbance, i.e. specific kinds of chemical or organic pollution or drastically altered flow regimes will also be reflected by a change in the natural macroinvertebrate assemblage.

Functionally, aquatic macroinvertebrates are important processors of organic matter. They serve a vital function in purifying water and also provide a valuable food resource for larger animals within, and even outside the river system. In order to continue functioning optimally, the component species in a river system require regular inputs of nutrients, sediments and water flow. Specific river systems evolve particular assemblages of species forming functional communities within reaches. These communities are optimally adapted to the prevailing conditions such as substrate composition, water temperature, sediment transport and nutrient flows. A reduction or increase in flow, sediment transport or nutrient loads will lead to changes in community structures through loss of certain species and increases in others.

There are more than 40 undescribed species of aquatic insects in the middle reaches of the Mkomazi River (Ephemeroptera 19 spp., Coleoptera 5 spp., Trichoptera 11 spp., Simuliidae 2 spp. and Tipulidae 3-4 spp.). These need further attention, firstly to be described, then to establish whether their distribution is more widespread and finally to find out what ecological role they play in the middle reaches of the river system.

The dense crusted algal growth on stones from riffles in the Mkomazi River near Impendle indicate that there is excessive nutrient enrichment in the river upstream of that site. The diversity and abundance of filter feeding hydropsychid caddisflies and baetid mayflies and the presence of certain upper-reach, running-water species found at lower altitudes characterised the Mkomazi River as a swift-flowing, cool, well-oxygenated river system with a diverse fauna able to process and clean up the present enrichment of the river. There are many macroinvertebrates that require a cool water regime for continued survival and hence the thermal regime of the river should also be considered in the river management programme.

It should be noted that the Mkomazi River is one of the few remaining moderate to large rivers which has not had dams built in its catchment. The almost complete lack of problem or pest species in this river indicates that its natural flow regime is sufficiently abundant and varied in discharge to maintain a diverse macroinvertebrate fauna not dominated by any pest or problem species for any great length of time. Severe modification of this natural flow pattern can lead to an enhancement of conditions which favour pest and problem species such as blackflies, mosquitoes and snail vectors of bilharzia. Reduced flow conditions and the removal of scouring floods can also lead to reed encroachment, a condition notably absent from the present river.

Philosophy behind the biological requirements of IFRs (Invertebrates)

Biologically the River has a count of 400 species of invertebrates presently identified. This is however not an exhaustive list of what occurs.

Changes in flow regimes, substrate type and availability govern the absence, presence and abundance of various species. Removing a few species or decreasing their abundance to very low levels has a range of influences on other species and it is difficult to predict which will become dominant save for a few obvious ones (Simulium spp., Chironomidae, a reduction in number of baetid mayflies, filter feeding caddis species.

The philosophy behind maintaining a diversity of species is to ensure that the functional self-purifying role of the river is kept at an optimum through maintaining the keystone species responsible for this, i.e. filter feeders, deposit feeders. These animals all help remove organic matter from the water and purify it. A diversity of species also helps contain any potential pest species. If the number of species is reduced, a few will attain numerical dominance and these could become problem or pest species requiring management with huge cost implications. Managing the flow of the river to maintain a large diversity of species is therefore a very important management option.

4.1.3 Riparian vegetation (Kemper, Appendix J)

Along every water course a band of vegetation exists which has evolved to cope with hydromorphic soils (periodically or continuously waterlogged). These species display an array of morphological, anatomical and physiological adaptations which allow them to flourish in such anaerobic soils.

Riparian vegetation often forms a continuum in which floristic composition is influenced greatly by the parochial effects of the river and to a lesser extent by the flanking vegetation types. In many instances the upper reaches of rivers support specialist species but the lower reaches are dominated by ubiquitous generalists. This vegetation is important in a number of ways including bank stabilization and retention of silts. Beyond the riparian vegetation exists the phreatic zone. Vegetation which occurs in the latter has access to deep moisture from the river but avoids continually waterlogged soils. The phreatic zone usually includes arborescent species.

The survey revealed that the Umkomazi is a highly modified river due to has levels of utilization. As a consequence of this disturbance the river system has been heavily infested with alien species and the diversity of the riparian vegetation has been drastically reduced.

The conservation status of most of the surveyed river sections is low. Species diversity within the riparian vegetation is very low despite the change in altitude and flanking vegetation types. It is postulated that all but the most resilient riparian species have been lost from most of the water course.

The boulder beds at Hella Hella contain two rare species, *Maytenus bachmannii* and *Eugenia zeyheri*, formerly thought to be endemic to the Pondoland Sandstones. This is the first record of these species out of the Pondoland sub-centre.

Tetradenia brevispica was collected at Lions Kloof in the vegetation flanking the river. This species has not been previously recorded in KwaZulu-Natal.

4.1.4 Fluvial geomorphology (Rowntree, Appendix I)

See Chapter 1 (1.4 - Overview of the Catchment) and Chapter 3 (3.1 - Zonation)

4.1.5 Social aspects (Huggins, Appendix O)

The methodology employed for the study incorporated
- a desktop analysis
- a review of available literature on social aspects of downstream impacts and water resource usage;
- the gathering of available data on the villages to be affected: identification through mapping; obtaining population estimates through the 1996 census.

In the Mkomazi study respondents in the "tribal trust' generally did not articulate strong feelings either for or against the need for conservation. For these people the ideal state of the river was one in which water quality was maintained as "clean". People living in the lower reaches of the river particularly articulated this. It was stressed that the quality of the river in winter is usually very good. People who indicated that their primary water sources (boreholes, springs and smaller tributaries) sometimes dried up in winter emphasised the importance of water quality in winter. For people in this category the major issue around the state of the river was therefore that it be kept clean and flowing in winter. High summer flows were generally regarded as a nuisance as the water was dangerous when flowing fast and generally too dirty to be used as a potable source.

Respondents for whom recreational canoeing was important did however express strong preferences for the river to be maintained in as pristine a condition as possible. This was regarded as particularly important as the Mkomazi was seen to be less disturbed than almost all other major rivers in KwaZulu-Natal.

People use the run of river water for drinking and domestic cooking, livestock watering, irrigation, building, washing, filling cattle dips, recreation, religious purposes, as an ingredient in medicines. The environment alongside the river was used for sand excavations for brick and block making, gathering building material, medicinal plants, material for handicrafts. Fishing tends to be of a recreational nature and it did not appear as if fish formed an important part of people's diets.

From a social perspective it appears that riverine environments commonly have both a utilitarian and a recreational value. For the canoeists the river was seen as a recreational resource of critical value. The point was repeatedly made that the river represents some of the last untamed "white water" in the country and that it should remain so.

In general a system that would regulate the river was regarded, by most respondents from the 'tribal areas', as a potentially positive initiative. People said that the regulation of the river would be a positive development if it:
- would prevent the situation whereby there was no water in the river reoccurring (or at least make this a less frequent event) and
- would prevent potentially destructive floods and river flows that impeded access.

Most respondents agreed that all role-players needed to co-operate towards promoting a positive interaction with the regional and local resource base. The introduction of sound water management rules and the establishment of appropriate local water bodies and/or committees to ensure the optimal and sustainable use of available resources were emphasised in this regard. Moreover, it was emphasised that all stakeholders should have a direct say in decisions regarding the seasonal timing of floods or regulated flood releases, and should receive early warning with regard to surplus flows (uncontrolled releases) and related matters.

4.2 OTHER

4.2.1 Hydraulics

River hydraulics forms an integral and essential component of the IFR assessment using the BBM by providing the means to convert hydrological data (discharge rates, frequency and timing of flows) into local hydraulic conditions, including, for example, flow depth, flow velocity, surface width, cross-sectional flow area and wetted perimeter. These hydraulic determinants enable flows in the river to be related to suitable habitat requirements for aquatic and riparian fauna and flora. Hydraulic information is site-specific, however, and is a function of the local channel geometry and geomorphology, bed and water surface slopes, and flow resistance components (sedimentological and vegetational).

The hydraulics component of the study involved the collection, analysis and presentation of information at the IFR specialist meeting on site-specific hydraulic relationships for cross-sections located at four selected sites along the Mkomazi River downstream of the proposed Impendle dam.

4.2.2 Hydrology (Hughes, Appendix N)

The Mkomazi River catchment is located in the southern part of the KwaZulu-Natal province and the river has its source in the southern Drakensberg. The Mean Annual Precipitation (MAP) for the entire catchment is 981 mm (WR90) and the Mean Annual Evaporation is 1252 mm. However, the MAP is higher in the upstream parts of the catchment (1000 - 1287) and correspondingly most of the runoff is generated upstream. The most downstream part of the catchment (approximately 33% of the total area) contributes less then 14% of total MAR.

Two streamflow gauges with flow records dating from early 1960s exist in the catchment. The first (U1H005) commands the upstream part of the catchment (1744 km^2), the second (U1H006) is close to the estuary (4349 km^2) and effectively records flow from the entire catchment. These historical records are stationary and are generally of reasonable quality with a few gaps due to missing data. The downstream gauge however has a low Discharge Table Limit (DTL) and therefore, unreliable high flow measurements.

The 1-day non-dimensional annual flow duration curves constructed for each gauge using the whole record period clearly illustrate the similarities in hydrological regime of the two sites. At the same time, gauge U1H006 demonstrates a slight increase in low flows relative to U1H005 (flows exceeded more than 90% of the time). These differences are more pronounced during dry months of the year. This may be indication of a slightly more baseflow-driven flow regime in the most downstream reaches of the Mkomazi River. On the other hand, the “truncated” high flows at U1H006 may reduce the mean daily flow estimated from observed records and consequently, “push up” the ordinates of the non-dimensional flow duration curves (annual or monthly).

4.2.3 Water Quality (Simpson, Appendix K)

The assessment of historical data and trends between 1976 and 1997 shows that:

- For both upper and lower catchment sample sites, the pH and nitrate values have risen slightly but not to levels detrimental to either the environment or other users and with no indication of pollution.
- Conductivity and TDS concentrations have not changed and are at acceptable levels.
- SRP concentrations are low and have remained low with no indication of pollution.

The assessment of current water quality and spatial trends at the IR sites shows that:

- Temperature increases down the catchment by between 2 and 5 degrees Celcius between sites and has seasonal ranges for sites of between 12 and 15 degrees Celsius.
- *E. Coli* counts increase down the catchment being far higher at IFR 4 than at the upper sites, approximately 350 compared to 150 cells/100ml for the medians. Measured against WQI classes, 40% of the results fall into class A water for IFR sites 1 to 3. In terms of water quality guidelines, IFR sites 1 to 3 would be suitable for full contact recreation for much of the time and suitable for intermediate contact recreation up to the 90th percentile. Bacterial contamination is less in the upper catchment than for the Midmar catchment.
- The pH value data distribution is suitable for all users.
- Turbidity and suspended solids concentrations increase down the catchment with 50th percentile values reflecting a class C to D water quality, satisfactory to poor. Above the 60th percentile, the poorest class, class E category prevails. For aquatic life, the suspended solids concentrations exceed the limit above the 80th percentile and for recreation above the 25th percentile. Compared to data for the Midmar catchment, turbidity and consequently erosion is much higher.
- Conductivity increases down the catchment, but the levels are suitable for all users.
- Neither nitrate, ammonia, phosphorus or total organic carbon (TOC) concentrations show any sign of significant pollution and from a nutrient aspect the quality may be classified oligotrophic to mesotrophic.

CHAPTER 5 : IFR RESULTS FOR DETAIL SITES

The IFR sites selected for detailed IFR determination were IFR site 2 and 4. These are the sites for which detailed motivations for each recommended flow are supplied and which will be discussed in this chapter.

Flows are provided for both maintenance flows (those flows that will maintain the system in the management class agreed on during years other than drought years) and drought years (flows that will only allow for survival of the most critical components of the ecosystem). The same approach is utilised for both maintenance and drought years, starting off with maintenance years.

The approach during this session followed the following steps:

- The highest low flow (note that this term is similar as base flows) month and lowest low flow month were selected as February and September respectively utilising the hydrological record to make this decision.
- These months were used to set the low flows and the range of flows that occur during the year was therefore fixed between the highest and lowest low flows.
- The low flow IFR for the rest of the months are extrapolated from the September and February flows following the natural shape of the annual hydrograph. This extrapolation is undertaken by the hydrologists and checked by the ecologists.
- Each specialist provided motivations describing how the required flows should look (eg water level, velocity, depth) and the reasons for requiring these flows. Some of the disciplines provided primary and some secondary motivations. Primary motivations refer to motivations provided by the disciplines that require a certain type of flow which is critical. Secondary motivations refer to motivations provided by disciplines that could maintain the component with less flows, but for which higher flows to satisfy the other components requirements will not be harmful.
- After each flow is agreed on, the flows specified were checked for realism in non-drought years. Normal or average hydrological years were utilised to provide this check.
- During the wet season high flow events were set and motivated for. High flows refer to freshes, small, medium and large floods. A fresh refers to a small increase in base flow. The high flows are given in m^3/s and the flow provided refers to an instantaneous peak. As the hydrology was provided in mean daily averages, the peaks recommended were converted to slightly lower flows to reflect the mean daily average.
  - In all cases the duration of the floods were provided in days.
  - The shape of the floods was based on the shape of the natural hydrograph.
  - The peaks provided include the low (base) flows
  - When the total volume of each flood was calculated, it excluded the low flow volume which is already included in the total low flow volume
- A hydrological check of each flood was repeated..

The same procedure was followed for drought years.

The results for the two sites for which detailed IFRs were set are as follows:

5.1 IFR 2 : HELLA HELLA

The following abbreviations are used in the tables below :
Hyd = Hydraulic. Pers observ = personal observation by the relevant specialist. Hydro = hydrological
Perim = perimeter

5.1.1 : Maintenance flows

Maintenance Low flows **September** **Flow : 2,3 m^3/s**

Description of flow	**Hyd param**	**Motivation**	**Why not lower**	**Source :**
PRIMARY MOTIVATOR				
Fish (cross-section 2B): 30 - 50 cm deep water over 20 m width of river, but only just wetting the prominent cobble bed near the right bank	Depth	Creates minimum acceptable habitat for *Amphilius*, requiring 20-25 cm of water over cobbles. Juvenile minnows and scaly will also find this water depth acceptable.	Lower levels would seriously limit habitat for *Amphilius*.	pers observ, hydro data
Riparian vegetation: 0,6m at 2B gets water into the roots of the *Arundinella* grass.	Depth	It is believed that this will maintain these grass patches during the winter months.	Will probably lead to a reduction in the patch site or possibly a loss of grass patches of this kind. However, it may also lead to the relocation of these patches within the macro channel floor.	Photos, curves
SECONDARY MOTIVATOR				
Aquatic invertebrates: Riffle maintained with good percentage (30%) of shallow water (<5cm), a good wetted perimter and velocity.	Wetted perim	Shallow water refugia for invertebrates good velocities to maintain filter feeding functions	n/a	

Maintenance Low flows **February** **Flow : 10 m^3/s**

Description of flow	**Hyd param**	**Motivation**	**Why not lower**	**Source :**
PRIMARY MOTIVATOR				
Fish (cross-section 2B): Gives about 25 cm depth over much of the cobble bar plus much deeper, faster flowing water in three channels.	Depth	25 cm deep water will satisfy the needs of fingerling fish, which will also occupy the quieter edges of the deep channels. *Amphilius* will occupy water up to 0,5 m deep, including the deeper channels. Migrating adult fish will be able to utilise the deeper channels to move between consecutive pools.	-	pers observ
Riparian vegetation (2B): Sufficient water depth to inundate the basal areas of the reeds (*Arundinella & Phragmites*) without exacerbating sedimentation.	Depth	This is the period/growth period for *Arundinella* and it is essential that adequate water is available to ensure optimum growth. Levels are sufficient to encourage growth of *Arundinella* which tends to occupy boulder beds (coarser sediments).	Lower levels of flow will increase sedimentation and may lead to a shift in species dominance to *Cyperus marginatus, Mariscus congesta and Phragmites australis*. Increases in these species will tend to encroach on the channel margins which may cause shifts in the habitat for other species and choking of the river margins. Would stunt the growth of *Arundinella* and restrict its distribution.	Photos, profiles, pers observ.
SECONDARY MOTIVATOR				
Aquatic invertebrates (2B): To maintain 30cm flow over cobbles in riffle area in cobble bank to wet additional perimeter.	Water velocity	To provide sufficient velocity of flow in riffle for filter-feeding species to maintain populations. To keep stones clean over cobble beds.	n/a	pers observ

Maintenance High flows (in instantaneous peaks) **October** **Flow : 6 m^3/s**

Description of flow	**Hyd param**	**Motivation**	**Why not lower**	**Source :**
PRIMARY MOTIVATOR				
Aquatic invertebrates: Based on hydrology	-	To flush water, move fine sediments, expand wetted area. Stimulate breeding in invertebrates.	-	-
Fish : Significant (double) increase over base flows	-	Increased flows needed to stimulate initial migration of fish away from deeper pools and redistribution throughout the river system prior to spawning.	Smaller "increased" flows may not cause fish to begin migrating.	Literature

Maintenance High flows **November** **2X** **Flow : 15 & 25 m^3/s**

Description of flow	**Hyd param**	**Motivation**	**Why not lower**	**Source :**
PRIMARY MOTIVATOR				
Fish (25) : Edge to edge flows	water surface level	Both freshes to be migration stimulators as well as early spawning stimulators.	Will not provide water to the edges where vegetation habitat and slower habitats are available.	pers observ, photos, plus hydro data
Riparian vegetation (25) Sufficient flow to inundate but not remove, germinating Persicaria sp.	Depth & velocity	Early growth flush - also minor recruitment of grass and sedge species. Persicaria is one of the primary riparian fringe species. This species has major recruitment from the seed produced in the previous autumn. Heavy flows too early will result in flushing of these seedlings but inadequate flows will result in desiccation of the young plants which will destabilise this element.	Lower will not irrigate the marginal fringe sufficiently to ensure combined seedling growth.	Photo's, survey, profile, pers observ
Geomorphology (25) : Flows within active channel, velocity range important	Velocity	Flows with a range of velocities to provide additional transport of sand and gravels in a loose bed in absence of shielding by coarser material. Adds variability to the system.	Lower flows will have insufficient velocity for significant sediment transport.	Hydraulic data, theoretical sediment transport equations.
Aquatic invertebrates :	velocity	Move sediment to maintain diversity - wet new areas and clean stones of accumulated algal growth. Floods in January, February and March are essential to maintain large-river invertebrates species component.		

Maintenance High flows **December** **2X** **Flow : 20 & 50 m^3/s**

Description of flow	**Hyd param**	**Motivation**	**Why not lower**	**Source :**
PRIMARY MOTIVATOR				
Riparian vegetation (50) Reasonable flushing to the *Arundinella* fringe.	velocity	Growth period of marginal vegetation. Mid-summer flush of *Arundinella* to remove some of the fine sediments of the reeds in an attempt to maintain the present community structure. Accumulation of sediments will lead to a shift towards *Phragmites and Cyparaceae*	Lower levels will not achieve a marginal flushing or regeneration and will lead to channel encroachment and deposition.	Photos, survey, profile
Geomorphology (50) :	Velocity	Flows with a range of velocities to provide additional transport of sand and gravels in a loose bed in absence of shielding by coarser material. Adds variability to the system.		
SECONDARY MOTIVATOR				
Riparian vegetation (20)	velocity and water surface	Maintain marginal species and prevent shifts in community structure to *Phragmites and Cyprus/Mariscus* dominance. This will cause increased stabilisation of the sand deposits on the river banks and encroach into the main channels. Germination of *Persicara* is usually very early in spring so small flood events should be later in the season than early November. *Persicara* is an important fringing species, usually associated with areas sheltered below *Arundinella*.		Personal observa/ profile/ survey
Aquatic invertebrates :		Move fine and coarse sediment to maintain diversity. Floods in January, February and March are essential to maintain large-river invertebrates species component.		

Maintenance High flows **January** **2X** **Flow : 30 & 50 m^3/s**

Description of flow	**Hyd param**	**Motivation**	**Why not lower**	**Source :**
PRIMARY MOTIVATOR				
Fish (50) : Bankfull plus some inundation of marginal vegetation and of marginal cobble beds.	Depth & water level	Spawning stimulation for catfish (on vegetation) and scaly over cobble beds.	Maximum inundation of marginal habitats is required for best spawning results.	Pers observ
Geomorphology (30 & 50) :		Flows with a range of velocities to provide additional transport of sand and gravels in a loose bed in absence of shielding by coarser material. Adds variability to the system.		
SECONDARY MOTIVATOR				
Riparian vegetation (30 & 50)	-	Growth period of marginal vegetation. Mid-summer flush of *Arundinella* to remove some of the fine sediments of the reeds in an attempt to maintain the present community structure. Accumulation of sediments will lead to a shift towards *Phragmites and Cyparaceae*.	-	-
Aquatic invertebrates (50):	velocity	Move sediment to maintain diversity. Floods in January, February and March are essential to maintain large-river invertebrates species component.		

Maintenance High flows **February** **3X** **Flow : 20 & 60 & 350 or 500 (1:5)m³/s**

Description of flow	Hyd param	Motivation	Why not lower	Source :
PRIMARY MOTIVATOR				
Fish (60) : Full coverage / inundation of 1st terrace	Depth and water level	Spawning stimulation, especially by catfish on flooded marginal vegetation (large-leaved plants, rather than *Cynodon* grass).	Maximum marginal inundation needed for maximum spawning.	-
Riparian (350) : Inundates the first riparian terrace which is covered by *Cynodon dactylon* grass	inundation level	This inundates this terrace and maintains a moisture regime which discourages the germination and survival of black wattle seedlings on this terrace - maintains *Cynodon* lawn for grazing. Feeds water into the next riparian terrace and encourages growth and recruitment in this area Deposits sediments on terrace and prepares a nutrient medium for growth of *Cynodon*.	Would not inundate the terrace and would probably result in the terrace being colonised by woody and exotic species such as wattles.	Field observ & photos.
Geomorphology (350) : Inundation of grassed flood bench, significant velocity in active channel for sediment transport. Flows above 200 m^3/s (just overtopping banks) to be maintained for approximately 1 day to allow sufficient sediment deposition.	area	Flow related to a significant morphological features showing evidence of frequent sand deposition. Flows of this magnitude in terms of velocities and shear stresses provide effective sediment transport in main channel and depth sufficient to construct flood benches i.e. maintains the linked channel-floodplain system. One or two year frequency flood generally considered as the most significant discharge for maintenance of active channel. Velocities sufficient to transport medium cobble in absence of shielding by larger material.	Lower floods will not give sufficient inundation (depth and duration) of flood bench to give effective sedimentation (peak 350 m^3/s is instantaneous) NB : Flood bench height measured at 2,65m, not 2,2 as given on profile - this is through an eroded section)	field surveys, profile, theoretical studies.
Riparian vegetation (500): Water inundates lower terrace at high velocity; inundates higher terrace and deposits sediments	Depth, area	Scours out lower terrace and removes exotic and other woody plants on this terrace and maintains *Cynodon* lawns. Deposits sediments on higher terrace and recharges higher riparian zone.	Would probably lead to colonisation of lower terrace by woody and exotic species. Lack of recharge of higher terrace would probably result in terrestialisation by acacias and other dry species.	Field observations, photo's
SECONDARY MOTIVATOR				

Geomorphology (60) : Flows within active channel, velocity range important	Velocity	Flows with a range of velocities to provide additional transport of sand and gravels in a loose bed in absence of shielding by coarser material. Adds variability to the system.	Lower flows will have insufficient velocity for significant sediment transport.	Hydraulic data, theoretical sediment transport equations
Aquatic invertebrates (20 & 60):		Move sediment and stones to maintain diversity. Floods in January, February and March are essential to maintain large-river invertebrates species component.	n/a	literature
Fish (350) : Bank-full flow plus good coverage of marginal vegetation & cobble beds	Depth & velocity	Spawning stimulation, chiefly by scaly on inundated gravel and cobble beds	n/a (150 sufficient)	personal observation

Maintenance High flows **March** **2X** **Flow : 20 & 50** m^3/s

Description of flow	Hyd param	Motivation	Why not lower	Source :
PRIMARY MOTIVATOR				
Riparian vegetation (20 & 50) :		Growth period of marginal vegetation. Mid-summer flush of *Arundinella* to remove some of the fine sediments of the reeds in an attempt to maintain the present community structure. Accumulation of sediments will lead to a shift towards *Phragmites and Cyparaceae*	Late and summer fruit set of marginal sedge communities and *Persicaria* requires lowered water stresses to maintain recruitment levels.	see above
Geomorphology (50) :		Flows with a range of velocities to provide additional transport of sand and gravels in a loose bed in absence of shielding by coarser material. Adds variability to the system.		
SECONDARY MOTIVATOR				
Aquatic invertebrates (20 & 50):		Move sediment to maintain diversity. Floods in January, February and March are essential to maintain large-river invertebrates species component	n/a	literature

5.1.2 IFR 2 : Drought flows

Drought Low flows **September** **Flow : 1 m^3/s**

Description of flow	Hyd param	Motivation	Why not lower	Source :
PRIMARY MOTIVATOR				
Fish : 0.15 - 0.4 m depth in 3 major channels over cobble beds	Depth	Minimal survival area / space remains for occupation by *Amphilius* (riffle-dweller) amongst cobbles of riffle. Since fish will also be found at the foot of the riffle in the headwaters of the pool.	Habitat for *Amphilius* becomes too limited for survival of adequate numbers of fish.	Pers observ, profile
SECONDARY MOTIVATOR				
Aquatic invertebrates Some flow maintained in channel.	flow	The river is perennial and it is dominated by species dependant on flowing water . (over 80% of species). Some flow will be maintained for filter feeding species. Minimal areas of high velocity to maintain the diversity of species and also keep the “large river” species present.	n/a	survey

Drought Low flows **February** **Flow : 5,5 m^3/s**

Description of flow	**Hyd param**	**Motivation**	**Why not lower**	**Source :**
PRIMARY MOTIVATOR				
Riparian vegetation: Flows of depth that should allow marginal wetting of the *Arundinella* root systems	Depth	This is the primary growth period for *Arundinella*. The plant tussocks appear to be fairly static so lower flows are likely to impact heavily on the presence of the species as a dominant in the riparian vegetation. These flows should also allow repositioning of the receding species such as *Persicaria*.	Lower levels will lead to attrition of the *Arundinella / Phragmites / Persicaria* communities	survey / profile / pers observ.
SECONDARY MOTIVATOR				
Aquatic invertebrates	wetted perimeter	Some wetting of cobbles at site 2 B would ensure survival of riverine invertebrates - therefore 75 cm depth required - would just keep the community going.	n/a	experience
Fish : Provides 10 - 15 cm depth over part of the cobble bar, deeper in the 3 channels	Depth	Creates reasonable survival habitat for *Amphilius* (riffle dependant) as well as for minnow species such as *Barbus viviparus*.		Survey

Drought High flows **November** **Flow : 6 m^3/s**

Description of flow	**Hyd param**	**Motivation**	**Why not lower**	**Source :**
PRIMARY MOTIVATOR				
Aquatic invertebrates	wetted perim, velocity	Increase in velocity to provide cues and flush fine sediments.	Some life cycles should be maintained, otherwise diversity of species will be impacted on.	Experience
General : Maintain variability				

Drought High flows **December** **Flow : 20 m^3/s**

Description of flow	**Hyd param**	**Motivation**	**Why not lower**	**Source :**
PRIMARY MOTIVATOR				
Riparian vegetation : Inundation of peripheral *Arundinalla* community with very marginal wetting of *Cynodon* vegetation nd *Persicaria* community should be flooded.	Depth	Maintenance flooding of *Arundinella* and associated hygrophytic species. This is main growing season and during drought periods basal flooding is still probably necessary to remove exotic weedy species and fine sands from the tussocks.	Lower floods will not inundate the *Arundinella* bases	Profile, survey, pers observ
SECONDARY MOTIVATOR				
Fish : Complete coverage of cobble bar, but minimal flooding of marginal vegetation	increase flow over base flow	Cue (delayed from October) for spawning migration. Provides some additional cobble habitat for *Amphilius* populations.	n/a	pers obser
Aquatic invertebrates :	Velocity	More coarse sediments will be moved	n/a	Experience

Drought High flows **January** **2X** **Flow : 12 & 12 m^3/s**

Description of flow	**Hyd param**	**Motivation**	**Why not lower**	**Source :**
PRIMARY MOTIVATOR				
Aquatic invertebrates :	-	Maintain diversity of flows to move sediments and wet new areas. Clean stones	-	Experience
General : Maintain variability				

Drought High flows **February** **2X** **Flow : 60 & 12 m^3/s**

Description of flow	**Hyd param**	**Motivation**	**Why not lower**	**Source :**
PRIMARY MOTIVATOR				
Riparian vegetation (60) : Flows which put water onto the lower part of the *Cynodon* fringe and the area in which the *Schizigium* is located	Depth	These flows will provide recharge to the rooting zone of the *Schizigium cordatum* trees in the areas covered by *Cynodon* and the areas just beyond them. These are the few remaining individuals of *Schizigium* left in the riparian zone, and since these are very sensitive to reductions in flow particularly during drought periods, it is essential to ensure that these are provided with their basic water requirements with this flood.	Would probably lead to the demise of the few remaining *Schizigium* individuals.	Field observation
Geomorphology (60): Small flood within active channel, well up but below active channel banks	velocity width	Velocity sufficient to move fine to medium gravels (up to 35 mm) through both pools and rapid. Sufficient bed load movement expected for habitat maintenance (gravel beds). THIS IS NOT MOTIVATED FOR AS A CHANNEL MAINTENANCE FLOOD.	Reduced efficacy for sediment transport.	Profile, hydraulic data, theoretical bedload equations.
SECONDARY MOTIVATOR				
Fish (60) : Bankfull flow, plus fair inundation of marginal vegetation, not covering the 1st terrace	area	Spawning stimulus for scaly & catfish on cobble beds and flooded marginal habitat.	n/a	pers obser
Aquatic invertebrates :	Velocity	Move more sediments and clean stones (60). Maintain diversity (12).	n/a	pers exper

Drought High flows **March** **Flow : 12 m^3/s**

Description of flow	**Hyd param**	**Motivation**	**Why not lower**	**Source :**
PRIMARY MOTIVATOR				
Aquatic invertebrates :	-	Maintain diversity of flows to move sediments and wet new areas. Clean stones	-	Experience
General : Maintain variability				

Water quality :

Flows decided upon by the primary disciplines should be acceptable for water quality with the following provisos :
Drought flows should be greater than recorded flows (if possible) since water quality will be poor with stagnant pools and continued local use. Flow should be sufficient to maintain flushing. A flow of 0.4 m^3/s should be sufficient for flushing. High flows can be lower than recommended as quality (specifically referring to turbidity) deteriorates at high flow.

The objective is to maintain water quality at the present level and improve through management. Targeted guidelines for critical water quality variables would be that, for existing summer and winter data sets, the 95th percentile values for turbidity, E. Coli, nutrients (phosphorus and nitrate and ammonia) and TOC should not be exceeded at any time. For temperature, the ranges for summer and winter should stay within the 5th and 95th percentiles. Benefits would be for local use (watering), recreation and ecosystem health. In terms of the Water Quality Index, this would be classes A to B in winter and B to C in summer.

5.1.3 SUMMARY OF IFR 2 REQUIREMENTS

Table 5.1 : **SUMMARY OF IFR 2 RESULTS**

FDC% : Indicates the percentage of time that the flow will be equalled to or exceeded under virgin circumstances.

IFR 2 : MKOMAZI RIVER Present state C/B Desired Future State B

IFR MAINTENANCE LOW FLOWS	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	TOTAL X6 m3/s	% of virgi MAR 909
FLOW (m3/s)	3	5	9	9.5	10	10	7.5	5.5	4	3.2	2.7	2.3		
DEPTH (m)	0.65	0.77	0.92	0.94	0.95	0.95	0.87	0.79	0.72	0.67	0.63	0.6		
WETTED PERIMETER (m)	30.3		47.1	47.7	48.4	48.4	44.9	41.8	35.3	31.4	29.2	27.6		
VELOCITY (m/s)	0.38		0.49	0.5	0.51	0.51	0.47	0.44	0.41	0.39	0.38	0.36		
FDC% (VIRGIN)	72	84	83	88	94	96	87	75	74	67	63	76		
VOLUME (x6m3)	8.03	12.96	24.1	25.4	24.2	26.8	19.4	14.7	10.4	8.6	7.2	6	187.79	20.67
IFR MAINTENANCE HIGH FLOWS														
FLOW (Instantaneous peak m3/s)	6	15 25	20 50	30 50	350 60 20	20 50								
DEPTH (m)	1.09	1.35 1.51	1.44 1.78	1.58 1.78	2.79 1.85 1.44	1.44 1.78								
DURATION (days)	2	3	3	3	5 3	3 3								
FDC% (VIRGIN)	46	42 23	56 24	56 36	6.7 38 82	77 36								
VOLUME (x6m3)	0.36	3.7	8.1	9.6	49.7 9.3	7.8							88.56	9.74

IFR DROUGHT LOW FLOWS	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	TOTAL X6 m3/s	% of virgi MAR 909
FLOW (m3/s)	1.5	2	3	4	5.5	5.5	4	2.5	2	1.8	1.5	1		
DEPTH (m)	0.53	0.58	0.65	0.72	0.79	0.79	0.72	0.62	0.58	0.56	0.53	0.46		
WETTED PERIMETER (m)	22.8	26.2	30.3	35.3	41.8	41.8	35.3	28.5	26.2	25.2	22.8	19.7		
VELOCITY (m/s)	0.34	0.35	0.38	0.41	0.44	0.44	0.41	0.37	0.35	0.35	0.34	0.32		
FDC% (VIRGIN)	92	98	96	97	98	100	98	95	92	90	91	96		
VOLUME (x6m3)	4.02	5.2	8.04	10.7	13.3	14.73	10.37	6.7	5.2	4.8	3.9	2.7	89.66	9.9
IFR MAINTENANCE HIGH FLOWS														
FLOW (Instantaneous peak m3/s)		6	20	12 12	60 12 20	12								
DEPTH (m)		1.09	1.44	1.28	1.85 1.28 1.44	1.28								
DURATION (days)		2	3	3	3 3	3								
FDC% (VIRGIN)		79	57	84	38 91 82	93								
VOLUME (x6m3)		0.48	2.64	2.49	9.5	1.01							16.12	0.02

5.2 IFR 4 : MFUME

5.2.1 Maintenance flows

Maintenance Low flows **September** **Flow :3,5 m^3/s**

Description of flow	**Hyd param**	**Motivation**	**Why not lower**	**Source :**
PRIMARY MOTIVATOR				
Aquatic invertebrates: To wet to base of island on right hand side in order to wet bases of reeds	water level	Provide habitat for various species.	Will no longer have marginal vegetation biotope.	personal observ, photos, profile.

Maintenance Low flows **February** **Flow : 12,5** m^3/s

Description of flow	**Hyd param**	**Motivation**	**Why not lower**	**Source :**
PRIMARY MOTIVATOR				
Riparian vegetation: Adequate inundation of *Arundinella* bases. Basal wetting of P*ersicaria*. No wetting of the *Cynodon* River banks	water level	To maintain adequate growth of *Aurndinella*. To retain its dominant position in the ecosystem, *Arundinell*a requires root and rhizome flooding. These levels will also prevent pioneer aliens due to waterlogging of the soils. Marginal populations of *Persicaria* will also be adequately irrigated at these flow levels.	Lower levels will impair the growth of *Arundinella* within the system and probably lead to alien (wattle) invasion.	Survey, photos, profile.
Fish : Right bank channel is filled 20 - 25cm deep.	Depth	Shelter for small weaker fish species is provided in right bank channel. Deeper channels provide adequate habitat for adult fish.	Lower water levels limit amount of shelter on right bank - but would make central channel more habitable by small fish (Good variety of habitat and depths here makes actual minimum water level less critical).	Survey, pers observ.
SECONDARY MOTIVATOR				
Aquatic invertebrates:		Wet all the available aquatic biotopes. To ensure sufficient flow velocity to maintain the hydropneustic aquatic invertebrates. Need to maintain this base flow for a sufficiently long time to allow breeding and development of pupae o root stocks and marginal vegetation.	n/a	pers. observ

Maintenance High flows (in instantaneous peaks) **October** **Flow : 10 m^3/s**

Description of flow	**Hyd param**	**Motivation**	**Why not lower**	**Source :**
PRIMARY MOTIVATOR				
Aquatic invertebrates: Based on hydrology	-	Increased velocity to move fine sediments and cues for invertebrates.	-	-
Fish : Significant (double) increase over base flows with increased velocity	Flow & velocity	Migration cue at start of summer, to move fish from overwintering sites to suitable spawning areas.	Lower flows would not constitute an adequate change from baseflow values and would probably not stimulate migration.	Personal observation

Maintenance High flows **November** **2X** **Flow : 15 & 25 m^3/s**

Description of flow	**Hyd param**	**Motivation**	**Why not lower**	**Source :**
PRIMARY MOTIVATOR				
Riparian vegetation (25) Inundation of *Arundinella, Persicaria sp*.	Depth & velocity	Persicaria seedlings recently germinated. Flooding will sustain growth. *Arundinella* will be in early stages of growth. Rhizome inundation will maintain growth at reasonable levels.	Lower levels will fail to reach the band of germinating *Persicaria* seedlings.	Photos, survey, profile, pers observ
Geomorphology (25) : Flow depth ranges from near top of mid-channel bars to top of grassy shelf on right hand bank.	Depth	In-channel sediment transport (sands up to medium gravels - 40mm) within a variable flow regime. Morphological indicators used as clues for frequent flood events.	Reduction in sediment transport capacity	Profile features, theoretical studies, bed material observ
SECONDARY MOTIVATOR				
Aquatic invertebrates (15) :	velocity	Velocity to create new habitats and to move sediments and clean stones of accumulated algal growths..	n/a	-

Maintenance High flows **December** **2X** **Flow : 60 & 28** m^3/s

Description of flow	**Hyd param**	**Motivation**	**Why not lower**	**Source :**
PRIMARY MOTIVATOR				
Fish (60) Increased coverage of marginal vegetation and cobble/gravel beds, just covering cobble bars on transect.	Increased wetted perimter	To permit access to gravel and cobble beds as well as broad leaved marginal vegetation for spawning by scaly and catfish. Floods will discourage establishment of carp in main river channel.	Decrease in habitat availability could impinge on abundance and diversity of species occurring.	Pers observ
Geomorphology (60) :		In-channel sediment transport (sands up to medium gravels - 40mm) within a variable flow regime. Morphological indicators used as clues for frequent flood events.		
SECONDARY MOTIVATOR				
Aquatic invertebrates (28) :		Velocity to create new habitats, to clean stones and to move fine and coarser sediments.		

Maintenance High flows **January** **2X** **Flow : 75 & 28** m^3/s

Description of flow	**Hyd param**	**Motivation**	**Why not lower**	**Source :**
PRIMARY MOTIVATOR				
November (28): Flooding of the marginal Persicaria, Arundinella and Phragmites	water level	Mid-summer high growth period for riparian vegetation. Irrigation of the fringe vegetation to maintain reasonable levels of growth.	Lower levels will not reach the tussock bases and so the growth and seedling recruitment will be impacted.	Pers observ, study, survey, profile
Geomorphology (75) :		See November		
SECONDARY MOTIVATOR				
Aquatic invertebrates (28 & 75):		See December		

Maintenance High flows **February** **3X** **Flow : 20 & 60 & 400** m^3/s

Description of flow	**Hyd param**	**Motivation**	**Why not lower**	**Source :**
PRIMARY MOTIVATOR				
Riparian vegetation (400): Get water onto the flood bench colonised by *Cynodon dactylon*	Depth	This will ensure adequate provision of water to wet and maintain the *Cynodon* grass on this bench. Will also ensure adequate deposition of sediments on the terrace and assist with growth of *Cynodon*. Will also discourage encroachment of the terrace by woody species such as black wattle.	Encourage colonisation by exotic woody species and restrict *Cynodon* growth on flood bench.	Field observ
Geomorphology (400) Lateral grassed bench on LHB inundated	water level	Channel forming discharge plus flood plain sedimentation. Velocities high enough to transport sediment up to medium cobble.	As flows drop below 400, less of flood bench is inundated. No inundation below 200.	Profile features, theoretical studies, pers observ of ben and bank sediments.
SECONDARY MOTIVATOR				
Aquatic invertebrates (20 & 60):		Scour sediments, create new habitats.	n/a	literature
Fish (60 & 20) : Nearly overtops right bank cobble bar	Increased wetted perimeter	Spawning stimulus for scaly and catfish on newly inundated marginal gravel and cobble beds, as well as marginal vegetation. Smaller flood to provide diversity of flows which will shift smaller fish species and also discourage carp from becoming established.	n/a	personal observation

Maintenance High flows **March** **2X** **Flow : 28 & 90 m^3/s**

Description of flow	**Hyd param**	**Motivation**	**Why not lower**	**Source :**
PRIMARY MOTIVATOR				
Riparian vegetation (90) : Floods get into edges of flood terrace and almost completely inundate islands in channel.	Depth	Floods introduce water into roots of fringe vegetation on edge of flood terrace and recharge the base of the terrace. Result in deposition of sediments on *Cynodon* islands and edge of flood terrace. Ensures growth and expansion of fringe vegetation and maintenance of vegetated islands:	Would probably lead to restriction of fringe vegetation and destabilisation of islands in the channel.	Photos & field observ.
Geomorphology (90) :		In-channel sediment transport (sands up to medium gravels - 40mm) within a variable flow regime. Morphological indicators used as clues for frequent flood events.		
SECONDARY MOTIVATOR				
Aquatic invertebrates (28):		Velocity to maintain diversity of new habitats.		

5.2.2 Drought flows

Drought Low flows **September** **Flow : 1,6 m^3/s**

Description of flow	**Hyd param**	**Motivation**	**Why not lower**	**Source :**
PRIMARY MOTIVATOR				
Fish : Very shallow inundation of 2nd channel, adequate/dept in left channel	Depth	Minimal occupiable habitat remains in the left channel for fish survival (second channel too shallow for occupation).	Fish habitat becomes dangerously limited.	Pers observation , profile
Riparian vegetation : Minimum level to reach the basal roots of *Arundinella*.	water level	Most fringing vegetation will be highly stressed. Below this level there is a strong possibility that the *Arundinella* community will be severely impacted. Already at these lower levels the receding component will have been virtually lost. *Persicara* will persist in the seed bank.	Grass seed is notoriously short lived and if the standing population of Arundinella is too stressed the damage many cause irreversible shifts in the population structure	survey, profile, pers observ
SECONDARY MOTIVATOR				
Aquatic invertebrates	-	Left channel with deep water, middle channel with shallow water. Maintenance of flows and some habitats.	n/a	survey, profile, pers observ.

Drought Low flows **February** **Flow : 6,5 m^3/s**

Description of flow	Hyd param	Motivation	Why not lower	Source :
PRIMARY MOTIVATOR				
Aquatic invertebrates		Allows wetting of the bank. Inundates some vegetation giving refuge for invertebrates - also 2 channels of deeper water. This allows retention of diversity of aquatic biotopes and hence species diversity and functual components of the invertebrate community.		
SECONDARY MOTIVATOR				
Riparian vegetation : Water level reaches the rooting base of the *Arundinella* islands	Depth	Maintains the growth and persistence of the *Arundinella* grass patches on islands within the macro-channel.	n/a	Photos, model and calculations

Drought High flows **November** **Flow : 6 m^3/s**

Description of flow	Hyd param	Motivation	Why not lower	Source :
PRIMARY MOTIVATOR				
Aquatic invertebrates	wetted perim, velocity	Increase flow in November to stimulate movement and increased activity.	Some life cycles should be maintained, otherwise diversity of species will be impacted on.	Experience
General : Maintain variability				

Drought High flows **December** **Flow : 20 m^3/s**

Description of flow	**Hyd param**	**Motivation**	**Why not lower**	**Source :**
PRIMARY MOTIVATOR				
Aquatic invertebrates :	increase flow over base flow	To add variety to base flow and allow maintenance of diversity.	-	-

Drought High flows **January** **2X** **Flow : 12 & 12 m^3/s**

Description of flow	**Hyd param**	**Motivation**	**Why not lower**	**Source :**
PRIMARY MOTIVATOR				
Aquatic invertebrates :	-	Maintain diversity of flows to move sediments and wet new areas. Clean stones	-	Experience
General : Maintain variability				

Drought High flows **February** **2X** **Flow : 75 & 12 m^3/s**

Description of flow	**Hyd param**	**Motivation**	**Why not lower**	**Source :**
PRIMARY MOTIVATOR				
Riparian vegetation (75) : Put water into edges of flood terrace and inundate some islands	water level	Recharges the flood terrace and deposits sediments on islands. Ensures the survival of the fringe vegetation and vegetation (*Arundinella and Cynodon*) on the islands:		Field observ., photos
Geomorphology (75): Overtops mid-channel bars, gets into channel shelf on right bank	water level, velocity	General channel bed maintenance : mobilization of bed sediments up to 20 mm (i.e. up to medium gravels), redistribution of tributary sediments	Reduced efficacy for sediment transport	Profile, hydraulic data, bedmaterial observation, theoretical bedload equations.
SECONDARY MOTIVATOR				
Aquatic invertebrates :	Velocity	Scour sediments and reset system	n/a	pers exper

Drought High flows **March** **Flow : 12 m^3/s**

Description of flow	**Hyd param**	**Motivation**	**Why not lower**	**Source :**
PRIMARY MOTIVATOR				
Aquatic invertebrates :	-	Maintain diversity of flows to move sediments and wet new areas. Clean stones.	-	Experience
General : Maintain variability				

5.2.3 Summary of IFR 4 requirements

Table 5.2 : SUMMARY OF IFR 4 RESULTS

IFR 4 : MKOMAZI RIVER : Present State C Desired future state B

IFR MAINTENANCE LOW FLOWS	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	TOTAL X6 m3/s	% of virgin MAR 1064
FLOW (m3/s)	3.7	6.2	11	11.8	12.5	12.5	9.3	6.8	3	4	3.5	3.5		
DEPTH (m)	0.97	1.08	1.22	1.24	1.26	1.26	1.18	1.1	1.03	0.98	0.95	0.95		
WETTED PERIMETER (m)	48.6	65.4	86.2	87.2	88	88	83.3	68.2	34.1	50.2	46.6	46.6		
VELOCITY (m/s)	0.23	0.28	0.33	0.34	0.34	0.34	0.31	0.29	0.26	0.24	0.22	0.22		
FDC% (VIRGIN)	83	89	88	90	93	88	80	80	80	78	75	85		
VOLUME (x6m3)	9.9	16.1	29.5	31.6	30.2	33.5	24.1	18.2	13	10.7	9.4	9.1	235.3	22.1
IFR MAINTENANCE HIGH FLOWS														
FLOW (Instantaneous peak m3/s)	10	15 25	60 28	75 28	400 60 20	90 28								
DEPTH (m)	1.2	1.31 1.46	1.77 1.5	1.86 1.5	2.67 1.77 1.39	1.93 1.5								
DURATION (days)	2	3	3	3	5 3	3 3								
FDC% (VIRGIN)	40	59 33	28 58	36 68	2 52 85	26 78								
VOLUME (x6m3)	0.76	4.29	10.26	12.35	62.8	14.5							104.96	10

IFR DROUGHT LOW FLOWS	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	TOTAL X6 m3/s	% of virgin MAR1064
FLOW (m3/s)	1.8	2.4	3.5	4.7	6.5	6.5	4.7	3	2.4	2.1	1.8	1.6		
DEPTH (m)	0.83	0.88	0.95	1.02	1.09	1.09	1.07	0.92	0.88	0.85	0.83	0.81		
WETTED PERIMETER (m)	40.3	44	46.6	52.9	66.6	66.6	52.9	45.6	44	42.7	40.3	38.9		
VELOCITY (m/s)	0.18	0.2	0.22	0.25	0.28	0.28	0.25	0.21	0.2	0.19	0.18	0.17		
FDC% (VIRGIN)	98	100	99	98	97	99	99	96	97	98	96	96		
VOLUME (x6m3)	4.8	6.2	9.4	12.6	15.7	17.4	12.2	8	6.2	5.6	4.8	4.1	107	10.1
IFR MAINTENANCE HIGH FLOWS														
FLOW (Instantaneous peak m3/s)		6	20	12 12	75 60 12	12								
DEPTH (m)		1.07	1.39	1.25 1.25	1.86 1.25	1.25								
DURATION (days)		2	3	3	5 3	3								
FDC% (VIRGIN)		90	69	90 90	52 93	95								
VOLUME (x6m3)		0.44	2.57	2.27	11.7	0.85							17.83	1.7

5.3 MATCHING OF IFR 2 AND IFR 4 RESULTS TO IFR 1 AND IFR 3

5.3.1 IFR 1 Results

A hydrological factor was utilised to extrapolate the IFRs from IFR 2 to IFR 1. These matched IFR flow recommendations were then converted to the hydraulic parameters of depth, wetted perimeter and velocity and were then checked by each discipline to determine whether they will maintain the site in the required protection class. The IFR 1 results were unchanged after checking and are tabled in Table 5.3 as follows:

Table 5.3 : Summary of IFR 1 results

IFR 1 : MKOMAZI RIVER : Present state C/B DFS B

IFR MAINTENANCE LOW FLOWS	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	TOTAL X6 m3/s	% of virgin MAR 690
FLOW (m3/s)	2.3	6.1	6.8	7.2	7.6	7.6	5.7	4.2	3	2.4	2.1	1.75		
DEPTH (m) section A	1.32	1.54	1.57	1.59	1.6	1.6	1.53	1.45	1.37	1.33	1.3	1.26		
DEPTH (m) section B	0.74	0.96	0.96	1	1.01	1.01	0.94	0.85	0.79	0.75	0.72	0.69		
DEPTH (m) section C	2.47	2.68	2.7	2.72	2.73	2.73	2.66	2.59	2.52	2.48	2.46	2.43		
FDC% (VIRGIN)	71	71	84	90	93	95	86	77	74	68	63	77		
VOLUME (x6m3)	6.16	15.81	18.2	19.3	18.4	20.3	14.8	11.2	7.8	6.4	5.5	4.5	148.37	21.5
IFR MAINTENANCE HIGH FLOWS														
FLOW (Instantaneous peak m3/s)	4.6	11.4 19	38 15.2	22.8 38	266 45.6 15.2	38 15.2								
DEPTH (m) section A	1.47	1.72 1.89	2.16 1.81	1.96 2.16	3.21 2.23 1.81	2.16 1.81								
DEPTH (m) section B	0.89	1.13 1.29	1.56 1.22	1.36 1.56	2.61 1.63 1.22	1.56 1.22								
DEPTH (m) section C	2.61	2.84 2.99	3.23 2.92	3.05 3.23	4.17 3.3 2.92	3.23 2.92								
DURATION (days)	2	3	3	3	5 3	3 3								
FDC% (VIRGIN)	47	42 22	58 24	57 37		78 37								
VOLUME (x6m3)	0.28	2.8	6.2	7.2	45.6	7.1							69.2	10

Including a 1 in 5 year flood in February which replaces the 266 with 380 (A=3.46; B=2.87, C4.41 depth)

IFR DROUGHT LOW FLOWS	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	TOTAL X6 m3/s	% of virgin MAR 690
FLOW (m3/s)	1.1	1.5	2.3	3	4.2	4.2	3	1.9	1.5	1.4	1.1	0.76		
DEPTH (m) section A					1.45							1.12		
DEPTH (m) section B					0.87							0.55		
DEPTH (m) section C					2.59							2.3		
FDC% (VIRGIN)	92	98	96	98	98	100	98	96	92	88	92	94		
VOLUME (x6m3)	2.9	3.9	6.2	8	10.2	11.2	7.8	5.1	3.9	3.7	2.9	2	67.8	9.8
IFR MAINTENANCE HIGH FLOWS														
FLOW (Instantaneous peak m3/s)		4.6	15.2	9.1 9.1	45.6 9.1	9.1								
DEPTH (m) section A		1.47	1.81	1.66 1.66	2.23 1.66	1.66								
DEPTH (m) section B		0.89	1.22	1.06 1.06	1.63 1.06	1.06								
DEPTH (m) section C		2.61	2.92	2.78 2.78	3.3 2.78	2.78								
DURATION (days)		2	3	3	5 3	3								
FDC% (VIRGIN)		80	58	84 84	38 92	93								
VOLUME (x6m3)		0.37	2	1.9	9.1	0.76							14.13	2

5.3.2 IFR 3 results

A hydrological factor was utilised to extrapolate the IFRs from IFR 4 to IFR 3. The same process as above was utilised to check for adequacy of IFRs. The IFR 3 results were unchanged after checking and are tabled in Table 5.4 as follows:

Table 5.4 : SUMMARY OF IFR 3 RESULTS

IFR 3 : MKOMAZI RIVER - PRESENT STATE D/C, DESIRED STATE B

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	TOTAL X6 m3/s	% of virgi MAR 100
IFR MAINTENANCE LOW FLOWS														
FLOW (m3/s)	3.5	5.8	10.3	11.1	11.8	11.8	8.7	6.4	4.7	3.7	3.3	3.3		
DEPTH (m) section A					0.7							0.45		
FDC% (VIRGIN)	70	82	81	87	93	95	86	72	71	65	58	63		
VOLUME (x6m3)	9.4	15	27.6	29.7	28.5	31.6	22.5	17.1	12.2	9.9	8.8	8.5	221.1	22
IFR MAINTENANCE HIGH FLOWS														
FLOW (Instantaneous peak m3/s)	9	14 24	26 48	26 71	19 57 377	26 86								
DEPTH (m) section A	0.64	0.75 0.91	0.93 1.16	0.93 1.33	0.83 1.23 2.4	0.93 1.42								
DURATION (days)	2	3 3	3 3	3 3	3 3 5	3 3								
FDC% (VIRGIN)	32	50 27	52 27	65 27	85 42 4	70 21								
VOLUME (x6m3)	0.66	1.27 2.83	2.44 5.86	2.32 9.32	1.12 7.03 51.2	2.21 11.5							97.79	9.7

Including a 1 in 5 year flood in February which replaces the 266 with 380 (A=3.46; B=2.87, C4.41 depth)

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	TOTAL X6 m3/s	% of virgi MAR 100
IFR DROUGHT LOW FLOWS														
FLOW (m3/s)	1.7	2.2	3.3	4.4	6.1	6.1	4.4	2.8	2.2	2	1.7	1.5		
DEPTH (m) section A					0.56							0.34		
FDC% (VIRGIN)	91	98	95	97	98	100	98	95	92	87	89	91		
VOLUME (x6m3)	4.5	5.7	8.8	11.8	14.8	16.3	11.4	7.5	5.7	5.4	4.6	3.9	100.4	10
IFR MAINTENANCE HIGH FLOWS														
FLOW (Instantaneous peak m3/s)		6	19	11 11	11 71	11								
DEPTH (m) section A		0.55	0.83	0.69 0.69	0.69 1.33	0.69								
DURATION (days)		3	3	3 3	3 5	3								
FDC% (VIRGIN)		81	63	87 87	93 34	96								
VOLUME (x6m3)		0.46	0.86	1.03 1.03	0.76 8.85	0.76							13.75	1.4

5.4 CONFIDENCE IN IFR RESULTS

Each specialist evaluated the confidence in the IFR results according to the table below. The evaluation column indicates an average and this information should therefore be used with care. Some of the components used for the evaluation should be weighted, before an average can be used with confidence.

TABLE 5.5 : IFR RESULT CONFIDENCE TABLE

PURPOSE : TO ATTACH A CONFIDENCE VALUE TO THE RESULTS OF THE IFR SET BASED ON THE DIFFERENT SPECIALIST VIEWPOINTS, I.E. CONFIDENCE THAT THE IFR SET WILL ADEQUATELY KEEP THE RIVER AT THE DESIRED STATE.

NONE = 0 LOW = 1 LOW - MEDIUM = 2 MEDIUM =3
MEDIUM - HIGH = 4 HIGH = 5 L = LOW FLOWS H = HIGH FLOWS

NOTE :

- Confidence are only attached to low or high flows where motivations are supplied. If, for example motivations were not supplied for low flows, no motivation for confidence for low flows is supplied.
- Motivation for evaluations are supplied whenever necessary, specifically for low flows.
- Hydrology : This evaluation is based on the hydrologists expert judgement on whether, based on the hydrology of the system, the answers are realistic

IFR SITES		IFR COMPONENT						EVAL
		HYDROL	FISH	RIP VEG	GEOMORPH	AQUATIC INVERTS	WATER QUALITY	
1	L	4	3	2-3	-	3	3	3.1
	H	3-4	3	3-4	4	3	5	3.7
2	L	4	4	2-3	-	3	2	3.1
	H	3-4	3	4	4	3-4	4	3.7
3	L	4	4	1	-	3-4	3	3.1
	H	3-4	3	2	3-4	3-4	5	3.2
4	L	4	3-4	1	-	1-2	3	2.6
	H	3-4	3	2	3	3-4	5	3.3

It was noted in general that the most important reason for low confidence experienced for this IFR study was the lack of low flows observed during the study period. In the more detail the following statements were made :

5.4.1 Geomorphology : confidence levels in IFRs (Rowntree)

- Confidence levels moderate-high for 1 year flood flows at 1 - 3 because cross-profile included clear morphological features. Sections across pools generally far more useful than rapids.
- Confidence level at 4 moderate for 1 year flood because strong bed rock influence makes interpretation more difficult.
- Confidence level for active channel sediment processes moderate due to lack of detailed surveys of river bed - no low flow site visits.
- Some morphological features difficult to interpret because of lack of access to opposite bank - high flows experienced during site visits.

Recommendations :

- Geomorphologist must liaise with surveyors and hydraulician so as to choose optimum transects for geomorphology and to interpret transects.
- One site visit must be made at low flow conditions to enable access to both river banks and to river bed.

5.4.2 Riparian vegetation : confidence levels in IFRs (Edwards & Kemper)

- Site 4 : Flood indicators on the profile, which were used on the sites above to devise flood recommendations, did not make sense at this site and led to low confidence
- Initial depths specified implied exceptionally large floods which were not supported by the hydrology. The floods were therefore reduced to be in line with the hydrology.
- Low confidence in the regularity and magnitude of floods needed to inundate the flanking vegetation (*Cynodon dactylon*).Flooding and sedimentation of this bench appears to be maintaining the dominance of indigenous grasses through inhibiting the growth of exotic seedlings eg, wattles, cassias, lantana. This is particularly important because of their impact on grazing of domestic animals in the area.
- No photographic record of low flow regimes and consequently the basal vegetation depths in the river are unknown. Extrapolation of reed bed (*Arudinella*) depths are critical since these appear to be structurally important components of the riparian fringe. The importance of maintaining marginal fringing vegetation in reasonable shape impacts on bank erosion, insect communities, fish communities.
- Site 3 : Extrapolated from 4 and consequently the same low confidence applies.

5.4.3 Water quality : confidence levels in IFRs (Simpson)

All data has only been collected since 1996, so the analysis is based on two years of data. Earlier data (DWAF collection since 1976) did not include critical variables from the river health and local use point of view and therefore cannot be used. Since 1996 and 1997 were ‘wet years” with above average runoff, there is greater confidence in high flow than low flow data. The confidence rating for high flow is given as 5 and for low flow as 3. Data needs to be collected in a drought year. The confidence for IFR 2 is downgraded as there is no sampling site nearby and results had to be calculated.

5.4.4 Aquatic invertebrates : confidence levels in IFRs

- IFR 2 is a contained channel and so the estimates may not cater for the broader range of biotopes at other sites eg. Above Lundy’s Hill.
- IFR 2 produced a lower diversity of species (68 taxa) than any other site surveyed (>100 taxa)- probably due to reduced biotope diversity. Therefore estimation based on these results may not cater for other sites.
- IFR 4 : The sites surveyed for invertebrates were at and below Goodenough weir, which is a very different type of site to IFR 4. Extrapolation to IFR 4 is therefore not wholly valid.
- There was a poor knowledge of the substrate types at IFR 4 which reduced the confidence especially at low flow conditions as there was no idea of potential biotopes.

CHAPTER 6 : IFR MODELLING AND FINAL IFR RESULTS

The IFR model represents an attempt to generate a representative time series of daily flow ecological requirements that are expected to result from the implementation of the output from an IFR workshop. The actual daily requirements are expected to be made up of a combination of low flow releases with flood event releases superimposed upon them. In keeping with the philosophy of the BBM methodology and the definition of when maintenance and drought flows should occur, the model uses climatic cues to determine the actual daily flow rates. The design flow rates are those which are defined through the workshop process. These are expected to vary from somewhat above the design maintenance low flows down to the drought requirements. In the case of the high flow requirements, the maintenance events represent the largest values and the climatic cues should determine when lower values are appropriate. The IFR model is fully described in a paper by Hughes, O'Keeffe, Smakhtin and King in Water SA, 23(1), 21-30.

The climatic cues within the model are derived by examining the daily flows within a 'Reference Flow' time series. This may be an observed record at an adjacent gauging station, or a simulated time series (by any appropriate model) of flows at the IFR site or elsewhere. The main consideration in the selection of an appropriate reference flow time series is that the patterns of flow are representative of the patterns of flow that would have occurred at the IFR site under natural (or other suitable development state that is considered acceptable to the workshop participants) conditions. The model derives the climatic cues in terms of low flow and high flow status values. These are expressed in terms of percentage points of the calender month 1-day flow duration curves for the reference flow site. Duration curve percentage points are used to allow better comparison across different catchments and are less affected by non-linear scaling effects than if flows were to be used directly. The low flow status value is a smoothed representation of the recent (past 30 days) baseflow conditions that have occurred at the reference flow site. The flood status value is a representation of the size of a flood that is about (within the next 10 days) to occur.

To be able to make use of the climatic cues (low flow and flood status values), a set of low flow and flood 'operating rules' are defined by the workshop participants. These represent threshold values which are compared, in the model, with the daily values of the climatic cues to determine the actual flow rate required on a specific day. For example, while the low flow status is above the relevant operating rule threshold a flow above the maintenance requirement would be simulated. As the low flow status decreases and drops to a level between the maintenance and drought rules, so the required flow decreases to below the maintenance design low flow toward the drought design low flow. A similar approach is used to control the flood or high flow requirements.

The operating rules are calibrated (progressively modified) until an acceptable pattern of time series of modified flows are achieved which satisfies the IFR workshop participants perceptions of the effects of their decision making process on the river. The types of thing that they should be looking for is how frequently the modified flows drop below the design maintenance flows, how frequently and for what duration are the flows close to, or at the design drought levels, etc. A statistical summary program is also provided that calculates (for each calendar month) the percentage of time that the modified flow regime is at, or above, maintenance, between maintenance and drought or at drought levels. These are effectively the recommended assurance levels of the different flows.

Once the model is satisfactorily calibrated, monthly summary data of total release volumes can be generated for the complete time series. These monthly time series data can then be further analysed to determine more detailed assurance values for the full range of flows that form part of the recommended modified flow regime. The time series or assurance levels can then be used in a conventional water resource assessment and reservoir yield model to determine if the planned impoundment can satisfy the expected abstraction demands as well as the IFR release requirement. The IWR at Rhodes University have also combined an existing daily reservoir simulation model with the IFR model to allow the same type of assessments to be made. In this model additional sets of operating rules have been established so that the abstractions are determined by reservoir storage levels and the IFR releases affected by rules based on the cumulative supply deficit as well as the climatic cues. This model is still in the development stage but is currently being applied, tested and evaluated.

Recent considerations and experience of the use of the models within IFR workshops suggest that it will be important in future to give more thought to what the ‘maintenance’ flows should be representing in terms of assurance levels. The models have conventionally been applied at the end of the workshop and it has been noted that the various specialists often have different perceptions of how frequently the maintenance flows should be occurring. It is suggested that this issue be clarified at the beginning of the workshop and that an approximate idea of what assurance level (or frequency of occurrence) the maintenance flows are to be designed for be agreed upon before setting the actual flow rates. The IFR model can be useful in this respect as it will allow the participants to develop a background impression of the natural variability of the flow regime and apply their specialist ecological knowledge in a better context.

Final IFR results at IFR 2 after the application of the IFR 2 model:

H:\HYMAS\PROJECT\FLH\MKOMASI\IFR1.FLH : New .FLH file selected
Monthly summary for Release Low Flow starting 01/08/1960
Time weighted totals

SA Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
01 1960	-9.0	-9.0	-9.0	-9.0	-9.0	-9.0	-9.0	3187.59	4781.69	6609.22	9149.60	19268.7	42996.82
01 1961	20881.7	18159.1	21547.1	15531.3	11743.4	8089.37	6665.57	5710.01	4608.23	6372.00	7408.43	19268.7	145985.0
01 1962	20881.7	19422.4	21547.1	13901.5	10976.1	8089.37	6665.57	5710.01	4789.52	6609.22	10467.5	19268.7	148328.9
01 1963	20881.7	19422.4	21547.1	15531.3	11743.4	8089.37	6665.57	5710.01	4789.52	6609.22	10541.4	19268.7	150799.9
01 1964	20881.7	20116.4	20619.8	15301.0	11743.4	8089.37	6665.57	5710.01	4789.52	6609.22	10541.4	19268.7	150336.4
01 1965	20881.7	19422.4	18059.0	10257.3	10052.8	7291.83	6665.57	5710.01	4789.52	6609.22	10541.4	18072.5	138353.6
01 1966	14583.8	19422.4	17847.2	8106.03	8763.45	7399.54	5599.85	4658.89	4647.62	5854.44	10532.0	19268.7	126684.1
01 1967	20881.7	19422.4	21547.1	15531.3	11743.4	8089.37	6665.57	5710.01	4789.52	5701.80	10101.5	19011.9	149195.8
01 1968	20881.7	19623.1	21402.9	15531.3	11743.4	8089.37	6665.57	5710.01	4789.52	5467.40	7693.13	19268.7	146866.2
01 1969	14443.3	10258.5	19507.9	15531.3	11743.4	8089.37	6665.57	5710.01	4789.52	6609.22	10541.4	19268.7	133158.4
01 1970	20795.9	19422.2	19839.6	8822.06	7486.30	4734.86	5180.08	4121.51	4650.74	6609.22	10541.4	18941.1	131145.2
01 1971	19028.0	19422.4	21109.5	15237.6	11743.4	8089.37	6665.57	5710.01	4789.52	6609.22	10541.4	19268.7	148215.0
01 1972	20881.7	20116.4	21547.1	15531.3	11743.4	8089.37	6665.57	5710.01	4789.13	6489.31	10272.6	18580.2	150416.3
01 1973	14148.8	17013.3	21547.1	15531.3	11743.4	8089.37	6665.57	5710.01	4789.52	6609.22	10541.4	19268.7	141657.9
01 1974	20881.7	19422.4	21547.1	15531.3	11743.4	8089.37	6665.57	5710.01	4789.52	6609.22	10069.0	19268.7	150327.5
01 1975	20434.8	19422.4	21547.1	15531.3	11743.4	8089.37	6665.57	5710.01	4789.52	6609.22	10541.4	19268.7	150353.0
01 1976	20881.7	20116.4	21547.1	15531.3	11743.4	7870.08	3878.95	2959.20	2508.04	6606.78	10541.4	14674.7	138859.3
01 1977	15217.1	19305.9	21547.1	15531.3	11743.4	8089.37	6665.57	5710.01	4756.04	6579.53	10541.4	18877.2	144564.2
01 1978	20830.8	19422.4	21547.1	15531.3	11743.4	8089.37	6665.57	5710.01	4789.52	6609.22	10541.4	19268.7	150749.0
01 1979	20881.7	19422.4	21542.7	13442.0	11738.8	8089.37	6665.57	5710.01	4789.52	6609.22	9000.44	18699.9	146591.9
01 1980	18247.9	20116.4	21436.4	15491.4	7177.97	6171.48	5526.73	4765.93	3954.09	6609.22	9704.23	18709.8	137911.8
01 1981	18539.3	19137.1	21547.1	14059.2	11365.7	7907.09	6239.98	5088.54	4785.41	6609.22	9195.76	18907.0	143381.7
01 1982	17539.2	12564.9	16726.2	15531.3	11641.8	7612.53	6337.03	4849.97	4047.76	4491.79	9193.80	8961.82	119498.3
01 1983	8202.98	11053.9	11837.0	8552.28	5428.36	3905.28	3754.07	3064.34	1991.63	3952.62	10541.4	19268.7	91552.78
01 1984	20881.7	19820.1	20779.2	15531.3	11743.4	8089.37	6665.57	5710.01	4789.52	6609.22	9956.70	13874.8	144451.1
01 1985	13086.7	19422.4	21547.1	14274.0	9580.21	6744.39	5931.63	4339.64	2659.85	4086.12	10263.7	19268.7	131204.6
01 1986	20881.7	19422.4	21221.5	15401.6	11743.4	8089.37	6665.57	5710.01	4789.52	6609.22	10541.4	19268.7	150344.6
01 1987	20881.7	18075.8	19866.1	15531.3	10988.9	7472.29	6611.90	5708.89	4789.52	6609.22	10541.4	19268.7	146345.9

01 1988	20881.7	20116.4	21547.1	15531.3	11743.4	8089.37	6665.57	5710.01	4789.52	6609.22	9831.94	19138.4	150654.1
01 1989	20881.7	19422.4	21547.1	15531.3	11743.4	8089.37	6665.57	5710.01	4554.55	4366.75	9578.98	19268.7	147360.0
01 1990	20688.6	19165.0	20976.0	15531.3	11743.4	8089.37	6665.57	5710.01	4789.52	6196.01	10316.7	16081.6	145953.4
01 1991	19883.9	19422.4	21547.1	15531.3	11743.4	8089.37	6665.57	5658.63	4144.77	6260.68	10541.4	19268.7	148757.5
01 1992	20881.7	16512.1	19844.5	8364.04	5136.48	3960.43	3810.23	2964.30	1984.60	2931.55	4041.00	6342.78	96773.89
01 1993	8004.96	11478.8	17119.4	15017.0	9838.06	4183.25	3940.17	3001.29	1984.60	4947.06	10541.4	19268.7	109324.9
01 1994	20881.7	19422.4	21547.1	15456.1	11416.0	6739.35	6382.93	5704.54	4598.79	5130.90	9264.65	7022.67	133567.4
01 1995	13813.4	19094.0	19639.4	15531.3	11743.4	8089.37	644.33	5369.32	3538.87	3931.28	8850.71	19245.6	135491.1
01 1996	20881.7	20116.4	21547.1	15531.3	11743.4	8089.37	6665.57	710.01	4789.52	6609.22	10541.4	19268.7	151493.9
01 1997	20881.7	19422.4	21547.1	-9.00	-9.00	-9.00	-9.00	-9.00	-9.00	-9.00	-9.00	-9.00	-9.00

Monthly summary for Release Flood starting 01/08/1960

01 1960	-9.0	-9.0	-9.0	-9.0	-9.0	-9.0	-9.0	0.00	0.00	0.00	2971.14	10024.8	12995.96
01 1961	0.00	45480.9	3415.15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3151.87	9287.80	61335.78
01 1962	7216.12	45480.9	5242.55	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3370.18	6728.81	68038.64
01 1963	7216.12	0.00	5909.76	0.00	0.00	0.00	0.00	0.00	0.00	357.69	3545.85	10024.8	27054.26
01 1964	7216.12	0.00	5058.18	0.00	0.00	0.00	0.00	0.00	0.00	357.69	3545.85	7490.14	23668.00
01 1965	6936.94	45480.9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	353.32	3545.85	0.00	56317.08
01 1966	7216.12	45480.9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3545.85	7142.05	63385.00
01 1967	5489.22	45480.9	5909.76	0.00	0.00	0.00	0.00	0.00	0.00	313.14	3584.99	10024.8	70802.90
01 1968	6529.06	16654.3	4576.98	0.00	0.00	0.00	0.00	0.00	0.00	37.71	301.74	9522.73	37622.61
01 1969	0.00	16755.1	5646.04	0.00	0.00	0.00	0.00	0.00	0.00	328.46	0.00	10024.8	32754.45
01 1970	7216.12	40710.1	1952.27	0.00	0.00	0.00	0.00	0.00	0.00	357.69	3545.85	8589.88	62372.00
01 1971	3864.14	39284.7	2327.60	2327.60	0.00	0.00	0.00	0.00	0.00	357.69	3545.85	10024.8	61732.51
01 1972	7216.12	42641.1	5909.76	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2608.25	0.00	58375.27
01 1973	617.05	40810.6	5447.33	0.00	0.00	0.00	0.00	0.00	0.00	357.69	3545.85	10024.8	60803.44
01 1974	6981.12	45480.9	5909.76	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3252.02	9456.08	71079.95
01 1975	7216.12	45480.9	5264.77	0.00	0.00	0.00	0.00	0.00	0.00	38.35	3852.71	10024.8	71877.75
01 1976	7216.12	45480.9	5909.76	0.00	0.00	0.00	0.00	0.00	0.00	357.69	3545.85	7877.29	70387.69
01 1977	4215.02	39098.7	5909.76	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4630.69	53854.23
01 1978	11246.8	42563.9	5510.13	0.00	0.00	0.00	0.00	0.00	0.00	357.69	3545.85	10024.8	73249.30
01 1979	5093.36	25645.7	5909.76	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3431.22	0.00	40080.12
01 1980	7216.12	42618.5	5340.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	10024.8	65199.98
01 1981	2626.81	45480.9	5296.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3117.13	8641.24	65162.23
01 1982	3376.52	13915.7	4119.05	0.00	0.00	0.00	0.00	0.00	0.00	39.74	317.95	1204.51	22973.49
01 1983	2716.85	0.00	2778.83	0.00	0.00	0.00	0.00	0.00	0.00	325.82	3545.85	10024.8	19392.19
01 1984	7216.12	29545.6	5529.11	0.00	0.00	0.00	0.00	0.00	0.00	357.69	0.00	0.00	42648.60
01 1985	7216.12	45480.9	4168.01	0.00	0.00	0.00	0.00	0.00	0.00	317.95	3400.73	10024.8	70608.61
01 1986	6358.31	38968.8	5909.76	0.00	0.00	0.00	0.00	0.00	0.00	338.48	3545.85	10024.8	65146.06
01 1987	6600.81	0.00	4773.47	0.00	0.00	0.00	0.00	0.00	0.00	357.69	3545.85	10024.8	25302.65
01 1988	5044.36	40014.7	5909.76	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1772.92	11797.7	64539.52
01 1989	7216.12	45480.9	4360.80	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3545.85	10024.8	70628.56
01 1990	6075.97	33126.1	5909.76	0.00	0.00	0.00	0.00	0.00	0.00	36.92	295.39	10024.8	55469.01
01 1991	7216.12	45480.9	3823.85	0.00	0.00	0.00	0.00	0.00	0.00	357.69	3545.85	9860.99	70285.48
01 1992	6898.97	30060.5	3331.21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	40290.76
01 1993	1644.81	29263.4	1186.78	0.00	0.00	0.00	0.00	0.00	0.00	357.69	3545.85	8740.97	44739.59
01 1994	7216.12	45480.9	4850.96	0.00	0.00	0.00	0.00	0.00	0.00	159.22	159.22	4377.14	62243.65
01 1995	7216.12	24513.6	5909.76	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3545.85	10024.8	51210.24
01 1996	5605.42	45480.9	5909.76	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3545.85	10024.8	70566.82
01 1997	7216.12	29154.5	5909.76	-9.00	-9.00	-9.00	-9.00	-9.00	-9.00	-9.00	-9.00	-9.00	-9.00

Monthly summary for Total Release starting 01/08/1960

01 1960	-9.0	-9.0	-9.0	-9.0	-9.0	-9.0	-9.0	3187.59	4781.69	6609.22	12120.7	29293.5	55992.79
01 1961	20881.7	63640.1	24962.2	15531.3	11743.4	8089.37	6665.57	5710.01	4608.23	6372.00	10560.3	28556.5	207320.9
01 1962	28097.8	64903.4	26789.6	13901.5	10976.1	8089.37	6665.57	5710.01	4789.52	6609.22	13837.7	25997.5	216367.5
01 1963	28097.8	19422.4	27456.8	15531.3	11743.4	8089.37	6665.57	5710.01	4789.52	6966.92	14087.3	29293.5	177854.2
01 1964	28097.8	20116.4	25678.0	15301.0	11743.4	8089.37	6665.57	5710.01	4789.52	6966.92	14087.3	26758.8	174004.4
01 1965	27818.6	64903.4	18059.0	10257.3	10052.8	7291.83	6665.57	5710.01	4789.52	6962.54	14087.3	18072.5	194670.7
01 1966	21800.0	64903.4	17847.2	8106.03	8763.45	7399.54	5599.85	4658.89	4647.62	5854.44	14077.8	26410.7	190069.1
01 1967	26370.9	64903.4	27456.8	15531.3	11743.4	8089.37	6665.57	5710.01	4789.52	6014.95	13686.5	29036.7	219998.7
01 1968	27410.7	36277.5	25979.9	15531.3	11743.4	8089.37	6665.57	5710.01	4789.52	5505.11	7994.87	28791.4	184488.8
01 1969	14443.3	27013.6	25154.0	15531.3	11743.4	8089.37	6665.57	5710.01	4789.52	6937.69	10541.4	29293.5	165912.8
01 1970	28012.0	60132.4	21791.9	8822.06	7486.30	4734.86	5180.08	4121.51	4650.74	6966.92	14087.3	27531.0	193517.2
01 1971	22892.1	58707.2	23437.1	17565.2	11743.4	8089.37	6665.57	5710.01	4789.52	6966.92	14087.3	29293.5	209947.5
01 1972	28097.8	62757.6	27456.8	15531.3	11743.4	8089.37	6665.57	5710.01	4789.13	6489.31	12880.8	18580.2	208791.7
01 1973	14765.8	57824.0	26994.4	15531.3	11743.4	8089.37	6665.57	5710.01	4789.52	6966.92	14087.3	29293.5	202461.4
01 1974	27862.8	64903.4	27456.8	15531.3	11743.4	8089.37	6665.57	5710.01	4789.52	6609.22	13321.1	28724.7	221407.5
01 1975	27650.9	64903.4	26811.8	15531.3	11743.4	8089.37	6665.57	5710.01	4789.52	6647.58	14394.2	29293.5	222230.7
01 1976	28097.8	65597.4	27456.8	15531.3	11743.4	7870.08	3878.95	2959.20	2508.04	6964.47	14087.3	22552.0	209247.0
01 1977	19432.2	58404.6	27456.8	15531.3	11743.4	8089.37	6665.57	5710.01	4756.04	6579.53	10541.4	23507.9	198418.5
01 1978	32077.7	61986.4	27057.2	15531.3	11743.4	8089.37	6665.57	5710.01	4789.52	6966.92	14087.3	29293.5	223998.4
01 1979	25975.0	45068.2	27452.5	13442.0	11738.8	8089.37	6665.57	5710.01	4789.52	6609.22	12431.6	18699.9	186672.0
01 1980	25464.0	62735.0	26776.9	15491.4	7177.97	6171.48	5526.73	4765.93	3954.09	6609.22	9704.23	28734.6	203111.8
01 1981	21166.1	64618.1	26843.1	14059.2	11365.7	7907.09	6239.98	5088.54	4785.41	6609.22	12312.8	27548.3	208543.9
01 1982	20915.7	26480.6	20845.3	15531.3	11641.8	7612.53	6337.03	4849.97	4047.76	4531.53	9511.75	10166.3	142471.7
01 1983	10919.8	11053.9	14615.9	8552.28	5428.36	3905.28	3754.07	3064.34	1991.63	4278.44	14087.3	29293.5	110944.9
01 1984	28097.8	49365.8	26308.4	15531.3	11743.4	8089.37	6665.57	5710.01	4789.52	6966.92	9956.70	13874.8	187099.7
01 1985	20302.8	64903.4	25715.1	14274.0	9580.21	6744.39	5931.63	4339.64	2659.85	4404.07	13664.4	29293.5	201813.3

01	1986	27240.0	58391.3	27131.2	15401.6	11743.4	8089.37	6665.57	5710.01	4789.52	6947.70	14087.3	29293.5	215490.7
01	1987	27482.5	18075.8	24639.5	15531.3	10988.9	7472.29	6611.90	5708.89	4789.52	6966.92	14087.3	29293.5	171648.6
01	1988	25926.0	60131.2	27456.8	15531.3	11743.4	8089.37	6665.57	5710.01	4789.52	6609.22	11604.8	30936.1	215193.7
01	1989	28097.8	64903.4	25907.9	15531.3	11743.4	8089.37	6665.57	5710.01	4554.55	4366.75	13124.8	29293.5	217988.5
01	1990	26764.6	52291.1	26885.8	15531.3	11743.4	8089.37	6665.57	5710.01	4789.52	6232.93	10612.1	26106.4	201422.4
01	1991	27100.1	64903.4	25370.9	15531.3	11743.4	8089.37	6665.57	5658.63	4144.77	6618.37	14087.3	29129.7	219043.0
01	1992	27780.6	46572.7	23175.7	8364.04	5136.48	3960.43	3810.23	2964.30	1984.60	2931.55	4041.00	6342.78	137064.6
01	1993	9649.77	40742.3	18306.1	15017.0	9838.06	4183.25	3940.17	3001.29	1984.60	5304.76	14087.3	28009.6	154064.5
01	1994	28097.8	64903.4	26398.0	15456.1	11416.0	6739.35	6382.93	5704.54	4598.79	5290.13	9423.88	11399.8	195811.0
01	1995	21029.6	43607.6	25549.1	15531.3	11743.4	8089.37	6644.33	5369.32	3538.87	3931.28	12396.5	29270.4	186701.4
01	1996	26487.1	65597.4	27456.8	15531.3	11743.4	8089.37	6665.57	5710.01	4789.52	6609.22	14087.3	29293.5	222060.8
01	1997	28097.8	48577.0	27456.8	-9.00	-9.00	-9.00	-9.00	-9.00	-9.00	-9.00	-9.00	-9.00	-9.00

CHAPTER 7 : CAPPING FLOWS

Definition:
Elevated base flows which, if exceeded for extended periods, would have undesirable effects on the communities and/or ecological processes in a river.

Examples:
The issue of capping flows generally arises where there is a requirement for large constant flows to be released for downstream users, resulting in unnaturally high and constant base-flows in parts of a river. A typical example occurs in the middle reaches of the Great Fish River, where water is fed from the Orange River, via the Grassridge Dam, mainly to provide for downstream irrigation. As a result, base flows in these reaches are generally maintained at between 3 and 8 cumecs, where in winter under natural conditions, the flow would have ceased or been reduced to a trickle for several months. Major consequences of these constant elevated flows have been a reduction in hydraulic habitat diversity through time, or a maintenance of one set of hydraulic conditions. In the Fish River (as in parts of the Vaal and Orange), these conditions happen to favour one particular species of blackfly (*Simulium chutteri*), females of which are blood feeders. Because of the predominance of favourable habitat, huge swarms of the blackfly emerge from the river in spring, and cause major damage and disturbance to livestock. Such pest-swarms were not experienced prior to the transfer of water from the Orange River in the mid-1970's.

The aim of setting capping flows:
To maintain as much of the natural diversity of flows (and therefore habitats) in a river as possible; to prevent the dominance of any one type of high flow; and to prevent reversal of seasonal flows (eg winter flows higher than summer flows in summer rainfall areas).

Guidelines for setting capping flows:
(The following guidelines were developed at the Maguga IFR Worksession on the Komati river)

1. No constant increase in winter base flows
2. Constant winter baseflows should not exceed summer baseflows
3. Maintain as much of natural flow variability as possible

And for hydro-power releases:

4. No frequent flow rate changes (at daily/weekly scales)
5. Changes in release rates should be gradual.

Quantifying Capping Flows:
It is extremely difficult to set precise limits for capping flows, because it is probably the relative seasonal changes in flow, and the maintenance of variability that is more important than actual discharge levels. For example, to set winter capping flows at 3 cumecs might be interpreted as allowing for constant flows of 2.9 cumecs through winter. It might also be interpreted as an embargo on **any** flows exceeding 3 cumecs. **Neither of these interpretations would be correct**.

The capping flows that are set should therefore be interpreted in the spirit of the above guidelines. In these terms a winter capping flow of 3 cumecs means that winter flows should fluctuate between the recommended IFR maintenance baseflow and 3 cumecs, but should be allowed to exceed this range in the event of unseasonal rainfall events, and to fall to the IFR drought recommendations during very dry years

The following rules for operating between the two dam sites were specified:

- No constant increase in winter base flows.
- No frequent flow rate changes at daily / weekly scales.
- Winter base flows not to exceed summer base flows.
- Maintain as much as possible of natural variability.
- Slow rates of change.

It became apparent that the river reach between the Smithfield and Impendle dams could be managed in such a way to avoid the above issues.

CHAPTER 8 : FURTHER WORK

Further work was specified during the specialist meeting which specifically relates to short-term practical work that could be undertaken to raise the confidence in the IFRs. The following aspects which require further work were specified:

- Low flow hydraulic measurements required to calibrate the hydraulic stage discharge curve. This is specifically relevant for IFR sites 2 and 4 which were used for the detailed IFR.
- Low flow photos - associated with the above.
- Confirm distribution of depth of hygrophilous community.
- Determine whether flooding or grazing are effecting the terraces.
- Low flow surveys of geomorphology / invertebrate habitats.
- Fish survey at IFR 4
- Impacts of natural barriers on fish migration (for future recommendations and motivations for fish ladders).
- Check riparian vegetation flood indicators at IFR site 4.
- Aquatic invertebrate surveys at IFR 4
- Geomorphology : natural and present sediment regimes need to be investigated as well as the effects of dams (long term study)

Continued monitoring of water quality should be undertaken, especially to determine the effects of low flows. This should be part of a continued monitoring programme.

The issue of catchment management was repeatedly raised as the flow regime alone will not be effective in maintaining the protection class without some aspects of catchment management in place. Umgeni Water made the following statement during the specialist meeting:

'It is quite apparent that catchment planning and management is an important issue. Therefore a message must be taken forward to DWAF and Umgeni Water that such action is necessary. The appropriate place for this recommendation to originate is the Environmental Task Group. That group should pick up on existing initiatives and find means to continue them. The Umkomaas Trust is not really effective at the present due to the lack of time (money) of the parties involved. It is thus suggested that DWAF is tasked to find the means of moving this forward. This should be an integral part of the environmental / social component of the whole project.'

Other aspects that were raised were the following:

- Project Planning (Mr Geringer) will provide Ms Louw with a list of all the implications of releasing and operating IFRs with specific reference to operational and design problems. The possible consequences will also be listed. These lists will be provided in a matrix format to the specialists to obtain from them which of the scenarios have serious implications to the environment.
- The various specialists that should be involved in studies identified in this chapter must provide a budget to IWR Environmental which will compile a proposal to forward to Ninham Shand (Mr Peter Blersch).

REFERENCES

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Kleynhans, C. J. 1996. A qualitative procedure of the conservation status of the Luvuvhu River (Limpopo system, South Africa).5: 1-14. Journal of Aquatic Ecosystem Health

APPENDIX A : PROGRAMME & PARTICIPANTS

MKOMAZI IFR STUDY

PROGRAMME

24 - 27 MARCH 1998
SCOTTBURGH

WORKSHOP OBJECTIVE

To determine the IFR for the Mkomazi River downstream from the Impendle Dam site to the estuary. The capability of the dams to provide the IFRs will NOT be taken into account during the workshop, but the proposed operation of the dam will be taken into account to aid in the setting of capping flows.

FACILITATOR : J O'KEEFFE
IFR CO-ORDINATOR : MD LOUW

ARRIVAL (non PMB participants) : MONDAY 23 MARCH 1998

ARRIVE REHOBOTH CHALETS (PIETERMARITZBURGH)

DAY 1 : TUESDAY 24 MARCH 1998

SITE VISIT
(DETAIL PROGRAMME IN SITE VISIT DOCUMENT)

07:00 MEET AT LUNDY'S HILL GAUGE

07:00	BREAKFAST AND INTRODUCTION
07:30	INVESTIGATION AT IFR 1 (Lundy's Hill)
09:00	DEPARTURE TO IFR 2 (Hela Hela)
10:00	INVESTIGATION IFR 2
11:30	DEPARTURE TO IFR 3 (Snt Josephine)
12:30	INVESTIGATION AND LUNCH IFR 3
14:00	DEPARTURE TO IFR 4
16:00	INVESTIGATION IFR 4

17:30	DEPARTURE TO BLUE MARLIN		
18:00	ARRIVAL BLUE MARLIN		

DAY 2 : WEDNESDAY 25 MARCH 1998

07:00	**[60]**	**BREAKFAST**	
08:00	[30]		HYDROLOGY OF THE IFR SITES D Hughes
08:30	[1h]		DESIRED FUTURE STATE FINALISATION AND DISCUSSION D Louw & J O'Keeffe
09:30	[30]		CONFIDENCE OF SITES FOR DETERMINING IFRs & SELECTION OF SITES FOR DETAIL IFR
10:00	**[30]**	**TEA**	
10:30	[2h]		DETERMINATION OF MAINTENANCE IFR ON SELECTED SITE
12:30	**[60]**	**LUNCH**	
13:30	[3h]		CONTINUE WITH PREVIOUS SESSION
16:30	[1h]		DETERMINATION OF DROUGHT IFR ON SELECTED SITE
17:30	**CLOSURE**		
19:30	**DINNER**		

DAY 3 : THURSDAY 26 MARCH 1998

07:00	**[60]**	**BREAKFAST**	
08:00	[1h]		CONTINUE WITH PREVIOUS SESSION
09:00	[1h]		CHECK RESULTS WITH NEXT IFR SITE

10:00	**[30]**	**TEA**
10:30	[2h]	DETERMINATION OF MAINTENANCE IFR ON SELECTED SITE
12:30	**[60]**	**LUNCH**
13:30	[2h]	CONTINUE WITH PREVIOUS SESSION
15:30	[1h]	DETERMINATION OF DROUGHT FLOWS ON SELECTED SITE
16:30	[30]	CHECK RESULTS WITH NEXT IFR SITE
17:00	**CLOSURE**	
19:30	**DINNER**	

DAY 4 : FRIDAY 27 MARCH 1998

07:00	**[60]**	**BREAKFAST**
08:00	[30]	MOTIVATED CONFIDENCE IN IFR RESULTS
08:30	[10]	PROPOSED OPERATION OF DAMS
08:40	[60]	SETTING OF CAPPING FLOWS
09:40	**[20]**	**TEA**
10:00	[2,5h]	DETERMINING OF FINAL IFRS LINKED TO A NATURAL TRIGGER BY CALIBRATING IFR RELEASE MODEL
12:30	**[1h]**	**LUNCH**
13:30	[60]	PRESENTATION OF DAM MODEL
14:30	[30]	FURTHER WORK & NEXT STEPS
15:00	**CLOSURE & DEPARTURE**	

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APPENDIX B
MKOMAZI -MGENI TRANSFER PRE-FEASIBILITY STUDY
ENGINEERING AND OPERATIONAL ASPECTS

1. GENERAL

The Reconnaissance phase of the Study has been completed and the Pre- feasibility phase is currently in progress. During the Reconnaissance phase, a number of possible schemes were identified and evaluated. Of these, two were selected for further study, namely the:

Impendle Scheme: A dam near Impendle, constructed in two, or possibly three phases, with a tunnel transferring water by gravity to Midmar Dam; and

Smithfield-Baynesfield Scheme: A first phase dam at Smithfield, with a pumpstation and tunnel transferring water to a waterworks near Baynesfield, followed by a second phase dam at Impendle.

It should be noted that the sizing of the schemes is preliminary and will be refined on the basis of further yield analyses once the IFR of each scheme has been determined.

2. SCHEME CHARACTERISTICS

The main characteristics of the schemes are as follows:

Impendle Scheme

Mean Annual Runoff (MAR)at dam site:	560 million m^3/a
Dam capacity (Phase 1, 2, 3):	58, 200, 680 million m^3
Historical firm yield (Phase 1, 2, 3):	115, 200, 380 million m^3
Dam wall height (Phase 1, 2, 3):	58, 73, 90 m
Dam type:	Rockfill with uncontrolled side channel spillway
Dam outlet works:	Multi-level intake tower, conduit, outlet works with sleeve valves
Dam outlet capacity:	Not yet defined
Tunnel intake:	Multi-level intake tower, approximately 1 km upstream of dam wall

Smithfield Scheme

Phase 1: Smithfield Dam

Mean Annual Runoff at dam site:	680 million m^3/a
Dam capacity:	170 million m^3
Historical firm yield:	200 million m^3

Dam wall height:	60 m
Dam type:	Rockfill with uncontrolled side channel spillway
Dam outlet works:	Multi-level intake tower, conduit, outlet works with sleeve valves
Dam outlet capacity:	Not yet defined
Tunnel intake:	Multi-level intake tower, approximately 1 km upstream of dam wall

Phase 2: Impendle Dam

Mean Annual Runoff at dam site:	560 million m^3/a
Dam capacity:	560 million m^3
Historical firm yield (Combined):	461 million m^3
Dam wall height:	60 m
Dam type:	Rockfill with uncontrolled side channel spillway
Dam outlet works:	Multi-level intake tower, conduit, outlet works with sleeve valves
Dam outlet capacity:	Not yet defined
Tunnel intake:	None

Note that the historical firm yields given above do not include an IFR allowance.

As indicated above, the dams will have uncontrolled spillways. The first phase dams are relatively small in relation to MAR and would therefore have a limited attenuating effect on small to moderate flood events. However, the second and third phase dams are large and their effect on floods will be more significant. These impacts have not yet been quantified

3. OPERATING PROCEDURES

3.1 Impendle Scheme

Water for transfer will be abstracted via the tunnel intake structure within the dam basin. Abstraction rates will be limited by tunnel capacity, but will be relatively flexible due to the large storage capacity at the delivery end (Midmar Dam). Water would not be transferred at times when Midmar Dam is full. For preliminary planning purposes, it was assumed that 340 million m^3 would ultimately be transferred.

River releases will be via the multi-level intake tower and conduit, enabling water to be drawn off near the surface of the reservoir. The outlets will be controlled with sleeve valves, enabling a wide range of flows to be released. Excluding IFR releases, which are, as yet, undefined, downstream demands are small in relation to the MAR.

3.2 Smithfield Scheme

Water for transfer will be abstracted via the tunnel intake structure within the Smithfield dam basin. Abstraction rates will be limited by pumpstation capacity, and will be demand-driven, as there is only limited storage provided at the delivery end (Midmar Dam). Water would be transferred virtually continuously. For preliminary planning purposes, it was assumed that 410 million m^3 would ultimately be transferred.

River releases from the Smithfield Dam will be via the multi-level intake tower and conduit, enabling water to be drawn off near the surface of the reservoir. The outlets will be controlled with sleeve valves, enabling a wide range of flows to be released. Excluding the as yet undefined IFR releases, downstream demands are also small in relation to the MAR.

In the second phase, water will be released from the Impendle Dam via the river to the Smithfield Dam, from where transfers will take place. The configuration of the Impendle Dam outlet works will be similar to that of the Smithfield Dam. The storage capacity of the Smithfield Dam will allow a great deal of flexibility in release patterns from the Impendle Dam and it will not be necessary to, for example, create excessively high dry season flows in the reach of river between the two dams.

PETER BLERSCH **NINHAM SHAND**

1998-03-02

APPENDIX C : SUMMARY OF IFR PLANNING MEETING

3.2 IFR PLANNING MEETING

Delana Louw, IWR Environmental

The IFR planning meeting is the first step in the IFR process following the determination of the Habitat Integrity. The purpose of the IFR meeting is to

- plan the IFR study;
- determine whether relevant information is available;
- determine the information required and correct format;
- ensure liaison between disciplines;
- undertake preliminary workshop planning;
- determine IFR reaches and number of sites;
- select possible sites from video;

The following is a summary of the minutes reflecting the process and decisions taken during the Mkomazi IFR planning meeting.

3.2.1 PARTICIPATION

The following persons participated in the meeting

- IWR & IWR Environmental : Prof J O'Keeffe, Ms D Louw, Mr N Kemper, Prof D Hughes, Prof K Rowntree, Mr E Doller.
- Streamflow Solutions: Mr A Birkhead
- Umgeni Water: Dr C Dickens, Mr D Simpson, Mr G Jewitt
- Ninham Shand: Mr P Blersch
- Geo-Environmental Services: Mr A Smith
- Natal University: Dr T Edwards
- Alletson Ecologicals: Mr J Alletson

3.2.2 PURPOSE OF THE MEETING AND ACTIONS REQUIRED FOR THE IFR STUDY

The actions that have been undertaken for the study and are still required are stipulated in the table below:

ACTIONS	DETAIL	PROGRAMME
BUDGET & PROPOSAL	Id study area Id team members Id possible extent of work required	Dec 96
HABITAT INTEGRITY	Helicopter flight & video Status report	Sept 97 Oct 97
IFR PLANNING MEETING	Bring team members together Plan work required Plan IFR sites Plan workshop	13 Oct 97
SELECTION OF IFR SITES	Video analysis Ground truthing First hydraulic calibration	13 - 16 Oct 97
DESIRED FUTURE STATE	Preliminary determination of DFS Comments from task group	13 - 16 Oct 97 23 Oct 97
ECOLOGICAL & BIOPHYSICAL STUDIES	Fish, invert, geomorph & rip veg surveys and starter doc reporting	Oct 97 - Feb 98
HYDROLOGICAL & HYDRAULIC STUDIES	Hydrological modelling and preparation of presentations Hydraulic calibration Hydraulic modelling and presentation	Oct 97 - Feb 98
STARTER DOCUMENT	Obtaining papers from participants Compiling document Sending document out	Month before workshop - Feb 98
WORKSHOP	Site visit IFR determination Confidence determination IFR modelling	March 98
REPORT	Compilation of workshop results Comments by participants Final report	April 98

3.2.3 IFR INFORMATION REQUIREMENTS

INFO NECESSARY	INFO AVAILABLE	STATUS	ACTIONS
HABITAT INTEGRITY (Kemper)	Video Preliminary results	incomplete	Detail report for starter document.
IFR SITES (Louw)	Video	incomplete	Selection by video. Ground truthing. Pro's and con's of sites from team. Report for starter document.
FLUVIAL GEOMORPH (Rowntree)	Reach analysis	incomplete	Reporting of reach analysis, hydraulic biotopes, and sites for starter doc. Obtain info from Jewitt re sedimentation - land use and vegetation cover.
RIPARIAN VEGETATION (Kemper)	Video	incomplete	Species to be identified on cross-section, analysis of requirements, report for starter document. Analysis of zones for presentation on cross-section - to be given to Birkhead. Edwards to mark diversity along the length of the river. Map to be available for starter document. Also to undertake extensive surveys on IFR sites.
FISH (Coke)	Extremely sparse database	incomplete	Surveys will be undertaken prior to the workshop to augment the limited database. Report to be supplied for starter document.
AQUATIC INVERTEBRATES (Dickens)	Invertebrate surveys	incomplete	Surveys and collection finalised at 5 sites Analysis by De Moor being undertaken. New data to be compared with some historic data of the 70's. Paper for starter document to be prepared.
WATER QUALITY (Simpson)	Umgeni Water sampling points	incomplete	General info known re Mkomazi water quality is the following: • Good water quality, better in upper than lower catchment. • Low in nutrients with no point sources in upper catchment. • High turbidity and suspended solids concentrations with high runoff. • Compared to Midmar catchment - lower in nutrients and E. coli due to less agriculture and settlement; - higher for turbidity and suspended solids due to erosion. Report for starter document required. Liaison with O'Keeffe required. Dickens to provide examples of previous IFR reports.

SOCIAL (Huggins)	Surveys	incomplete	Input re DFS and social importance of the river. Report for starter document.
HYDROLOGY (Hughes)	DWAF records of 2 gauges and BKS analysis	incomplete	Good records from the 1960's are available. Patching of the data is required. Analysis of data for the workshop is required as well as the IFR modelling.
HYDRAULICS (Birkhead)	None	incomplete	Survey of the sites. Calibrations (flow measurements and water level measurements). Modelling. Presentation of profiles and stage discharge curves. Presentation of vegetation zones on profiles.
PHOTO-POINT MONITORING (Louw & others)	None	incomplete	Upstream and downstream photographs of IFR sites (cross-section) at fixed points at each occasion when a flow measurement is undertaken. Comparative arrangements of photo's. Posters for workshop.
RIVER IMPORTANCE (J Alleison)	Habitat integrity Background by Dickens Social study	incomplete	Collect data from Mkomazi and compare to rivers around the catchment and wider. Liaise with Huggins - request to add questions to survey list specifically to determine social importance of the river. Report for the starter document.
DESIRED FUTURE STATE (Louw, O'Keeffe)	Methodology available	incomplete	Habitat integrity results. Specialist on the ground visit. Determining present state category. Determining environmental importance. Presentation to ETG for comment. Preliminary DFS category. Ground truthing during surveys. Report for starter document. Final DFS determination during workshop.

3.2.4 IFR WORKSHOP

- **Approach**

The approach followed at the workshop will be a one group approach, therefore the workshop will be limited to approximately 16 persons.

The following steps will be followed during the workshop:

- Site visit with discussion of papers on site;
- DFS discussion;
- Determine confidence in IFR sites;

- Select 2 IFR sites for detail IFR;
- Determine IFR for above sites;
- Extrapolate and test to other sites based on above results;
- IFR modelling with results to determine final IFR;
- Determine confidence of IFR results;
- Stipulate next steps required;

- **Participants**

PARTICIPANTS	
1. Facilitator	O'Keeffe
2. IFR co-ordinator & report	Louw
3. Invertebrates	Dickens
4. Fluvial geomorphology	Rowntree
5. Hydrology	Hughes
6. Hydraulics	Birkhead
7. Water quality	Simpson
8. Riparian vegetation	Kemper
9. Fish	M Coke
10. River importance	J Alletson
11. Social	G Huggins
12. Engineering	P Blersch
Training 14. Geomorphology	A Smith
15. Riparian vegetation	T Edwards
Other Client	W Shafer
Client	G Munro/J Geringer
Water Law and ecological reserve - Client	H MacKay

It was decided that the approach experienced by Ms Louw and Prof O'Keeffe in Australia would be applied. ETG members will be invited to observe the process on a daily basis. Any members or somebody from the body they represented will therefore be welcome to come to any or all of the days. However strict guidelines will form part of the invitation. Persons will be able to act as observers only, comments can be given at the follow-up ETG meeting. Due to the severe time constraints during such a workshop, no disruptions during the workshop can be accommodated.

- **Contents of starter document**

The contents for this document and the responsibilities for the chapters were allocated.

APPENDIX D : MKOMAZI IFR SITE SELECTION

MD Louw & NP Kemper (IWR Environmental)
With input from the IFR site selection team

This paper aims to

- give a detail explanation of the function of IFR sites;
- explain the theoretical approach to select IFR sites;
- document the IFR site selection process specific to the Mkomazi study.

REFER TO MAPS IN LOCALITY SECTION OF STARTER DOCUMENT

1. PURPOSE OF IFR SITES

In order to determine the Instream Flow Requirements (IFRs) of a river system, it is necessary to determine the flow requirements at a number of points within the system.

More than one IFR site is usually selected within the system for a number of reasons:

- Tributaries entering the system may introduce different channel, bank and or habitat conditions which may need to be considered separately.
- The Desired Future State (DFS) of particular reaches of the river may differ from the rest and may therefore require specific IFR.
- A river system displays biological diversity along its length, and consequently, a single IFR point is unlikely to adequately reflect this range of diversity.
- Various hydrological stage points are required within the system to cater for the inflows of tributaries and losses down the length of the system.

A range of hydrological, hydraulic, geomorphological and ecological data is collected at each IFR site. This information is then utilised during the IFR workshop to determine the IFR for the system.

2. SELECTION OF IFR SITES

The selection of IFR sites is guided by a number of considerations such as:

- The locality of gauging weirs with good quality hydrological data.
- The locality of the proposed developments.
- The locality and characteristics of tributaries.
- The habitat integrity/conservation status of the different river reaches.
- The reaches where social communities depend on a healthy river ecosystem.

- The suitability of the sites for follow-up monitoring.
- The habitat diversity for aquatic organisms, marginal and riparian vegetation.
- The suitability of the sites for accurate hydraulic modelling throughout the range of possible flows, especially low flows.
- Accessibility of the sites.
- An area or site that could be critical for ecosystem functioning. This is often a riffle which will stop flowing during periods of low or no flow. Cessation of flow constitutes a break in the functioning of the river. Those biota dependant on this habitat and/or on continuity of flow will be adversely affected. Pools are not considered as critical since they are still able to function as an ecosystem or at least maintain life during periods of no flow.
- The locality of geomorphological reaches and representative reaches within the geomorphological reaches.

When selecting IFR sites, a decision making process is followed which consists of the following steps:

2.1 IFR STUDY AREA

The first step in selecting the IFR sites is to define this area. This is also necessary due to the inherent complexity of river systems, and the need to confine the IFR assessment to specific stretches of the river.

Factors which were considered for this study were the location of features such as the proposed development (which will define its upstream extent), perennial tributaries and points of access.

The study area was defined as the Mkomazi River downstream from the proposed Impendle Dam to the estuary.

2.2 SELECTING RIVER STRETCHES IN WHICH IFR SITES SHOULD BE SITUATED

Prior to selecting the IFR sites, river stretches in which the IFR sites must be situated are identified on a map with input from hydrologists, river ecologists and planners. (Note that the term stretches are used here as these river stretches are different from the geomorphological reach) The same considerations as described under 2 are applicable when selecting the river stretches.

During the IFR planning meeting (13/10/97), possible stretches were suggested within which the IFR sites should be situated based on the results of the habitat integrity analysis and the geomorphological macro reaches. The stretches were the following:

- Impendle Dam site to the end of the geomorphological macro reach.
- From the above border to the end of the next geomorphological macro reach.
- From the above border to upstream of the estuary. Due to the length of this stretch, it was decided to have two sites in it equally spaced.

The lack of distinct large tributaries made the process difficult to select with confidence logical reaches. It was decided that the above decision will be revisited after the video has been viewed. After the site visit, the geomorphologist indicated that the most downstream IFR stretch actually consists of two geomorphological reaches and that a site should be selected in each. The last stretch was therefore divided into two reaches with a site in each.

2.3 HELICOPTER FLIGHT TO SELECT IFR SITES

The process of selecting IFR sites can be aided by means of a helicopter flight which is usually undertaken for the sake of the Habitat Integrity analysis and capturing the river on video. During this flight, the location of potential IFR sites are recorded using a GPS (Global Positioning System).

2.4 USE OF THE RIVER VIDEO FOR THE IDENTIFICATION OF POSSIBLE IFR SITES

A multi-disciplinary team is identified to select the IFR sites. This team consists of the IFR co-ordinator, a riparian vegetation specialist, a fluvial geomorphologist, the relevant fish and aquatic invertebrate specialist and an hydraulic engineer.

The following persons formed part of the IFR sites selection team:

C Dickens	Aquatic invertebrates -
D Louw	IFR co-ordinator, IFR site selection
N Kemper	Riparian vegetation
M Coke	Fish
A Birkhead	Hydraulics
K Rowntree	Fluvial Geomorphology
A Smith	Geologist

The first step in this process requires viewing of the stretches identified in 2.2 and the sites identified during 2.3. The objective of this is to eliminate possible IFR sites and to streamline the next step in the process, i.e. the identification of the sites on the ground.

The video was watched by the site selection team and all possible IFR sites with access were selected. Thereafter theses sites were again investigated to narrow it down to possible options. Due to the difficulty of undertaking flow measurements at all the sites, it was specified that two sites should be located near the upstream and the downstream gauge. During the ground truthing exercise (see next point), the video was repeatedly scrutinised when problems with sites selected from the video were experienced and alternatives selected.

2.5 GROUND TRUTHING - FINAL SELECTION OF SITES

IFR stretch 1 : Two sites near the gauge were visited and the more downstream site selected as it represented more diversity in habitat and it occurred on a straight river stretch compared to the upstream site.

IFR stretch 2 : One site was selected from the video in the reasonable pristine area in this stretch. The site was found to be biologically diverse and suitable but hydraulically complex. The video was viewed again and a site just downstream of the site that was more favourable for hydraulic calculations were selected.

IFR stretch 3 : One site was selected that was situated midway between the IFR site 2 and the possible IFR site 4. The access to this site was however problematic during rains even with 4x4 vehicles. It was therefore decided that the risk that the site could not be visited during periods required for site visits etc was too high and the video was again viewed. The only other reasonable access site was near Josephine's Bridge and a site was selected near the bridge. Although this site was quite close to the most downstream site, it was still situated in a the same geomorphological macro reach and the site was therefore deemed suitable.

IFR stretch 4 : This area is quite disturbed and sedimentation in the river is present. The sites will be difficult to utilise during IFR determination. The most suitable site was selected from the video and found to be suitable during the site visit.

2.5.1 PLACING OF CROSS-SECTIONS

After the site is selected, the cross sections have to be placed exactly. This is also done on a multi-disciplinary basis, with the hydraulics being the overriding factor. Each site was investigated longitudinally on both banks and decisions were made as follows:

IFR 1 : Lundy's Hill

Three cross-sections were selected.
A : The most upstream section runs through a pool at the head of the riffle. This site was selected for riparian vegetation requirements, but will also be utilised for geomorphology.
B : The middle section runs through the riffle and is selected for the instream components.
C : A downstream section that crosses a pool was selected. This section was selected for geomorphological reasons as it crosses an area with sand and boulder deposits.

IFR 2 : Hella Hella

A : An upstream cross-section in the pool section just upstream of the rapid was selected for riparian vegetation and geomorphological purposes.
B : A cross-section near the downstream end of the rapid was selected for the instream components. The cross-section was selected near the end of riffle as small cobbles are deposited between the boulders where the velocity decreases, creating more habitat for aquatic invertebrates.

IFR 3 : Snt Josephine's Bridge

Only one cross-section through the riffle was selected. It was placed best suited for the riparian and geomorphologically uses crossing the downstream bit of a high flow secondary channel.

IFR 4 : Mfume

Only one cross-section was selected based on hydraulics and to cover the most variety of instream habitats.

3. CHARACTERISTICS, ADVANTAGES AND DISADVANTAGES OF IFR SITES

3.1 IFR 1 : LUNDY'S HILL

Coordinates : S 29° 44,603 E 29°54,688
Locality : Situated about 1 km downstream of the Camden gauge, just downstream of the arch bridge (gravel bridge) next to the tar bridge.

Advantages:

- Accessible by any vehicle.
- No flow measurements required in the main stream as the gauge could be utilised.
- View for fixed photo-point monitoring excellent.

Invertebrates

- Some moveable stones in current in the island, and also some vegetation.

Fish

- Habitat diversity better on right bank than on left.

Riparian vegetation

- Both banks have good vegetation cover
- LIIB best with well defined riparian zone and *C. erythrophyllum* in a flood channel situation
- typical of vegetation in that reach of the river
- access to vegetation very good due to bridge

Geomorphology

- Representation of macro-reach satisfactory.
- Well-defined bank morhpology.
- Good range of instream morphological assemblages
- Good hydraulic habitat diversity.
- Pools allow assessment of aggradation potential

Hydraulics

- The location of upstream gauging weir (1km) that will be used to accurately measure discharge.

DISADVANTAGES

- A small stream comes in between the gauge and the site which needs to be measured.

Aquatic invertebrates

- Diversity of habitat fairly poor and dominated by fast moving water and bedrock.
- Pools, proper stones out of current, mud banks and softer submerged vegetation (sedge bases only available) are not present. (Pools on the bedrock on the left bank, that are fed by seepage and by flood waters, were not sampled as they appeared to be independent of instream flows. They would nevertheless be altered during times of high flow.)

Fish

- Habitat diversity is less than at the site upstream of the bridge. Sampling will need to be spread out to encompass best options.

Riparian vegetation

- RHB comprised of high mudstone banks, vegetation is therefore not all riparian, some is dry terrestrial stuff
- high flood and annual flood levels are difficult to determine by vegetation characteristics due to unexplained *C. erythrophyllum* distribution at a very high level
- grazing a serious problem

Geomorphology

- No obvious disadvantages

Hydraulics

- Small tributary entering the river between the site and gauging weir.
- Influence of bedrock likely to result in non-zero flow depths at
- the cessation of flow, particularly at the upstream (A) and
- downstream (C) cross-sections that run through pools.
- Non-horizontal flow levels within the middle cross-section (B) positioned
- through a rapid.
- Non-uniform flow conditions at the site.

3.2 IFR 2 : HELLA HELLA

Coordinates : S 29°55,260 E 30° 05,069
Locality : Located approximately 1,5 km downstream of the Hella Hella bridge.

ADVANTAGES

- Site is accessible with a high clearance vehicle.
- Clear view for fixed photo point monitoring.
- Site representative of the undisturbed gorge wilderness area.
- Bridge near by for flow measurements during high flows.

Aquatic invertebrates

- The base of the riffle contained more, but only a few, loose stones in current.
- Also the bar near the middle of the river had more loose cobbles.
- Abundant reeds on the riparian zone, well inundated.

Fish

- Fairly good habitat diversity

Riparian vegetation

- *S. guinieense* individuals on LHB which could be used ?????

Fluvial geomorphology

- Well defined bank morphology
- Satisfactory range of instream morphologies
- Satisfactory diversity of hydraulic habitat

Hydraulics

- The location of a reasonable measuring site upstream of section A.

DISADVANTAGES

No gauge therefore hand flow measurements which is difficult during medium flows due to the depth of the pool are required.

Aquatic invertebrates

- Habitat diversity fairly poor.
- Dominated by high velocities.
- Very few moveable stones.

Fish

- Narrowness of river bed makes it difficult to sample at moderate and high flows. Other nearby sites will need to be sampled to supplement data.

Riparian vegetation

- riparian zone depleted of vegetation
- few remnant indicator species remaining which can be used
- mostly terrestrial and exotic species
- access to RHB not possible at time of site visit
- RHB riparian zone poor
- grazing a serious problem

Fluvial Geomorphology

- Not representative of anabranching channel systems which are very common with this macro-reach.
- Channel steeped and narrower than average.

Hydraulics

- Potential for non-horizontal water profiles at low flows at the downstream cross-section (A), which runs through a boulder rapid.
- Difficulty of obtaining accurate measurements of stage due to wave action along the banks at intermediate and high flows.

3.3 IFR 3 : SNT JOSEPHINE'S BRIDGE

Coordinates : S 30° 00,492 E 30° 14,342
Locality : Approximately 500 m upstream of the bridge.

ADVANTAGES

- Site accessible with high clearance vehicle.
- Photo point monitoring opportunities good - clear view of the site both upstream and downstream.

Aquatic invertebrates

- Riffle present

Fish

- Site not seen. Area has nice and varied habitat diversity.

Riparian vegetation

- *C. erythrophyllum* individual on LHB possibly could be used ???
- *Ficus sur* on RHB could possibly be used ???

Fluvial Geomorphology

- Reasonably representative of longer reach
- Cross-section across riffle has clear bank morphology on the RHB
- Upstream pool should allow assessment of aggradation potential

Hydraulics

- The location of a reasonable measuring site in the pool upstream of the section.

DISADVANTAGES

- Disturbed site.
- Need a boat to gauge during low flows.
- Limited habitat variability

Aquatic invertebrates

- Of all the sites, the most limited in habitat diversity, basically a uniform riffle with a pool above.

Fish

- Site not seen : Rocks where previously sampled was slimy and slippery, making shocking difficult.

Riparian vegetation

- riparian zone depleted of vegetation
- mostly exotic and terrestrial species present
- access to RHB not possible during site visit
- grazing a serious problem

Fluvial Geomorphology

- No obvious disadvantages

Hydraulics

- Potential for non-horizontal water profiles at low flows for the cross-section which runs through a boulder rapid.
- Non-uniform flow conditions at the site.
- Difficulty of obtaining accurate measurements of stage due to wave action along the banks at intermediate and high flows.

3.4 IFR 4 : MFUME

Coordinates: S 30°07,575 E 30°40,122
Locality: Site situated about 10 km upstream of the Good Enough Weir.

ADVANTAGES :

- Near a good gauging weir - no flow measurements required.
- Photo-point monitoring view good.
- Access good for normal vehicle.

Aquatic invertebrates

- Good habitat, especially along the edges, (backwaters etc).
- Range of flow velocities.

Fish

- Site not seen : Sandy habitat may favour fresh water gobies but not a large diversity of species.

Riparian vegetation

- *Millettia grandis* present on LHB, could be used for bank recharge ??

Fluvial geomorphology

- Reasonable representation of lower reaches of macro reach
- Satisfactory definition of bank morphology

Hydraulics

- The location of a downstream gauging weir (6km) that will be used to accurately measure discharge.

DISADVANTAGES

- Area disturbed.
- Sandy river bed which will have subsurface flows present and for which it is difficult to determine habitat requirements.

Aquatic invertebrates

- Dominated bedrock and sand with few stones in current anticipated (not sampled).

Fish

- Siltation probably results in limited habitat diversity.

Riparian vegetation

- riparian zone depleted of vegetation
- access to RHB not possible during site visit
- mainly exotic species present
- grazing a serious problem
- highly disturbed riparian zone

Fluvial geomorphology

- Dominance of bedrock in active channel banks may hinder interpretations of water levels in terms of channel forming discharges.

Hydraulics

- Non-horizontal stages within the channel for the braided site at low flows.
- The potential for change in channel geometry given the alluvial nature of the site.

4. SURVEYING OF THE IFR SITES

After the IFR site selection, cross-sectional surveys are undertaken at the IFR sites. This is done by a survey team under supervision of a hydraulic engineer and with input of the riparian vegetation and fluvial geomorphologist specialists. They indicate exactly which vegetation species and other features they want indicated on the cross-section. The cross-sections are then prepared for the following purposes:

- To indicate where various zones and species of riparian vegetation occur.
- To indicate where specific geomorphological features occur in order to establish required flows for various purposes eg. bankful discharge.
- To establish a stage discharge relationship.

This information is then presented to the workshop for identification of IFR at the sites.

APPENDIX E
A DRAFT ASSESSMENT OF THE HABITAT INTEGRITY OF THE MKOMAZI RIVER SYSTEM

N. KEMPER, IWR ENVIRONMENTAL, March 1998

1. INTRODUCTION

This report is a contribution to the determination of the Instream Flow Requirements for the Mkomazi River. The purpose of this report is to assess the current habitat integrity of the Mkomazi River based on selected key indicator criteria in pre-determined segments of the river. This assessment will also serve as a baseline that will be used to monitor the integrity of the river following future modifications to the flow regime as a consequence of construction of either the Smithfield or Impendle Dams in the short to medium term and other dams lower down in the system in the long term.

The ecological integrity of a river is defined as its ability to support and maintain a balanced, integrated composition of physico-chemical and habitat characteristics, as well as biotic components on a temporal and spatial scale that is comparable to the characteristics of natural ecosystems of a specific region. This definition is based on the concept of biological integrity that has been described as "the ability to support and maintain a balanced, integrated, adaptive community of organisms having a species composition, diversity and functional organisation comparable to that of natural habitat of the region "(Karr and Dudley 1981). Habitat integrity refers to the maintenance of a balanced, integrated composition of physico-chemical and habitat characteristics on a temporal and spatial scale that is comparable to the characteristics of natural habitats of the region. Essentially, the habitat integrity of a river will provide the template for a certain level of biotic integrity to be realised. In this sense the assessment of the habitat integrity of a river can be seen as a precursor of the assessment of biotic integrity. It follows that habitat integrity and biotic integrity together constitutes ecological integrity.

This approach differs from the initial approach used for the assessment of river conservation status that was defined as an assessment of the degree to which the river has been modified from its hypothetical natural state (Kleynhans et al., 1988). Habitat integrity assessment places less emphasis on the hypothetical natural (e.g. pristine) state of the river as a baseline against which to measure deterioration or modification. More importance is placed on the functionality of the river to provide suitable living conditions for biota within the context of the temporal and spatial scale of the habitat compared with what is considered likely to have been the case in the absence of artificially created disturbance regimes. The determination of the natural baseline conditions (including natural disturbance regimes) is essentially based on three data sources (listed in the order of decreasing applicability to the particular river under investigation):

1. Recent and historical information on the specific river itself. This includes information on the hydrology, hydraulics, water quality, catchment characteristics, development, exotic or

alien biota, etc.

2. Recent and historical information on neighbouring rivers within the same region. This would include information on hydrology, hydraulics, water quality, catchment characteristics, development, etc.

3. Recent and historical information on rivers in the same region. This would include information on hydrology, hydraulics, water quality, catchment characteristics, development, etc.

Prior to the assessment of the Levuvhu river (Kleynhans & Engelbrecht, 1994), previous assessments considered the conservation status of the abiotic and biotic components with no separation of the riparian zone and the in-stream channel (Kleynhans, 1992; Kleynhans and Engelbrecht, 1993).

2. METHOD

The method employed for this study was essentially that described by Kleynhans (1996). The same method has subsequently been applied on a number of rivers throughout South Africa namely the Mvoti River (Kemper, 1996), Bivane River (Kemper, 1996) and the Komati River (Kemper, 1998). For the sake of convenience, the description of the method employed was directly transcribed to this report with the necessary additions and changes applicable to this study.

2.1 Information sources

Primary information on the integrity of the Mkomazi River was collected during a low level helicopter survey of the river conducted during September 1997. Prior to the survey the river was divided into 5 km segments from the confluence of the Loteni River about 30 km upstream of the proposed Impendle Dam site, to the sea about 220 km downstream. The coordinates of these segment breaks were determined and stored in a GPS to assist with navigation of the river during the survey. A continuous video recording was made of the segmented portion of the river. The survey was carried out at an altitude of approximately 50 to 200 feet above ground level and the flight path followed the middle of the stream channel as far as possible. To assist with the determination of the exact location of potential IFR sites from the video, a continuous GPS track log was also maintained during the survey.

Additional data of the catchment was also obtained from other readily available sources such as the Reconnaissance Phase Report the development of the Mkomazi River. However, an important contribution to the final analysis is achieved with input from specialist surveys which are conducted for the sake of the IFR workshop itself. The relevant specialist reports were not available during the compilation of this assessment and therefore it was not possible to finalise the assessment at this stage. It is anticipated that findings of the macro-invertebrate, fish and riparian vegetation surveys and the assessment of the geomorphological characteristics of the study area will assist significantly in refining this assessment. A final assessment will be provided at the IFR workshop.

2.2 Data Management and Analysis

During the subsequent viewing of the video material, all assessment data from the survey and the video were transcribed onto field data forms. Information on the following aspects as well as an assessment of the severity of modifications was transcribed for each segment of the river:

Flow (relative abundance); dry (0), none (1), little (2), moderate (3), strong (4).
Water habitat types and relative abundance; Types - fast flowing, pools & ponds, weirs and impoundments; abundance - none (1), few (2), moderate (3), common (4), exclusive (5).
Number of; weirs, impoundments and pumps.
Impact of; roads & bridges, rubbish dumping, bed & channel modification, stream bank erosion, removal of natural riparian vegetation, encroachment by exotic riparian vegetation, presence of cultivated lands and plantations on stream bank and presence of exotic aquatic macrophytes.

General remarks were also made on the following; species of exotic and indigenous riparian vegetation and exotic macrophytes observed; water fauna observed; general description of stream bed; general description of stream bank; general assessment of habitat diversity (including the stream bank) according to, low (1), moderate (2), large (3), very large (4), unique (5).

Criteria considered indicative of the habitat integrity were selected on the basis that modification of their characteristics can generally be regarded as the primary causes of degradation of the habitat integrity of the river. The severity of certain modifications will, therefore, have a detrimental impact on the habitat integrity of a river. The method is primarily habitat oriented with emphasis on a qualitative interpretation of the habitat quality, size, diversity, variability and predictability as influenced by various human made modifications.

An assessment of the severity of impact of modifications is based on six descriptive classes with scores ranging from 0, indicating no impact and 21-25, signifying extremely severe impact. Scoring is guided by a description of the severity of the impact of the modification for each score. Based on the relative importance of the criteria, scores are weighted. Scores for riparian zone and in-stream criteria are summed separately and expressed as a percentage of the maximum (100%) possible. This figure is subtracted from 100 to arrive at an estimate of the habitat integrity. The general descriptive procedure that was used to estimate the impact of modifications is indicated in Table 1.

Table 1. Descriptive classes for the assessment of modification to habitat integrity

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

The criteria used as indicators of the status of the in-stream facet of the river and the weights assigned to these criteria are reflected in Table 2.

Table 2. Criteria and weights used for the assessment of in-stream and riparian zone habitat integrity

IN-STREAM CRITERIA	WEIGHT	RIPARIAN ZONE CRITERIA	WEIGHT
Principle criteria:		Principle criteria	
Water abstraction	14	Indigenous vegetation removal	13
Flow modification	13	Exotic vegetation encroachment	13
Bed modification	13	Bank erosion	14
Channel modification	13	Channel modification	12
Water Quality	14	Water abstraction	13
Inundation	10	Inundation	11
Supplementary criteria:		Supplementary criteria:	
Exotic macrophytes	9	Flow modification	12
Exotic fauna	8	Water quality	13
Solid waste disposal	6		
TOTAL	100	TOTAL	100

Impact was estimated as follows:

Rating for the criteria/maximum value (25) x the weight (%) e.g., it is found that water abstraction is critical and it receives a score of 25. In such a case it has a weight of 14%. If a score of 10 was awarded, the calculation proceeds as follows:

10/25 x 14=5,6

In the case of in-stream criteria, provision was made for principal and supplementary criteria. Principal in-stream criteria are regarded as being of fundamental importance to the maintenance of the habitat integrity of this facet with consideration to the maintenance of the quality and structural characteristics of the habitat. Supplementary in-stream criteria are considered to be of relatively lower importance.

A preliminary assessment of the habitat integrity was made based on these weights. However, as a cautionary measure, the final estimate of the principal criteria of the in-stream facet received an additional negative weight if their impacts were considered to be large, serious or critical. The aim of this approach was to accommodate the possible cumulative (and integrated) negative effects of such impacts. The following arbitrary rules were followed in this respect:

Impact = Large, lower status by 33% of the weight for each criterion of this nature.
Impact = Serious, lower status by 67% of the weight for each criterion of this nature.
Impact = Critical, lower status by 100% of the weight for each criterion of this nature.

These negative weights were added for each facet, where applicable, and the total negative weight subtracted from the provisionally determined status to arrive at a final status estimate. For comparative purposes, both the provisional and final status estimates are indicated for each river.

The eventual scores for the in-stream component are used to place the habitat integrity in a specific descriptive habitat integrity class. Thus, the result of the assessment is primarily descriptive and not quantitative. The habitat integrity assessment classes are indicated in Table 3.

Table 3. Habitat integrity assessment classses

CLASS	DESCRIPTION	SCORE (% OF TOTAL)
A	Unmodified, natural.	90-100
B	Largely natural with few modifications. A small change in natural habitats and biota may have taken place but the ecosystem functions are essentially unchanged.	80-90
C	Moderately modified. A loss and change of natural habitat and biota have occurred but the basic ecosystem functions are still predominantly unchanged.	60-79
D	Largely modified. A large loss of natural habitat, biota and basic ecosystem functions has occurred.	40-59
E	The loss of natural habitat, biota and basic ecosystem functions is extensive.	20-39
F.	Modifications have reached a critical level and the lotic system has been modified completely with an almost complete loss of natural habitat and biota. In the worst instances the basic ecosystem functions have been destroyed and the changes are irreversible.	0-19

All calculations were carried out and associated graphics produced with the aid of a Quattropro spreadsheet shell (Kleynhans, 1994).

3. RESULTS AND DISCUSSION

3.1 In-stream Habitat Integrity

The Mkomazi River study area with its associated river segments is displayed in Fig. 1.
Figure 2 reveals the scores assigned to the in-stream criteria considered during the assessment. Evidently bed modification in the form of sedimentation, inundation, water abstraction and flow modification are the primary components which explain the present in-stream integrity of the river. Figure 3 reveals the integrity scores derived from these criteria for the length of the river. These scores generally reflects a high in-stream integrity score, ranging from a Class D towards the estuary and a Class B for the majority of the river. In the occasional areas this falls to a Class C in response to local disturbances such as abstraction, areas of erosion, inundation etc. This signifies an in-stream component in good condition. Areas of concern for the future would obviously be the extent of erosion and extent of sediment production. This is largely due to the extent of grazing of cattle in the catchment in general, particularly in the riparian zone, where extensive trampling and removal of cover are responsible for extensive areas of erosion.

3.2 Riparian Zone Habitat Integrity

The riparian zone assessment criteria (Figure 4) reveal that vegetation removal, the extent of exotic vegetation infestations, bank erosion and localised inundation of the riparian zone are indeed the major problems in the riparian zone. The integrity of the riparian zone shows a different picture to that of the in-stream component (Figure 5). The integrity of the riparian zone is generally lower throughout the length of the river, and ranges between a Class E towards the estuary and a Class B in some areas. However, it generally displays a Class C integrity. Variation in the integrity of the riparian zone is more pronounced, this is often a consequence of the impact of localised disturbances which commonly affect the status of the riparian zone first. The riparian zone is evidently being impacted extensively by various forms of utilisation, particularly vegetation removal for firewood and building materials and for grazing of cattle. However, a large proportion of vegetation has also been removed by floods such as that of Domoina and the 1987 floods. However, since the pressure of grazing in the riparian zone is so high, very little potential exists for the recovery of the riparian zone. As further grazing and erosion takes place, the integrity is predicted to fall further to the point that the in-stream component will eventually become sedimented up to such a degree that its integrity will also drop to lower levels.

3.3 Total Habitat Integrity

The comparison of the in-stream and riparian zone Habitat Integrity scores (Figure 6) reveals the extent of the differences between the two components. Further degradation of the riparian zone will bring about reductions in the in-stream component

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6. ACKNOWLEDGEMENTS

The author would like to thank Dr. Neels Kleynhans of the Department of Water Affairs and Forestry, Institute for Water Quality Studies for the use of his Quattropro spreadsheet shell compiled for the assessment of Habitat Integrity for Southern African rivers.

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MKOMAZI RIVER
HABITAT INTEGRITY

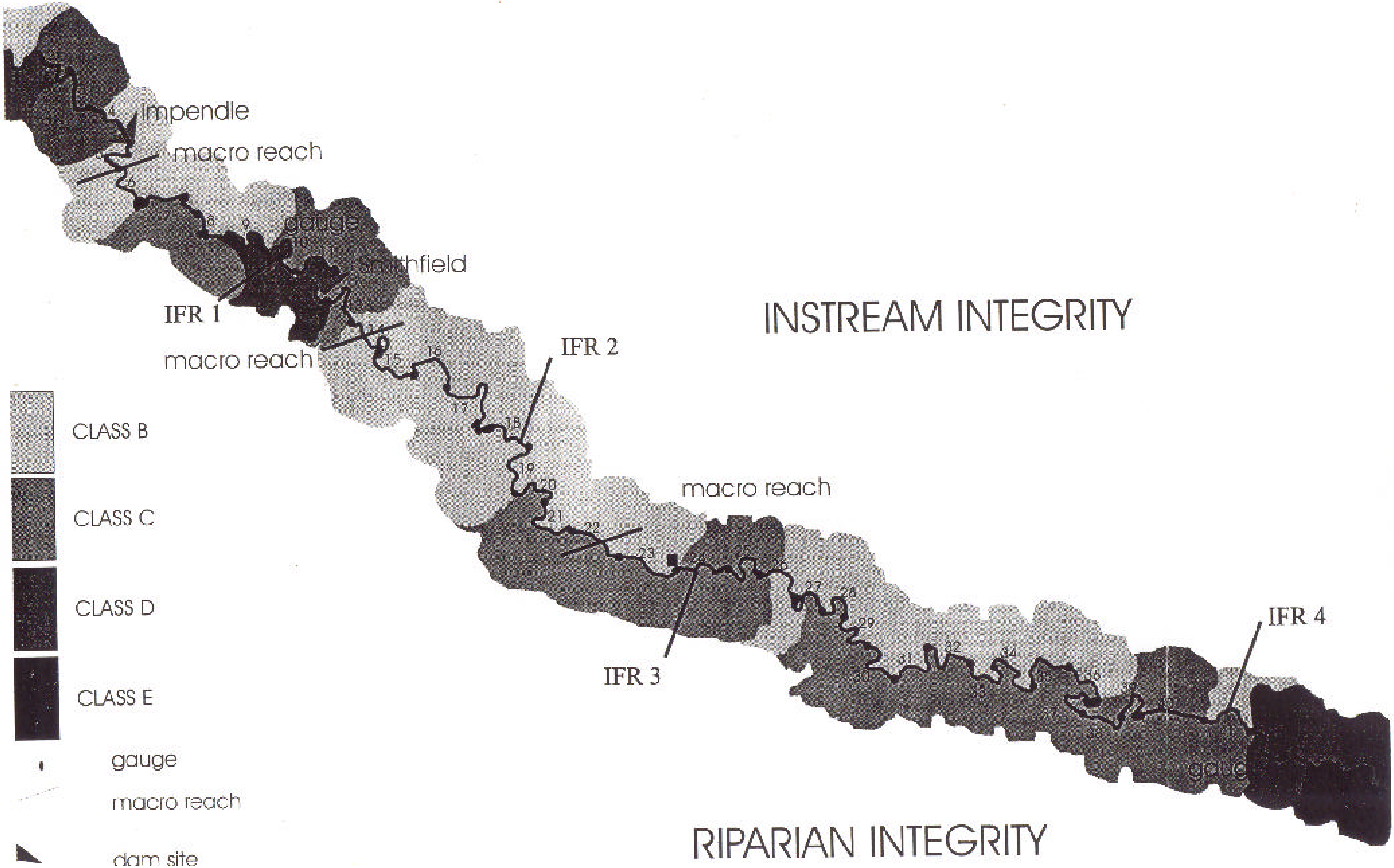


FIGURE 1 - MAP OF THE MKOMAZI RIVER IFR STUDY AREA

Showing 5km segments for Habitat Integrity survey

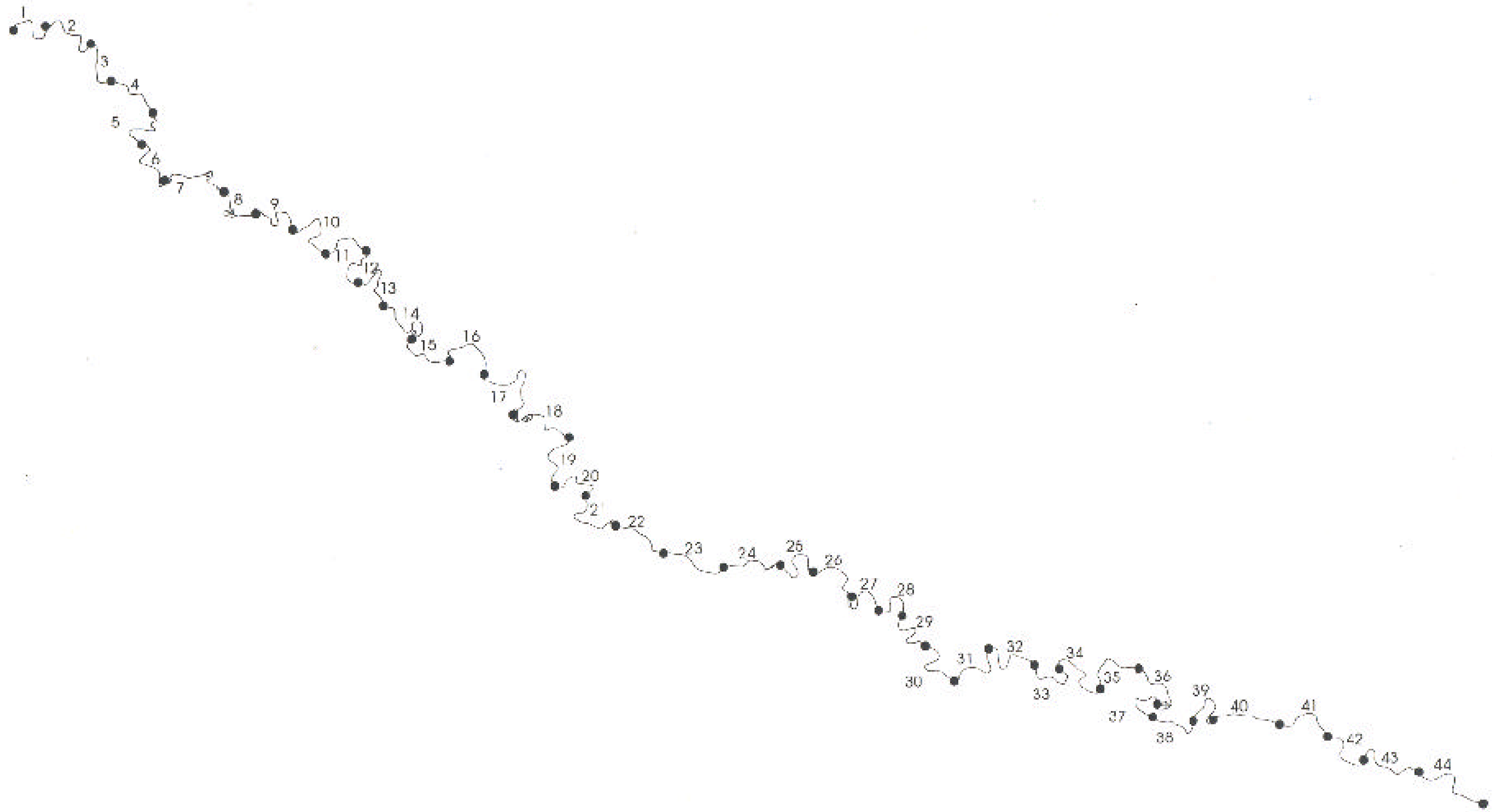


Fig 2: INSTREAM CRITERIA MKOMAZI RIVER

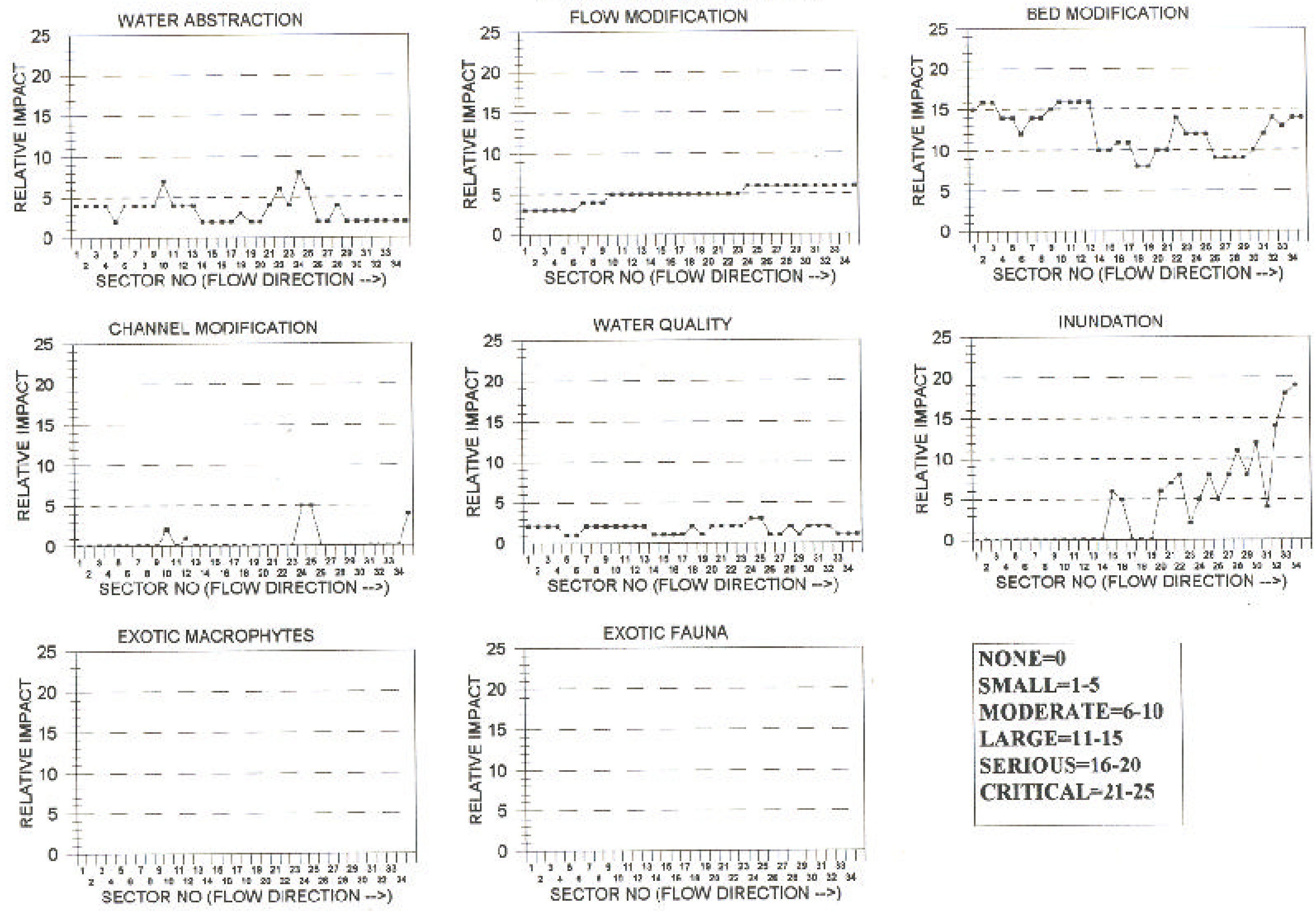


Fig. 3: INSTREAM HABITAT INTEGRITY MKOMAZI RIVER

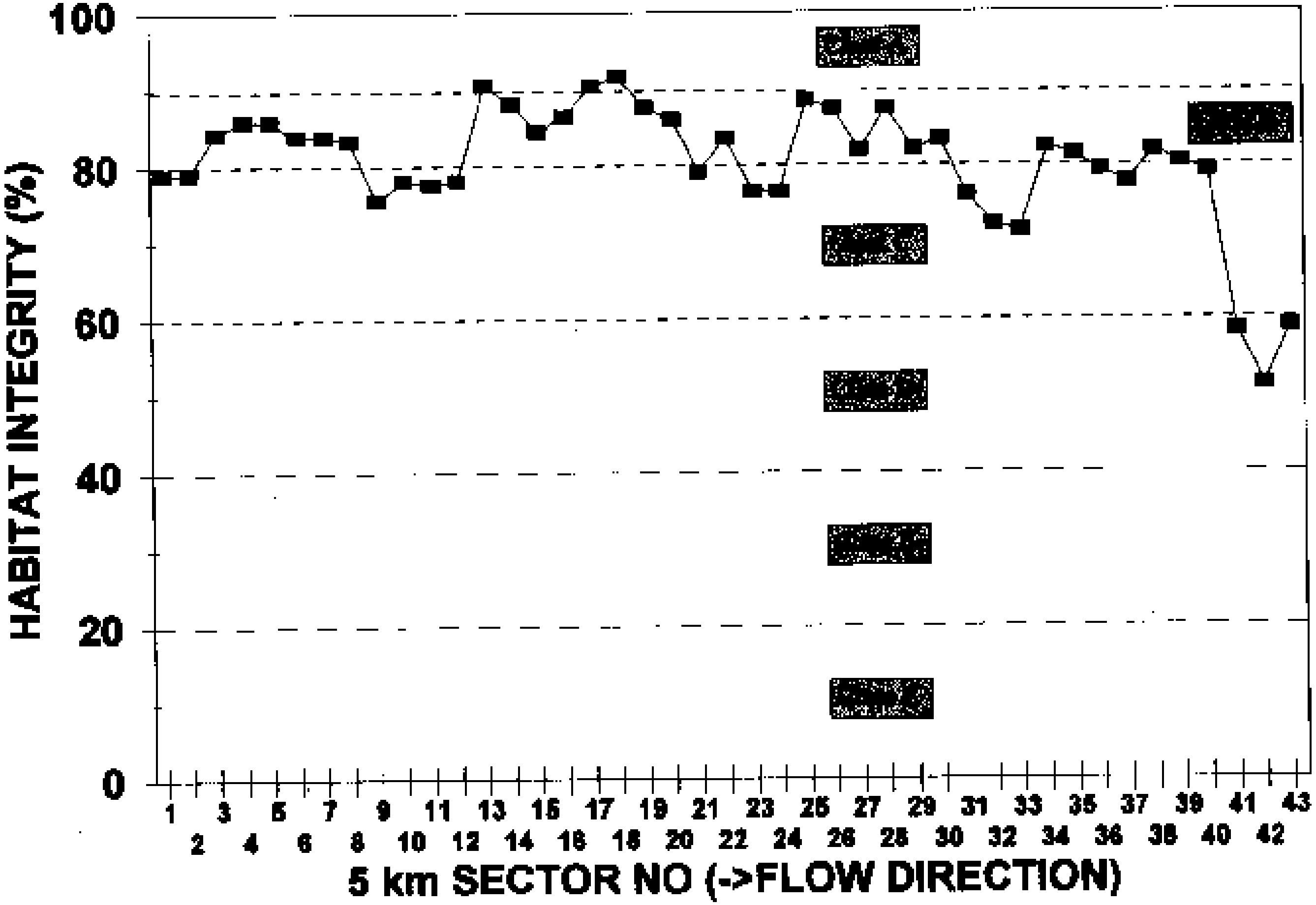


Fig 4: RIPARIAN ZONE CRITERIA
MKOMAZI RIVER

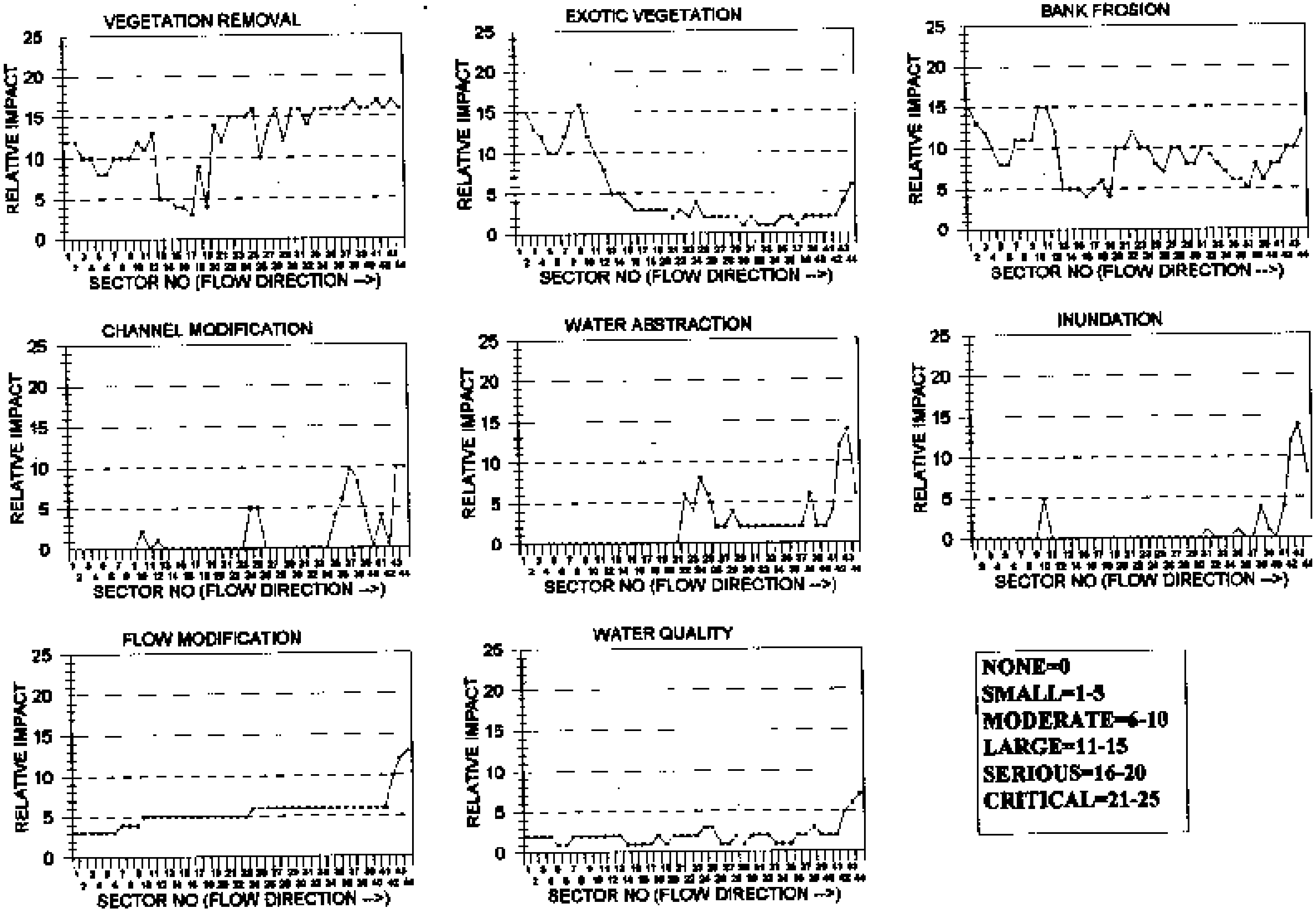


Fig 5: RIPARIAN ZONE HABITAT INTEGRITY MKOMAZI RIVER

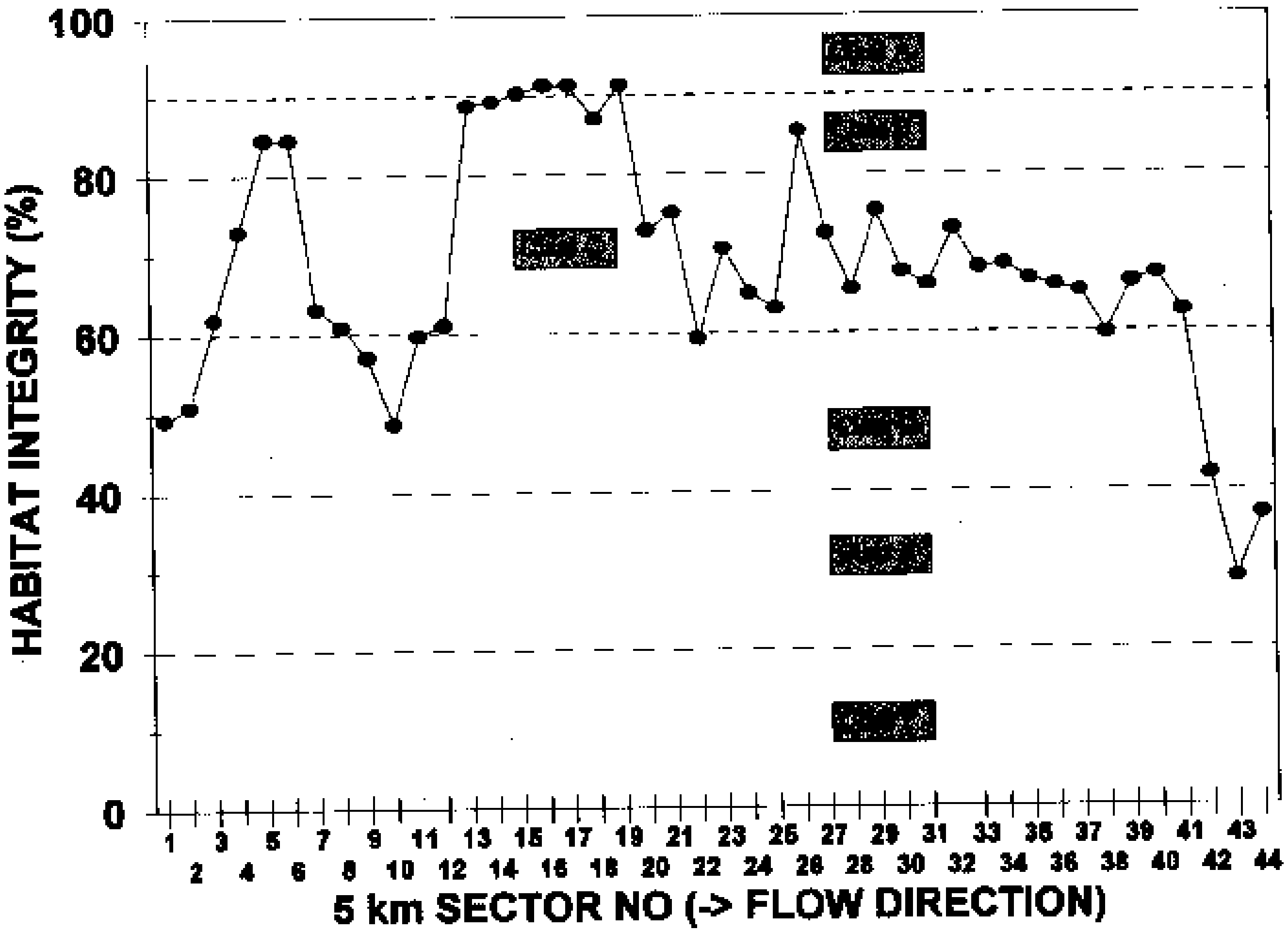
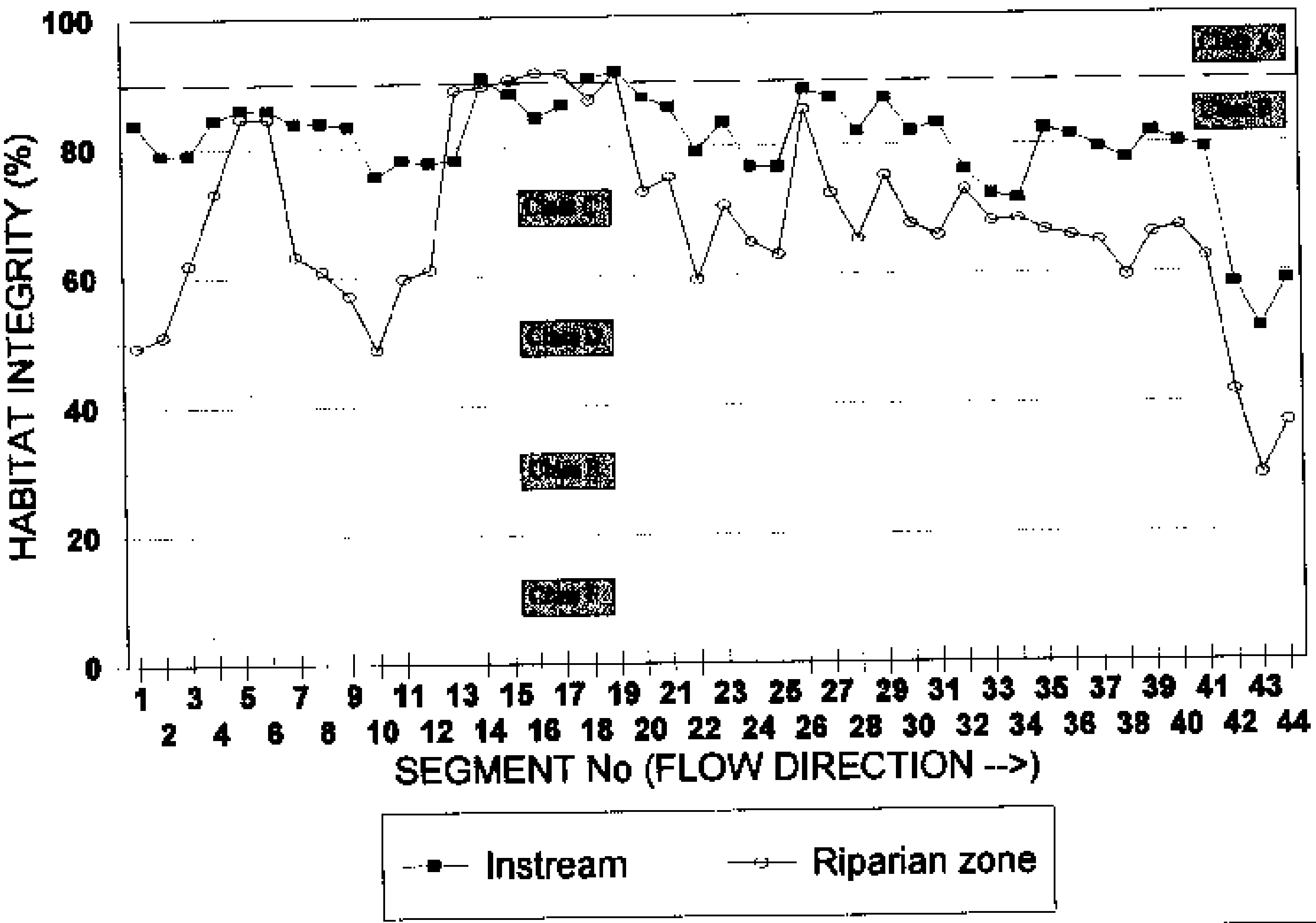


Fig 6 : HABITAT INTEGRITY - MKOMAZ INSTREAM & RIPARIAN ZONE



APPENDIX F
MKOMAZI RIVER INSTREAM FLOW REQUIREMENTS STUDY

RIVER IMPORTANCE

D.J. Alletson
Alletson Ecologicals

This document seeks to compare the Umkomaas (Mkomazi) River with those rivers in the surrounding catchments. This is done in order that the anticipated changes to the river, which will be the consequences of impoundment, water abstraction, and flow regime alteration, may be evaluated in a regional context. The information on which the assessment will be based is derived from:

(a) other investigations which are part of the same Instream Flow Requirement (IFR) study,

(b) expert knowledge and interviews with specialists, and

(c) consideration of catchment-wide management initiatives.

Assessment Criteria

The assessment of catchment attributes will largely follow that used for the Mooi River IFR study (Alletson 1995[1]). The criteria to be considered are:

Uniqueness
Condition
Biodiversity
Human usage
Planning initiatives

The scoring system to be used also follows that from the Mooi River study and is as follows:

Attribute Score	Significance of score
5	Feature is highly important. It will require extensive mitigatory measures if impacted by the development scheme.
3	Average score. All features are considered to have this score

1. ALLETSON, D.J. 1995.An assessment of the importance of the Mooi River (Natal) system in regard to ecological and human usage attributes. Department of Water Affairs and Forestry. Mooi River IFR Workshop Papers.

unless otherwise stated. It is also the score which all features would be allocated in a landscape *totally devoid of any human influence.*

Scoring cont'd. 0 Feature is of low significance. It is present but developments or actions which impact upon it will require very little, or no, mitigation.

Scoring of the river system

1. Uniqueness.

The Umkomaas River rises in the KwaZulu/Natal high Drakensberg and hence is one of a relatively small group which (with their tributaries) includes the Tugela, the Umkomaas and the Umzimkulu Rivers. For purposes of comparison, the Umkomaas and the Umzimkulu must be seen as a pair. They originate in the wettest area in the KZN Drakensberg and lie adjacent to each other for much of their length. Their overall gradient is relatively steep and both have a catchment shape that is relatively narrow in relation to its length. They also differ in other catchment characteristics from the Tugela and the Umzimvubu systems which lie to the immediate north and south respectively. Both are in an area which is generally more temperate than that of the Tugela basin but warmer than that of the Umzimvubu. These differences are reflected in the compositions of both the instream and the terrestrial catchment biota.

Both the Umkomaas and the Umzimkulu have catchments that are broadly characterised by having the headwaters in an area which is under conservation and then passing through alternating bands of subsistence farming and commercial agriculture (including timber growing). The Umkomaas is subject to significant sediment inputs at a higher altitude but, by the time the Umzimkulu has reached the town of Riverside, there is probably little difference between them. Thereafter, however, the condition of the Umzimkulu is adversely affected by the considerable reaches of denuded landscapes along its southern bank.

From the above it should be apparent that the two rivers are relatively similar in many regards but that they stand apart from the other major KZN rivers. Overall the Umkomaas is considered to be in a slightly less degraded condition by the time it reaches its estuary and so it is allocated a score of 4,0.

2. Condition.

The condition of the river is assessed on a composite of instream integrity, riparian integrity, and water quality. The base information for these is taken from studies which are a part of the present initiative and only those reaches of the river which may be affected by the dam(s) are considered.

Between the Impendle Site and the Smithfield Site the instream integrity is predominantly in Class B with a small reach in Class C. These classes indicate a system that is in generally good condition. The riparian condition is not scored as highly as there is a considerable reach of Class D. The reasons for the presence of the latter are in common with many rivers in KwaZulu-Natal. They are a composite of flood damage and overutilisation of the riparian zone by a variety of agricultural activities with overgrazing probably being the most significant factor. Water quality in this section is, with the exception of turbidity, generally good. On the basis of these classifications, the reach between the two dam sites, including IFR 1, is scored at 4,0. With the exception of some deterioration close to the coast, the instream and riparian classifications below the Smithfield Site are generally similar to those immediately upstream of that site. The water quality, although still generally "fair to good" does tend to decline down the length of the river. This criterion reduces the overall score of the reach to 3,0.

3. Biodiversity.

Biodiversity is assessed on the basis of fish, macroinvertebrates and riparian vegetation. In the present study, eighteen fish species are indicated. These include one Red Data species and three South African endemic species. Of the latter, one (*Barbus natalensis*) is endemic, although common, to KwaZulu-Natal. The fish fauna of the Umkomaas is very similar to that of the Umzimkulu in terms of its species composition.

The aquatic macroinvertebrate population contains high species diversity and appears to have changed little in the past 23 years. One possible provincial endemic (*Aphelocheirus corbeti*) is present but it is possible that more may be found when all the undescribed species, of which more than 40 are present, are named. There appear to be no pest species.

The riparian vegetation appears to consist primarily of common species with there being no listed indigenous species of concern. As it is recognised that the species lists are not complete it is possible that some such species may be present. However, it is also probable that such species will also occur along the various tributaries of the river and in neighbouring sub-catchments.

On the basis of the above taxa it is apparent that the Umkomaas does contain moderate to high levels of species biodiversity although there would seem to be relatively few species of major concern. For this reason the biodiversity in the system is scored at 4,0.

4. Human usage.

Human usage of the river is diverse. Stock water is important in virtually all areas and irrigation is significant along certain, relatively small, reaches. Human reliance on the water for domestic purposes appears to vary from place to place but is generally significant during dry periods when springs and side streams cease flowing. The river is also used recreationally and for spiritual purposes. Associated with the river are a number of resources which are not necessarily related to the water resources itself. Included here are building materials, medicinal plants and craft materials.

Of particular note is the very high importance attached to the river for canoeing and it is held to be one of the best rivers in the country for this purpose.

Overall the river is scored at 3,5 in terms of importance.

5. Consideration of catchment-wide management initiatives.

For some years the Umkomaas River has been the focus of catchment-wide planning initiatives. The Umkomaas River Trust was formed for this purpose. It had its origins in disputes about the condition of the estuary and the effects of pollution from SAPPI SAICCOR. On investigation it was realised that, other than the source of pollutants, certain problems, especially that of turbidity, were catchment related. Thus an effort to plan landuses in the catchment was initiated. The catchment was divided into seven sub-catchments and desirable environmental and social criteria were loosely defined for each. The task of taking those criteria to the people of the catchment was commenced but progress has been, inevitably, slow. Despite this, the work done should not be ignored and may be seen as a model for other such undertakings. For this reason the Umkomaas catchment is scored at 4,5 for catchment planning initiative.

Conclusion

The various attribute scores are summarised in the Table below.

ATTRIBUTE	SCORE
Uniqueness	4,0
Condition	3,0
Biodiversity	4,0
Human usage	3,5
Planning initiatives	4,5

As all the criteria are ranked at 3,0 or better it is apparent that the Umkomaas is a river of some importance. For this reason, it is imperative that the IFR determination process be undertaken against the background consideration that the present character of the river should, at least, be maintained.

APPENDIX G

MKOMAZI IFR STUDY : DESIRED FUTURE STATE (DFS)

MD Louw, IWR Environmental, February 1997

1. BACKGROUND

IFRs for any specified river depend on the Desired Future State of that river. Therefore, any one river can have various IFRs depending on the DFS. A river which has a DFS that relates to a high protection class, or high aspirations (eg the river is in good condition and must stay in good condition) should have a higher IFR than if the river is degraded, not important, and has a DFS relating to low aspirations for the river.

It is therefore imperative that the DFS for the river is correct, as the IFR will be set according to the DFS.

Terminology : The Desired Future State term is not accepted terminology at present and has changed to either a protection class, or more preferred, a management class. Please note that whenever one of these terms are used, they are synonymous to the concept of DFS.

1.1 First process followed to set the DFS during IFR studies.

A fixed procedure for determining the DFS of a river has not been established during the first IFR studies. The process consisted of dividing the river into logical reaches based on location and size of tributaries and the results of the habitat integrity, and thereafter coupling a descriptive DFS to each of the reaches. The process followed the following steps:

- Determine during the planning meeting whether specialists are aware of any vital information on specific communities or problems related to the river which warrants mention in a DFS. This included social aspects relating to the sustainable use of the riverine ecosystem by communities dependant on it.
- Based on the above information, an overall or 'motherhood' statement was formulated during the planning meeting.
- After the habitat integrity report became available, the river was divided into similar (according to status results) reaches.
- These reaches were then given to the biophysical and social specialists who then attached a DFS to each reach based on their specialist viewpoint. The DFS were descriptive and subjective.
- During a short discussion period at the beginning of the workshop, this information was presented to the participants to confirm the overall DFS and to agree on the DFS for each

reach.

Problems were experienced with this process as it was not consistent and differed from river to river. The description of the DFS however tended to sound similar for most rivers and the process was not quantifiable.

1.2 Development of the present DFS process

During the Water Law Review process, documentation was prepared which suggested that a protection system based on different classes should be established. These protection classes relate to the management objectives or goals for the river and to the DFS. Different classes for each protection class were described in a draft document based on the Habitat Integrity system (devised by CJ Kleynhans). This system was described in a draft document presented as part of the Water Law Review process. In short the process can be described as follows:

- A **present state** must be allocated to the river reach which requires the establishment of a protection class. The present state is described by allocating a class (see Table 1) to the river reach. The present state is described in six classes of which A being near pristine and F is irreversibly changed. These classes are based on the Habitat Integrity classes (see Chapter 3.4).
- The river importance (social, economic and ecological) is then established and considered when determining the protection class.
- After a process of consultation, a protection class is allocated to the river reach. The protection class is described in classes ranging from A (near pristine) to D (largely modified) (see Table 2). The protection classes do not range to E and F as do the present state classes as a class E and/or F river does not represent a sustainable river. A high protection class relates to a flow that will ensure a high degree of sustainability and a low risk of ecosystem failure. A low protection class will ensure marginal maintenance of sustainability and a high risk of ecosystem failure. This relationship is described in Fig 1.

The following quotations from the White Paper on a National Water Policy for South Africa illustrate the principles of this process that will be incorporated in the new Water Act to be tabled in June 1998.

"A national resource protection classification system will be introduced. Through a process of consensus-seeking among water users and other stakeholders, the level of protection for a resource

TABLE 2 : DESIRED FUTURE STATE CLASSES BASED ON ECOSYSTEM HEALTH / ECOLOGICAL INTEGRITY STATUS

CAT	DESCRIPTION
A	• Unmodified, natural - the natural abiotic template should not be modified; • The characteristics of the resource should be completely determined by unmodified natural disturbance regimes; • There should be no human induced risks to the abiotic and biotic maintenance of the resource. • The supply capability of the resource will not be utilised.
B	• Largely natural with few modification - only a small risk of modifying the natural abiotic template and exceeding the resource base should be allowed. • Although the risk to the well-being and survival of especially intolerant biota (depending on the nature of the disturbance) at a very limited number of localities ma be slightly higher than expected under natural conditions, the resilience and adaptabi of biota must not be compromised. • The impact of acute disturbances must be totally mitigated by the presence of suffici refuge areas.
C	• Moderately modified - a moderate risk of modifying the abiotic template and exceed the resource base may be allowed. Risks to the well-being and survival of intolerant biota (depending on the natura of the disturbance) may generally be increased with some reduction of resilience and adaptability at a small number of localities. Howev the impact of local and acute disturbances must at least partly be mitigated by the presence of sufficient refuge areas.
D	• Largely modified - a large risk of modifying the abiotic template and exceeding the resource base may be allowed. Risks to the well-being and survival of intolerant bio (depending on the nature of the disturbance) may be allowed to generally increase substantially with resulting low abundances and frequency of occurrence, and a reduction of resilience and adaptability at a large number of localities. However, the associated increase in the abundance of tolerant species must not be allowed to assur pest proportions. The impact of local and acute disturbances must at least to some extent be mitigated by the presence of adequate refuge areas.;

will be decided by setting objectives for each aspect of the Reserve (water quality, quantity and assurance, habitat structure, and living organisms). The objectives for each aspect of the Reserve will show what degree of change or impact is considered acceptable, and unlikely to damage a water resource beyond repair.

Resources will be grouped into a number of protection classes, with each class representing a certain level of protection. Where a high level of protection is required, the objectives will be strict, demanding a low risk of damage and the use of great caution. In other cases, the need for short to medium term use may be more pressing and the need for protection lower. Some resources may already need action to restore them to a healthy state, and, in future, no resources should be allowed to become irreversibly degraded."

2. APPROACH TO DETERMINE THE DFS

The above concept has not been applied in practice and the methods have not been finalised. However, during the last five BBM IFR studies, these ideas and the categories have been utilised to determine a DFS for which to set the IFRs. The approach is demonstrated in Fig 2, a flow diagram which shows the broad approach and the focus of the IFR study. The steps as illustrated in the flow diagram can be described as follows:

The process follows these basic steps:

- *Determine the present ecological/environmental state.*
- *Determine the ecological/environmental importance of the river.*
- *Determine the DFS which would ensure a healthy ecosystem.*
- *Quantify the flow required to ensure the DFS.*
- *Determine the social and economic importance of the system and the objective for the river from these viewpoints (Eg. The Maguga study is determining the importance of the river as a source of irrigation water).*
- *Quantify the flow required to achieve the objectives.*
- *Knowing all the factors and implications of all the flows required, determine an acceptable state for the river.*

3. PRELIMINARY RESULTS OF THE MKOMAZI DFS

This phase of the Mkomazi IFR study focuses on the first, second, third and fourth bullet above. The actual steps undertaken for the Mkomazi study to achieve the above were the following:

- *Determine the present ecological environmental state.*

  A habitat integrity analysis was undertaken to determine the present state categories of the river. The results of this are demonstrated in the Habitat Integrity chapter (chapter 3.4).

During a site visit by the multi-disciplinary IFR specialist team, a general feel about present and DFS categories of the river was obtained. These results are relevant for the major part of the river. It is possible however that the lower 40 km of the river could be a different (probably lower) present state but this issue will have to be clarified at the workshop.

After the site visit during which the IFR sites were selected, each specialist attached a present state class to the river according to Table 1 as follows (note that this is preliminary, based on one site visit and limited field work by some specialist). The outstanding cells will be filled in during the workshop.

Table 3 : The Present state Class for reach 1 and 2 of the Mkomazi River

	REACH 1		REACH 2	
Component	**Class**	**Motivation**	**Class**	**Motivation**
Invertebrates	B			
Fish	B			
Vegetation	C			
Geomorphology	B			
Water Quality				
Habitat Integrity	B			
Social				
OVERALL	B			

- *.Determine the ecological/environmental importance of the river*
  Prof J O'Keeffe defined the ecological importance of a river as "a measure of the value of a river for conservation, including natural, socio-economic and cultural aspects". Criteria for evaluating natural aspects included rarity, special features, resilience/fragility and the degree of modification. The information provided in the starter document as well as additional information will be analysed and presented at the workshop by Mr Jake Alletson

- *Determine the DFS which would ensure a healthy ecosystem.*
  A nationwide five year project is being run by DWAF to determine the management categories for all rivers. In the interim period, the suggestion was made by DWAF that the following approach should be followed:

PRESENT CLASS	⇨	MANAGEMENT CLASS
A	⇨	A
B	⇨	B
C	⇨	C
D	⇨	C
E	⇨	D
F	⇨	D

Prior to the above suggestion being made, the specialist decided that the overall category and for the individual components should be for a B river, matching the above suggestion. This was presented to the Environmental Task Group (ETG) during their second meeting and was accepted by the ETG.

During the IFR workshop, the concept of a B river will also be broken down further. Each specialist representing a component should specify specific objectives to attain the desired class as described.

E.g., the aquatic invertebrate community for the Komati River was in an A/B state. The specific objectives were described as

- the SASS 4 scores should be maintained within the range previously measured (except after major floods and during droughts)
- no group should consistently dominate the fauna.

- *Quantify the flow required to ensure the DFS.*
  This will be undertaken during the workshop in March 1998.

FIG 1
PROTECTION CLASSES (DFS)

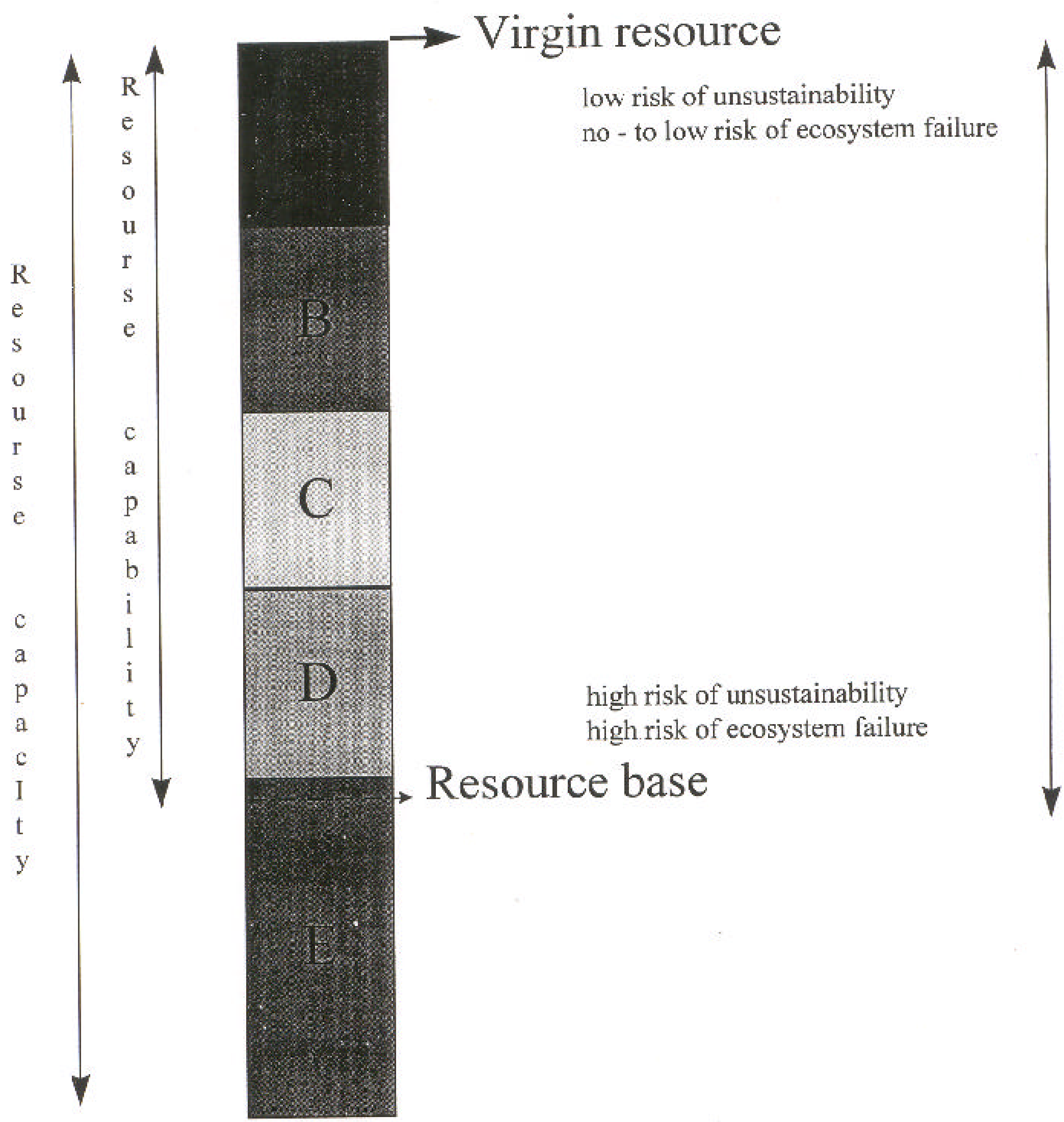
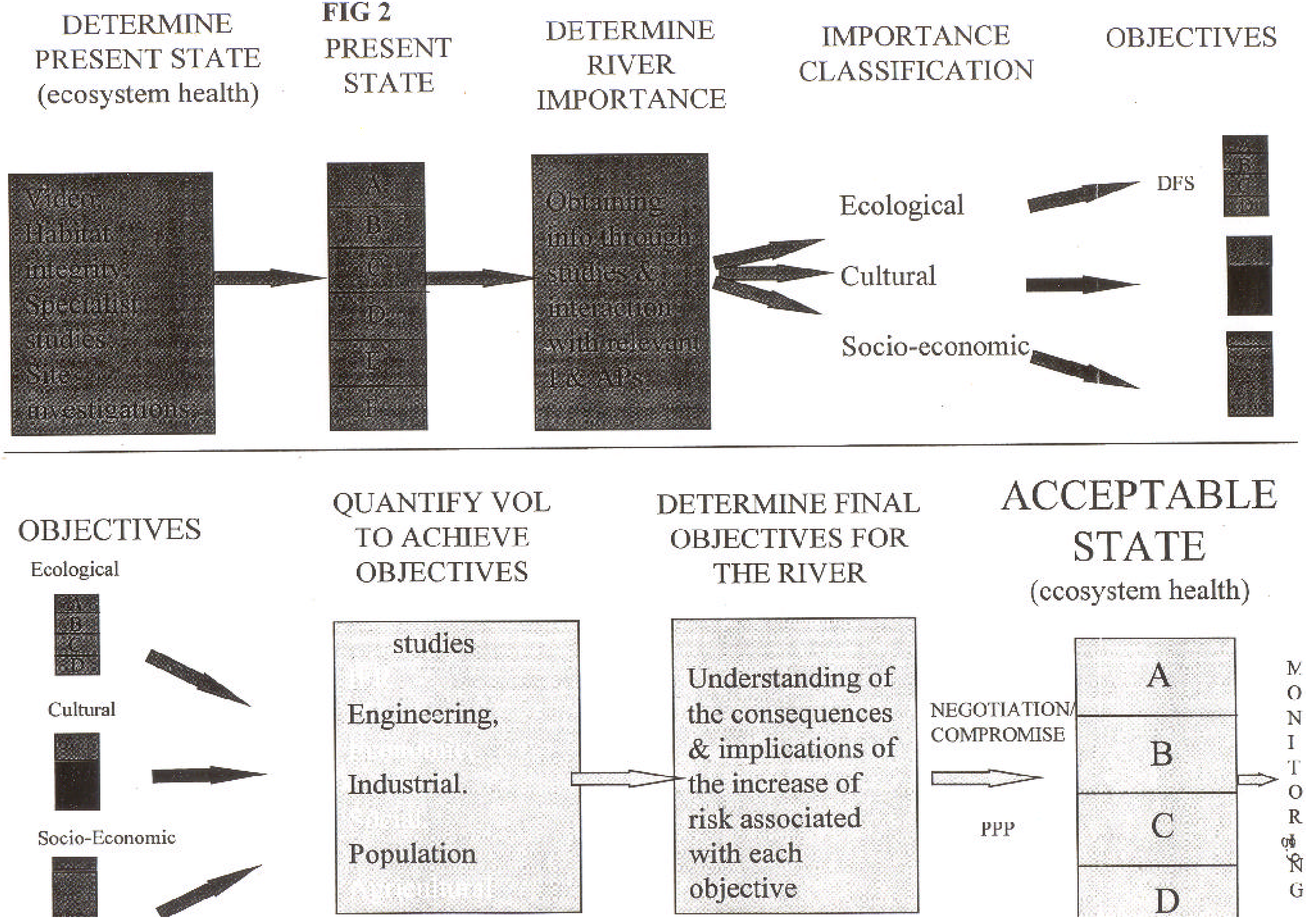


FIG 2


DETERMINE PRESENT STATE (ecosystem health)
PRESENT STATE
DETERMINE RIVER IMPORTANCE
IMPORTANCE CLASSIFICATION
OBJECTIVES
Video, Habitat integrity, Specialist studies, Site investigations
A B C D E F
Obtaining info through studies & interaction with relevant I&APs
Ecological
Cultural
Socio-economic
DFS
OBJECTIVES
Ecological
Cultural
Socio-Economic
QUANTIFY VOL TO ACHIEVE OBJECTIVES
studies
Engineering,
Industrial.
Population
DETERMINE FINAL OBJECTIVES FOR THE RIVER
Understanding of the consequences & implications of the increase of risk associated with each objective
NEGOTIATION/ COMPROMISE
PPP
ACCEPTABLE STATE
(ecosystem health)
A
B
C
D
MONITORING

APPENDIX H

3.7 PROBLEMS EXPERIENCED DURING THIS IFR STUDY

Delana Louw, IWR Environmental, February 1998

- *Cross-sectional surveys*

Due to the time programme of this study, high flows were prevalent during the major part of the study. The sites were selected in October and would have been surveyed immediately afterwards. However, rains started during the site selection visit and when the surveys took place immediately after the site visit, the flows were too high to measure the IFR 3 site.

- *Access*

Access was a serious problem in this study area. Some of the areas with the highest habitat integrity could not be selected as there was no access to these potential sites. This means that the sites selected are not necessarily the most sensitive or the most critical for IFRs. This is more relevant for the latter half of the river (the area in which IFR 3 is situated). In summary it can be said that the overriding criteria for selecting the sites were access.

- *Hydraulic calibrations*

During the last year, the base flows were generally high, even in the dry season. Implementing the study so late, meant that even the high winter base flows were not experienced at most sites, and low flows generally were not experienced. This impacts seriously on the hydraulic calibrations of the sites and the accuracy of the IFRs. Normally four to five calibrations reflecting a dry and wet season are obtained. In this case four calibrations were obtained in the time period October to February. In theory, October should have been a low flow calibration, but the rains started during the calibration visit, and only site one reflected relatively low flows. All other calibrations obtained reflected high or flood flows.

- *Number of IFR Participants*

The IFR study culminates in an IFR workshop which is a technical working group meeting. The number of participants at this workshop is normally restricted to 16 persons. In this case 24 persons will be attending. This is due to a training component as well as an engineering interest in these workshops. Additional persons imply that the facilitation and management of such a workshop become problematic and can have serious consequences in finishing within the restricted time. Normally the IFR workshop is attended by specialists who are mostly experienced with the method and in depth explanations and theoretical discussions are not necessary. In this case, the timing available for the workshop is the same as normal even with the additional persons, but it is expected that problems will exist in achieving all objectives within the correct time frame.

Lessons learnt ?

The time period of an IFR study is six to eight months. However, the site selection visit and first calibrations usually take place in the 2nd month of the study period and the workshop during the last month. This effectively makes the time available for hydraulic calibrations three to five months. It is VITAL that this period includes a dry and wet period, or at least the dry period. As low flows

- form a more important part of the drought IFRs;
- are the most difficult to model hydraulically;
- are required to undertake cross-sectional surveys in rapid and riffle areas;

this period has, worst case scenario, to include the dry season.

Although the above has been reiterated over and over again, it is still usually ignored when an IFR study is initiated and is often seen as the problem of the specialists undertaking the study. IFR results are usually required as part of the overall study and to feed into other aspects of the overall study. When, due to the problems of the IFR study being so dependant on the seasons and elements, answers or answers of high confidence cannot be provided in the time frame required, the IFR study team is usually held responsible for this. It is important that those who initiate IFR studies realise the following:

The BBM was designed as a method to provide answers in response to planning needs and was seen by the scientists involved in designing the method as a quick and superficial study. However, it is now generally acknowledged that this is probably the most detailed study that will be undertaken in South Africa, and presently even more simple methods are being designed to be even quicker, less costly and more superficial. The BBM therefore, even though never tested, is now regarded as the most detailed and highest confidence IFR method for important rivers. The scientific research on which much of the BBM is based is limited and it is therefore imperative that as much effort as possible is made to ensure that the BBM is applied as best as possible to provide the best results. ***Applying the BBM well requires that the timing and seasons are taken into account when planning deadlines for the overall study.***

APPENDIX I

GEOMORPHOLOGY

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The Catchment

The Mkomazi catchment drains an area of 4387 km^2 in KwaZulu-Natal. The Great Escarpment around Sani pass forms the headwaters of the Mkomazi, and it exits into the Indian ocean at Umkomaas. The upper catchment geology is relatively simple, with Karoo sequence Elliot and Clarens sandstone being capped by the Drakensberg lavas. The upper-middle catchment is dominated by the Tarkastad mudstones and Dolerite, while the Ecca and Beaufort Group dominate the middle catchment. The lower middle and lower catchment displays a complex geology. The catchment lithology here forms part of the Natal structural and metamorphic province, consisting of granites and gneiss. The terrain is faulted, and thus structural control of the channel is considerable. Basement geology means that the upper catchment has steep relief, while the middle and lower-middle catchment can be classified as undulating. Steep relief in the lower catchment is a function of the underlying lithology.

Rainfall distribution is reasonably consistent along the catchment, ranging from nearly 1300mm per annum at the headwaters to 1000 mm p.a in the middle and 900mm p.a. in the lower reaches of the catchment. The lithology produces clay to clay loam soils, which are only moderately erodible. According to WR90 (after Rooseboom), sediment yield from the catchment is around 155 t/km^2/yr for the upper, middle and lower-middle catchment. The lower catchment produces around 175-189 t/km^2/yr. Catchment land use is mainly grazing and commercial forestry (wattle, pines and eucalyptus). Under 'natural conditions', the upper catchment vegetation would be dominated by pure grassveld and temperate and transitional forest and scrub, with false grassveld and coastal tropical forest dominating the middle and lower catchment. Overgrazing and high population densities in the upper-middle and lower parts of the catchment probably produces an increased sediment yield, while commercial forestry plantations have a great capacity for increasing catchment sediment yield and reducing base flows.

Mkomazi River Reaches

Four macro reaches have been identified for the Mkomazi below the upper dam site (Figure 1). These reaches were identified from an analysis of channel gradients taken from the 1:50 000 topographic sheets. Because of the complex nature of the local geology, plus rejuvenation due to tectonic uplift and sea-level change, within each macro-reaches there are a number of reaches which probably represent distinct channel types separated by marked gradient changes.

Table 1 describes the main features of each macro-reach with observed and inferred channel morphology. Characteristic channel gradients are detailed for each reach, together with the number of such reaches and their total length.

Characteristics of macro-reaches

Macro - reach	General characteristics	gradient class	F	total length (km)
1	0-400m. Confined to semi-confined valley, hilly topography in intrusive granites with some sedimentaries in the upper reaches; many small 1st and 2nd order tributaries. Valley bushveld dominating in valleys. Very high rural population density. Cultivation on terraces and fans on valley footslopes. Anabranching channels common, sandy foothill zone with mixed alluvial-bedrock channel, pool-riffle morphology, sand or gravel bars. Local steepening to include pool rapid sections.	0.0019 - 0.0024 0.0028 - 0.0029 0.0032 - 0.0036 0.0041 - 0.0045 0.0053 - 0.0060	4 3 7 4 2	37.712 21.077 41.998 18.130 7.068
2	400 - 820m Confined to semi-confined valley, cultivation on valley floors in unconfined sections. Sedimentary rocks (shales and mudstones) with extensive dolerite intrusions. Forested slopes (valley bushveld). Commercial farming. Single channel with well developed lateral bars, above 680m valley becomes steep-sided and gorge like, with an anabranching channel within an alluvial bed. Rejuvented foothills and rejuvenated cascade zones with mixed pool-riffle or pool-rapid morphologies in lower gradient sections, bedrock or boulder/large cobble dominated channels in steeper sections, rapids, cascades and bedrock controlled pools common.	0.0035 0.0047 0.0057 - 0.0066 0.0077 - 0.0091 0.0111 - 0.0143 0.0216 - 0.1290	1 2 4 7 5 2	5.726 8.585 12.942 16.651 7.739 1.082
3	820-1020m Confined to semi-confined valley within hilly topography, sedimentary rocks (shales and mudstones) with dolerite intrusions. Moderate population density with extensive cultivation, especially within the Lubane catchment. Irregular channels with infrequent islands, cobble bed foothills zone with gravel/cobble bed river, pool-riffle or pool-rapid morphology, locally bedrock controlled. Narrow flood plain of sand and/or gravel may be present.	0.0035 - 0.0037 0.0045 - 0.0049 0.0053 - 0.0060	3 3 4	16.747 12.753 14.130
4	Confined valley in sedimentary rocks (sandstones) with dolerite intrusions. Low population density. Cobble bed foothills to mountain stream zone, with cobble and boulder bed channel characterised by plain beds, step pool morphology, rapids and pools. Flood plain generally absent, but lateral depositional bench features may occur.	0.0049 0.0072 0.0081 - 0.0090	1 1 3	4.108 2.769 6.979

F - frequency, number of reaches within this gradient class.

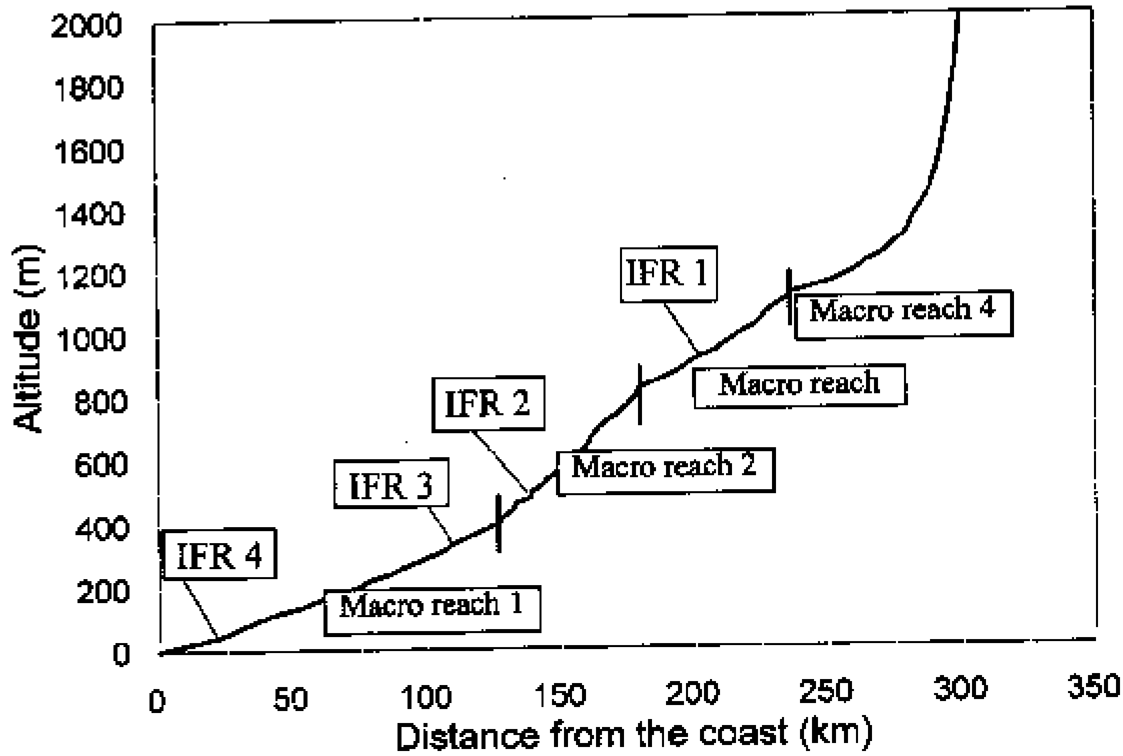

Figure 1. Long profile of the Mkomazi River showing macro-reaches and IFR sites

The IFR sites

The IFR sites 1 to 4 were situated in macro-reaches 3, 2 and 1. The sites were chosen to best represent the different reach morphologies within the constraints of access. Macro-reach 2 presented particular problems because of its gorge like character. Two sites (IFR 3 and 4) were located in macro-reach 1, one representing the more transitional zone below macro-reach 2, one representing the more depositional zone lower down the river.

According to the gradient analysis of reaches, Sites 1, 3 and 4 are all representative of the local river condition. Site 2 in macro-reach 2 represents an over steepened channel. From the video and also from the ground it was clear that much of the Mkomazi river in macro-reaches 1 and 2 is characterised by anabranching (divided) channels. None of the sites represented this river condition. It is likely that the IFR for an anabranching channel would be higher than for a single channel. This should be borne in mind when setting the IFRs at the selected sites.

All sites were characterised by relatively steep gradients, resulting in a strong bedrock control, even at the lowest site. Another characteristic of all sites was the presence of a compound channel, with a distinct flood bench lying alongside the river within a larger macro-channel. Whilst the macro-channel is flooded infrequently, the lower flood bench is presumed to be related to a frequent flood channel is flooded infrequently, the lower flood bench is presumed to be related to a frequent flood which can be considered to be the modern channel forming discharge. This is likely to approximate to the annual flood.

At a number of sites there was clear evidence in the form of flood debris that the macro-channel had been active in the recent past. At least some of the flood debris would relate to the 1987 flood.

Cross-sections indicating geomorphological features will be presented at the workshop.

Apart from IFR site 1, flows were moderately high due to widespread rain over the catchment during the site visit. This meant that it was at times difficult to get into the river to take standard observations. Where the river bed was accessible, it was found that cobble and gravel on the beds were loosely packed, indicating frequent movement. Sand accretion on the flood benches suggested active bank formation. The river may still be in a recovery period after the 1987 floods. A dense grass cover imparted good stability at all sites. There was some evidence of high silt deposition in pools and slackwaters, possibly associated with erosion in the catchment.

GEOMORPHOLOGY OF IFR SITES

IFR Site	Altitude (m)	Local reach gradient	Channel morphology	Channel condition	Hydraulic biotopes
1	920	0.0049	Mixed bedrock and boulder channel, pool-rapid and planar bedrock, narrow flood bench within a macro-channel.	Stable banks, dense grass cover or bedrock exposures. Accretion of lateral bars and silt drapes over boulders indicates aggradation.	Backwater, slackwater, glide, chute, run, riffle and rapid all common in rapid areas, slackwater, glide and run in pools.
2	520	0.1290	Mixed bedrock and boulder channel with pool-boulder rapid morphology. Macro-channel with clear bench. Loosely packed gravels present between boulders, fines, sand and boulder in pool. Banks composed of boulders within a sandy matrix.	Generally stable banks with local bank erosion. Lower bench actively acreting, silt deposits in pool.	Rapid morphology dominated by rapid, run and cascade flow, with local slackwater. Pools dominated by glide with some run.
3	370	0.0034	Cobble bed pool-riffle/rapid channel, site across a point bar on LHB. Macro-channel with sandy flood bench on RHB. Bedrock channel bank upstream on LHB. Small boulder and cobble in riffle.	Stable flood bench and macro-channel bank, both well vegetated. Channel bed condition not known.	Rapid flow over cobble riffle, strong glide or run in pools. Slackwater along channel edge in vegetation.
4	55	0.0021	Bedrock dominated channel with sand and boulder deposits. Pool-rapid and planar bedrock morphologies present. Bedrock flood bench with sand accretion within macro-channel with silt/clay banks Dominant morphology bedrock pool with rapids and backwaters, mid-channel bars of sand and boulder plus bedrock core bars common.	Very stable banks (lower bench), some local sub-aerial erosion of macro-channel bank. Water too strong to get into the channel to examine bed conditions. From its position in long profile, would expect this to be the depositional zone.	Rapid and cascade dominated rapids, run and glide dominated pools with local backwater and slackwater.

APPENDIX J
Preliminary Survey of Riparian Vegetation on the Umkomazi River System

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1) Introduction

Riparian studies in South Africa are few and are derived from two distinct points of departure, commercial forestry and conservation (ROGERS 1995). The studies currently being undertaken by Umgeni Water form a third category which overlaps with conservation to some degree. These studies however provide an opportunity to examine the dynamics of riparian systems in relation to gauged flow rates. From the outset it is necessary to generate representative baseline data on biological diversity so that patterns, produced by the manipulation of flow rates, can be interpreted. It is important to understand that the process is likely to be an empirical one and that the most successful management regime is likely to be produced by an understanding of the important components within the system.

The Umkomazi River spans a linear distance of approximately 220 km. Its is situated on the Natal monocline and consequently also encompasses a wide altitudinal range from its source at about 2800 m to sea level. The Umkomazi traverses a number of the wetland regions as outlined by COWAN (1995). The upper Umkomazi falls within the Mountain Wetland Region passing into the Coastal Slope Wetland Region and ending in the Coastal Plain Wetland Region. These different regions are partly defined by their differing geomorphology and associated changes in temperature and rainfall. Unfortunately inventories of species within geographic areas are rare for South Africa so it is important to undertake field studies to provide some idea of the biodiversity and range of habitats along the watercourse.

Recent impact assessments invariably point out the lack of data with respect to riparian vegetation in South Africa but seldom address this problem by generating their own raw data. The subsequent suggestions regarding the volumes of water required to maintain the ecological integrity of the riparian vegetation are thus hamstrung by the lack of basic inventories. Monitoring changes within dynamic systems is an ongoing process reliant on a sound baseline data for it is only through a sound initial study that changes, resulting from the modification of flow rate, can be inferred.

1.1 Veld Types adjacent to the Umkomazi

An examination of the Umkomazi River in the context of Acocks (1988) reveals that the river traverses 4 veld types. In its upper reaches (approximately 30 km) the river flows through Highland Sourveld (Acocks Veld Type 44). In the upper reaches most parts of the rivers are flanked by extensive boulder beds inhabited by forbes of limited distribution (*Glumicalyx, Zaluzianskya, Argyrolobium,* *Indigofera, Otholobium, Sutherlandia, Geranium, Sebaea, Chironia, Nemesia, Sutera, Limosella, Hebenstretia* and *Lotononis* spp.) some of which are endemic to the region. This vegetation type correlates to Moist Upland Grassland of Low *et al.* (1996).

Approximately 60 km of the upper river traverses Southern Tall Grassveld (Acocks Veld Type 65). The altitudinal range of this vegetation is 600-1350 m and it frequently grades into Valley Bushveld. Generally Southern Tall Grassveld is a savanna which is dominated by *Hyparrhenia* and *Themeda*. The dominant tree species are *Acacia sieberiana* at higher altitudes, being replaced by *A. caffra* at the transtition with Valley Bushveld.

Nearly 100 km of the river course passes through Valley Bushveld (Acocks Veld Type 23). This vegetation type is common along many of the rivers of the eastern seaboard and is characterised by xeric vegetation. Most of the valleys receive less than 900 mm of rainfall per annum. Valley Bushveld extends across a latitudinal gradient and as one moves north the tropical influence on species composition increases. The Umkomzi River displays this northern species composition which is, in esscence, a transition to Lowveld vegetation (Acocks Veld Type 10). This vegetation correlates to Valley Thicket of Low *et al.* (1996).

The last vegetation type through which the Umkomazi passes is Coastal Forest and Thornveld (Acocks Veld Type 1). This vegetation type has, for the most part, been replaced by agriculture. The vegetation is a melange of true forest species and species associated with scrubby savanna. The true forest elements include species such: *Milletia grandis, Protorhus longifolia* and *Ficus natalensis*. Forest pioneers and secondary forest species such as *Strelitzia nicolai, Croton sylvaticus, Acacia ataxacantha* and *Albizia adianthifolia* occur in disturbed areas which constitute the thornveld component. *Syzygium cordatum, Voacanga thoursii* and *Rauvolphia caffra* constitute some of the hygrophilous trees which naturally common in the riparian zone.

2) Methods and Materials

A rudimentary floristic inventory was undertaken which provides a basic understanding of the species diversity and community structure within the river vegetation. This inventory was initiated during January 1998 and comprised field sampling along the water course. Vegetation samples were collected where access the river was possible. Herbarium specimens were made of reproductive individuals of unknown species and these are housed in the Natal University Herbarium (NU). Known species were identified and recorded on site. These form the basis of a rudimentary floristic inventory.

Data gathered in the field was compared with the aerial scan of the river to see if any obvious communities were missed due to lack of access points along the river.

The changes in floristic and physiognomic structure of the riparian vegetation was recorded for the length of the river. This record provides rough estimates of the relative importance of each of the species within the sampled communities.

Floristic comparisons of the 2 rivers involved in the water transfer should be undertaken in order to evaluate vegetational shifts due to the introduction of foreign genetic material. Such introductions may shift the balances in species dominance and threaten scarce taxa. This is however beyond the scope of the current report.

Where possible rare and unusual species distributions are highlighted.

An attempt was made to predict vegetational shift likely to be induced by diverting water from the Umkomazi.

3) Vegetational Outline

Along every water course a band of vegetation exists which is evolved to cope with hydromorphic soils (periodically or continuously waterlogged). These species display an array of morphological, anatomical and physiological adaptations which allow them to flourish in such anaerobic soils.

Riparian vegetation often forms a continuum in which floristic composition is influenced greatly by the parochial effects of the river and to a lesser extent by the flanking vegetation types. In many instances the upper reaches of rivers support specialist species but the lower reaches are dominated by ubiquitous generalists. This vegetation is important in a number of ways including bank stabilization and retention of silts. Beyond the riparian vegetation exists the phreatic zone. Vegetation which occurs in the latter has access to deep moisture from the river but avoids continually waterlogged soils. The phreatic zone usually includes arborescent species.

3.1 Survey Results (abridged)

1) Phytodiversity and vegetation status

The survey revealed that the Umkomazi is a highly modified river due to excessive levels of utilization. As a consequence of this disturbance the river system has been heavily infested with alien species and the diversity of the riparian vegetation has been drastically reduced.

The conservation status of most of the surveyed river sections is low. Species diversity within the riparian vegetation is very low despite the change in altitude and flanking vegetation types. It is postulated that all but the most resilient riparian species have been lost from most of the water course.

The boulder beds at Hela Hela contain two rare species, *Maytenus bachmannii* and *Eugenia zeyheri*, formerly thought to be endemic to the Pondoland Sandstones. This is the first record of these species out of the Pondoland sub-centre.

Tetradenia brevispica was collected at Lions Kloof in the vegetation flanking the river. This species has not been previously recorded in KwaZulu-Natal.

2) Important Communities:

2.1 Herbaceous communities.

Riparian vegetation is dominated by monocotyledonous plant species which are, for the most part, incapable of becoming trees. This size restriction makes these species particularly vulnerable to scandent and arborescent alien species which can overtop them and effectively shade them out.

In the mouth of the river the riparian vegetation is markedly dominated by the tall sedge *Schoenoplectus littoralis*. This species is characteristic of most of the estuaries of the Natal South Coast. The species approaches 3 m in height and forms dense stands in the shallow marginal waters. On the flanking flood plains the vegetation is dominated by *Phragmites australis* with small patches of *Hibiscus tiliaceus*, *Arundo donax* and *Typha capensis*.

The lower and middle reaches of the river are dominated by *Phragmites australis* which is also sporadic in the upper reaches. The species is common in backwaters and in fast flowing waters associated with rapids throughout the system. The marginal hygrophilous grass *Arundinella nepalense* occurs in larger or smaller stands for virtually the length of the river, often in coarser sediments in fast flowing sections. *Miscanthus capensis* occurs sporadically for the length of the river in alluvial deposits. This species is susceptible to burning and *Cymbopogon-Miscanthus* communities which probably once occurred on the river are no longer present.

The following hygrophilous grasses occur sporadically in the riparian zone and it is postulated that these were once important components of the vegetation:

Leersia hexandra (with a wide altitudinal range)
Hemarthria altissima (with a wide altitudinal range)
Phalaris arundinaceus (in the middle altitudes)
Agrostis lachnantha (with a wide altitudinal range)
Andropogon appendiculatus (with a wide altitudinal range)
Cymbopogon validus (with a wide altitudinal range)
Hyparrhenia cymbaria (with a wide altitudinal range)

Juncus exsertus dominates the riparian fringe across most areas of the middle and lower reaches and this species is commonly interspersed with the toxic composite *Matricaria nigaellifolia* and *Percicaria lapathifolia (= Polygonum lapathifolium).*

2.2 Arborescent species

Salix mucronata is locally common in the upper reaches and constitutes the sole natural arborescent component of the riparian fringe in the areas above and just below Lundy's Hill. The willow has probably been replaced by wattles which dominate the upper reaches of the river. Large stands of indigenous trees are unlikely to have been common in the areas flanked by Highland Sourveld due to the seasonality of this vegetation type and the concomitant incidence of fire.

Acacia caffra, Combretum erythrophyllum, Ziziphus mucronata and *Dias cotinifolia* are the main phreatic species in this area.

In the middle reaches of the river *Syzygium cordatum, Ficus sur* and *Combretum erythrophyllum* occur sporadically in the riparian zone. These species are common components of rivers traversing Valley Bushveld. The phreatic zone is dominated by *Acacia karroo* intespersed with smaller trees such as *Dalbergia obovata, Tricalysia lanceolata* and *Kraussia floribunda*. Many sections of the middle reaches are not heavily utilized but even here the riparian vegetation is not well developed. The predominance of boulder beds and exposed rock are testimony to the highly erosive nature of the river in the areas dominated by Valley Bushveld.

In the river mouth *Hibiscus tiliaceus, Phoenix reclinata* and *Bridelia micrantha* occur in the riparian fringe.

3) IFR SITE DESCRIPTIONS

3.1 Lundy's Hill

This area is heavily degraded and considerable infestation by wattle has led to loss of the fringing riparian species and lateral erosion of banks is common. A few remnants of the riparian vegetation remain. The large number and diversity of pioneer species indicates high levels of disturbance. *Cynodon dactylon* is very common indication fairly high grazing pressure.

Riparian Vegetation:

Poaceae:

Arundinella nepalensis sporadic

Echinochloa crusgalli occasional

Phragmites australis sporadic

Cynodon dactylon common

Cyperaceae:

Cyperus marginatus occasional

Mariscus congestus rare

Polygonaceae:

Persicaria lapathifolium common

Compositae:

Matricaria nigaellifolia occasional

Equisetaceae:

Equisetum ramosissimum rare

Alluvial pioneers:

Poaceae:

Digitaria sanguinalis common weed
Paspalum urvillei common
Cynodon dactylon common
Melinus repens occasional
Setaria sphacelata occasional
Paspalum dilatatum common weed
Chloris gayana common

Ephemoral weeds:

Cannabis sativa rare
Sida rhombifolius occasional
Solanum nigrum occasional
Phytolacca dodecandra rare
Verbena bonariensis common
Conyza floribunda common
Datura stramonium common

Consolidated flood plain:

Poaceae:

Sporobolus africanus common
Hyparrhenia hirta common
Cynodon dactylon common

Equisetaceae:

Equisetum ramosissimum occasional

3.2 Hella Hella

While the riparian vegetation in this area is not very well developed the occurrence of two narrowly endemic dwarf trees raises the conservation status of this area. The natural vegetation is fairly intact and there are no signs of heavy grazing apparent in the other IFR sites. Alien species are making inroads into the area but infestation is currently at a fairly low level and the riparian vegetation is not being degraded. Large scale deposition of sand is obvious on the flood plains and this appears to be heavily contaminated with black and silver wattle seed.

Riparian Vegetation:

Poaceae:

Arundinella nepalensis common riverian grass
Phragmites australe sporadic
Miscanthus capense sporadic
Cynodon dactylon sporadic

Juncaceae:

Juncus exsertus fairly common

Cyperaceae:

Cyperus marginatus sporadic
Mariscus congestus rare

Polygonaceae:

Persicaria lapathifolium sporadic

Asteraceae:

Matricaria nigellifolia sporadic

Ranunculaceae:

Ranunculus multifidus sporadic

Boulder beds and sand banks with sparse vegetation:

Poaceae:

Eragrostis curvula common
Hyparrhenia hirta common
Melinus repens common

Leguminosae:

Acacia caffra occasional
Chamaechrista plumosa common
Tephrosia macrocarpa common
Acacia karroo common
Dalbergia obovata common

Miscellaneous Trees:

Syzygium cordatum occasional
Eugena zeyheri rare
Combretum erythrophyllum occasional
Kraussia floribunda rare
Ficus sur occasional
Maytenus bachmannii rare
Tricalysia lanceolata occasional

Weeds:

Persistent weeds:

Acacia delbata saplings common
Sesbania punicea saplings common
Lantana camara occasional
Caesalpinia decapetala saplings common

Ephemeral weeds:

Conyza floribunda common
Ricinus communis sporadic
Verbena bonariense common

3.3 Josephines Bridge

This site displays a well developed riparian zone. The hygrophilous grasses in close proximity to the bridge have been protected from excessive grazing and form a broad band. Large banks of sand with wattle seed appear to be deposited regularly in this area. An array of riparian trees is also present.

Riparian Vegetation:

Poaceae:

Phragmites australis Very dominant
Echinochloa crus-galli occasional
Arundinella nepalensis Dominant
Hemarthria altissima common

Polygonaceae:

Persicaria lapathifolia common

Compositae:

Matricaria nigaellifolia occasional

Flood Plain (mostly alluvial sand):

Poaceae:

Panicum maxima common
Hyparrhenia hirta common
Cynodon dactylon common
Paspalum urvillei common
Melinus repens occasional
Sorghum halepense occasional
Chloris gayana common weed

Leguminosae:

Argyrolobium tomentosum occasional
Chamaechrista plumosa common
Crotalaria pallida occasional
Rhynchosia carribaea occasional
Vigna vexillata occasional
Tephrosea macropoda occasional

Weeds:

Persistant weeds:

Sesbania punicea common
Melia azedarach common
Acacia delbata seedlings common
Senna didymobotrya occasional

Ephemoral weeds:

Chenopodium album common
Ipomoea sp. occasional
Tagetes minuta common
Oenothera jamesii occasional
Lactuca indica occasional
Leucas lavendulifolium occasional
Conyza floribunda common
Verbena bonariensis common
Acanthospermum australe occasional
Datura stramonium occasional

Phreatic Zone:

Miscellaneous Trees:

Acacia karoo
Melia azedarach
Syzygium cordatum
Capparis tomentosa
Ficus sur
Combretum erythrophyllum
Ziziphus mucronata
Pavetta lanceolata

3.4 Mfume

The vegetation of this valley is exceedingly modified. Riparian vegetation has been drastically altered by heavy grazing. The river margins are clothed in a closely cropped lawn of *Cynodon dactylon* intespersed with small weedy species.

The surrounding Valley Bushveld is heavily infested with *Lantana camara* and *Chromalaena odorata.*

Riparian Zone:

Poaceae:

Phragmites australis occasional patches
Cynodon dactylon very dominant

Juncaceae:

Juncus exsertus occasional

Cyperaceae:

Cyperus sexangularis occasional
Cyperus dives rare

Onagraceae:

Ludwigia octovalvis rare

Polygonaceae:

Persicaria lapathifolia common

Compositae:

Matricaria nigaellifolia occasional
Denekia capensis occasional

Weeds:

Persistent weeds:

Cassia didymobotrya
Lantana camara
Ricinus communis
Caeslpinia decapetala
Eupatorium odorata
Sesbania punicea
Melia azedarch

Ephemoral weeds:

Ageratum conyzoides
Commelina benghalensis
Leucas lavendulifolia
Desmodium incanum

Senna didymobotrya *Conyza floridunda*

3.5 Estuary Mouth

While this is not a IFR site it is included because of its distinct vegetation assemblage. *Schoenoplectus littoralis* is dominant within the river mouth forming a 1-4 m fringe, *Phragmites australis* dominates the flood plain.

Riparian zone:

Cyperaceae:

Schoenoplectus littoralis dominant
Cyperus sexangularis occasional

Flood plain:

Poaceae:

Arundo donax occasional
Panicum maximum common
Sporobolus africanus common
Paspalum urvillei common
Sorghum haplense occasional

Typhaceae:

Typha capensis occasional

Arecaeae:

Phoenix reclinata occasional

Malvaceae:

Hibiscus tiliaceus common in the mouth

Compositae:

Ambrosia maritima occasional

Leguminosae:

Sesbania bispinosa occasional
Crotalaria pallida occasional
Vigna vexillata occasional
Albizia adianthifolia occasional

Euphorbiaceae:

Bridelia micrantha occasional

Weeds:

Ephemerals:

Verbena bonariensis
Conyza floribunda
Lactuca indica
Tagetes minuta

Persistent:

Coix lachryma-jobi
Ricinus communis
Senna didymobotrya
Cardiospermum grandiflorum
Lantana camara
Chromolaena odorata
Montanoa bipinnatifida
Schinus terabinthifolius

Acacia delbata *Psidium guajava*

4) Aliens

The alien species within the system are dispersed by different vectors. Dispersal of ornithochorous species (using bird vectors) and anemophilous species (using wind) will be little affected by changes in flow volumed however establishment of these species may benefit from decreased scouring of alluvial soils. The structurally important species in this category are *Lantana camara, Solanum maurtianum* and *Chromolaena odorata*. Invasion of these species into the riparian fringe occurs in the lower reaches of the Umkomazi. The result of this succession is a moribund riparian zone in which the hygrophilous indigenous species are outcompeted by the aliens and bank stability is lost.

A third group of alien species are commonly dispersed within flood waters. The most important of these species are arborescent and, through the competitive edge gained by their size, they shade out the riparian species. The *Acacia* species *A. delbata* and *A. mearnsii, Senna didymobotrya, Senna occidentalis, Caesalpinia decapetala* and the spurge *Ricinus communis* are frequent weeds on the flood plains and they are dispersed in this manner. Wattles are very common in the upper reaches of the Umkomazi system and saplings are ever present in the silts deposited downstream. Most leguminous seeds have a very long resonance within ecosystems due to coat-imposed dormancy displayed by their seed. Consequently the current expression of seedling growth in the lower reaches of the Umkomazi represents a gross understatement of the treat posed by both *Acacia mearnsii* and *A. delbata*. It is postulated that the problem will be exacerbated by decreases in the flow rates but more specifically by decreasing the amplitude of high flow periods. Currently flooding removes the seedlings by scouring the alluvial deposits. While this situation is far from ideal it does lower the impact of the wattles on the remaining riparian species and thus maintain some degree of bank integrity. In situations where wattles become dominant the riparian species are shaded out. Bank stability is reliant on the extensive fibrous root systems of the hygrophilous riparian species. Wattles, by contrast, are deep rooted and their dominance leads to lateral undercutting of the banks.

A number of insignificant aliens occur within the vegetatiton and these are for the most part small contributers in terms of biomass. They are also r-strategists which indicates high levels of disturbance. The natural occurrence of annual species within the vegetation of Natal is very low. This is an indication of a general lack of disturbance within the grasslands in terms of evolutionary selection. Most of these species are herbaceous and either weakly perennial or annual. They take advantage of temporary windows of disturbance within ecosystems but do not pose a structural threat to the ecosystem. As pioneers, these species undergo natural attrition when disturbance of the ecosystem is lowered. This group includes:

Leucas lavendulifolium (Lamiaceae) *Oenothera jamesii* (Onagraceae)

Oenothera rosea
Verbena venosa (Verbenaceae)
Verbena bonariensis
Tagetes minuta
Acanthospermum australe
Ageratum houstonianum
Chenopodium album
Datura stramonium (Solanaceae)
Verbena tenuisecta
Cirsium vulgare (Compositae)
Bidens pilosa
Conyza floribunda
Amaranthus viridis (Chenopodiaceae)

4.1 Mitigation against Wattle

The most severe threat of alien invasion within the system comses from the Black and Silver wattle populations upstream. Biocontrol measures are available for these species and are currently being tested under field conditions in the Eastern Cape (Ms. D. Donnelley PPRI). The species under investigation is a seed-boring weevil (*Melanterius servulus*) which reduces the seed bank of the species. It may be possible to utilize this biocontrol agent when the flow rates in the Umkomazi are dropped in an attempt to reduce the seedbank.

A second species of insect, the indigenous bagworm (*Chaliopsis junodi*), is effective as a defoliant. This insect is prevalent in the Lundy's Hill area and may be worth introducing in the lower and upper reaches in an attempt to reduce the reproductive output of the riverine wattle populations.

5. Suggestions on Riparian Vegetation Management.

The corollary of adaptations to cope with waterlogged, anaerobic soils in riparian species is that they are usually poorly adapted to cope with drought. Bearing this in mind it is clear that changes in water levels hold serious consequences for the riparian vegetation. Flow rates need to be designed to mitigate against massive shifts within the ecological equilibrium of the riparian fringe for such changes may facilitate invasion by alien opportunists and exacerbate erosion during periods of high flow.

Reduced flow rates within the Umkomazi has the potential to impact positively upon the riparian vegetation due to reduced scouring. This requires monitoring shifts within a number of keystone riparian species which are likely to become dominant if the shifts in the flow regime are not too severe. A number of phenological aspects need to be established:

1) is population growth reliant on sexual reproduction or apomixis?
2) in sexual species when does flowering occur?
3) in sexual species when does fruiting occur?
4) how long do seedlings take to become established?
5) in apomictic species is reproduction through inflorescence plantlets (Cyperaceae) or tillers (Poaceae)?

6) when are asexual propagules produced and is their establishment reliant on soil moisture or inundation?

Having established these criteria flow regimes may be modified to facilitate population growth of the keystone riparian species listed below.

A. ***Arundinella nepalensis*** **Trin.**

This is the most imortant grass in the riparian vegetation. It is the sole representative of the genus in South Africa but within the Republic traverses a wide altitudinal range from Lesotho to the coast. Plants are perrenial and tall (0.9-1.5 m) and consequently have a competitive edge. The species occurs throughout Africa and into Asia. The species is intolerant of shading and is thus susceptible to competition with arborescent invaders such as Wattle. In terms of binding ability Arundinella is an excellent bank stabilizer.

B. ***Miscanthus capensis*** **(Nees) Anderss.**

Sporadic perennial 1.5-2 m tall, spanning a wide altitudinal range from the coast into Lesotho. Confined to riparian fringe (glycophytic) and backwaters (helophytic). The species has good binding attributes but is sensitive to fire. The present populations of Miscanthus are almost certainly remnants.

C. ***Persicaria lapathifolia*** **(L.) S.F. Gray**

The dominant fringing vegetation in many areas, spanning the length of the river. Plants form monotypic stands in full sun and are frequently shaded out by arborescent aliens. At higher altitudes ths species is susceptible to frosting and is reliant on recruitment through annual reseeding and resprouting from subterranean rootstocks. In subtropical areas the species has perennial aerial parts. Persicaria is important on banks and in backwaters often intermingled with *Arundinella nepalensis* and *Phragmites*.

D. ***Phragmites australis*** **(Cav.) Steud.**

Perennials 0.6-3 m tall, common in the riparian fringe and locally dominant in some areas. This species has the potential to become dominant within the system if the altered flow rates lead to a reduction in annual scouring. Currently the populations are very fragmented.

E. ***Cynodon dactylon*** **(L.) Pers.**

It is unlikely that the grazing regime on the banks of the river will change in the forseeable future and so this species is of critical importance. It is a sward-foming perennial, dominant along much of the river especially where the river is heavily grazed. In large areas the species has completely replaced the true riparian vegetation. The species is remarkable for its ability to withstand a range of envirinmental conditions from severe drought to innundation for considerable periods. Commonly a pioneer but Cynodon will remain dominant in areas of high disturbance. The monotypic stands of *Cynodon* which dominate much of the river are the single most important factor averting massive erosion. This species will be replaced by taller riparian species of grass only if there is a shift away from the heavy grazing pressures currently experienced.

F. ***Schoenoplectus littoralis***

This sedge is widely distributed in estuaries in southern Natal and appears to be tolerant of a range of salinity however theis aspect should be monitored. A second aspect which needs consideration is the impact of reduced flow rates on water levels in the river mouth as this may contribute to the decline of *Schoenoplectus littoralis*.

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APPENDIX K

UMGENI WATER · AMANZI
Managing Water for Life

WQP 3/98

A WATER QUALITY ASSESSMENT OF THE MKOMAZI RIVER CATCHMENT WITH RESPECT TO SELECTED IFR SITES AND THE EFFECTS OF IMPOUNDMENT ON FUTURE WATER QUALITY

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SCIENTIFIC SERVICES
UMGENI WATER

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CONTENTS

1. INTRODUCTION

The proposed scheme to abstract water from the Mkomazi catchment to augment the Mgeni bulk supply system for potable water at present involves one of two options, namely:

- A single dam at Impendle with a tunnel bored through intervening terrain to deliver water to Midmar dam and upgrading of the Midmar Water Works.
- A combined dam option with a dam at Smithfield first and then one later at Impendle with delivery of raw water to a new WTW at Baynesfield (see Figure 1).

The demand for water from the Mkomazi river is expected to start in the year 2004 with initial abstraction of 26 million (M) m^3 per annum rising to 258 Mm^3 by the year 2020. The estimated annual present day runoff from the entire 4 400 km^2 Mkomazi catchment is only 920 Mm^3, and therefore these large abstraction volumes will have a significant effect on the existing natural flow regime of the river. Present day water quality in the Mkomazi river will also be greatly affected as the water quality from dam releases will be different from existing due to change by in-dam processes. The proposed dams are large, particularly the Impendle dam which will have volumes of 680 Mm^3 and 560 Mm^3 for the two schemes respectively. By comparison, the Midmar and Inanda dams are much smaller, being only 180 Mm^3 and 256 Mm^3 respectively and consequently, impoundment effects on inflow water quality by the proposed dams are likely to be as or even more significant than those taking place in the existing dams.

The proposed development is major both in terms of infrastructure, water abstraction and cost, which is currently estimated to be in excess of R1 000 million and therefore a comprehensive study of the post development in-stream flow requirements (IFR) has been commissioned to make recommendations to minimize impacts and provide dam release rules to ensure sustainability of the river habitat for all users. As part of the study, a water quality assessment of the effect of the proposed developments was requested which is the basis of this report.

2. OBJECTIVES

Four IFR sites have been selected by the team for setting flow and quality requirements. However, there are no set guidelines to determine what the in-stream water quality should be at the sites, as there are for flow requirements. It is a likely goal though that future water quality, without considering flow requirements should be of a similar or even better quality to that existing in order to maintain current biodiversity and habitat in the river, while at the same time satisfying the needs of local inhabitants and of irrigators. Seasonal variability of quality may also be an important requirement for the habitat. To provide the necessary background for decision making on required future water quality, the following are specific objectives of this assessment:

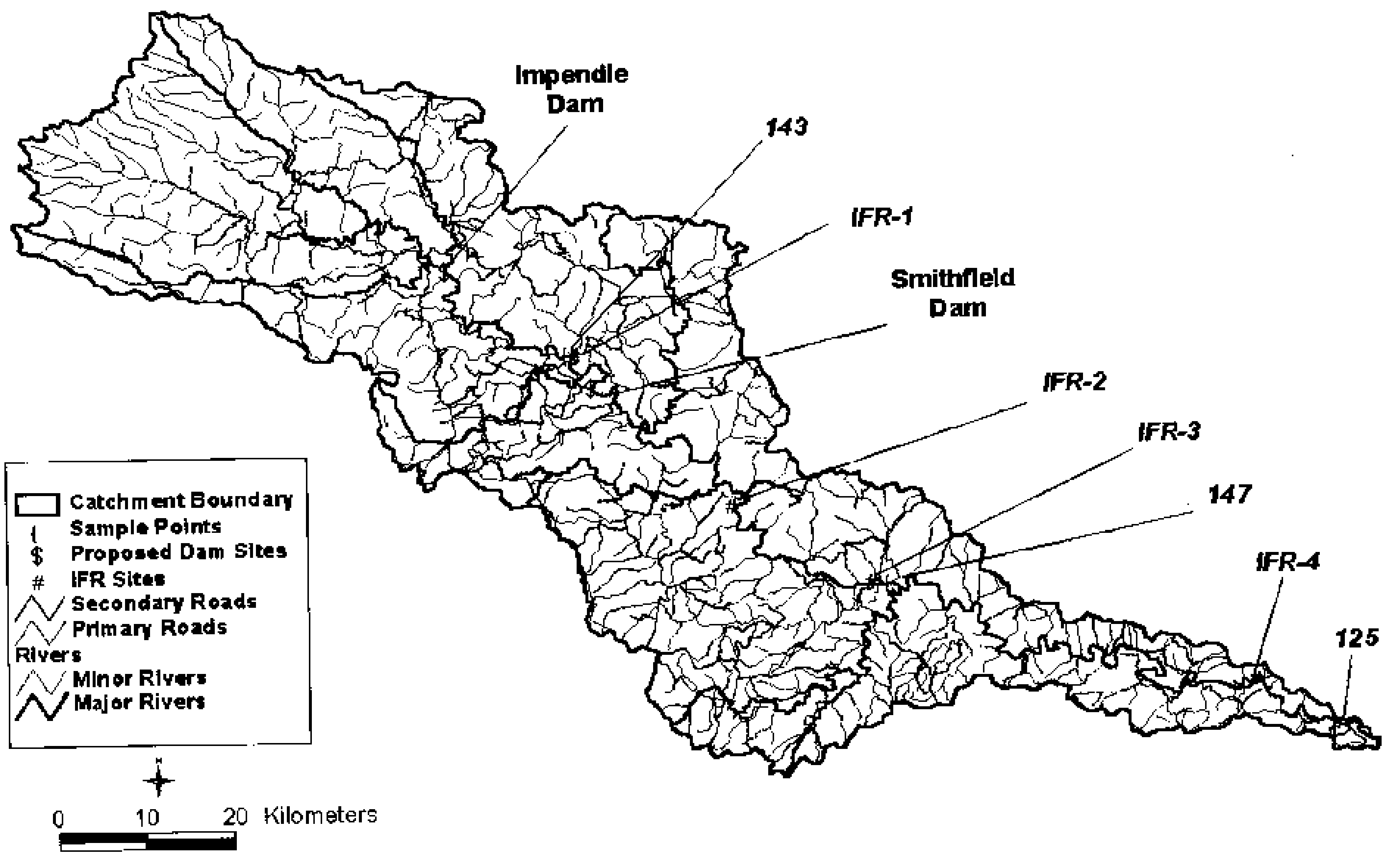
- To describe past water quality using available historical data and identify any temporal trends.
- To describe the present day water quality, the short term and seasonal variability at the IFR sites in terms of a Water Quality Index (WQI) and DWAF water quality guidelines for the aquatic environment and other users.
- To compare Mkomazi water quality to that of other catchments such as at the inflow to Midmar dam.
- To predict the future water quality changes at the IFR sites with the dams in place.
- To set limits for future water quality at the IFR sites based on likely user needs.

3. DATA SOURCES

The following are the data sources that have been used:

- Historical DWAF sample data from 1976 to 1995 for the Lundy's Hill weir, U1H005 (upper catchment) and the Goodenough weir U1H006 (lower catchment).
- Umgeni Water data at three sampling sites 143, 147 and 125 (upper, middle and lower catchment) sampled from October 1995 to January 1998.
- Umgeni Water data for the Midmar and Inanda dams to predict the effect that the proposed dams will have on water quality when released (temperature, *E. coli*, turbidity, pH, phosphorus).

Fig 1 : MKOMAZI CATCHMENT, SAMPLING, DAM AND IFR SITES

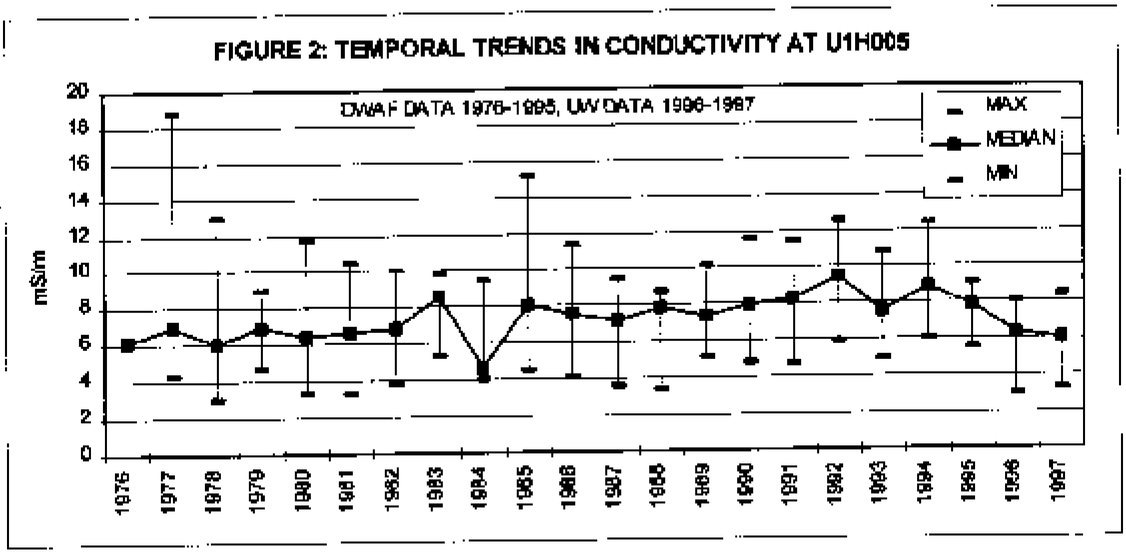


4. RESULTS

4.1 Historical Water Quality and Trends

DWAF water quality data from 1976 to 1995 for conductivity, total dissolved solids (TDS), pH, nitrate and phosphate values for the weirs U1H005 and U1H006 have been assessed for general quality and to identify any trends in quality. For the years 1996 and 1997, Umgeni Water data have been added in for comparison as our sampling frequency at the sites, and therefore confidence in the results is much higher (weekly sampling against DWAF sampling frequency which ranged from 44 to as little as 2 results per year). The location of the sample sites may be seen from the Mkomazi catchment map in Figure 1. DWAF phosphate results which were expressed as "PO_4" have been changed to expression as elemental "P" as this is the more common method used today. For each year the median, minimum and maximum values have been calculated and are graphed in Figures 2 to 11.

4.1.1 U1H005



Conductivity shows a rising trend from a level of 6 to 8 mS/m up to 1995 , the DWAF data, but the more recent Umgeni Water data does not corroborate this general rise and has medians more in line with 6 mS/m, the level shown in the 1970's. A similar situation, that is a rising trend may also be seen for the TDS concentrations. but as above the Umgeni Water values are lower and more in-line with the earlier values. No conclusion on the presence of a trend can therefore be drawn for either conductivity or TDS. The fluctuations may well be due to flow variations.

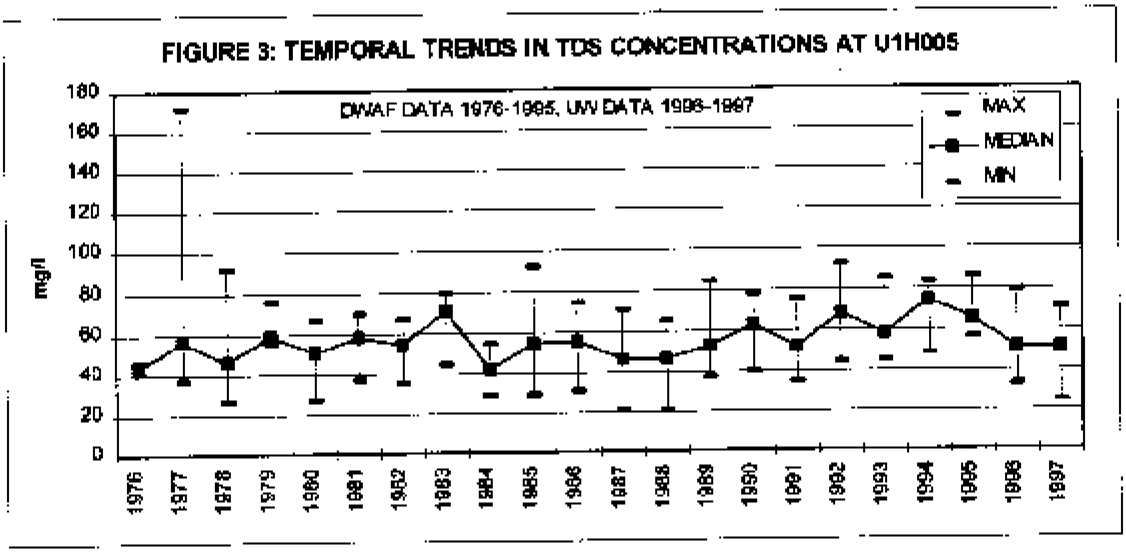
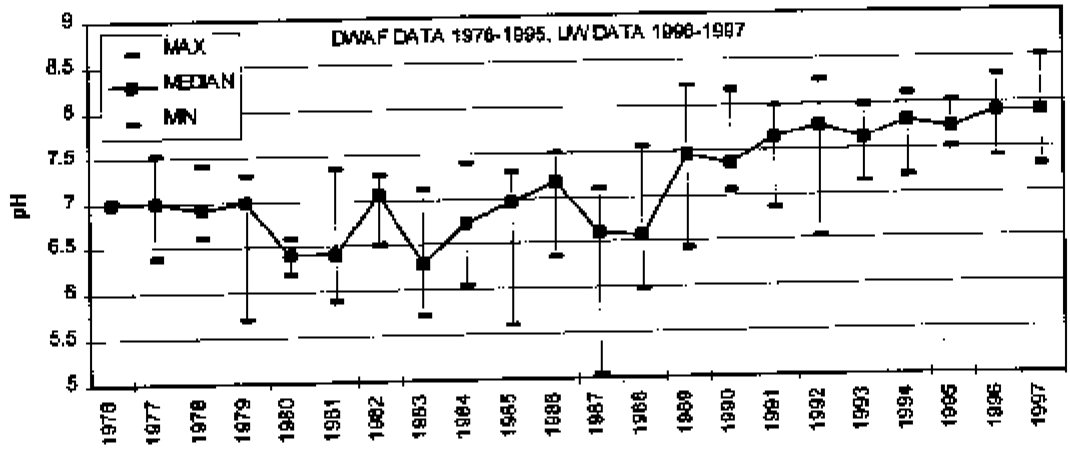
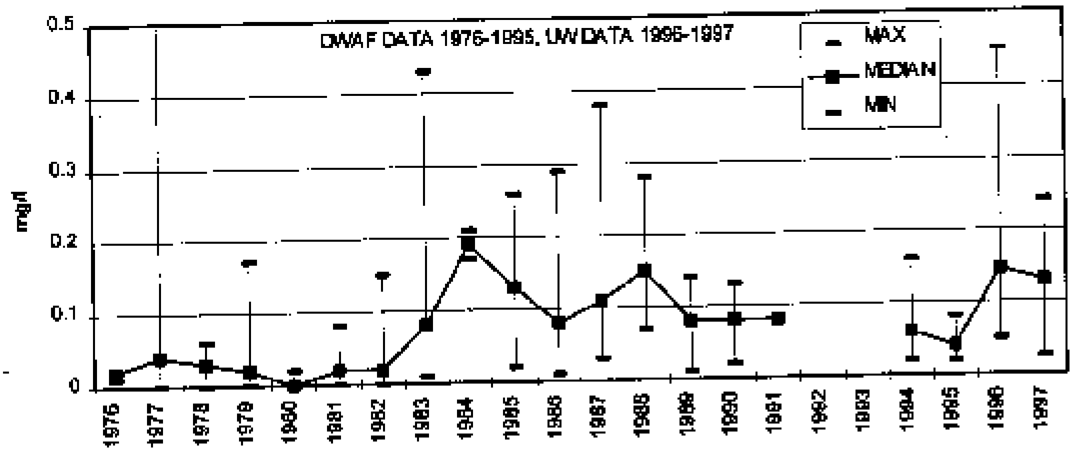


FIGURE 4: TEMPORAL TRENDS IN pH VALUES AT U1H005



The pH values show a very distinctive rising trend from a level of pH 7 to between pH 7.5 - 8 as given by the medians and the Umgeni Water data supports this trend. No particular reason for the change can be advanced and the trend may be a reflection of developments that have taken place in the catchment over the period. The current median and range values are, however, quite acceptable for all users, but it may be noted that some earlier minimum values in the 1980's below pH 6 are unlikely and possibly are errors.

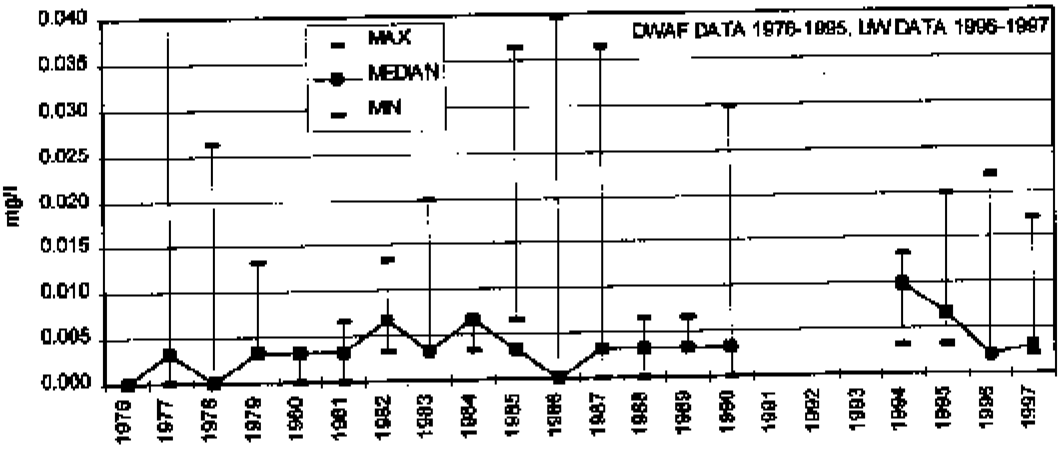
FIGURE 5: TEMPORAL TRENDS IN NITRATE CONCS. AT U1H005



The median nitrate concentrations indicate a slight rise over the years to a level of about 0.15 mg/ℓ with maximum values up to 0.45 mg/ℓ. These levels are probably a reflection of increased activities (forestry, animal raising) in the catchment but at the same time are not high at all.

Soluble Reactive Phosphorus (SRP) concentrations do not show any significant change over the period and are generally low at less than 0.005 mg/ℓ for the medians. Even the maximum concentrations are not particularly high and do not show any significant enrichment in this nutrient.

FIGURE 6: TEMPORAL TRENDS IN SRP CONCS. AT U1H005



4.1.2 U1H006

The median conductivity values for the lower weir, U1H006, generally range between 10 and 20 mS/m with no trend evident. Similar results are shown for TDS and the variations between years are probably more a reflection of changes in flow regimes than due to any changes in landuse activities.

FIGURE 7: TEMPORAL TRENDS IN CONDUCTIVITY AT U1H006

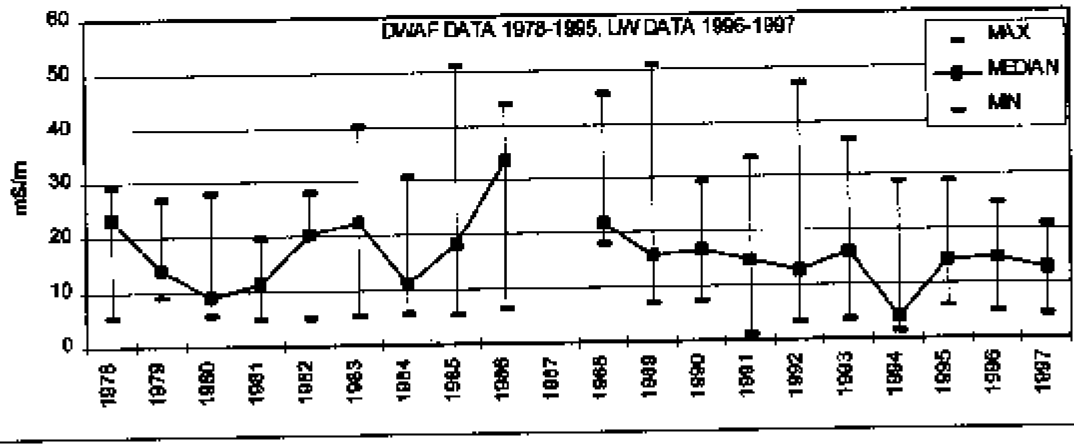
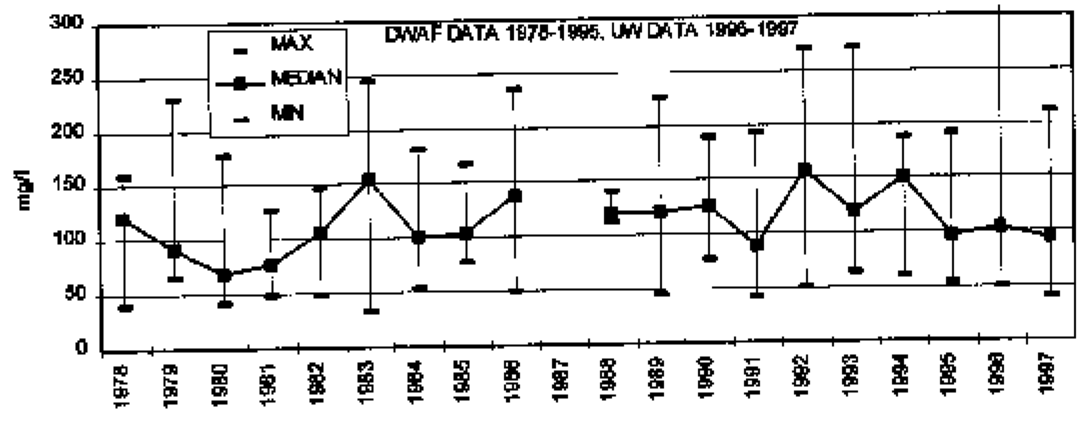
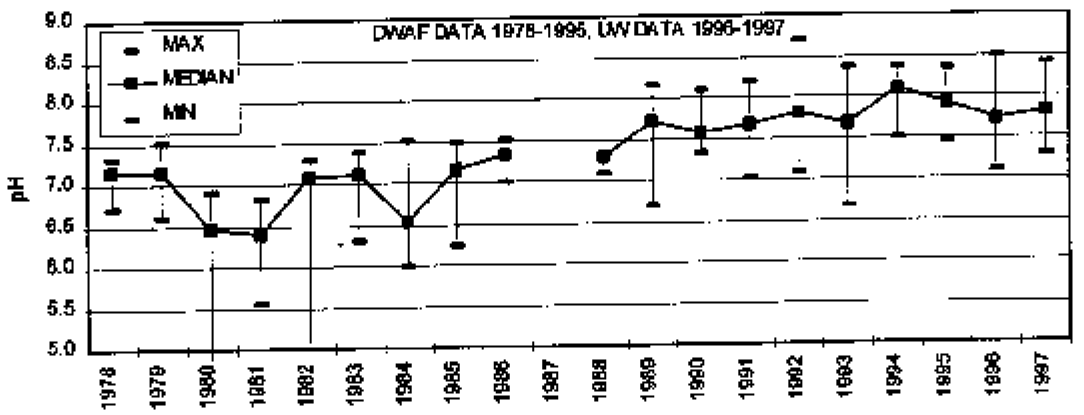


FIGURE 8: TEMPORAL TRENDS IN TDS CONCENTRATIONS AT U1H006



As was shown for U1H005, pH also indicates a rise from a base value of pH 7 to pH 7.5 - 8 with acceptable maximum values, but some dubious minimum values. Similar remarks apply.

FIGURE 9: TEMPORAL TRENDS IN pH VALUES AT U1H006



Unfortunately there are gaps in the data for nitrate and SRP concentrations, but indications are that as for site U1H005, the nitrate concentrations have risen slightly to between 0.2 - 0.3 mg/ℓ, while there has been no clear change in SRP concentrations from a generally low level of 0.005 mg/ℓ.

FIGURE 10: TEMPORAL TRENDS IN NITRATE CONCS. AT U1H006

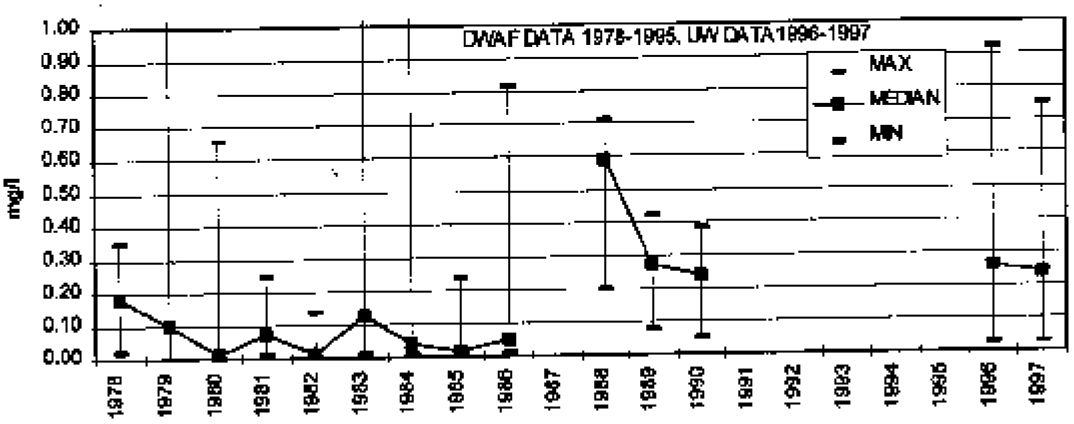
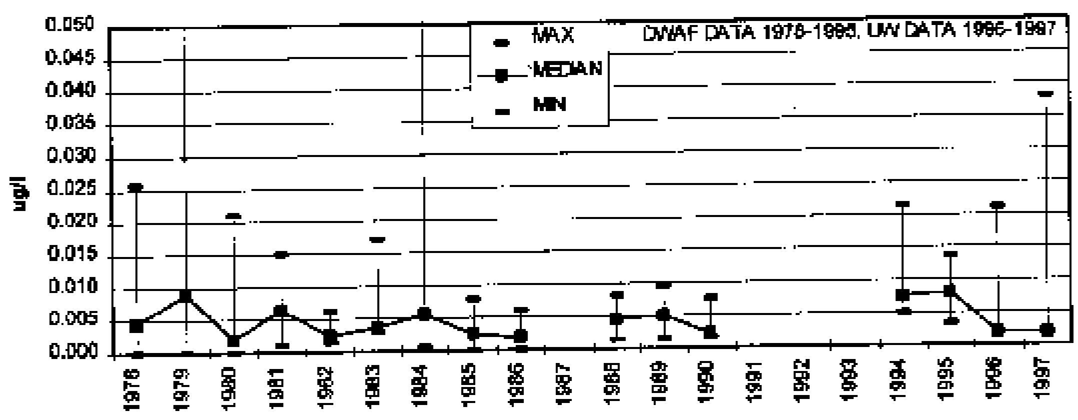


FIGURE 11: TEMPORAL TRENDS IN SRP CONCS. AT U1H006



To summarize, the historical data show that at the upper and lower catchment sampling sites both pH and nitrate values have risen slightly, but not to levels detrimental to either the environment or to other users. SRP concentrations do not appear to have changed at all from their relatively low levels and therefore it may be stated that the eutrophication potential of the river has not increased with development that has taken place in the catchment over the period. Similarly conductivity, as a measure of dissolved salts concentration and TDS, as dissolved solids concentration have not changed materially. Unfortunately, there was no measure of turbidity or suspended solids concentrations in the samples taken and therefore these trends cannot be assessed. These analyses have been included since Umgeni Water commenced monitoring.

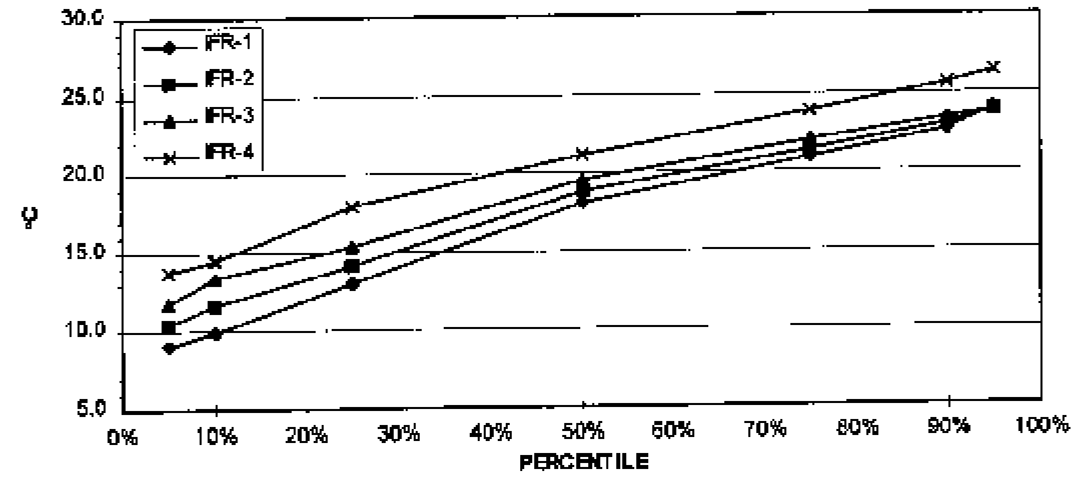
4.2 Current Water Quality at the IFR Sites

The routine Umgeni Water sampling sites are shown in the map of Figure 1 together with the location of the IFR sites selected. As may be seen, IFR-1 is just below sampling site 143, IFR-2 is between sites 143 and 147, IFR-3 is close to site 147 and IFR-4 is close to site 125. Consequently, the collected quality data for site 143 has been assumed for IFR-1, the mean results between sites 143 and 147 assumed for IFR-2, site 147 assumed for IFR-3 and site 125 assumed for IFR-4. The data sets for sites IFR-1 to IFR-3 then contain up to 97 results, while for IFR-4 have up to 120 results as monitoring was set up a little earlier for this site. An approximately two year monitoring period has been covered which lends a fair degree of confidence to the data analysis.

To show the distribution of the site results, percentile analysis was performed on each entire data set and then on site data subsets for summer (October - March) and winter (April - September) to characterize seasonal effects. Tests and analyses routinely carried out on the samples are temperature and pH measurements at site and analysis for *E. coli*, colour, turbidity, conductivity, alkalinity, calcium, magnesium, iron, manganese, nitrate, ammonia, chloride, sulphate, total phosphorus, SRP, TDS, suspended solids, total organic carbon (TOC) and total kjeldahl nitrogen (TKN) at the laboratory. The results are given in Tables 1, 2, 3, and 4 for the sites respectively in the Appendix. As may be expected, there is high variability in the individual data sets with means generally greater than medians for the solids associated variables (*E. coli*, colour, iron, manganese, total phosphorus, suspended solids, TOC and TKN) due to high concentrations caused by surface washoff during high flow events. Median values are better descriptors of water quality. The percentile distribution for the summer and winter data sets are quite different with regard to medians and range, which are generally far lower for the winter than for the summer data.

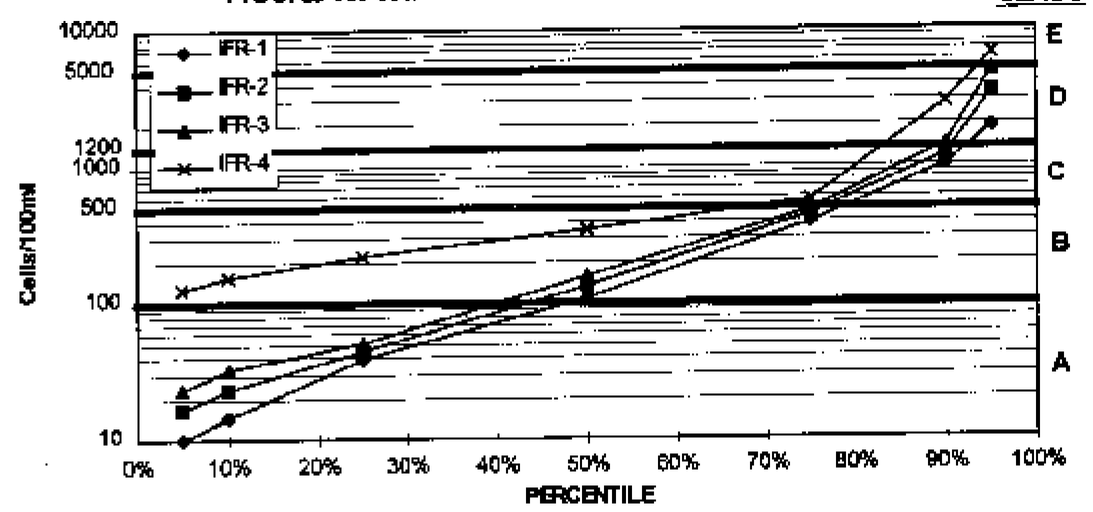
To more clearly show variability in quality at the sites and also between the sites, the percentile values for temperature, *E. coli*, pH, colour, turbidity, conductivity, ammonia, total phosphorus, SRP suspended solids and TOC from the 5^{th} to the 95^{th} have been graphed in Figures 12 to 23. The change in quality between sites progressively down the catchment and the distribution of the variable data for each site can easily be seen in the Figures. However, to give more meaning and substance to the description of quality, the Umgeni Water, Water Quality Index (WQI), which is routinely used to describe river water quality in the Operational Area has for the variables used in the index (*E. coli*, turbidity, conductivity, nitrate, total phosphorus, SRP, suspended solids and TOC) been entered onto the graphs for discussion. The derivation of the WQI is briefly as follows: based on experience and data collected for the Mgeni catchment, concentration ranges for the above variables, which can indicate degrees of water quality status, were drawn up to describe A class (excellent) through to E class (unsatisfactory) water quality. Then, using variable weightings and other manipulations, application of the procedure results in a single class classification to describe a sample. A full description of the WQI is given in the Appendix. For this purpose, however, only the individual variable classifications have been used to categorize water quality. The different classes are A for excellent, B for good, C for satisfactory, D for poor and E for unsatisfactory.

FIGURE 12: VARIATION IN TEMPERATURES



The temperature variation between the 5th and 95th percentiles at the sites ranges from 12 to 15 degrees and there is also a distinctive gradient between the sites of between 2 and 5 degrees rise for each percentile from the topmost site down to the lowest one in the catchment. Altitude and climate will be the driving factors here. This pattern, however, will be altered in the upper catchment with construction of the dams.

FIGURE 13: VARIATION IN *E. COLI* CONCENTRATIONS

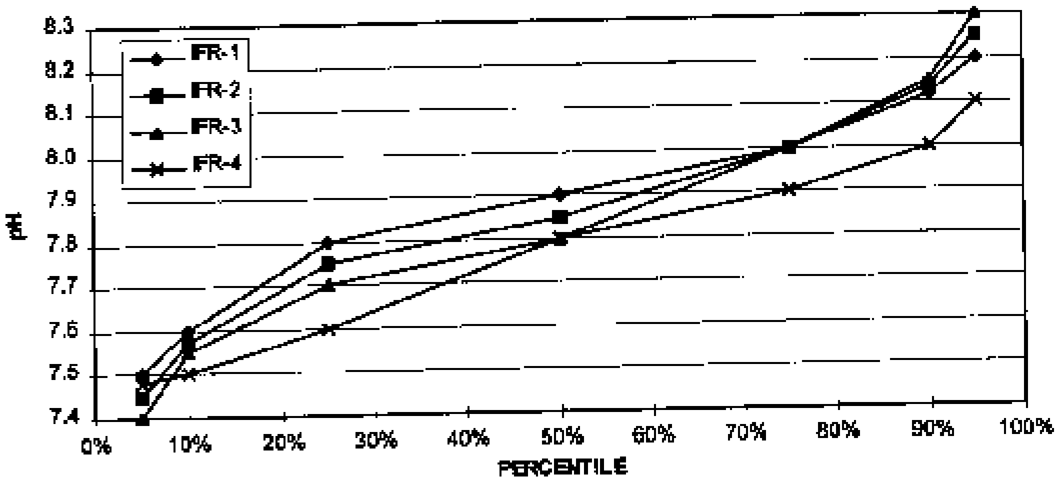


The *E. coli* count distributions show an almost stepwise increase in bacterial contamination from the uppermost site IFR-1 to the lowest IFR-4. Such a pattern could be expected due to increased activities and development down the catchment and more usage of the river by local inhabitants and animals. The medians for IFR sites 1 to 3 are grouped between 100 and 200 cells/100 mℓ, but the median for site IFR-4 falls between 300 and 400 cells/100mℓ. Similarly, there are large differences at the upper end of the distribution, the 95th percentile with a range from 2 000 (IFR-1) to 6 400 cells/100mℓ (IFR-4). For the WQI classes, 40% of the counts for IFR sites 1 to 3 fall into class A water, while all fall into class B for the median counts. Very poor water quality, classes D and E are only present at the 90th percentile and above.

In terms of Water Quality Criteria (DWAF guidelines, 1996) for direct potable use, none of the sites are suitable for this purpose, as the health risk becomes significant above an *E. coli* count of

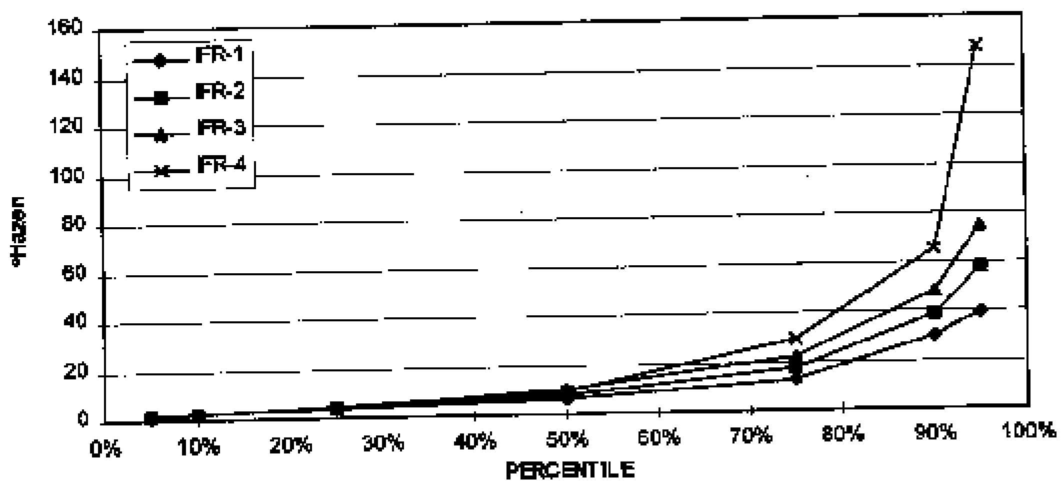
20 cells/100 mℓ. For full contact recreation such as swimming, IFR sites 1 to 3 would have minimum risk, the criteria being a median of less than 130 cells/100mℓ. Additionally the sites would be suitable for intermittent contact recreation such as boating up to the 90th percentile, or in other words not be suitable for only 10 % of the time. The criteria here is up to 1 000 cells/mℓ. A similar risk applies to the irrigation of crops that are eaten raw. Clearly, IFR site 4 with the highest level of contamination would be least suitable for the above purposes. There are no aquatic life guidelines for *E. coli*. To give perspective to these statistics for the Mkomazi sites, a comparison with the inflow to Midmar dam shows generally lower bacterial contamination for IFR site 1 with median counts of 128 and 330 cells/100mℓ respectively (Umgeni Water report WQP 4/97). In other words, the *E. coli* counts in the Mkomazi catchment are not high and are lower than those found in the Mgeni system, particularly after river flow through developed areas.

FIGURE 14: VARIATION IN pH VALUES



The pH data distribution shows that values fall slightly from the upper to the lower catchment although the differences are not large and the overall range from pH 7.4 to 8.3 is well within the accepted guidelines for all users. The aquatic life criteria for pH is that it should not be altered by more than 0.5 units or by more than 5% from the background value.

FIGURE 15: VARIATION IN COLOUR



The water colour increases down the catchment from IFR-1 to IFR-4 which is a pattern to be expected. Values increase rapidly at the 95th percentile which will be associated with high flow periods in summer (see seasonal data in Tables 1 to 4). There are no guidelines for colour for aquatic life, only being applicable for potable and recreational use. Again, comparison with the inflow to Midmar dam shows a lower median for the upper Mkomazi site and therefore it may be concluded that the current colour in the river is acceptable for all users.

FIGURE 16: VARIATION IN TURBIDITY LEVELS

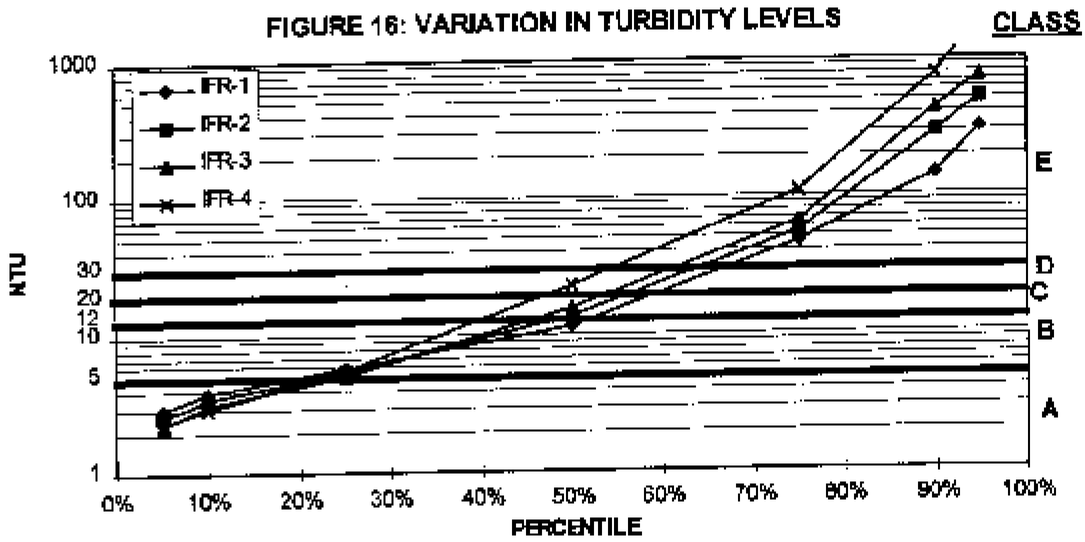
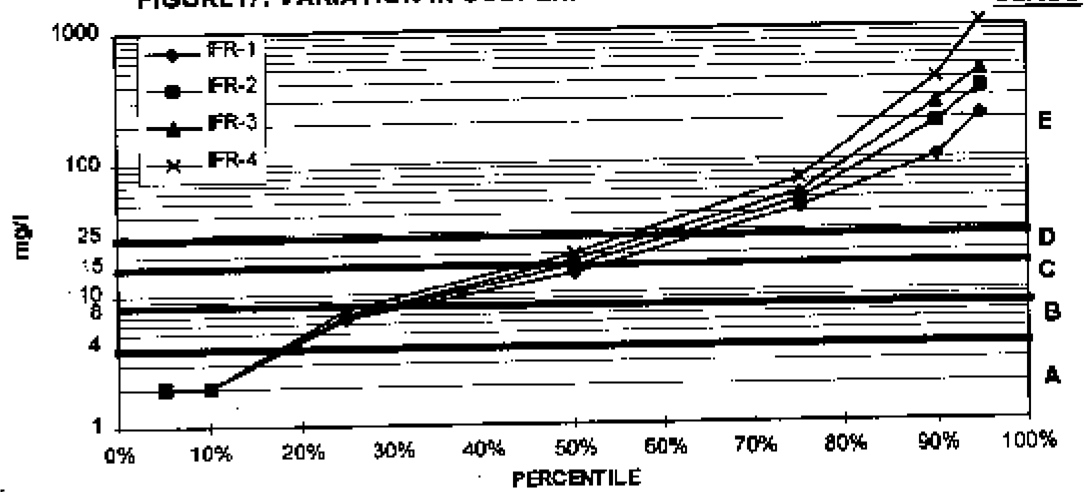
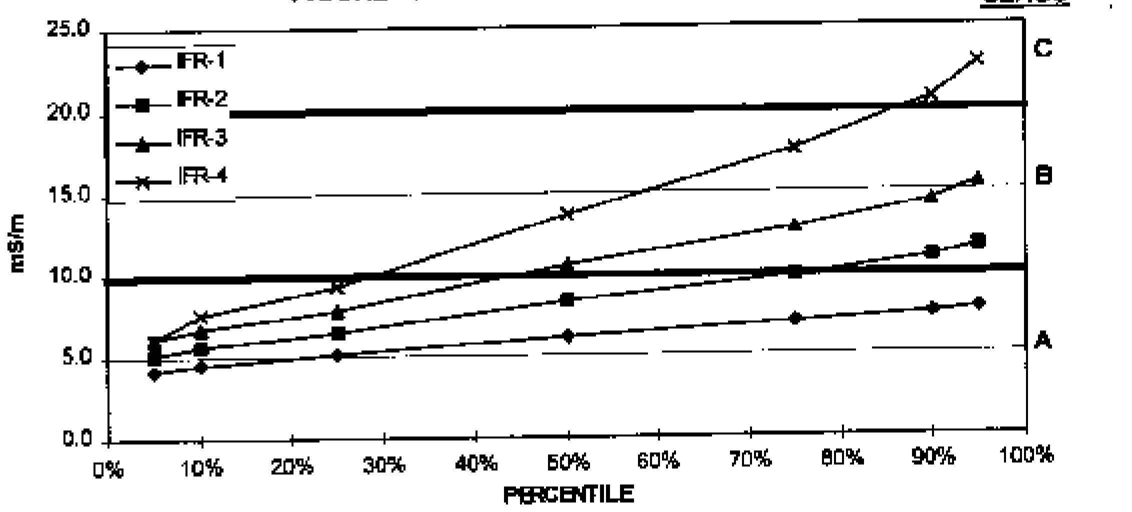


FIGURE17: VARIATION IN SUSPENDED SOLIDS CONCENTRATIONS



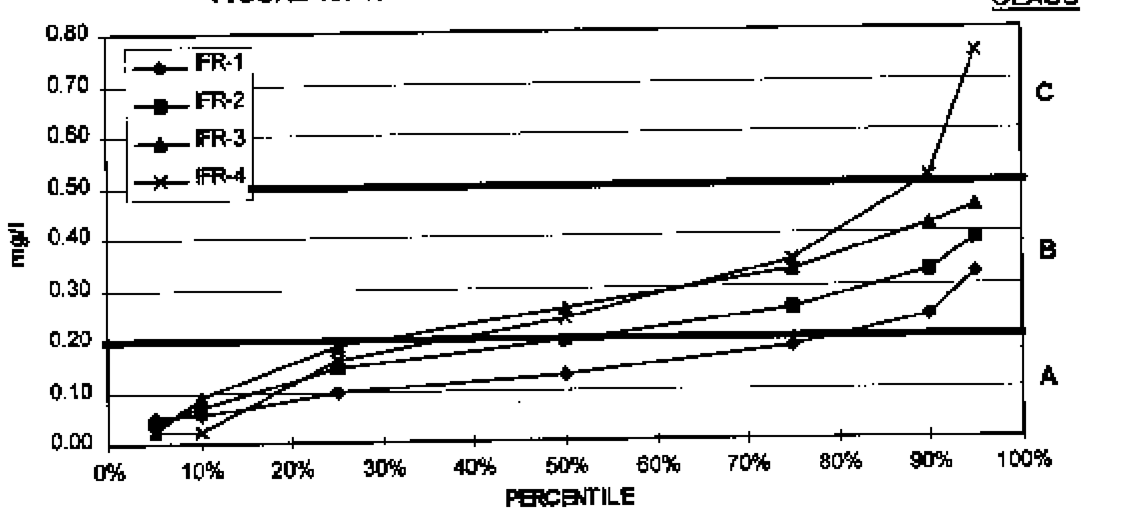
The site turbidity and related suspended solids data percentiles show the expected increase progressively down the catchment from IFR-1 to IFR-4. The WQI class distributions for both variables are similar and show class A water for only about 20% of the results, median results in C to D classes and unsatisfactory, class E, above the 70th percentile. Compared to data for Midmar dam inflow, the medians and lower percentiles are similar, but turbidities for the higher percentiles are much greater for the Mkomazi data (306 against 67 NTU for turbidity and 213 against 77 mg/ℓ for suspended solids for the 95th percentile) indicating higher erosion in the Mkomazi catchment. For aquatic life, the Target Water Quality Range (TWQR) is a concentration of less than 100 mg/ℓ suspended solids, or an increase of not more than 10% above background. The IFR sites fail the concentration limit variously between the 80th and 90th percentiles, but this situation will be improved with impoundment of the river. From a recreational perspective, the TWQR of a maximum of 5 NTU is only met at the sites up to the 25th percentile. For drip irrigation, the TWQR is a maximum of 50 mg/ℓ suspended solids which is met for more than half of the results, but would be problematic in the summer months (see Tables 1 to 4). Erosion appears to be the greatest problem affecting water quality and users in the Mkomazi catchment.

FIGURE 18: VARIATION IN CONDUCTIVITY

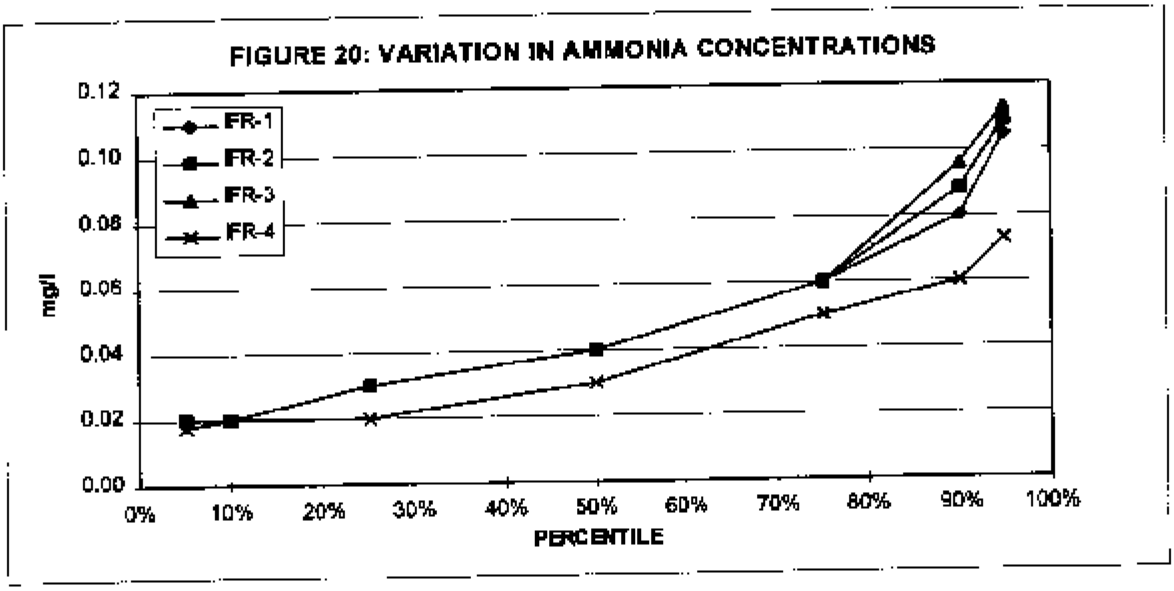


As seen for other variables, the conductivity of the Mkomazi increases in a downstream direction as the salt concentration increases. Most of the values fall into the A and B WQI classes which are described as good having low salt contents. A high conductivity, such as greater than 70 mS/m would generally indicate pollution and hence the reason for the categories, although a high value could still be due to salts derived from the geology of the region. The range of conductivity values shown here do not pose a problem to any users, as the taste threshold is at 45 mS/m, the TWQR for irrigation is less than 40 mS/m and for aquatic life the conductivity should not change by more than 15% from the background. The only threat to any users would be start up of some activity/industry in the catchment that discharged effluent or return flows that were highly saline. These data therefore serve as a background record to monitor changes against.

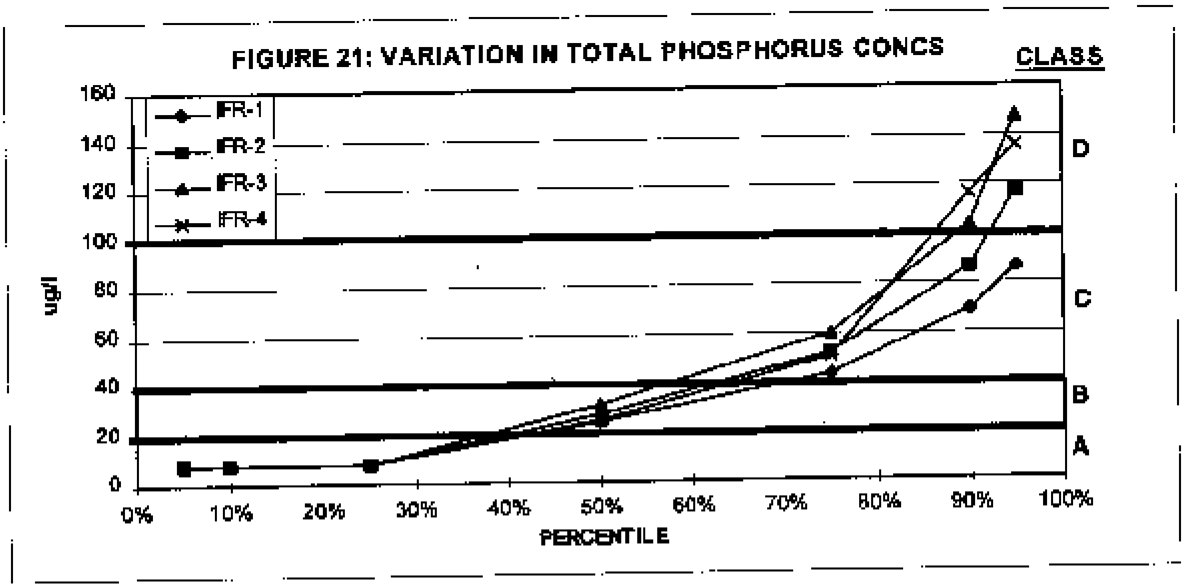
FIGURE 19: VARIATION IN NITRATE CONCENTRATIONS



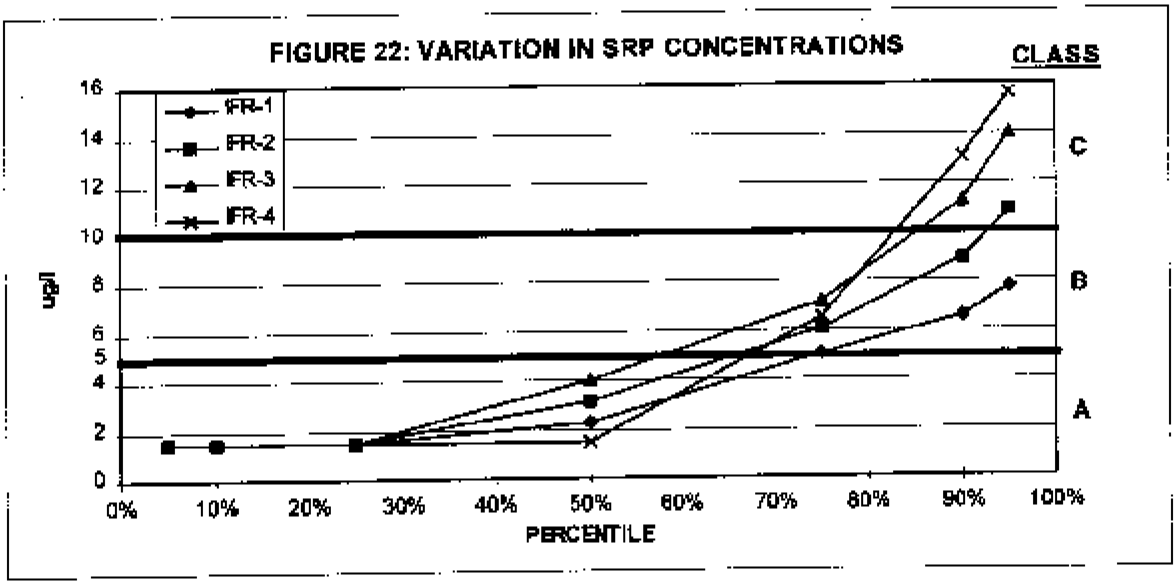
The nitrate concentrations also show increasing levels down the catchment reflecting addition from landuse activities such as agriculture and settlements. Almost all of the data distribution falls into the A and B WQI classes and does not indicate any pollution of significance. A median range of 0.01 to 0.03 mg/ℓ nitrate is typical of a water low in this nutrient with an oligotrophic classification for trophic status and suitable for all other users. Compared to the Midmar dam inflow, the above concentrations are generally less than half those of Midmar dam inflow which certainly has more agriculture in the catchment. It may be noted that there is little difference in the summer and winter data set distributions for nitrate, unlike the case for the solids associated variables.



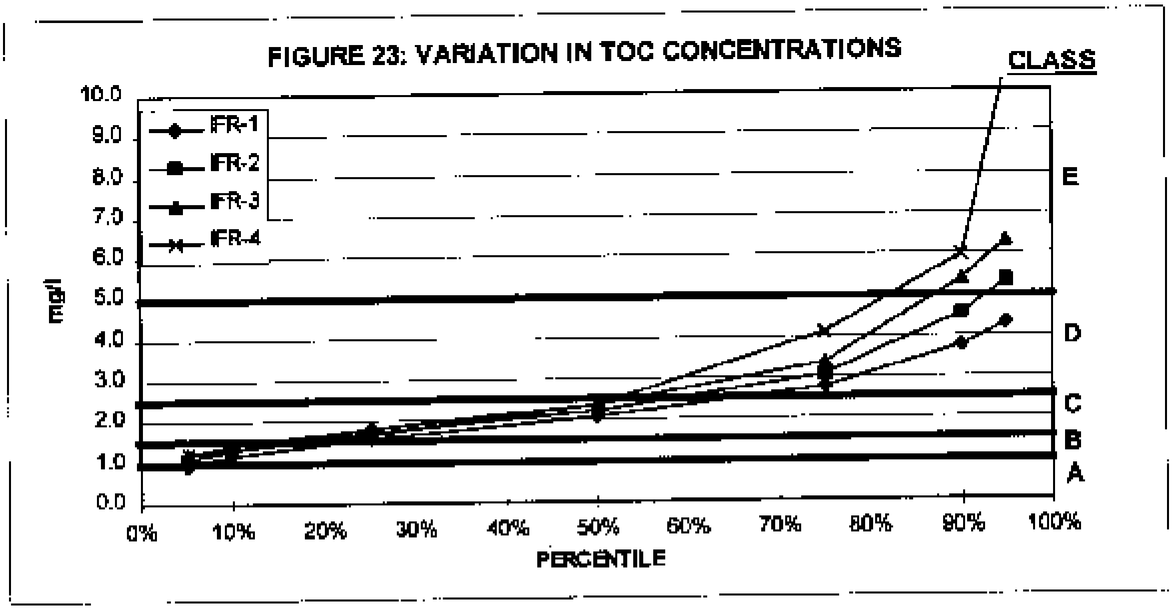
The only criteria for ammonia concentration in the WQI is that a concentration above 0.2 mg/ℓ is indicative of pollution and as may be seen none of the Mkomazi data falls into this category. From an aquatic life TWQR, the criteria is that the free ammonia concentration, "NH_3" should be less than 0.007 mg/ℓ to avoid toxicity to the most sensitive biota. The analytical test does not distinguish between "NH_3" and "NH_4" forms and the free ammonia concentration present will depend on the pH and temperature of the water, with dissociation to free ammonia increasing with pH and temperature. Applying the approximate median values for pH and temperature for the sites, 7.9 and 20 °C respectively, to a graph relating these factors together shows that only about 4% of the ammonia-N present will be in the free ammonia form. Then from a median ammonia concentration of 0.04 mg/l it may be calculated that the free ammonia concentration would be less than 0.002 mg/ℓ, which is well below the TWQR. Even at higher percentile values such as the 90[th] with dissociation of 10%, the free ammonia concentrations would not be particularly harmful. The pH - temperature dissociation relationship is shown as a graph in the Appendix.



For total phosphorus, the medians for all IFR sites fall into the B class with C and D classes above the 60[th] percentile. Since phosphorus is strongly adsorbed to sediments, the higher concentrations will be directly due to high suspended solids concentrations during summer flows discussed earlier. There is indication of pollution from these concentrations.



The SRP data distribution shows similar WQI classes to those for total phosphorus with no evidence of any significant pollution. Many of the results were actually below the test detection limit of 3 µg/ℓ. For aquatic life the TWQR is that any change from background should not be more than 15%, which should not occur unless the catchment was developed far more agriculturally or with settlements than is the case at present. The nutrient levels present equate to an oligotrophic eutrophication status for 50 to 70% of the results and going into mesotrophic status for the remainder of the results.

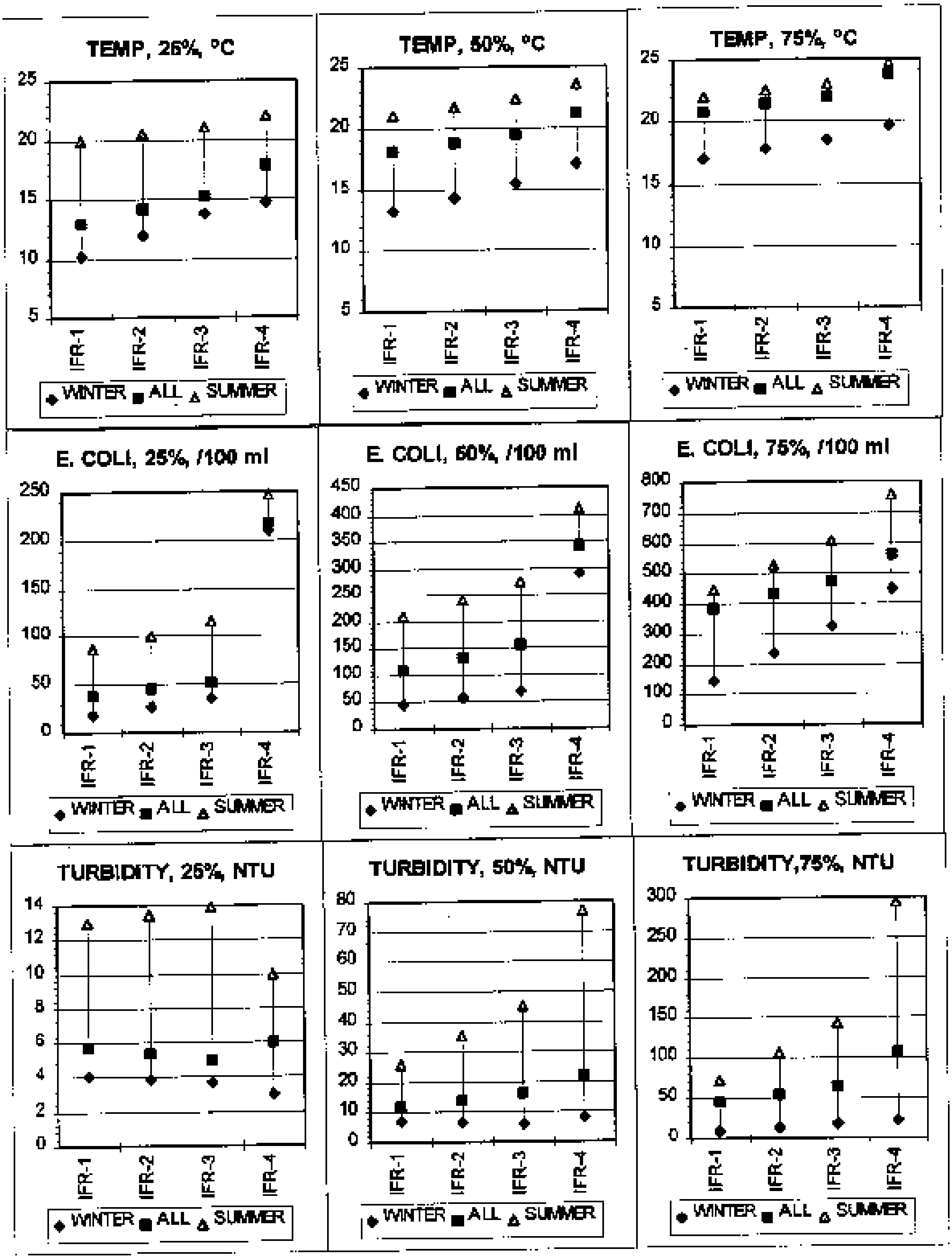


TOC is a measure of organic enrichment which may be due to either or both diffuse and point source pollution and the WQI classes are designed to give this indication. As seen before, in terms of TOC concentration the quality decreases down the catchment, with unsatisfactory levels above the 90th percentile which is due to high flow events and entrainment of suspended materials. Compared to Midmar dam inflow, however, the equivalent concentrations for percentiles for the upper Mkomazi IFR site are distinctly lower, which as stated before would be due to less agricultural and related activity in the catchment. Here again there is no direct threat to water quality. There are no aquatic life guidelines for TOC.

4.3 Seasonal Variation in Water Quality at the IFR Sites

The three most common water quality variables that are affected seasonally are temperature, bacterial counts and turbidity, although there are related variables such as suspended solids, total phosphorus, TOC and TKN that will vary in a similar manner. To show seasonal effects, the 25th, 50th and 75th percentiles for these variables are plotted in Figure 24 for summer and winter periods.

Figure 24: Seasonal variation in water quality at IFR sites, Oct. 1995 to Jan. 1998.



For temperature, the warming pattern down the catchment is clearly shown and the range between summer and winter is greatest for the uppermost IFR site, with a maximum of 10°C at the 25th percentile, while the minimum change shown is 5°C. To minimise impact on the current river biota when the dams are built, these ranges should not be changed or exceeded. The *E.coli* graphs show very distictive differences between summer and winter counts, with median winter counts of about 50 cells/100mℓ for IFR sites 1 to 3 against 200 - 300 cells/mℓ for summer. IFR-4 has by far the highest counts but still with a large difference between winter and summer. To maintain this reasonable bacterial water quality for local users (inhabitants, recreation, irrigators) these counts should not be increased by allowing uncontrolled activities/developments to take place in the catchment. As would be expected, turbidity differences between summer and winter percentile values are large as shown by medians of less than 10 NTU during winter for all IFR sites and summer medians ranging between 26 and 78 NTU. The summer - winter turbidity ranges are shown to increase considerably down the catchment for the 50th and 75th percentiles.

As stated earlier, the data has shown erosion to be high in the Mkomazi compared to the Midmar catchment resulting in high turbidity and related variable concentrations with strong flows which must be to the detriment of the aquatic life and other users. Catchment management initiatives need to be taken to prevent further deterioration in quality beyond the limits shown.

4.4 Effect of Impoundment on Water Quality

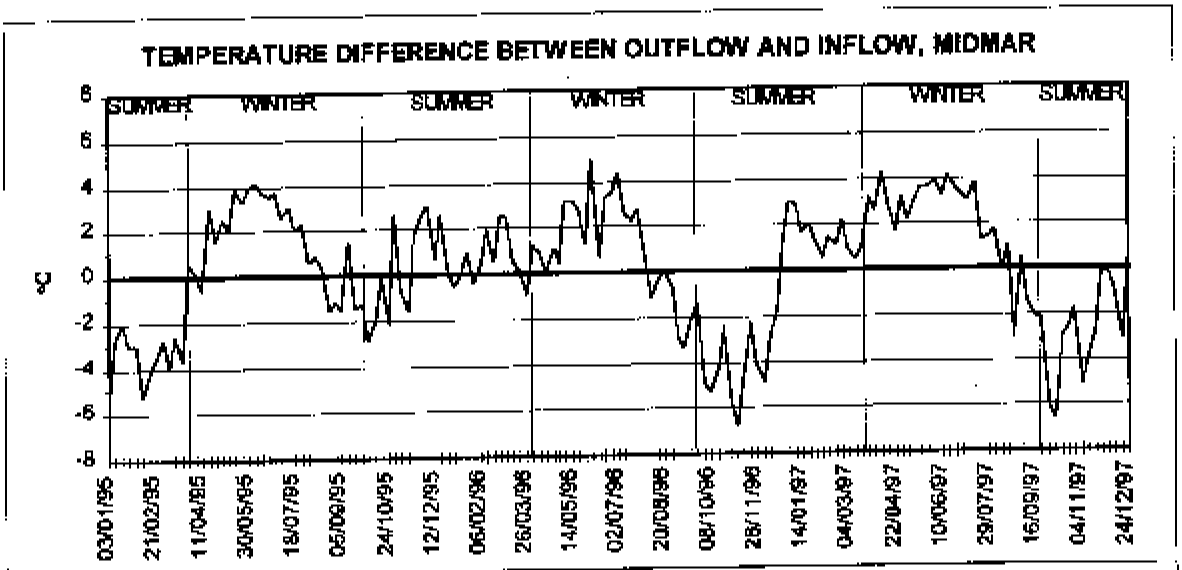
When a dam is constructed, whether it be only one (as proposed for the Impendle option) or two (for the Smithfield - Impendle option), the existing water quality in the river at the point of release from the dams is going to be greatly altered. Released dam water quality will be far less variable for temperature and constituents such as *E. coli*, turbidity, suspended materials, total phosphorus and to a lesser extent for the soluble nutrients than the natural run-of-river variability. Provided that the release is not bottom water containing sediments, the water will be an improvement in quality. Pertinent data for the Midmar and Inanda dams have been assessed to show the type and extent of the changes in water quality likely to be brought about by impoundment and to predict the future water quality for the IFR sites when development has taken place.

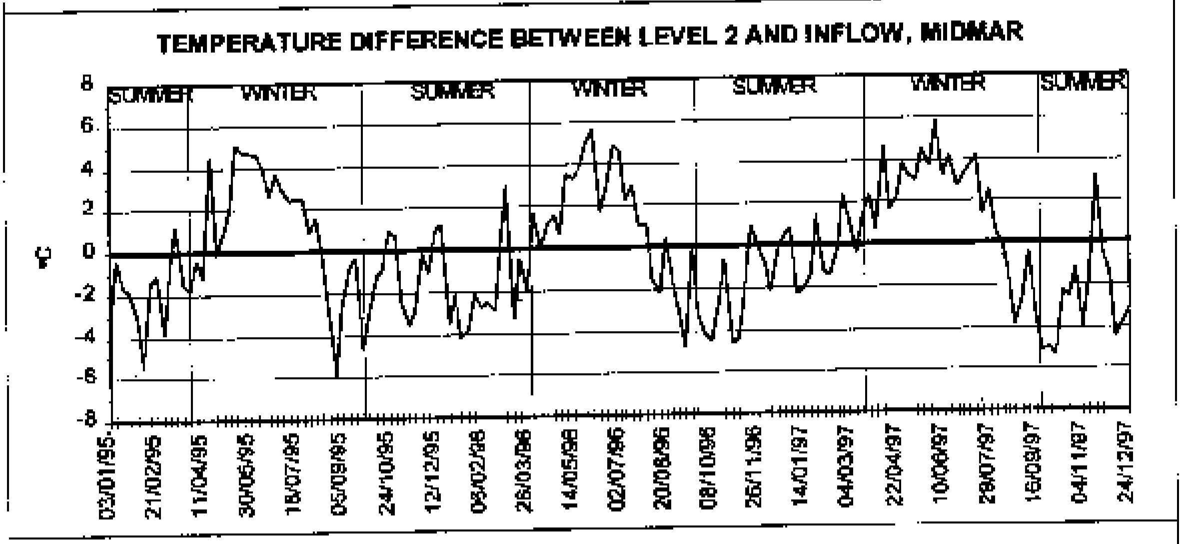
4.4.1 Temperature

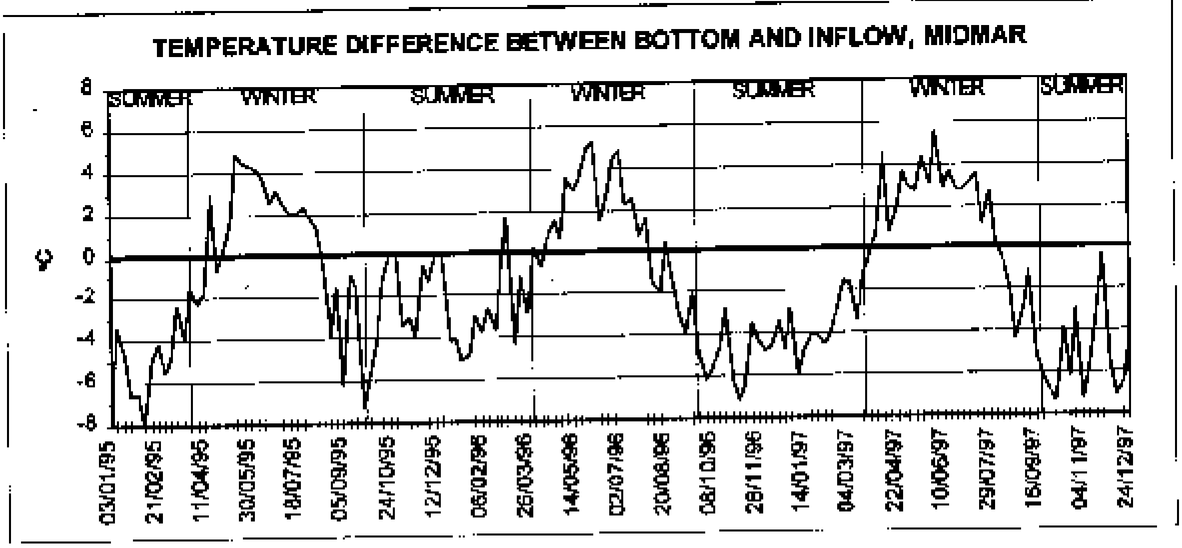
Midmar dam has a similar altitude to the proposed Mkomazi dams and river and dam temperature regimes are likely to be similar. In fact, an earlier data asssessment showed that the temerature data distribution for Midmar dam inflow and site 143 were similar with medians of 18.9 and 19.2°C respectively (UW WQP 4/97) Data for Midmar dam from 1995 to 1997 shows that the inflow water temperature is appreciably different to the dam outflow (release and overflow), a typical drawoff level at 10 m depth or bottom water. The relative changes in temperature from the inflow, positive and negative, are shown as time series graphs for the above possible dam release points in Figure 25. Summer, October to March, and winter, April to September, periods have been marked in the figures to illustrate the seasonal changes. It is suggested that changes of this order may be be expected for different releases/overflows from the Mkomazi dams. Comments are:

- The general pattern is that all possible outflow points from the dam show decreases in temperature during the summer periods and increases in winter over inflow temperatures.
- The highest decreases in summer are shown for bottom water, up to 8°C, and the highest increases in winter for the drawoff level, 6°C, although the temperatures for the other sites for the same periods are not much different.
- The outflow graph shows an apparent anomaly for the summer period, October 1995 to March 1996, with higher instead of lower temperatures as is the case for the other summer periods. This was caused by a simultaneous period of very strong inflow into Midmar dam resulting in high spill volumes of up to 60 Mm³/week of warmer surface water instead of colder released water. The high inflow and spill effect may be seen for the same period but to a lesser extent in the other graphs.
- The change in temperature, particularly for decreases in summer, may even be greater in the proposed Impendle dam as it will be much larger and deeper than Midmar dam.

Figure 25: Temperature changes from inflow to possible outlets for Midmar dam



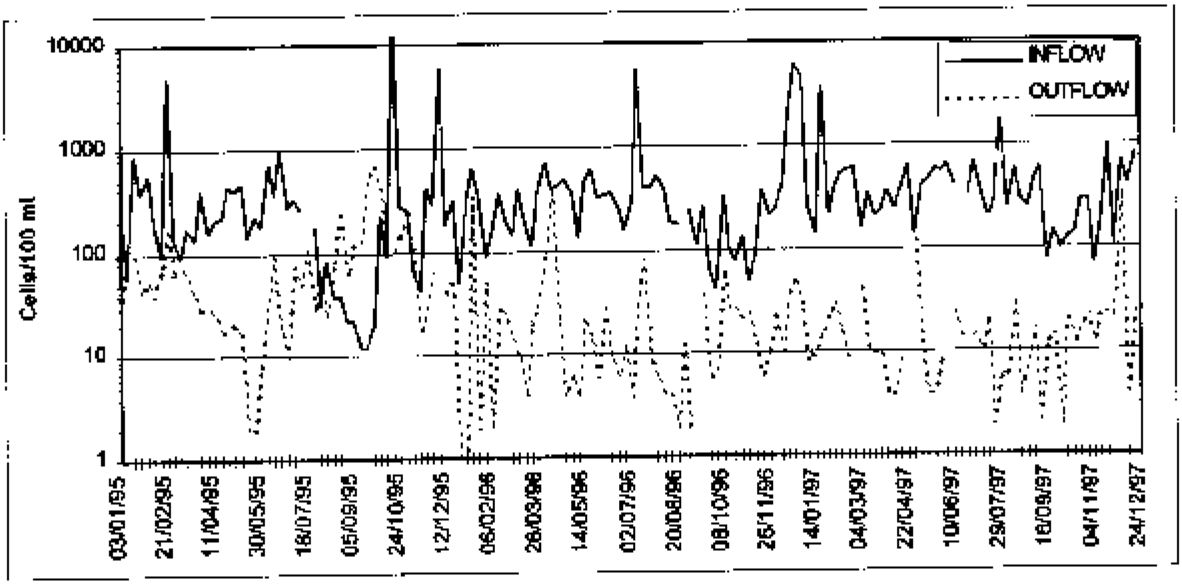




4.4.2 *E. coli*

Bacteria die off during impoundment due to the effects of UV radiation and a long retention time and therefore releases usually contain far lower counts than the inflow. The time series plot of *E. coli* counts for inflow and outflow for Midmar dam are shown in Figure 26. Clearly, there is a great improvement in water quality brought about in the dam.

Figure 26: *E. coli* counts in the Inflow and outflow from Midmar dam



To quantify the change in *E. coli* counts, the distribution of the data as percentile values is given below. The changes are at least an order of magnitude or more and could be expected to occur in the proposed Mkomazi dams.

Table 5: *E. coli* data distribution for inflow and outflow data for Midmar dam

		Percentile							
	Mean	0%	5%	25%	50%	75%	95%	100%	n
Inflow	673	12	40	140	270	415	1950	26000	151
Outflow	49	1	2	8	20	42	217	650	149

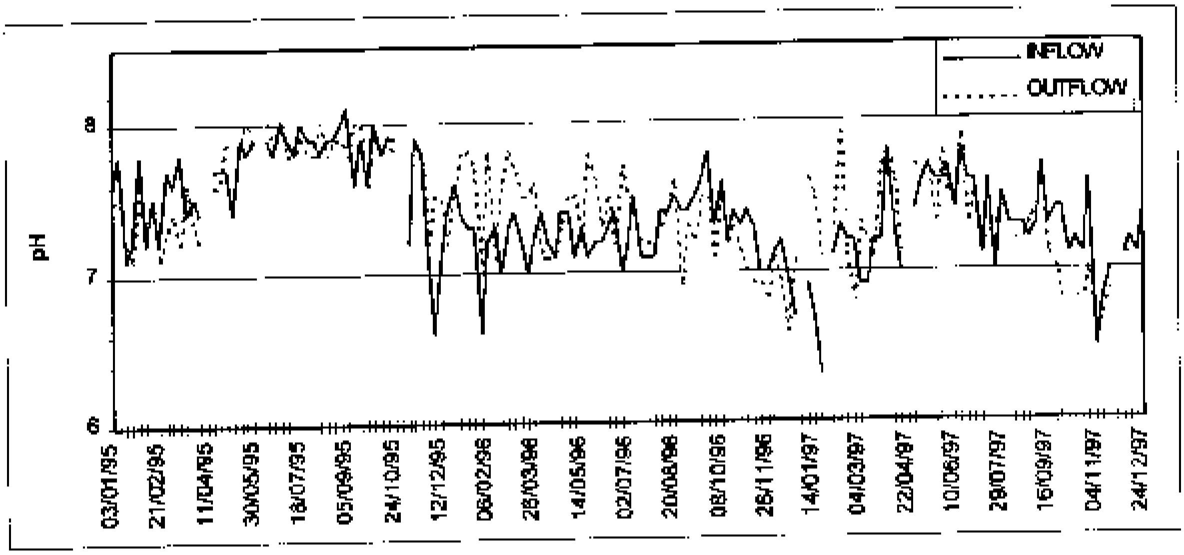
4.4.3 pH

These data were looked at in a similar manner as pH may change in a dam due to algal growth altering the alkalinity balance or other factors such as the acidity from rain. A comparison of inflow and outflow is graphed in Figure 27. The inflow pH generally shows greater variability and lower absolute values, while the outflow pH shows higher values at times, probably due to algal growth taking up carbon dioxide. Overall, however, the changes are small as is shown in the data ditribution table below.

Table 6: pH data distribution for inflow and outflow data for Midmar dam

		Percentile							
	Mean	0%	5%	25%	50%	75%	95%	100%	n
Inflow	7.4	6.3	6.9	7.2	7.4	7.6	7.9	8.1	148
Outflow	7.4	6.5	6.8	7.2	7.5	7.7	7.9	8.0	145

Figure 27: pH in the inflow and outflow from Midmar dam



4.4.4 Soluble Reactive Phosphorus

Soluble reactive phosphorus is the phosphorus form and usually the limiting nutrient for algal growth in dams and rivers as opposed to the other nutrient, inorganic nitrogen. Phosphorus attached to suspended solids also may provide nutrient, but in dams rapid sedimentation usually takes place and the adsorbed phosphorus is trapped and unavailable to a degree. The change in SRP concentrations through Midmar dam is shown in Figure 28 and the data distribution given as an indication of the effects likely to occur in the Mkomazi dams.

Figure 28: Soluble Reactive Phosphorus in the inflow and outflow from Midmar dam

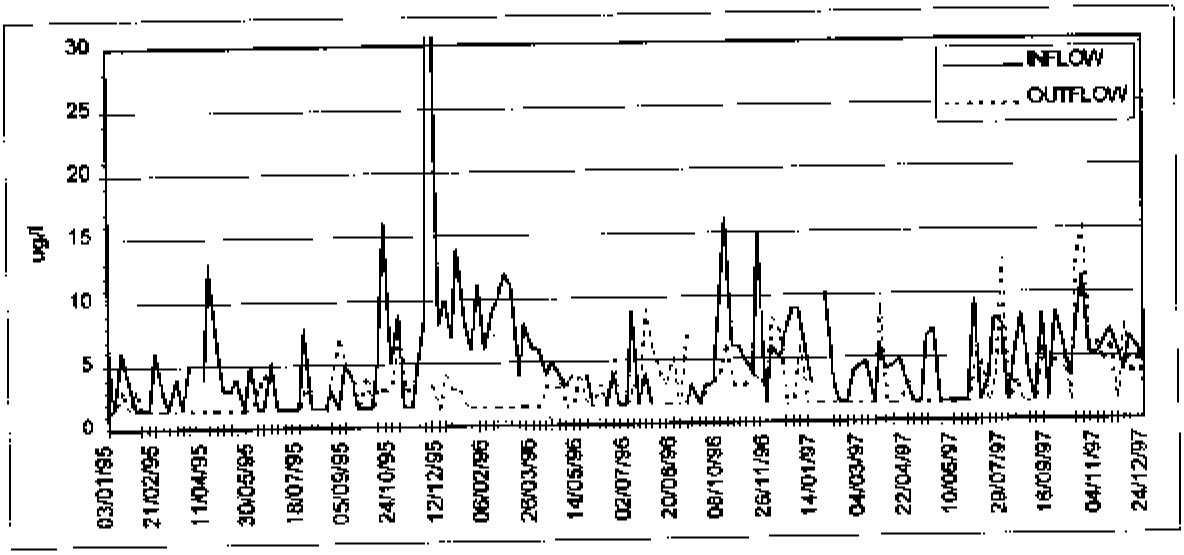


Table 7: Soluble Reactive Phosphorus data distribution for inflow and outflow data for Midmar dam

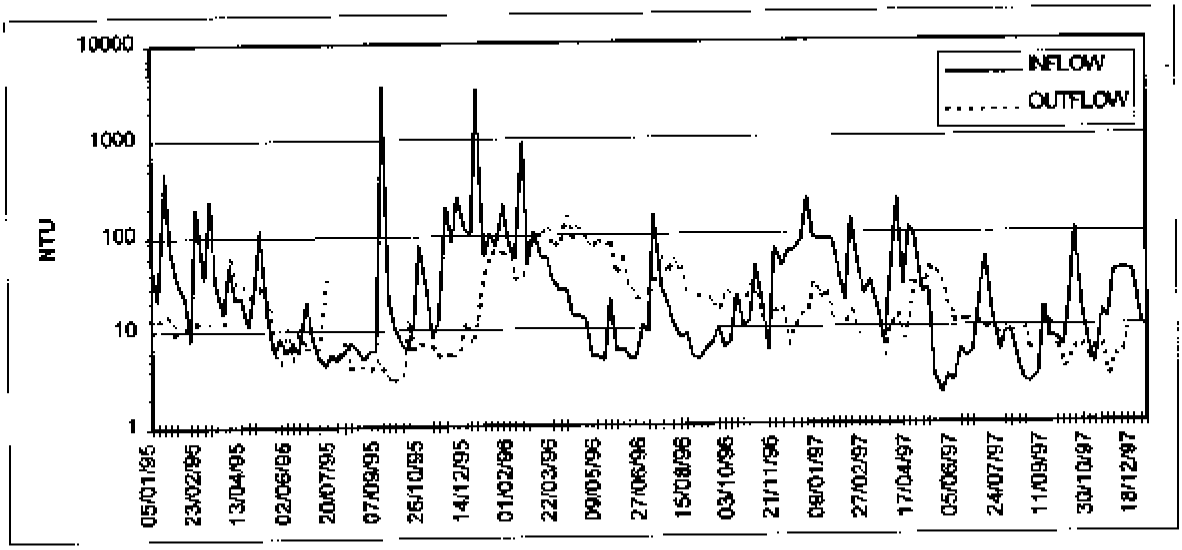
		Percentile							
	Mean	**0%**	**5%**	**25%**	**50%**	**75%**	**95%**	**100%**	**n**
Inflow	5.2	1.5	1.5	1.5	4.0	6.6	11.2	57.0	149
Outflow	3.0	1.5	1.5	1.5	1.5	4.0	7.3	15.0	150

The data shows higher SRP concentrations in the inflow than in the outflow which implies that the nutrient is taken up by algal growth and possibly adsorption onto suspended solids. Both the figure and data distribution table indicate relatively high inflow concentrations at times which will be related to strong inflows. A similar pattern of reduction would be expected in any Mkomazi dams built, which from a water quality point of view would mean a lower growth potential water being discharged from a dam than under natural conditions. This may or may not be considered an advantageous change to the river in this particular case. It should be borne in mind that the SRP concentrations are low with no indication of enrichment.

4.4.5 Turbidity

To show the likely impoundment effects of the proposed dams on the natural river turbidity, data for Inanda dam rather than the Midmar have been used as the inflow turbidity regime at Inanda dam is hig..er than that at Midmar dam and closer to Mkomazi data set. The time series data for a 3 year period is shown in Figure 29. As expected, considerable clarification takes place in the dam through sedimentation, although relatively high outflow turbidities are shown for the summer months at the beginning of 1996, which was caused by very high inflow to the dam and resultant spill volumes of more than 100 Mm^3/week. This is pertinent to include as similar events could happen with the Mkomazi dams.

Figure 29: Turbidity in the inflow and outflow from Inanda dam



River water compensation releases from a dam would not necessarily be overflow and could be water released from an intermediate level drawoff off or from the scour, in which case different turbidity levels would result. To make this point, the data distribution for:

- Inanda dam outflow which would be a combination of overflow and releases at times or just release water only,
- A drawoff level 8 m below the FSL and,
- Bottom water which may approximate scour water release are shown in the table below.

Table 8: Turbidity data distribution for inflow, outflow, level drawoff and bottom water for Inanda dam

		Percentile							
	Mean	0%	5%	25%	50%	75%	95%	100%	n
Inflow	90	2	4	7	15	51	208	3701	157
Outflow	24	3	4	7	12	28	87	146	149
Level	16	1	1	3	6	19	66	168	137
Bottom	204	6	9	29	54	122	1273	3020	154

At the 50th percentile, there is not much difference between inflow, outflow and the level turbidities, but at higher percentiles the differences become quite large, particularly at the 95th percentile and the extreme values. Clearly, impoundment changes turbidity levels very significantly. What this means is that instead of the Mkomazi river at impoundment sites being subjected to periodic turbidity levels of between 290 and 2 700 NTU above the 90th percentile (10% of the time during summer, see Table 1), much lower turbidities well below 100 NTU will prevail. Since the proposed Impendle dam will be almost 3 times the size of Inanda dam, settlement and clarification is likely to be even greater than shown above, resulting in lower turbidities. The aquatic life specialists must decide if this change is advantageous or not. Turbidity levels shown for bottom water are generally higher than those for the inflow and if this quality was assumed to be typical possible scour release water, then turbid water could be released if required. However, this water would be anoxic and contain reduced elements such as sulphides, iron and manganese and may not be considered a good policy for aquatic life and other users.

4.5 Predicted Water Quality at the IFR Sites With Dams Built

The existing water quality at the IFR sites has been described as well as typical water quality that could be expected from releases from the proposed dams. These data have been combined to estimate the changed water quality that could be expected at the IFR sites, making the following assumptions:

- That the dam release volumes will approximate the natural catchment runoff.
- That percentile data distribution can be combined for two sites, in this case the data set for existing water quality at an IFR site with the data set for typical dam release water quality (overflow from a dam as described above). Each data set would be weighted by the respective contributing catchment areas to give a mean water quality, incremental catchment area for site data and dam catchment area for the dam release water quality.
- That there will be two dams.

Relevant data are given in the table below.

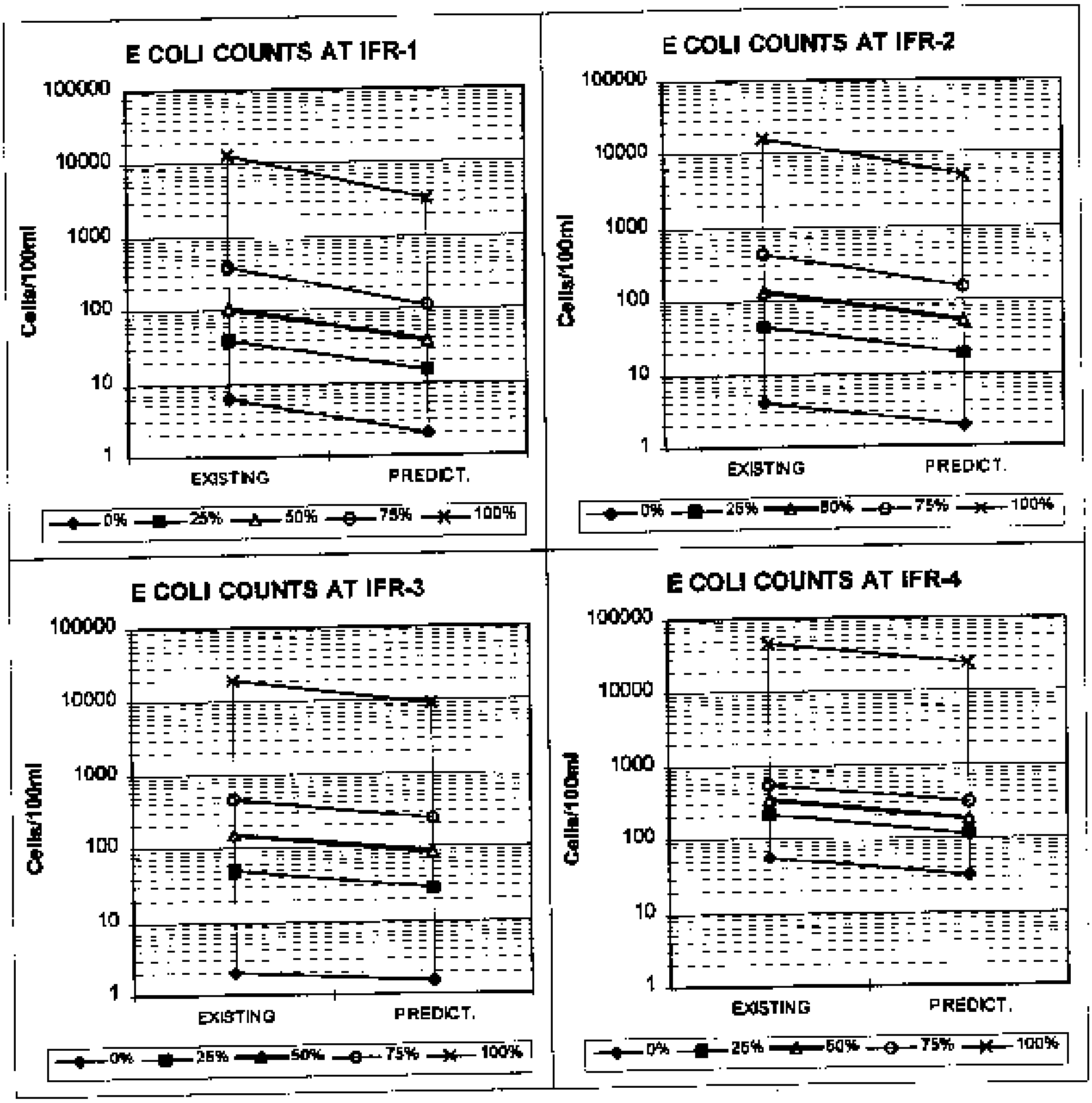
Table 9: Catchment areas and percent contributions from dam and natural runoff

	Total catchment area, km^2	Incremental catch. Area, km^2	% Contribution from Dam	% Contribution from natural runoff
Impendle dam	1442			
IFR-1 site	1810	368	80	20
Smithfield dam	2074			
IFR-2 site	2924	850	71	29
IFR-3 site	3910	1836	53	47
IFR-4 site	4314	2240	48	52

The dam effect on future water quality will be greatest for IFR-1, as the proposed Impendle dam will dominate by contributing 80% of the flow at the site. The dam contribution below the Smithfield dam, however, will be lower ranging down to 48% for IFR-4. Temperature changes at the sites caused by impoundment as shown earlier have not been considered in this analysis as their effect will only be high close to point of release, and will be dependent upon the type of release and the rate at which ambient temperatures return in the river which is not known. This potential change should, however, still be borne in mind when considering impacts and what type of release is preferable. Basic data distribution for the existing, the anticipated dam release and the calculated future water quality for the IFR sites are given in Table 10 in the Appendix.

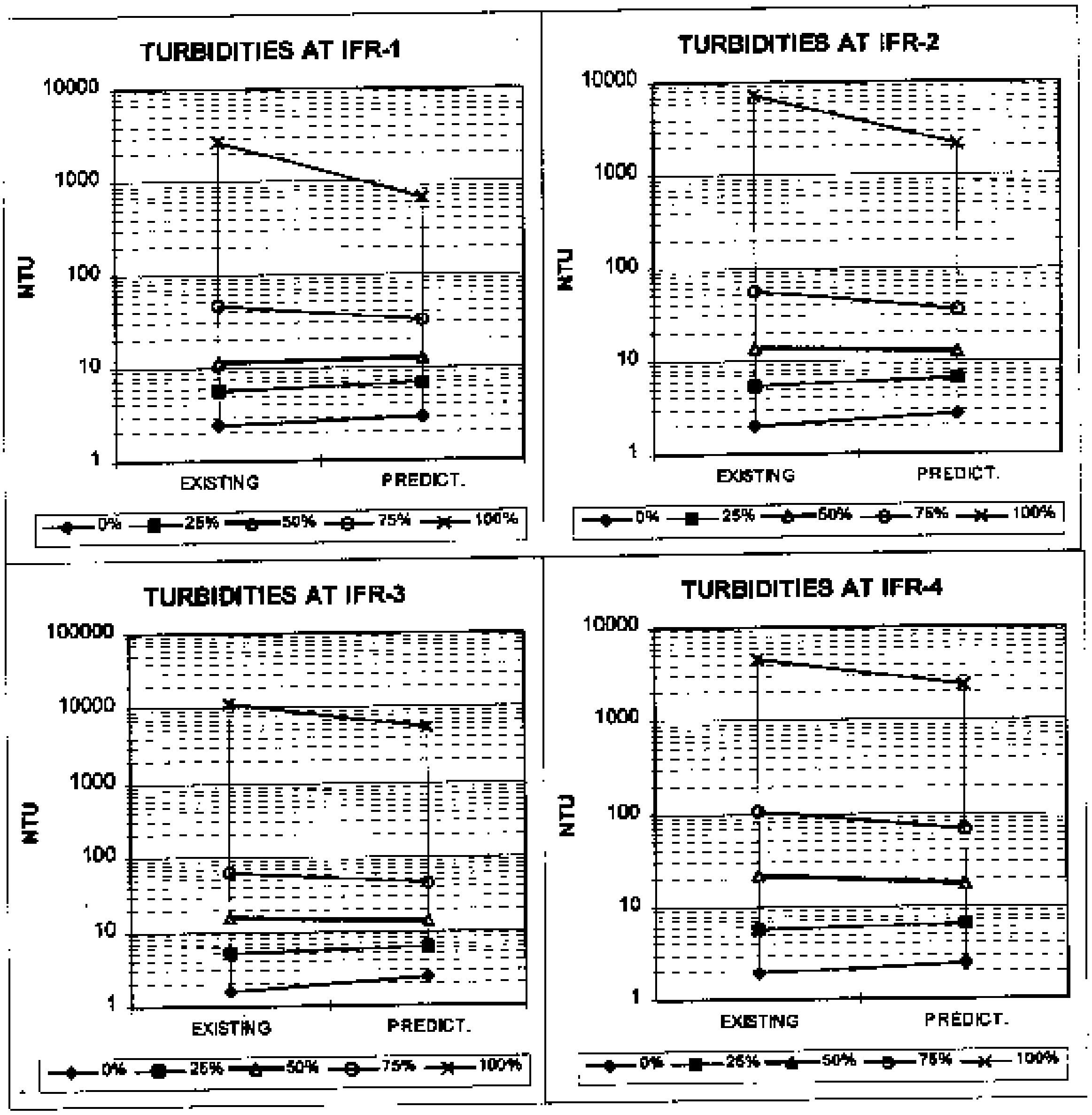
The most significant changes will be for *E. coli* counts and turbidity values, while for SRP the change is unlikely to be large as the existing concentrations at the IFR sites are already at low levels. To see the projected changes in water quality at the IFR sites, the data have been graphed in Figures 30 to 32.

Figure 30: Predicted changes in *E. coli* counts at the IFR sites



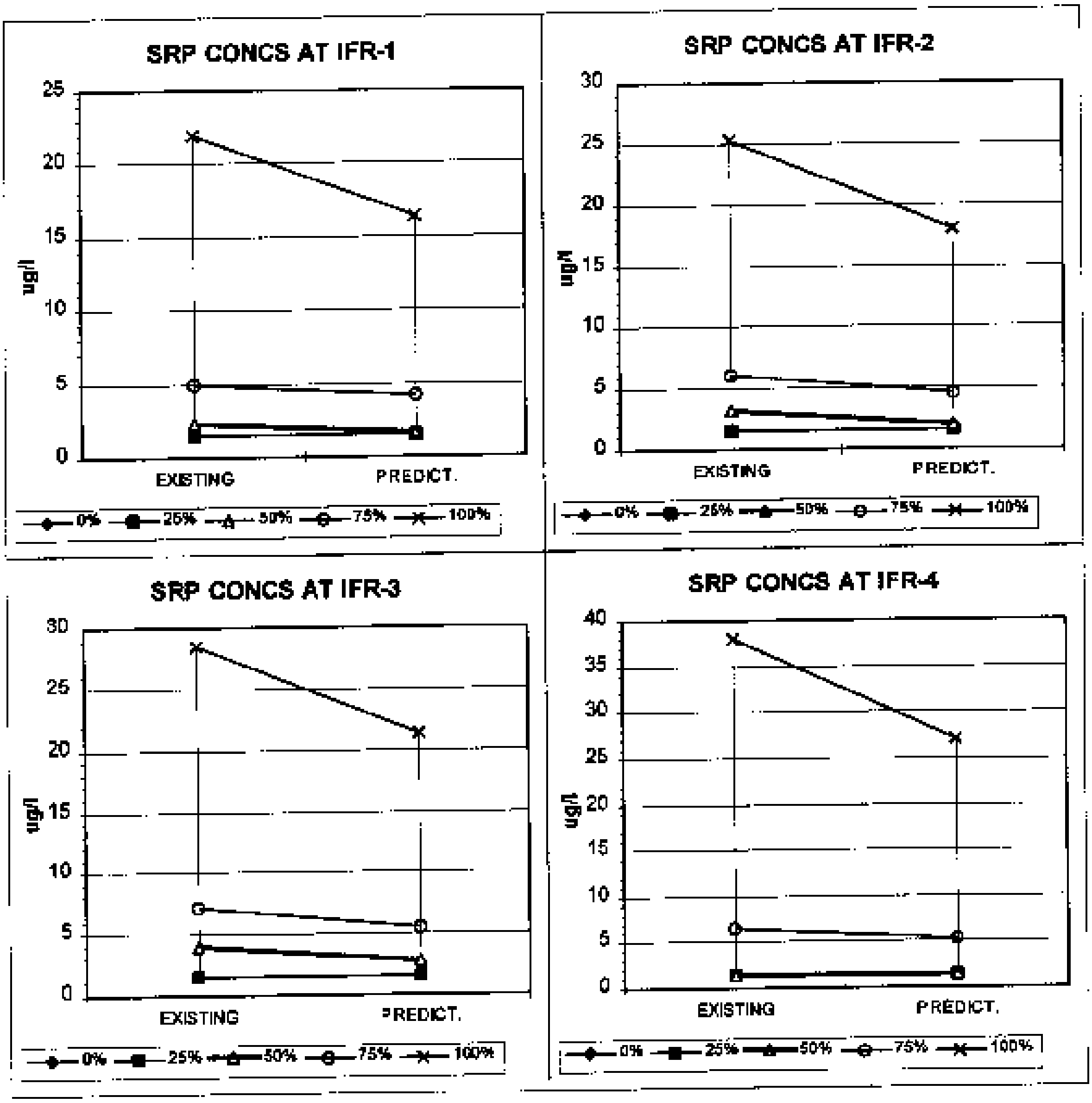
The improvement in *E. coli* counts for all IFR sites is predicted to be considerable throughout the data distribution, particularly for the the 50^{th} percentile and above. At IFR-1 the median will change from 110 to 38 cells/100mℓ and the extreme value from 13 000 to 3 200 cells/mℓ. Similar reductions are shown for the other sites. Recalling the WQI classification scheme discussed earlier, the prediction for median counts for IFR sites 1 to 3 shows a movement from a class B to a class A water, while the extreme for IFR-1 improves from class E to D. These lower bacterial counts will be advantageous to all direct users of the river, but the effect on aquatic life is not known as no criteria are given.

Figure 31: Predicted changes turbidity values at the IFR sites



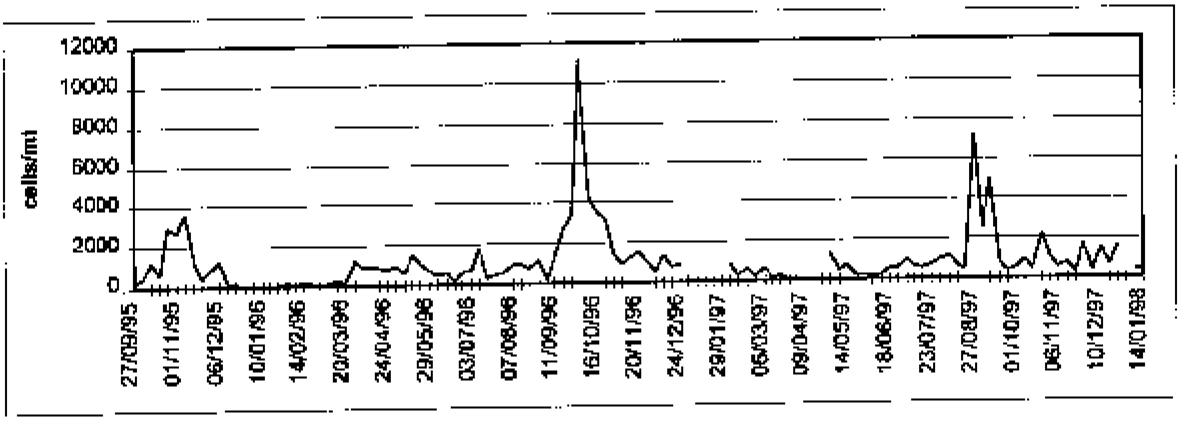
As shown for *E. coli*, large changes in turbidity are predicted. In this case the changes for the medians are not great but are significant at the 75th percentile and above. This effectively means clearer water for longer periods in the river. There will still be times when turbidities may rise to 3 000 and 24 000 NTU for sites IFR-1 to IFR-4 respectively during flood flow, but this will still be a great improvemnt on recorded prior levels of 13 000 to 47 000 NTU. A similar pattern of reduction may be expected for related variables such as total phosphorus due to the phosphorus bound to sediments, TOC and TKN. The future water quality for these variables has not been calculated, but could be if required.

Figure 32: Predicted changes SRP concentrations at the IFR sites



The graphs show that extreme, 75[th] and 50[th] percentile SRP concentrations will fall significantly with the exception of the median for IFR-4 which is already at the method detection limit. The lowering of the SRP concentrations will mean a lower algal growth potential in the river, but on the other hand algal counts may well be bolstered by algae grown in the dams and released by overflow or from a level drawoff. It is difficult to estimate the concentrations of algae that will result from dam releases as algal populations in dams can be quite variable. When the dams are initially filled, it is likely that algal blooms will develop as a result of the release of nutrients from vegetation not removed from the flooded area. However, in time when this effect has been flushed from the dams and algal growth becomes more dependent on the nutrients contained in river inflow, the algal population will fall considerably. Without even considering loading models, and just looking at algal responses in Midmar dam and taking into acount the fact that nutrient concentrations in the upper Mkomazi are lower than those in Midmar dam inflow, it may be predicted that lower algal counts will pertain in the dams. Consequently, in the longer term discharge of high algal content water is not expected to occur and impact detrimentally on the IFR sites. Monitoring of algal counts at sites 143 and 147 was started in November 1997 to obtain background values which average out at 460 and 660 cells/mℓ respectively, which is not high. Longer term data is available for site 125 in the lower catchment and is shown in Figure 33. As may be noted, high counts above baseline values occur at the beginning of summer in October of each year. The pattern for the upper sites has yet to be established, but counts are likely to be lower.

Figure 33: Total algal counts at site 125 (close to IFR-4)



5. SUMMARY

The assessment of historical data and trends between 1976 and 1997 show that:

- For both upper and lower catchment sample sites, the pH and nitrate values have risen slightly, but not to levels detrimental to either the environment or other users and with no indication of pollution.
- Conductivity and TDS concentrations have not changed and are at acceptable levels.
- SRP concentrations are low and have remained low with no indication of pollution.

The assessment of current water quality and spatial trends at the IFR sites shows that:

- Temperature increases down the catchment by between 2 and 5°C between sites and has seasonal ranges for sites of between 12 and 15°C.
- *E. coli* counts increase down the catchment, being far higher at IFR-4 than at the upper sites, approximately 350 compared to 150 cells/100 mℓ for the medians. Measured against WQI classes, 40% of the results fall into class A water for IFR sites 1 to 3. In terms of water quality guidelines, IFR sites 1 to 3 would be suitable for full contact recreation for much of the time and suitable for intermediate contact recreation up to the 90[th] percentile. Bacterial contamination is less in the upper catchment than for the Midmar catchment.
- The pH value data distribution is suitable for all users.
- Turbidity and suspended solids concentrations increase down the catchment with 50[th] percentile values reflecting a class C to D water quality, satisfactory to poor. Above the 60[th] percentile, the poorest class, class E category prevails. For aquatic life, the suspended solids concentrations exceed the limit above the 80[th] percentile and for recreation above the 25[th] percentile. Compared to data for the Midmar catchment, turbidity and consequently erosion is much higher.
- Conductivity increases down the catchment, but the levels are suitable for all users.
- Neither nitrate, ammonia, phosphorus or TOC concentrations show any sign of significant pollution and from a nutrient aspect the quality may be classified oligotrophic to mesotrophic.

The assessment of seasonal water quality shows that:

- Medians for *E. coli* counts for IFR sites 1 to 3 for summer and winter are very different, being approximately 250 and 50 cells/100 mℓ respectively. Other percentile counts differ similarly.
- For turbidity, the winter medians for all sites were below 10 NTU, class B, while summer medians for the sites varied between 26 and 78 NTU, mostly class E.

The effect of impoundment of water quality using inflow and outflow data for Midmar and Inanda dams shows that:

- Compared to the inflow water temperature, temperatures at other sites in the dam such as the combined overflow and release water, a drawoff level in the dam at a depth of 10 m and bottom water are higher in summer, up to 6°C and lower in winter periods, up to 8°C. Depending on compensation release water policy, the natural temperature regime of the river below the dams may be substantially altered.
- Bacterial die off is considerable through the dam with changes of at least an order of magnitude taking place. Typical median inflow and outflow counts were 270 and 20 cells/100 mℓ respectively.
- pH changes are small with generally less variability in the dam pH's compared to the inflow.
- There is loss of SRP through the dam due to in-dam processes taking place such as algal growth and sedimentation, and consequently a water with a lower growth potential will be released.
- Turbidity will be greatly reduced for percentiles above the 75th as well as for seasonal variability, as released turbidities will be far more constant. The choice of discharge release, overflow, from a level or from the scour will give different turbidities.

The predicted water quality at the IFR sites when the dams are built are that:

- The effect will be greatest for IFR-1 as the remaining natural catchment will only constitute 20% of the total catchment but increasing up to 52% for IFR-4.
- The *E. coli* counts for the medians will improve considerably ranging from 65% for IFR-1 to 45% for IFR-4, but the greatest improvement will be seen for the extreme values, eg: from 13 000 down to 3 200 cells/100 mℓ for IFR-1.
- For turbidity there will be clearer water for longer periods and extreme values will be greatly reduced, typically from 2 700 to 670 NTU for IFR-1. Suspended solids, TOC and TKN concentrations will be expected to follow a similar pattern.
- SRP concentrations will be lowered, albeit from an already low base level. There will be more consistent concentrations at the sites without periodic high concentrations and the growth potential will accordingly be lowered.

6. WATER QUALITY REQUIREMENTS AT THE IFR SITES

It must be assumed that the present water quality and its variability, together with flow variability is suitable to sustain the present river biodiversity and habitat in a satisfactory condition, and also to satisfy the requirements of other users such as local inhabitants and irrigators. When the dam or dams are built, the water quality will most certainly change for some variables, and as has been shown a change for the better for users such as local inhabitants, irrigators and persons pursuing recreation. Umgeni Water and SAPPI-SAICCOR as abstractors for water treatment in the lower catchment will also benefit from improved raw water quality. However, from the river health and aquatic life point of view there is less certainty as:

- Suspended materials which may act as a food supply for some river biota will be removed to some degree.
- There will not be the normal variability in low-high concentrations of solids related variables and high seasonality in these variables will be lost.
- There will be greater clarity in the water for longer periods which could increase algal growth, although the nutrient supply as SRP from the dams will be less and therefore limit growth.
- There could be different algal genera introduced from the dams and differences in terms of numbers depending upon where the dam release comes from.
- There will be a different temperature regime introduced immediately below the dams.

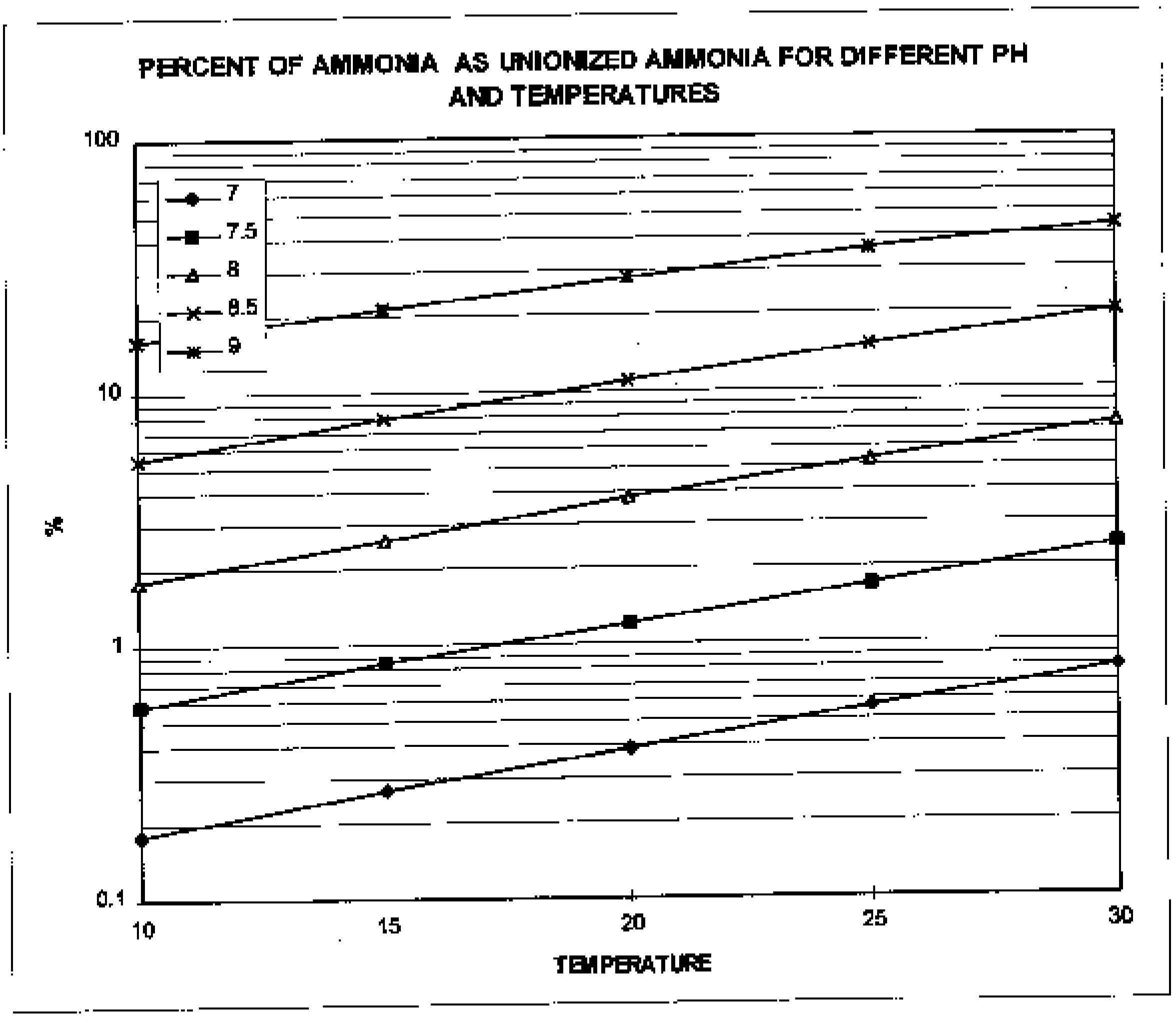
All these factors need to be considered by the specialists as being beneficial or not to current aquatic life. If certain water quality is required at times from the dams, high or low solids, algae or temperature, then provision needs to be made for release of water from appropriate dam sites such as overflow if possible, a level drawoff or scour.

Guidelines for the aquatic environment could be set by stipulating that water quality at the sites should remain within the 5th and 95th percentiles for existing water quality, but this clearly could not be met with the dams in place. A more practical approach would be to accept the changes that the dams will bring about and set requirements according to the water quality that will result with planned control of dam release volumes, ie: operating rules. In this way, dilution or concentration of natural runoff could be achieved to meet water quality requirements and then variable limits could be set. For other users, water quality requirements could be set in a similar manner by manipulating dam release volumes for their benefit. For example, strategies such as supplementing flows in winter to dilute natural pollution taking place, thereby ensuring sufficient water of good quality for the users.

Of course, the above analysis tacitly assumes that the present water quality will not change with future development or landuse changes in the catchment. Development and change, however, are bound to happen and this will be the greatest threat to water quality. The present landuse may be seen in Table 11 in the Appendix, which shows a relatively undeveloped catchment compared to catchments such as the Mgeni. The major landuse is listed as unimproved grassland (53%) followed by forestry, natural and plantations (13%). Agriculture is not high (8%) and urbanized areas make up a mere 0.16%, population being sparse with no major urban centres or significant point sources of pollution. As has been shown the present major threat to water quality is high turbidity and suspended solids concentrations at times from erosion, mainly thought to be caused by overgrazing. Consequently, to maintain or improve the present relatively good water quality, a management plan for the catchment needs to be drawn up and implemented to control development and activities that would constitute threats to water quality.

Dean Simpson
Scientist, Water Quality Planning

APPENDIX



Data from DWAF Aquatic Guidelines, 1996.

Table 1: Percentile water quality data for IFR-1 (site 143) between March 1996 and January 1998 for all and summer and winter data subsets

IFR-1 SITE	TEMP ºC	E. COLI /100 ml	pH	COL ºH	TURB NTU	COND mS/m	ALK mg/l	CA mg/l	MG mg/l	FE mg/l	MN mg/l	NO_3 mg/l	NH_3 mg/l	CL mg/l	SO4 mg/l	TP µg/l	SRP µg/l	TDS mg/l	SS mg/l	TOC mg/l	TKN mg/l
ALL DATA USED																					
MEAN	17.1	556	7.9	14	112	6.0	30.6	5.7	2.7	0.68	0.06	0.15	0.05	1.49	1.12	32	4	50	103	2.6	0.58
MINIMUM	7.9	6	7.3	1	2	3.0	12.9	3.1	1.4	0.09	0.01	0.03	0.01	0.71	0.68	8	2	24	2	0.7	0.10
5%	9.1	10	7.6	1	3	4.2	20.7	3.7	1.8	0.17	0.01	0.05	0.02	0.56	0.61	8	2	34	2	1.0	0.10
10%	9.9	15	7.8	2	4	4.5	22.6	4.0	1.9	0.19	0.01	0.05	0.02	0.96	0.57	8	2	38	2	1.2	0.10
25%	13.0	39	7.8	4	6	5.2	25.7	4.8	2.1	0.24	0.01	0.10	0.03	1.17	0.95	8	2	43	6	1.6	0.10
50%	18.1	110	7.9	6	17	6.1	30.6	5.8	2.6	0.35	0.02	0.13	0.04	1.45	1.08	24	2	51	14	2.1	0.34
75%	20.9	385	8.0	13	45	7.0	36.4	6.5	3.0	0.60	0.04	0.18	0.06	1.70	1.25	43	5	55	43	2.8	0.61
90%	22.6	985	8.1	30	140	7.5	38.4	7.2	3.2	0.93	0.36	0.24	0.08	1.98	1.40	69	6	63	103	3.7	1.23
95%	23.8	1606	8.2	39	306	7.7	39.0	8.3	3.6	1.05	0.19	0.32	0.11	2.22	1.57	88	8	70	213	4.3	2.80
MAXIMUM	28.4	13000	8.5	147	2721	8.4	42.7	10.6	8.4	14.10	0.88	0.45	0.13	4.11	2.21	180	22	79	2435	16.3	4.44
n	94	94	89	93	94	95	92	93	93	96	96	93	91	93	94	91	82	75	92	94	89
SUMMER DATA ONLY																					
MEAN	20.7	926	7.8	20	202	5.5	28.2	5.6	2.6	1.00	0.10	0.13	0.05	1.38	1.17	36	4	50	192	2.7	0.62
MINIMUM	14.7	34	7.3	1	3	3.0	12.9	3.6	1.4	0.18	0.01	0.03	0.02	0.71	0.68	8	2	24	2	0.9	0.10
5%	15.8	44	7.4	2	6	3.5	20.6	3.7	1.6	0.23	0.01	0.05	0.02	0.81	0.82	8	2	33	6	1.3	0.10
10%	17.3	50	7.5	4	7	4.1	21.4	3.9	1.8	0.25	0.01	0.05	0.02	0.88	0.88	8	2	37	8	1.5	0.10
25%	20.0	67	7.7	5	13	4.8	23.9	4.5	2.0	0.28	0.03	0.07	0.03	1.02	0.96	17	2	45	14	1.6	0.10
50%	21.0	210	7.8	10	28	5.5	26.1	5.2	2.3	0.40	0.03	0.12	0.04	1.23	1.15	33	2	51	30	2.1	0.33
75%	22.0	448	8.0	19	72	6.1	31.7	6.3	2.7	0.74	0.05	0.15	0.06	1.61	1.30	45	5	55	64	2.8	0.60
90%	24.0	1180	8.2	40	284	7.5	36.9	7.4	3.3	1.00	0.11	0.26	0.09	1.97	1.42	75	7	60	131	3.8	1.42
95%	25.0	4050	8.2	66	1462	8.0	39.1	8.8	4.7	2.21	0.69	0.31	0.12	2.17	1.71	89	15	67	1703	5.5	2.92
MAXIMUM	28.4	13000	8.3	147	2721	8.4	42.7	10.6	8.4	14.10	0.88	0.45	0.13	3.53	2.21	98	22	79	2435	16.3	4.44
n	46	46	42	46	46	47	44	46	46	47	47	46	44	47	47	43	44	33	44	46	42
WINTER DATA ONLY																					
MEAN	13.7	202	7.9	8	28	6.5	32.7	5.9	2.8	0.33	0.01	0.16	0.04	1.60	1.06	28	3	51	22	2.2	0.57
MINIMUM	7.9	6	7.5	1	2	4.3	17.8	3.1	1.6	0.09	0.01	0.05	0.01	0.98	0.72	6	2	33	2	0.7	0.10
5%	8.9	7	7.6	1	3	4.9	22.8	3.7	1.9	0.12	0.01	0.08	0.02	1.11	0.81	8	2	35	2	0.8	0.10
10%	9.1	10	7.6	2	3	5.2	24.8	4.2	2.2	0.17	0.01	0.10	0.02	1.21	0.89	8	2	39	2	1.0	0.10
25%	10.2	18	7.8	3	4	6.1	29.0	5.2	2.5	0.20	0.01	0.12	0.03	1.29	0.95	8	2	43	2	1.6	0.10
50%	13.2	44	7.9	5	7	6.8	34.1	6.0	2.8	0.28	0.01	0.15	0.04	1.49	1.04	16	3	51	7	2.0	0.34
75%	17.0	145	8.0	9	11	7.1	36.8	6.6	3.1	0.46	0.02	0.18	0.05	1.72	1.14	33	5	54	15	2.8	0.65
90%	18.8	505	8.1	17	52	7.5	38.5	7.2	3.2	0.75	0.03	0.23	0.07	1.98	1.26	67	6	63	42	3.4	1.10
95%	19.0	840	8.2	30	170	7.6	38.8	7.6	3.4	0.96	0.05	0.30	0.08	2.47	1.44	82	7	70	105	4.2	2.04
MAXIMUM	19.9	2220	8.5	33	242	7.7	40.5	8.6	3.8	1.13	0.12	0.42	0.11	4.11	2.08	180	9	71	260	6.1	3.17
n	48	48	47	47	46	48	48	47	47	49	49	47	47	46	47	48	48	42	48	46	47

Table 2: Percentile water quality data for IFR-2 (sites 143+147) between March 1996 and January 1998 for all and summer and winter data subsets

IFR-2 SITE	TEMP °C	E. COLI /100 ml	pH	COL °H	TURB NTU	COND mS/m	ALK mg/l	CA mg/l	MG mg/l	FE mg/l	MN mg/l	NO_3 mg/l	NH_3 mg/l	CL mg/l	SO4 mg/l	TP µg/l	SRP µg/l	TDS mg/l	SS mg/l	TOC mg/l	TKN mg/l
ALL DATA USED																					
MEAN	17.9	849	7.9	18	196	8.2	34.8	6.7	3.3	0.65	0.05	0.21	0.05	4.84	2.75	40	5	66	120	2.8	0.59
MINIMUM	8.7	4	7.2	1	2	3.3	11.5	3.7	1.7	0.08	0.01	0.03	0.01	1.11	0.92	8	2	34	2	0.8	0.10
5%	10.4	17	7.5	1	3	5.1	22.4	4.2	2.2	0.13	0.01	0.04	0.02	1.84	1.43	8	2	44	2	1.1	0.10
10%	11.6	24	7.6	2	3	5.7	24.4	4.7	2.4	0.18	0.01	0.07	0.02	2.27	1.53	8	2	48	2	1.3	0.10
25%	14.2	45	7.8	4	5	6.5	27.8	5.4	2.7	0.24	0.01	0.15	0.03	3.22	1.95	8	2	54	7	1.7	0.10
50%	18.8	133	7.9	8	14	8.4	35.2	6.8	3.3	0.37	0.02	0.20	0.04	4.65	2.61	28	3	65	16	2.2	0.33
75%	21.4	430	8.0	17	55	9.8	41.7	7.7	3.8	0.70	0.04	0.26	0.06	5.95	3.34	52	6	74	50	3.1	0.71
90%	23.0	1188	8.1	39	281	10.9	45.1	8.4	4.2	1.10	0.10	0.33	0.09	8.02	4.14	86	9	85	181	4.5	1.17
95%	23.9	3392	8.3	57	515	11.6	46.3	9.4	4.5	1.42	0.14	0.39	0.11	8.77	4.43	117	11	90	338	5.3	2.13
MAXIMUM	26.6	16000	8.6	240	7121	13.4	49.2	12.9	8.7	8.90	0.83	1.17	0.36	13.51	6.16	333	25	121	3128	22.1	5.11
n	94	95	95	94	95	96	95	95	94	96	97	95	93	95	96	93	94	77	93	94	88
SUMMER DATA ONLY																					
MEAN	21.4	1186	7.8	25	252	7.3	31.4	6.3	3.2	0.88	0.09	0.19	0.06	4.21	2.56	47	5	65	213	3.2	0.68
MINIMUM	16.5	36	7.4	1	3	3.3	11.5	4.0	1.7	0.13	0.01	0.03	0.01	1.11	0.92	8	2	34	2	1.0	0.10
5%	17.3	50	7.5	3	5	4.3	21.4	4.3	2.0	0.20	0.01	0.04	0.02	1.59	1.25	8	2	41	6	1.4	0.10
10%	18.4	61	7.5	4	7	5.0	22.6	4.4	2.2	0.23	0.01	0.04	0.03	1.82	1.43	8	2	47	8	1.5	0.10
25%	20.5	101	7.7	6	13	5.8	25.5	5.1	2.4	0.29	0.02	0.10	0.04	2.54	1.65	20	2	54	16	1.8	0.10
50%	21.6	343	7.8	13	35	6.8	30.2	5.9	2.9	0.47	0.04	0.17	0.05	3.45	2.14	38	3	61	39	2.3	0.38
75%	22.5	529	8.0	27	108	8.6	37.5	7.1	3.5	0.87	0.07	0.24	0.07	5.32	3.12	99	6	76	104	3.5	0.76
90%	23.9	1840	8.1	54	450	10.5	43.7	8.5	4.3	1.31	0.13	0.33	0.10	8.22	4.29	101	9	85	284	4.7	1.49
95%	25.5	4938	8.2	87	1809	11.6	45.5	10.0	5.2	2.09	0.58	0.37	0.12	8.76	5.15	119	18	90	1296	6.0	2.75
MAXIMUM	26.6	16000	8.2	240	3075	13.4	49.2	12.9	8.7	8.90	0.83	0.73	0.14	13.22	6.16	171	25	121	3128	22.1	5.11
n	44	46	44	46	46	47	45	46	46	46	47	46	45	47	47	44	45	33	45	45	42
WINTER DATA ONLY																					
MEAN	14.8	532	7.9	11	143	9.1	37.8	7.0	3.5	0.44	0.02	0.24	0.05	5.41	2.92	34	4	66	35	2.5	0.50
MINIMUM	8.7	4	7.3	1	2	5.3	22.1	3.9	2.2	0.08	0.01	0.08	0.01	1.93	1.42	8	2	40	2	0.8	0.10
5%	10.3	12	7.5	1	2	6.1	25.3	4.6	2.5	0.10	0.01	0.11	0.02	2.95	1.64	8	2	46	2	0.9	0.10
10%	10.4	17	7.6	2	3	6.9	27.7	5.2	2.8	0.16	0.01	0.13	0.02	3.38	1.92	8	2	51	2	1.1	0.10
25%	11.9	27	7.8	3	4	8.2	33.8	6.3	3.2	0.20	0.01	0.17	0.03	4.18	2.40	8	2	57	2	1.6	0.10
50%	14.3	56	7.9	6	6	9.2	39.1	7.2	3.6	0.29	0.01	0.22	0.04	5.33	2.98	17	2	67	8	2.2	0.31
75%	17.7	235	8.0	11	15	10.1	42.4	7.9	3.9	0.55	0.02	0.26	0.05	6.39	3.36	35	6	73	18	2.8	0.65
90%	19.2	755	8.2	27	57	11.0	45.6	8.4	4.2	0.90	0.04	0.33	0.07	7.74	3.97	76	8	82	50	4.2	0.96
95%	20.0	1987	8.3	45	199	11.6	46.3	8.8	4.3	1.17	0.05	0.47	0.09	8.73	4.29	105	9	89	135	4.8	1.61
MAXIMUM	20.6	9110	8.6	91	5881	12.0	47.6	9.5	4.6	2.33	0.23	1.16	0.35	10.29	5.13	333	14	102	635	8.6	2.68
n	50	49	49	48	49	50	50	49	48	50	50	49	49	49	49	49	49	44	49	49	46

Table 3: Percentile water quality data for IFR-3 (site 147) between March 1996 and January 1998 for all and summer and winter data subsets

IFR-3 SITE	TEMP °C	E. COLI /100 ml	pH	COL °H	TURB NTU	COND mS/m	ALK mg/l	CA mg/l	MG mg/l	FE mg/l	MN mg/l	NO_3 mg/l	NH_3 mg/l	CL mg/l	SO4 mg/l	TP µg/l	SRP µg/l	TDS mg/l	SS mg/l	TOC mg/l	TKN mg/l
ALL DATA USED																					
MEAN	18.7	1142	7.8	22	280	10.4	39.0	7.6	4.0	0.62	0.05	0.28	0.06	8.19	4.38	49	5	81	137	3.2	0.58
MINIMUM	9.4	2	7.1	1	2	3.6	10.0	4.3	2.0	0.06	0.01	0.03	0.01	1.50	1.15	8	2	44	2	0.8	0.10
5%	11.8	24	7.4	2	2	6.1	24.1	4.8	2.7	0.09	0.01	0.03	0.02	2.82	2.04	8	2	55	2	1.2	0.10
10%	13.3	33	7.6	2	3	6.8	26.4	5.4	2.9	0.17	0.01	0.09	0.02	3.58	2.20	8	2	59	2	1.4	0.10
25%	15.3	52	7.7	4	5	7.8	29.9	6.1	3.3	0.23	0.01	0.19	0.03	5.27	2.94	8	2	65	7	1.8	0.10
50%	19.5	156	7.8	10	16	10.6	39.7	7.8	4.1	0.39	0.02	0.26	0.04	7.84	4.16	31	4	78	18	2.4	0.31
75%	22.0	475	8.0	22	64	12.7	46.9	8.8	4.6	0.80	0.04	0.33	0.06	10.20	5.43	60	7	94	57	3.3	0.80
90%	23.3	1390	8.2	48	423	14.4	51.8	9.7	5.2	1.27	0.14	0.41	0.10	14.06	6.88	104	11	107	260	5.4	1.11
95%	23.8	4875	8.3	75	725	15.5	53.6	10.4	5.4	1.80	0.16	0.45	0.11	15.33	7.28	147	14	111	464	6.3	1.67
MAXIMUM	26.7	19000	8.7	333	11520	18.3	55.7	15.1	9.0	3.70	0.67	1.89	0.58	22.90	10.10	485	29	162	382..	27.8	5.78
n	93	96	96	94	96	97	97	96	95	96	97	97	95	97	97	95	95	78	94	94	86
SUMMER DATA ONLY																					
MEAN	22.1	1447	7.8	30	302	9.1	34.7	7.1	3.8	0.76	0.09	0.24	0.06	7.05	3.96	58	6	80	234	3.7	0.75
MINIMUM	18.2	38	7.4	1	2	3.6	10.0	4.3	2.0	0.07	0.01	0.03	0.01	1.50	1.15	8	2	44	2	1.2	0.10
5%	18.6	56	7.5	4	4	5.0	22.3	4.8	2.4	0.17	0.01	0.03	0.02	2.37	1.68	8	2	48	5	1.4	0.10
10%	19.5	71	7.5	4	7	5.8	23.9	5.0	2.7	0.21	0.01	0.03	0.03	2.78	1.99	8	2	58	9	1.6	0.10
25%	21.0	115	7.7	7	14	6.9	27.1	5.6	2.9	0.29	0.02	0.13	0.04	4.07	2.34	23	2	63	17	1.9	0.10
50%	22.3	275	7.8	17	45	8.2	32.4	6.6	3.5	0.53	0.04	0.22	0.05	5.66	3.13	43	4	72	48	2.5	0.43
75%	23.0	610	7.9	34	143	11.1	43.2	7.9	4.3	0.99	0.09	0.33	0.08	9.03	4.95	73	7	97	144	4.4	0.91
90%	23.9	2500	8.1	68	607	13.5	50.5	9.5	5.4	1.62	0.15	0.41	0.11	14.47	7.16	127	12	110	437	5.7	1.57
95%	26.1	5825	8.1	78	2156	15.3	52.0	11.1	5.7	1.96	0.46	0.44	0.12	15.41	8.60	148	21	112	889	6.6	2.57
MAXIMUM	26.7	19000	8.1	333	3429	18.3	55.7	15.1	9.0	3.70	0.67	1.00	0.14	22.90	10.10	243	29	162	3821	27.8	5.78
n	42	46	45	45	45	46	46	46	46	45	46	46	45	46	46	45	45	32	45	44	41
WINTER DATA ONLY																					
MEAN	16.0	863	7.9	15	260	11.6	42.9	8.1	4.3	0.50	0.02	0.32	0.05	9.22	4.77	41	5	82	47	2.7	0.43
MINIMUM	9.4	2	7.1	1	2	6.4	26.3	4.6	2.8	0.05	0.01	0.10	0.01	2.87	2.12	8	2	47	2	0.8	0.10
5%	11.6	18	7.4	2	2	7.3	27.8	5.4	3.1	0.07	0.01	0.14	0.02	4.79	2.47	8	2	56	2	1.0	0.10
10%	11.8	24	7.6	2	3	8.5	30.6	6.2	3.4	0.14	0.01	0.16	0.02	5.54	2.94	8	2	64	2	1.3	0.10
25%	13.7	36	7.7	3	4	10.3	38.6	7.4	4.0	0.19	0.01	0.22	0.02	7.07	3.86	8	2	71	3	1.7	0.10
50%	15.4	68	7.9	6	6	11.6	44.2	8.4	4.3	0.31	0.01	0.29	0.04	9.17	4.92	18	2	83	8	2.3	0.28
75%	18.5	325	8.0	13	18	13.1	48.1	9.1	4.7	0.64	0.02	0.34	0.05	11.05	5.58	37	7	93	20	2.8	0.65
90%	19.8	1005	8.3	36	62	14.5	52.7	9.7	5.1	1.06	0.04	0.42	0.07	13.30	6.68	64	10	102	58	3.0	0.82
95%	20.9	3035	8.4	57	228	15.6	53.7	10.1	5.3	1.36	0.06	0.54	0.10	14.99	7.13	129	12	108	164	5.4	1.19
MAXIMUM	21.2	16000	8.7	149	11520	16.4	54.6	10.4	5.4	3.52	0.34	1.89	0.38	16.46	8.18	485	20	133	1011	11.1	2.18
n	51	50	51	49	50	51	51	50	49	51	51	51	50	51	51	50	50	46	49	50	45

Table 4: Percentile water quality data for IFR-4 (site 125) between October 1995 and January 1998 for all and summer and winter data subsets

IFR-4 SITE	TEMP ºC	E.COLI /100ml	ALGAE /ml	pH	COL ºH	TURB NTU	COND mS/m	ALK mg/l	CA mg/l	MG mg/l	FE mg/l	MN mg/l	Tot AL µg/l	NO_3 mg/l	NH_3 µg/l	CL mg/l	SO4 mg/l	TP µg/l	SRP µg/l	TDS mg/l	SS mg/l	TOC mg/l
ALL DATA USED																						
MEAN	20.6	1484	1090	7.8	33	298	14.2	44.4	9.3	5.1	0.97	0.12	808	0.28	0.04	14.92	7.01	45	5	113	168	3.5
MINIMUM	10.5	58	0	7.1	1	2	4.3	18.9	4.6	2.5	0.05	0.01	13	0.03	0.01	1.90	2.40	8	2	41	2	0.7
5%	13.7	130	42	7.5	2	2	6.1	23.8	5.5	3.0	0.10	0.01	33	0.03	0.02	4.11	2.84	8	2	57	2	1.3
10%	14.5	169	147	7.5	3	3	7.6	25.9	5.9	3.2	0.13	0.01	47	0.03	0.02	5.24	3.32	8	2	65	2	1.3
25%	17.9	218	308	7.6	4	6	9.3	33.3	7.2	3.9	0.20	0.01	80	0.16	0.02	7.86	3.95	8	2	83	8	1.7
50%	21.2	340	877	7.8	9	22	13.5	46.2	9.1	5.0	0.48	0.02	171	0.24	0.03	12.65	5.59	25	2	102	19	2.4
75%	23.8	560	1047	7.9	29	108	17.5	54.6	11.0	5.8	0.98	0.09	524	0.35	0.05	18.80	8.34	50	7	121	72	4.1
90%	26.5	2810	2222	8.0	65	784	20.6	50.9	12.5	6.9	2.26	0.26	1447	0.51	0.06	23.66	12.24	116	13	174	399	6.0
95%	26.3	6435	3515	8.1	147	1675	22.7	64.1	13.2	7.4	3.79	0.54	2704	0.75	0.07	27.49	15.30	136	16	226	1064	10.5
MAXIMUM	29.3	47000	13664	8.5	384	4425	53.8	84.6	16.7	14.5	Ā 88	2.42	21547	1.60	0.14	136.00	18.10	480	38	448	2659	19.8
n	118	120	111	117	119	120	118	119	118	118	117	119	107	119	116	119	28	97	97	107	98	116
SUMMER DATA ONLY																						
MEAN	23.4	2109	1088	7.7	48	449	13.2	41.0	8.9	4.9	1.34	0.16	1350	0.28	0.04	14.28	8.86	60	8	122	264	4.0
MIN	17.5	58	0	7.1	1	2	4.3	18.9	4.6	2.5	0.07	0.01	18	0.03	0.01	1.90	2.40	8	2	41	2	1.1
5%	19.5	145	0	7.3	3	4	6.6	22.1	5.4	2.9	0.13	0.01	37	0.03	0.02	3.42	2.76	8	2	50	5	1.3
10%	20.1	170	64	7.5	4	6	6.2	23.8	5.5	3.0	0.18	0.01	64	0.03	0.02	4.35	2.96	8	2	60	6	1.4
25%	22.0	246	253	7.6	6	10	8.0	29.6	6.5	3.4	0.28	0.02	140	0.06	0.03	6.42	3.71	21	2	80	15	1.9
50%	23.6	410	531	7.7	21	77	11.0	36.0	7.7	4.2	0.76	0.06	354	0.26	0.04	9.92	4.87	39	5	106	55	3.1
75%	24.7	760	1061	7.9	46	284	16.5	52.9	11.2	6.0	1.64	0.19	1220	0.38	0.05	16.70	9.83	100	9	130	210	4.5
90%	26.3	3920	1868	8.0	64	1094	20.6	63.4	13.0	7.1	3.49	0.44	2352	0.51	0.07	24.42	13.56	131	16	218	699	8.3
95%	26.9	9960	4325	8.0	231	3107	24.7	66.2	16.4	8.5	5.01	0.76	5239	0.74	0.09	33.20	16.36	144	26	251	1231	11.7
MAX	28.3	47000	13664	8.1	384	4425	53.8	84.6	16.7	14.5	8.66	2.42	21547	1.80	0.13	136.00	18.10	260	38	448	2659	19.8
n	67	69	62	66	68	69	67	68	67	67	66	68	58	69	68	68	16	46	46	59	43	65
WINTER DATA ONLY																						
MEAN	17.1	637	1092	7.8	17	101	15.4	46.8	9.8	5.3	0.50	0.03	190	0.29	0.03	15.74	7.23	33	3	102	78	2.8
MIN	10.5	62	0	7.2	1	2	6.1	25.8	5.9	3.3	0.05	0.01	13	0.03	0.01	5.16	3.61	8	2	56	2	0.7
5%	12.9	116	86	7.6	1	2	8.9	31.4	6.6	3.9	0.08	0.01	31	0.14	0.01	7.17	4.11	8	2	67	2	1.1
10%	13.3	140	212	7.6	2	2	10.7	33.1	7.3	4.0	0.10	0.01	45	0.16	0.02	8.40	4.54	8	2	76	2	1.3
25%	14.7	210	411	7.7	3	3	12.7	44.5	8.8	4.8	0.16	0.01	60	0.20	0.02	11.98	6.07	8	2	87	5	1.5
50%	17.1	260	749	7.8	5	8	15.4	50.6	9.9	5.4	0.34	0.01	116	0.24	0.03	16.00	6.97	16	2	101	10	2.0
75%	19.6	450	1032	8.0	12	23	17.7	55.7	10.8	5.8	0.69	0.02	169	0.32	0.04	18.88	8.58	31	2	113	23	3.1
90%	20.9	700	2484	8.1	28	46	19.9	57.9	12.3	6.6	0.99	0.04	462	0.50	0.05	23.28	8.65	52	8	128	48	5.5
95%	21.6	1940	3191	8.2	80	350	20.9	60.3	12.8	6.9	1.16	0.11	507	0.74	0.00	24.60	11.78	65	12	144	263	7.8
MAX	23.4	11000	9584	8.5	166	2509	22.7	61.9	13.1	7.3	3.67	0.50	1530	0.82	0.14	29.29	14.37	480	15	180	1542	12.6
n	52	51	50	52	52	52	52	52	52	52	52	52	50	52	51	52	12	52	52	49	61	52

TABLE 10: DATA DISTRIBUTION FOR EXISTING AND PREDICTED WATER QUALITY AT IFR SITES

	EXISTING			DAM RELEASE			FUTURE (CALC.)		
IFR-1	E. COLI /100ml	TURB NTU	SRP µg/l	E. COLI /100ml	TURB NTU	SRP µg/l	E. COLI /100ml	TURB NTU	SRP µg/l
MEAN	556	112	3.7	49	24	3.0	152	42	3.1
MINIMUM	6	2	1.5	1	3	1.5	2	3	1.5
25%	39	6	1.5	8	7	1.5	14	7	1.5
50%	110	12	2.3	20	12	1.5	38	12	1.7
75%	385	45	5.0	42	28	4.0	112	31	4.2
MAXIMUM	13000	2721	22.0	650	146	15.0	3161	670	16.4
IFR-2									
MEAN	849	196	4.5	49	24	3.0	282	74	3.4
MINIMUM	4	2	1.5	1	3	1.5	2	3	1.5
25%	45	5	1.5	8	7	1.5	19	7	1.5
50%	133	14	3.2	20	12	1.5	53	13	2.0
75%	430	55	6.1	42	28	4.0	155	36	4.6
MAXIMUM	16000	7121	25.3	650	146	15.0	5112	2173	18.0
IFR-3									
MEAN	1142	280	5.3	49	24	3.0	563	144	4.1
MINIMUM	2	2	1.5	1	3	1.5	1	2	1.5
25%	52	5	1.5	8	7	1.5	28	6	1.5
50%	156	16	4.0	20	12	1.5	84	14	2.7
75%	475	64	7.1	42	28	4.0	245	45	5.5
MAXIMUM	19000	11520	28.5	650	146	15.0	9287	5487	21.3
IFR-4									
MEAN	1484	298	5.1	49	24	3.0	794	166	4.1
MINIMUM	58	2	1.5	1	3	1.5	31	2	1.5
25%	218	6	1.5	8	7	1.5	117	6	1.5
50%	340	22	1.5	20	12	1.5	186	18	1.5
75%	560	106	6.5	42	28	4.0	311	68	5.3
MAXIMUM	47000	4425	38.0	650	146	15.0	24717	2368	26.9

Table 11: Classification of landuse in the Mkomazi catchment

LANDUSE DESCRIPTION	Area (km^2)	% Area
Barren rock	0.028	0
Cultivated: permanent - commercial sugarcane	16.808	0.38
Cultivated: temporary - commercial dryland	38.11	0.87
Cultivated: temporary - commercial irrigated	108.406	2.47
Cultivated: temporary - semi-commercial/subsistence dryland	209.384	4.77
Degraded: thicket & bushland (etc)	47.552	1.08
Degraded: unimproved grassland	241.077	5.5
Forest	47.827	1.09
Forest and Woodland	0.147	0
Forest plantations	541.729	12.35
Improved grassland	15.752	0.36
Shrubland and low Fynbos	15.417	0.35
Thicket & bushland (etc)	744.339	16.97
Unimproved grassland	2,344.55	53.44
Urban / built-up land: industrial / transport	0.6	0.01
Urban / built-up land: residential	5.573	0.13
Urban / built-up land: residential (small holdings: bushland)	0.83	0.02
Waterbodies	7.856	0.18
Wetlands	1.061	0.02
TOTAL AREA	**4,387.05**	**100**

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UMGENI WATER

WATER QUALITY DEPARTMENT
SCIENTIFIC SERVICES

WATER QUALITY INDICES FOR RIVERS AND IMPOUNDMENTS

WATER QUALITY VARIABLES

A water quality index is a convenient management tool for the assessment of water quality and provides a concise statement regarding the status of water in a river reach or in an impoundment. It allows comparison of water quality at different sampling sites and temporal and spatial trends may be identified.

Separate water quality indices have been developed for river sampling and dam sampling sites as potential water quality problems associated with each are different. The index for selected sampling points is calculated each month using the median value of weekly results. A computer programme assists in swift calculation of the indices. The index in its present form may not be ideal, but has been found to be a valuable management tool. It will be subjected to ongoing re-assessment for improvement. The variables used are given in Table 1.

TABLE1: SELECTED WATER QUALITY VARIABLES AND INDICATED PROBLEM

RIVERS	PROBLEM INDICATED	IMPOUNDMENTS
E. Coli	faecal pollution	*E. Coli*
Total phosphorus	trophic status, nutrients indicating potential for algal growth	Total phosphorus
Soluble reactive phosphate	nutrients indicating potential for algal growth	Soluble reactive phosphate
Total organic carbon	indication of organic pollution, algal growth, oxygen demand potential	Total organic carbon
Electrical conductivity	total dissolved salts, inorganic pollution	Electrical conductivity
Suspended solids	particulate material, erosion, siltation	Suspended solids
Turbidity	particulate matter, erosion, coagulant demand, algal growth	Turbidity
Nitrate	nutrients indicating potential for algal growth	
Ammonia	sewage discharge, anaerobic conditions, nutrients indicating potential for algal growth	
	trophic status, treatment problems, oxygen demand, possible recreational impairment, possible health hazards	Total algal numbers
	trophic status, specific treatment problems	Taste and odour causing algal numbers
	specific treatment problems	Filter clogging algal numbers
	trophic status, treatment problems, indication of algal biomass production	Chlorophyll *a*

CALCULATION OF INDICES

Depending on the range into which each median river sample site result fits, fixed scores are assigned to each variable. These are shown in Table 2. The scores are then multiplied by the respective weighting factors for each variable. Tables 3 shows the weighting factors which have been assigned. The total scores for each site are then divided by the sum of weighting factors, that is 36 to give a weighted score or class value. Table 6 shows the classes which are finally assigned to rivers, ie: A - E.

1. VARIABLE 'A' CONCENTRATION = SCORE FOR VARIABLE 'A'

2. SCORE FOR VARIABLE 'A' X WEIGHTING FACTOR FOR VARIABLE 'A' = WEIGHTED SCORE

3. CLASS VALUE = $\dfrac{\text{SUM OF WEIGHTED SCORES FOR ALL VARIABLES}}{\text{SUM OF WEIGHTING FACTORS}}$

TABLE 2: CLASS INTERVALS AND SCORES FOR SELECTED WATER QUALITY VARIABLES - RIVER SAMPLE POINTS

CONCENTRATION RANGE FOR EACH WATER QUALITY VARIABLE								SCORE
E. Coli (cells/ 100 ml)	TOTAL PHOSPHORUS (µg/l)	SOLUBLE REACTIVE PHOSPHATE (µg/l)	NITRATE (mg/l)	TOTAL ORGANIC CARBON (mg/l)	ELECTRICAL CONDUCTIVITY (mS/m)	SUSPENDED SOLIDS (mg/l)	TURBIDITY (NTU)	
0 - 100	<21	<5	<0.2	<1	<10	<4	<5	95
101 - 499	21 - 40	5 - 10	0.2 - 0.5	1 - 1.5	10 - 20	4 - 8	5 - 12	82
500 - 1200	40 - 100	10 - 20	0.5 - 1.2	1.5 - 2.5	20 - 40	8 - 15	12 - 20	67
1201 - 5000	100 - 200	20 - 50	1.2 - 2.0	2.5 - 5.0	40 - 60	15 - 25	20 - 30	52
>5000	>200	>50	>2.0	>5.0	>60	>25	>30	37

NOTE:

- ANY RIVER SITES WHERE MEDIAN *E. Coli* RESULTS > 10 000 cells/100 ml ARE OBSERVED AUTOMATICALLY RATES CLASS "E" FOR UNSATISFACTORY STATUS.
- ANY RIVER SITES WHERE MEDIAN ELECTRICAL CONDUCTIVITY RESULTS > 60 mS/m ARE OBSERVED AUTOMATICALLY RATES CLASS "E" FOR UNSATISFACTORY STATUS.
- ANY RIVER SITES WHERE MEDIAN AMMONIA RESULTS > 0.2 mg/l ARE OBSERVED AUTOMATICALLY RATES CLASS "E" FOR UNSATISFACTORY STATUS.

TABLE 3: WEIGHTING FACTORS FOR SELECTED WATER QUALITY VARIABLES - RIVER SAMPLE POINTS

E. Coli	SOLUBLE REACTIVE PHOSPHORUS	TOTAL ORGANIC CARBON	SUSPENDED SOLIDS	NITRATE	TOTAL PHOSPHORUS	ELECTRICAL CONDUCTIVIT Y	TURBIDITY
8	7	6	5	4	3	2	1

TABLE 6: CLASSES FOR WATER QUALITY VARIABLES FOR RIVERS

CLASS VALUE	CLASS	DESCRIPTION
>85	A	EXCELLENT
75 - 85	B	GOOD
60 - 75	C	SATISFACTORY
45 - 60	D	POOR
30 - 45	E	UNSATISFACTORY

NOTES:

1. It is stressed that the assignment of classes and descriptions given, such as excellent to unsatisfactory are an opinion of general river water health and treatability and do not imply that the water could be consumed by the public if given an excellent rating. This fact should be made clear if ratings based on this WQI are published.

2. This document should be considered confidential between the user and Umgeni Water, ie not for general distribution.

APPENDIX L

THE FISH OF THE MKOMAZI RIVER, AND THEIR INSTREAM FLOW REQUIREMENTS

M Coke KwaZulu-Natal Nature Conservation
February 1998

INTRODUCTION

The aim of this report is to contribute to the assessment of instream flow requirements for nature conservation in the Mkomazi river, with particular reference to fish.

The Mkomazi river system as a whole contains 23 indigenous and 5 alien fish species. Amongst the former, *Amphilius natalensis* is of particular interest in that it reaches the southern limit of its distribution in this river system. The proposed construction of a dam threatens to alter the flow regime of the river and to affect the migration of fish in it.

STUDY AREA AND METHODS

Four IFR sites were selected at Lundy's Hill, Hela Hela, St Josephine's Bridge and Mfume, at or near all of which fish samples were collected by means of electro-shocker. Historical collection data were also reviewed. The habitat and water-flow requirements of each species were reviewed, relative to their migration, breeding and living requirements.

RESULTS AND DISCUSSION

Seventeen indigenous and one alien fish species were found in the study area (Table 1). One Red Data species, *Hypseleotris dayi*, occurs in the lower reaches of the river. Whilst its breeding habitat requirements are as yet unknown, it is thought to utilise quiet sandy backwaters and side-streams for this purpose, and is therefore unlikely to be seriously affected by altered flows in the main river. The freshwater mullet *Myxus capensis* is endemic to South Africa and also occurs in the lower reaches of the river. Here its migrations are affected by three weirs, two built by SAICCOR and one by

DWAF. Whereas it occurs up as far as Goodenough weir, insufficient sampling has yet been done above the weir to show whether or not this is now its upstream limit.

The Natal mountain catfish, *Amphilius natalensis*, is the only riffle-dependent species in the system. It occurs in the upper and middle reaches of the river and its tributaries, down at least as far as St Josephine's bridge. Since the Mkomazi marks the southern limit of its distribution its survival here is of particular conservation concern. It lives and breeds in cobble beds, which are abundant throughout most of the system and which would still be partially or totally inundated by even the lowest water-flows. Since it undertakes only minor migrations these are unlikely to be much affected by a dam, although there would be some habitat loss due to inundation.

The major migratory species in the system are the scaly, the sharptooth catfish and three species of eel. The scaly, *Barbus natalensis*, is endemic to KwaZulu-Natal but occurs throughout the province. Its spawning migrations would be affected by the building of a dam. The spawning migrations of the sharptooth catfish, *Clarias gariepinus*, which is widespread in South Africa, would be similarly affected. Three species of eel occur in the system and migrate up from the sea as juveniles to live in the river before returning to the sea to breed. They are capable of passing the existing weirs but could be stopped by a major dam. The release of summer spate flows would stimulate migration and spawning by all flood-dependent species, even within the limits imposed by the building of an impassable dam. Nevertheless the provision of a fishway, or at least an eelway, at such a dam is considered necessary.

Carp, an alien species, occur in the system and are an angling resource. It is possible that they may invade and eventually become dominant in an impoundment if one were constructed.

Freshwater crayfish, *Macrobrachium spp*, occur as far upstream as IFR4 but are unlikely to be much affected by flow reductions.

CONCLUSION

The Mkomazi river supports a moderate diversity of fish species, with many of these being limited to the lower reaches near the coast where the impact of a dam in the middle reaches would probably be minimal. *Amphilius natalensis* is the only riffle-dependent species present, but riffle habitats are likely to remain available even if river flows become reduced. The impact of a dam on the migrations of scaly, sharptooth catfish and eels could be considerable and therefore the provision of a fishway, or at least an eelway, is considered essential. The release of summer spate flows from the dam would probably stimulate successful breeding by the flood-dependent species.

Table 1: Fish of the Mkomazi river, their distribution, flow dependence, breeding and migration habits.

SPECIES	IMPORT-ANCE	DISTRIBUTION				FLOW DEPEND-ENCE	BREEDING HABITAT	MIGRATION HABITS
		IFR1	IFR2	IFR3	IFR4			
Anguilla bengalensis African mottled eel	A			n	n	P	sea	major
Anguilla marmorata giant mottled eel	A				n	P	sea	major
Anguilla mossambica longfin eel	A	n	n	n	n	P	sea	major
Barbus anoplus chubbyhead barb			n	n		P, S	vegetation	minor
Barbus natalensis scaly	E, A	n	n	n	n	P	gravel	major
Barbus viviparus bowstripe barb			n	n	n	P, S	vegetation	minor
Cyprinus carpio carp	Al, A		n	n	n	P	vegetation	medium
Amphilius natalensis Natal mountain catfish		n	n	n		P,S,R	cobbles	minor
Clarias gariepinus sharptooth catfish	A	n	n	n	n	P, S	vegetation	major
Mugil cephalus flathead mullet	Aq				n	P	sea	medium
Myxus capensis					n	P	sea	medium

freshwater mullet							
Oreochromis mossambicus		F, A		n	n	P	sand
minor							
Mozambique tilapia							
Eleotris fusca			n	P	?		minor
dusky sleeper							
Hypseleotris dayi	RD, E		n	P, S	?		minor
golden sleeper							
Awaous aeneofuscus			n	P	sand		minor
freshwater goby							
Glossogobius callidus			n	?, S	sand		minor
river goby							
Glossogobius giuris			n	P, S	sand		minor
tank goby							
Stenogobius kenyae			n	P	?		minor
Africa rivergoby							

KEY :-

A = angling
E = endemic
Al = alien
Aq = aquaculture
F = food
RD = Red Data

P = perennial rivers
S = seasonal rivers
R = riffle-dependent
? = unknown

APPENDIX M

EXECUTIVE SUMMARY

Dr Ferdi de Moor, Albany Museum, March 1998

The Department of Water Affairs in conjunction with Umgeni Waters are assesing the feasiblity of an interbasin transfer of water from the Mkomazi River to supplement the water supply of the Umgeni River catchment. Before planning an interbasin transfer of water it is important to consider sociopolitical and biological factors that may be detrimentally effected.

From a biological viewpoint it is important to consider whether there may be any transfer of undesirable biota from one catchment to another. The possibility of the modified flow regime leading to an increase in pest species in either the donor or recipient river system should also be taken into account. The biological integrity of a river system must be cared for and an increase or decrease in flow can have deleterious influences on the riverine biota and impinge on the natural ecological functioning of the river.

In March, October and December 1996 a survey of the aquatic macroinvertebrates of the Mkomazi and Mkomazana Rivers and some of their tributaries was conducted by staff of Umgeni Waters and the Albany Museum. Twenty sites along the rivers and streams, ranging in altitude from 2865 to 10 metres above sea level, were selected for determining the flow and ecological requirements of the instream biota. In addition samples were collected at a number of these sites in July and August 1996 to provide additional ecological information. These samples have not been synthesised for the present report. A survey of aquatic invertebrates collected from river sites in the Mkomazi River catchment in June 1973 (Kemp et al 1976) was also referred to in the study.

A range of specialised collecting techniques aimed at getting the greatest diversity of species present was employed. Standard SASS collecting techniques (Moore and McMillan 1992) were also used, with a modification that as many biotopes as possible were sampled at each site and material collected from each biotope was preserved separately. Although it was not possible to study and analyse all the samples collected during the surveys, examination of 55 of the 112 samples collected revealed that the Mkomazi and Mkomazana Rivers had a diverse fauna with 297 taxa identified to date with at least an additional 40 or more species of Chironomidae still to be considered. The fauna was numerically dominated by filter feeding species such as hydropsychid Trichoptera (11 species) and Simuliidae (19 species). There was also a great diversity of Ephemeroptera (49 species), orthocladine Chironomidae (? 40+ species) and elmid Coleoptera (7+ species) in the swift flowing reaches of rivers. Many species could be identified as keystone and umbrella taxa, species which could provide more detailed information on instream flow requirements of the biota.

Because of time constraints identification of many of the invertebrate groups could not be carried down to species level in this study. Ostracoda, Cladocera and Copepoda as well as certain families of Diptera (especially Chironomidae) and Coleoptera will be further identified in time and with specialist identification services.

In order to answer the question as regards instream flow requirements to maintain biological processes, the first requisite is a good knowledge of the extant fauna of the river. The above mentioned and present surveys provide a baseline but also revealed that much additional ecological work needs to be done to understand some of the unique features of the rivers of the Mkomazi River catchment.

To quantify the needs of aquatic macroinvertebrates as regards physical water-flow requirements, an approach known as "Hydraulic Stream Ecology" has been developed (Statzner, Gore and Resh 1988). Habitat requirements of selected species are used to characterise requirements of the communities in specified biotopes in which these species are found. Factors such as current speed, depth and substrate characteristics are the major components considered.

In South Africa studies on instream flow requirements to accurately determine flow requirements of selected species have only been undertaken recently in selected rivers (King and Tharme 1994). The procedure outlined (see Figs. 1, 4 and 5) is detailed and time consuming and although it provides the most accurate data on which to base instream flow requirements for selected species, this was outside the scope of this study. Extrapolation of requirements of particular species in one catchment to other species in other catchments have serious shortcomings. As one moves from rivers in a more temperate region to those in a more tropical realm, a reduction in flow and water volume will have a concomittantly larger increase in water temperature. This will directly influence the dissolved oxygen levels in the water which are a controlling factor enabling certain species to exist in a river.

A detailed assessment of instream flow requirements of the biota was therefore outside the scope of this study. In this report reference is made to the known ecological requirements of species assessed from the most frequent occurrence of selected species in riverine biotopes.

The identification of species present in different reaches of the Mkomazi River can be used to assess the flow requirements of the biota of the donor river systems. As previous surveys were conducted around 23 years ago it was deemed necessary to determine what changes in species composition may have occurred in the present unregulated system. All information was synthesised to determine if there were any rare or endangered species or possibly species with special environmental requirements that should be taken into account. Ideally flows in these rivers should be maintained to ensure the survival of the extant communities along the river. It is with this concept in mind that the structure of the invertebrate communities was examined.

A comparison of the macroinvertebrate fauna between 1976 and 1997

In order to make data from each site comparable, and also to compare the present results with an earlier study (Kemp et al , 1976), the stones in current biotope was used as a standard comparable biotope. An examination of the latitude and longitude coordinates of sampling sites for the 1973 and 1996 surveys revealed five sites where stones-in-current biotopes were surveyed which were comparable. The results of these surveys expressing each species as a percentage (number of any species collected from the stones in current biotope against the total number of individuals in a sample) were compared.

A major problem with comparing the faunal composition of species from the 1970,s with the more recently collected samples is that different techniques and net pore sizes were used. In 1973 Surber samples were used to sample stones-in-current biotopes whereas in 1997 SASS nets and kicking of substrates were used. Both these techniques would inadvertently pick up a percentage of organic drift. The SASS net technique would under-collect sesile organisms such as Simuliidae and because a courser mesh size (1000 m as opposed to 280 m) is used, smaller animals such as certain species of entomostracan Crustacea, Chironomidae and oligochaete worms belonging to the genus *Nais* , would also be underepresented. This would give a skewed representation as regards the dominance of different species. Oliff (1960a) reports that a reduction in the pore size of sampling nets from 1000 m to 280 m resulted in a two-fold increased the abundance of animals collected. This would naturally influence the dominance and representation of species in community analysis. The sites selected for the 1996 survey are also not all the same as sites used during the 1973 survey and although the locality of certain sites was close to those of earlier surveys this discrepancy adds to the level of error in comparisons.

Regarding species composition, the fauna has not changed very much over a 23 year period. Ephemeroptera are still a diverse and dominant taxonomic group. Of the approximately 106 estimated species for South Africa (McCafferty and de Moor 1995) 49 are recorded for the Mkomazi/Mkomazana River catchment in the present survey. It should be noted that there are many name changes and some of the species recorded during the present survey may have been present but could not be identified in 1976 with the taxonomic features used in those days.

In some instances species dominance has altered. This is to be expected, with a bias in favour of the larger animals in the 1996 survey where a courser mesh net was used for the general collecting for which numerical analysis of fauna was conducted. The abundance of Ephemeroptera appears to have increased significantly since the 1973 survey. *Baetis glaucus* and *B. harrisoni* were less abundant and *Tricorythus discolor* , *Adenophlebia* spp. and *Castanophlebia* spp. have become more abundant. Overal species composition has remained similar indicating long-term ecological stability in the River.

For the Plecoptera *Neoperla spio* s.l. was more abundant in the recent survey than in 1973 and Notonemouridae which were recorded as far down as Lundy's Hill in 1973 were only found down to Vergelegen in the present survey.

It appears that the diversity of Simuliidae has increased with 19 species recorded now and only 11 in 1973. This may, however, reflect a more detailed level of identification for the present survey. The numerical abundance of Simuliidae has however declined considerably and from being the single most dominant taxonomic group at all sites in 1976 they now share dominance with Ephemeroptera and hydropsychid Trichoptera at a number of sites. Although Simuliidae were more abundant at all sites during the 1973 survey, this recorded observation would be influenced by the sampling technique being different as mentioned above. Therefore, not too much significance should be placed on this observation. *Simulium vorax* was still the dominant species in the Mkomazi River in the middle to lower sites. *Simulium damnosum*, *S. letabum* and *S.wellmani* have all become more abundant in the recent survey. Whereas *S. medusaeforme* and *S. vorax* have become less abundant. The absence of *S. bovis* in the 1996 survey at all four sites is interesting and may indicate a decline of this species in the river. It was, however, still found in low numbers in the lower reaches (Sites 19 and 20).

The family Tipulidae with 27 species collected during the recent survey are also well represented indicating a diversity of aquatic and semi-aquatic biotopes.

The 1996 survey revealed the appearance of *Cheumatopsyche afra* and *C. maculata* which were absent during the 1973 survey. All species of Hydropsychidae appear more abundant in the 1996 than in the the 1973 survey. Cheumatopsyche FMC type 1 and FMC type 2 have extended their distribution further downstream than was evident during the 1973 survey. A large number of *Cheumatopsyche* sp. were recorded for the 1973 survey and detailed study of these, to determine the species, may resolve some of these anomalies. A number of other Trichoptera species, present low numbers during the present survey, were not recorded during the 1973 survey. Whether these changes reflect a real change, a bias in sampling techniques or a site difference, will have to be confirmed by further studies.

Several groups of Coleoptera were more abundant during the present survey than during the 1976 survey. Elmidae in particular formed a significant component representing 3.6 and 7.1% of the invertebrates at sites 12 and 14 where they represented a maximum of only 0.4% in 1973.

The 1996 survey shows a much greater diversity and equitability of species at all sites compared with the 1973 survey, with no single taxon showing more than 18% representation. The total number of taxa at each of the five compared sites was also significantly higher during the 1997 survey than during the 1973 survey. This would suggest that the rivers were in a better state in 1996 than in 1973. As good rains had fallen in the Mkomazi catchment in 1996 this would have influenced the aquatic biota diversity favourably. It can, however, be stated with confidence that the overall composition of the biota has not changed significantly over the 23 year period and that the rivers are in a "healthy state" at present.

Flow requirements of the aquatic macroinvertebrates

The abundance of filter feeding Hydropsychidae represented by a longitudinal zonation of 11 or 12 species indicates that within the running water biotopes there is a variety of flow conditions capable of supporting species with a range of different ecological requirements. The 19 species of Simuliidae also show this zonational pattern quite clearly. The distribution of these different species indicates that the Mkomazana and Mkomazi Rivers have a distinctive and varying functional component of filter feeding species at different altitudes. Maintaining this rich diversity of Hydropsychidae and Simuliidae species in the middle reaches of the Mkomazi River would ensure that ecological functional processes are not jeopardised. Ecological requirements of the biota are strongly governed by the flow regime of the river and long-term unidirectional modification of sediment deposition or erosion will lead to species eradication and functional community structural changes.

The discovery of the naucorid bug *Aphelocheirus ?corbeti* was very interesting. *Aphelocheirus* spp. never leave the submerged biotopes and like elmid beetles rely on plastron repiration. They require swift-flowing water with high levels of dissolved oxygen and cannot tolerate pollution. This species may be endemic to certain KZN rivers. A species such as *A. ?corbeti* could be used as an umbrella species whose ecological requirements could be used to protect a community of co-occurring species.

Elmid beetles were found at almost every site analysed except on small or polluted tributaries (the Mpofini and Lufafa Rivers) or in the river with a sandy substrate (the Mkomazi River at Gravesend Estate). A total of seven species were identified during the survey sampled in the stones-in-current-biotope. Elmidae and aquatic hydraenid species are most likely to be affected by modifications of the flow regime due to their highly specific habitat requirements and dependency on plastron respiration. Lower flows will result in warmer water with lower oxygen levels. Apart from reducing the absolute number of stones-in-current biotopes, lower flows will result in greater siltation of the river channel and a possible smothering of available stoney biotopes. In a similar way, the populations of psephenid larvae may be adversely affected by flow reductions, especially as the larvae of this particular species tend to be found in the middle reaches of larger fast-flowing rivers.

Discussion

The MKomazi and Mkomazana show an exceptional diversity of aquatic insects dominated by hydropneustic groups. Both rivers are swift flowing with mostly stony reaches and there are diverse communities of filter feeding Hydropsychidae and Simuliidae as well as Elmidae and baetid mayflies. This rich diversity of species with low numbers of individuals for each species indicates a healthy rich heterogeneous environment with a wide range of ecological conditions which has also ensured that pest species have not become abundant and problematic in the Mkomazi River.

Comparing the species composition of the Mkomazi/Mokomazana Rivers with that of the Mooi River, a tributary of the Tugela River it is notable that the Species of Hydropsychidae are very different with only two of the twelve species from the Mkomazana and Mkomazi Rivers also being found in the Mooi River (see de Moor 1995). There are also more species of Leptoceridae in the Mkomazana and Mkomazi Rivers with several species of Oecetis , Triaenodes and Trichosetodes which are absent from the Mooi River. *Simulium wellmani* and *S. letabum* are also absent from the Mooi River.

Recommendations

A measure of the abundance and diversity of aquatic macroinvertebrates in a river provides information on the status or "environmental health" of that system. Because different species of invertebrates have varying aquatic life-cycle durations, the community structure of aquatic invertebrates can provide a time-integrated measure of the prevailing conditions. The presence or absence and relative abundance of macroinvertebrate species can be used to assess disturbance events which occurred prior to sampling. Water chemical samples which give an instantaneous record of prevailing conditions do not provide such information. Because of their small size and relatively sedentary nature aquatic macroinvertebrates are vulnerable to ecological disturbances, unlike fish which can move away from unfavourable areas and return again once this has passed. The macroinvertebrate species need time to recolonise sections of river and various species do this at differential rates. For this reason certain species may be eliminated from sections of river for a considerable time as a result of ecological disturbances. Species composition of macroinvertebrate communities therefore also provide information as to how long ago a disturbance event occurred. In certain instances the form of the disturbance, i.e. specific kinds of chemical or organic pollution or drastically altered flow regimes will also be reflected by a change in the natural macroinvertebrate assemblage.

Functionally aquatic macroinvertebrates are important processers of organic matter. They serve a vital function in purifying water and also provide a valuable food resource for larger animals within, and even outside the river system. In order to continue functioning optimally, the component species in a river system require regular inputs of nutrients, sediments and water flow. Specific river systems evolve particular assemblages of species forming functional communities within reaches. These communities are optimally adapted to the prevailing conditions such as substrate composition, water temperature, sediment transport and nutrient flows. A reduction or increase in flow, sediment transport or nutrient loads will lead to changes in community structures through loss of certain species and increases in others.

There are more than 40 undescribed species of aquatic insects in the middle reaches of the Mkomazi River (Ephemeroptera 19 spp., Coleoptera 5 spp., Trichoptera 11 spp., Simuliidae 2 spp. and Tipulidae 3-4 spp.). These need further attention, firstly to be described, then to establish whether their distribution is more widespread and finaly to find out what ecological role they play in the middle reaches of the river system.

As a management proposal for the Mkomazi River system it is recommended that efforts should be made to maintain the rich diversity of species in the riffle and running water biotopes. No single group of animals or certain species of Simulium should be allowed to dominate the fauna of these biotopes. Maintenance of species diversity will ensure that pest species such as certain Simulium spp. do not become abundant, a problem which would have to be further managed.

The dense crusted algal growth on stones from riffles in the Mkomazi River near Impendle indicate that there is excessive nutrient enrichment in the river upstream of that site. The diversity and abundance of filter feeding hydropsychid caddisflies and baetid mayflies and the presence of certain upper-reach, running-water species found at lower altitudes characterised the Mkomazi River as a swift-flowing, cool, well oxygenated river system with a diverse fauna able to process and clean up the present enrichment of the river. There are many macroinvertebrates that require a cool water regime for continued survival and hence the thermal regime of the river should also be considered in the river management programme.

It should be noted that the Mkomazi River is one of the few remaining moderate to large rivers which has not had dams built in its catchment. The almost complete lack of problem or pest species in this river indicates that its natural flow regime is sufficiently abundant and varied in discharge to maintain a diverse macroinvertebrate fauna not dominated by any pest or problem species for any great length of time. Severe modification of this natural flow pattern can lead to an enhancement of conditions which favour pest and problem species such as blackflies, mosquitoes and snail vectors of bilharzia. Reduced flow conditions and the removal of scouring floods can also lead to reed encroachment, a condition notably absent from the present river.

THE FULL DOCUMENT IS AVAILABLE ON REQUEST FROM DELANA LOUW.

APPENDIX N

MKOMAZI IFR - Mkomazi River: Hydrology

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1. INTRODUCTION

The Mkomazi River catchment is located in the southern part of the KwaZulu-Natal province and the river has its source in the sou.hern Drakensberg. The Mean Annual Precipitation (MAP) for the entire catchment is 981 mm (Surface Water Resources of South Africa, 1990, further referred to as WR90) and the Mean Annual Evaporation (MAP) is 1252 mm. However, MAP is higher in the upstream parts of the catchment (1000 - 1287 mm) and correspondingly most of the runoff is generated upstream. The most downstream part of the catchment (approximately 33% of the total area) contributes less then 14% of total MAR (1089 MCM, WR90).

To provide the background hydrological information for the assessment of environmental requirements of the river, this study has primarily made use of the available observed records. The current document describes the data and the technique that have been used to generate representative daily streamflow time-series at 4 pre-selected IFR sites and summarises the hydrological information at these sites using a series of graphs which illustrate annual runoff variability, seasonal flow distribution during wet, intermediate and dry years, 1-day annual flow duration curves and daily flow hydrographs for one wet and one dry year. The document also contains a table which lists some typical flow characteristics at IFR sites on a month-by-month basis: range of expected baseflow discharges, number, magnitude and duration of 'flood' events. The data used in all cases may be considered to represent natural flow conditions in the catchment.

2. AVAILABLE STREAMFLOW AND WATER USE DATA

Two streamflow gauges with flow records dating from early 1960s exist in the catchment. The first (U1H005) commands the upstream part of the catchment (1744 km^2), the second (U1H006) is close to the estuary (4349 km^2) and effectively records flow from the entire catchment. These historical records are stationary and are generally of reasonable quality with a few gaps due to missing data. The downstream gauge however has a low Discharge Table Limit (DTL) and therefore, unreliable high flow measurements.

The 1-day non-dimensional annual flow duration curves constructed for each gauge using the whole record period clearly illustrate the similarities in hydrological regime of the two sites (Figure 1). At the same time, gauge U1H006 demonstrates a slight increase in low flows relative to U1H005 (flows exceeded more than 90% of the time). These differences are more pronounces during dry months of the year. This may be the indication of a slightly more baseflow driven flow regime in the most downstream reaches of the Mkomazi river. On the other hand, the "truncated" high flows at U1H006 may reduce the mean daily flow estimated from observed records and, consequently, "push up" the ordinates of the non-dimensional flow duration curves (annual or monthly).

Monthly flow time series data for virgin flow conditions in the catchment for a standard 70 year period (1920-1990) are available from WR90 (for each of the 12 quaternary subcatchments in the basin). These data have been simulated using Pitman's monthly rainfall-runoff model.

An update of the Pitman model simulations (for a period from 1925 to 1995) has been acquired from BKS. These simulations have been made for three proposed dam sites in the catchment (Impendle, Smithfield and Ngwadini) as well as for the catchment outlet. These sites are not necessarily coincident with the quaternary catchment boundaries and with the IFR sites (see below). The simulations have been carried out for present day development conditions in the catchment. The estimates of the MAR's at different sites are summarised in Table 1, which also contains some present day water-use data (BKS).

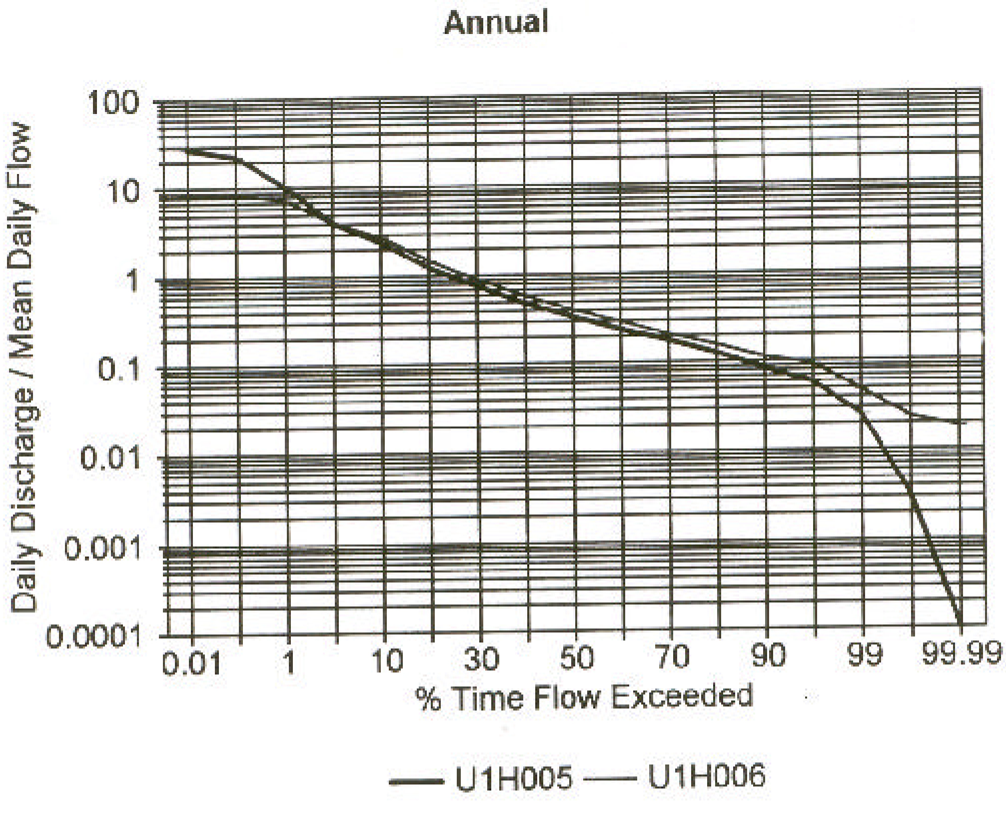


Figure 1 1-day annual flow duration curves for streamflow gauges U1H005 and U1H006

Table 1. Estimated MARs and water use data for Mkomazi catchment at different sites within the catchment (all values are in MCM).

Site	MAR natural (BKS)	MAR natural (WR90)	Forestry use	Dams	Direct Abstractions	MAR, present (BKS)	MAR, historical
Impendle	568	558	12.4	3.5	10.4	542	
U1H005	676	661					640
Smithfield	731	745	24.9	3.5	10.4	692	
Ngwadini	1056	1075	57.5	35.4	14.3	948	
U1H006	1063	1080					926
Estuary	1067	1089	57.8	35.4	14.3	959[2]	

[1] Natural MARs at the gauges are estimated by interpolation

[2] Includes 54.7 MCM taken by SAPPI. The actual MAR at the estuary is therefore 904.7 MCM

Table 1 illustrates that there are no significant differences between simulated natural MARs from two different sources. The differences between present day and natural MARs are normally in the range of 5- 10%. The estimate of the MAR at U1H005 from observed records is only slightly less than natural MAR (which may be partially related to the differences in the length of record). The estimate of the MAR at U1H006 is approximately 13% less than that of the BKS natural. This difference may be partially related to the increased water use development downstream. However, as has already been mentioned, this gauge has a low DTL and that may significantly decrease the estimated MAR value. Generally, historical daily flow time series may be used to generate representative daily flow sequences for the IFR sites with a high degree of confidence..

3. IFR SITES LOCATION

Four IFR sites have been established. The first (IFR1- Lundy's Hill; 29° 44' 36" S and 29° 54' 41" E) is located about 1 km downstream of the gauge U1H005 and for all practical hydrological purposes may be assumed to be coincident with it. The gauge and the site are situated at the outlet of quaternary subcatchment U10E. Two of the possible dam sites (Impendle and Clayborne) are located above this IFR site in the quaternary catchment U10E.

The second site (IFR2 - Hella Hella: 29° 55' 15" S and 30° 05' 04" E) is coincident with the outlet of quaternary subcatchment U10H, where two other possible dam sites are located (Smithfield and Ndonyane).

The third site (IFR3 - St Josephine's Bridge: 30° 00' 29" S and 30° 14' 20" E) is roughly coincident with the outlet of quaternary catchment U10J. A small left-hand tributary however comes in between the site and quaternary catchment outlet. The site is approximately half-way between the two streamflow gauges along the main river channel.

The last site (IFR4 - Mfume: 30^0 07 34"S and 30^0 40' 07" E) is located about 10 km upstream of the gauge U1H006, close to the outlet of the whole Mkomazi catchment and close to the outlet of quaternary subcatchment U10M. Ngwadini dam is above this site.

4. GENERATION OF REPRESENTATIVE DAILY STREAMFLOW SEQUENCES FOR THE IFR SITES.

Representative daily streamflow time series for the IFR sites have been generated using a spatial interpolation technique described by Hughes and Smakhtin (1996). The technique is based on typical flow duration curves for each calendar month of the year and on the assumption that flows occurring simultaneously at sites in reasonably close proximity to each other correspond to similar percentage points on their respective flow duration curves.

In the case of the Mkomazi River, all the IFR sites are located on the main stream between the two gauged sites which, as has been illustrated by Figure 1, have very similar normalised flow duration curves. It therefore may be expected that flow regimes at the IFR sites are very similar to the recorded ones. The first step in the generation technique is:

- Generation of flow duration curve (FDC) tables for source (gauged) sites and destination (IFR) sites for each month of the year.

For source gauged sites it is done directly using the available observed records. For ungauged IFR sites there exist a variety of ways to approach this problem (e.g. use either averaged/regional flow duration curve or the curve from the nearest gauge, etc). Several of these approaches have been tried and they all resulted in a time series which were only marginally different. The final FDC tables have been generated using the FDC table from the nearest gauge and a corresponding correction factor to account for the differences in natural MARs at the gauge and at the IFR site. No correction factor was used for IFR1 since it is almost coincident with U1H005 and its natural MAR is within 5% of the historical estimate. IFR sites 2 and 3 are located close to the quaternary catchment boundaries, and therefore the estimates of the natural MARs for these IFR sites are available from WR90. On the other hand, no estimates of the natural MARs are available for these IFR sites from the BKS monthly simulations. In order to reconcile two different simulations (WR90 and BKS), the MARs at IFR2 and IFR3 have been estimated as:

$$MAR_{WR90,\ IFRi} / MAR_{WR90,\ MKOMAZI} * MAR_{BKS,\ MKOMAZI}$$

where $MAR_{WR90,\ IFRi}$ is the MAR estimate at the IFR site obtained from WR90, $MAR_{WR90,\ MKOMAZI}$ is the MAR estimate of the entire Mkomazi catchment (WR90), and $MAR_{BKS,\ MKOMAZI}$ -the BKS estimate of the MAR for the entire catchment. For IFR4 the natural MAR has been calculated by simple interpolation between BKS natural MAR estimates at Ngwadini site and at the estuary.

The second step in the generation procedure is

- actual simulation of the time series using established flow duration curves for the IFR sites.

This also includes several subsequent steps:

1. For each source gauge assign a weighting factor associated with the degree of similarity between the source flow regimes and the IFR site's flow regime.
2 For each day: i) identify the percentage point position of the source site's streamflow on the source site's flow duration curve (for the relevant month) and ii) read of the flow value for the equivalent percentage point from the destination site's flow duration curve.
3 The weighted average of the estimated destination site flow values is then assumed to be a final destination site's flow value for this day.

The use of several source sites is an attempt to account for the fact that an IFR destination site time series may be the result of several influences, which may not be reflected in a single source site time series. Also, part of an individual source site time series may be missing and the use of several (2 in this case) will decrease the number of missing values in the resultant time series at the IFR site. In all the cases gauge U1H005 had a larger weight then U1H006 since the latter is more affected by developments in the catchment. However, different weights combinations have been found to produce only slight differences to a resultant time series.

The combined use of 2 observed flow records allows the daily time series data at IFR sites to be generated for a period from 1960 to 1996 (36 years) which should be sufficient for any hydrological analysis. Table 2 contains the final MAR values at each IFR site estimated from the simulated daily time series.

Table 2 Natural MAR values at IFR sites estimated from the generated daily time series data for a period of 1960- 1996

Site	IFR1	IFR2	IFR3	IFR4
Area, km	1741	2931	3436	4340
MAR, MCM	690	909	1004	1064

4. HYDROLOGICAL REGIME OF THE IFR SITES

The generated daily time series data are used in this document to illustrate the characteristic features of each IFR site's flow regime. The following characteristics of the flow regime are presented in graphic form:

- plots of annual streamflow volumes as a time series for available period;
- annual 1-day flow duration curves;
- seasonal distribution of monthly flow volumes for 3 wet years;
- seasonal distribution of monthly flow volumes for 3 intermediate years;
- seasonal distribution of monthly flow volumes for 3 dry years;
- representative hydrographs for one wet and one dry year;

Table 3 contains the details of some typical flow sequences at the IFR sites for each calendar month including the range of baseflows, magnitude, number and duration of floods and freshes (the largest floods have normally been ignored for the compilation of this table, since they cannot be managed).

In some cases where the resultant graphs (or flow sequences for Table 3) are very similar either for the whole catchment or for several sites (e.g. for IFR sites 2 and 3), the results for only selected IFR sites are presented.

The data presented in this report are a brief summary of the daily streamflow regime, which aims to highlight its main distinct features. Additional detail will be available at the workshop through the various display options of the IWR HYMAS computer package.

Table 3. Typical flow characteristics for IFR sites (natural conditions). Flows are in m^3/s, and durations are in days.

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
IFR1												
Range of Baseflow	0.5-3.0	1-7.0	1.0-10	1.0-10	3.0-12	7.0-15	3.5-11	2.0-10	1.0-6.0	0.2-0.4	0.5-3.5	0.5-3.0
No. of Events	1	2	2-3	2-3	2	2	1-2	<1	<1	<1	<1	1
Range of Peaks	10-45	13-55	30-195	75-300	60-350	50-180	18-90	10-22	5.5-12	6-12	5-10	3-20
Main Duration	2 - 3	3 - 4	3 - 4	3 - 4	3 - 4	3	3	3	3	3	3	3
IFR2 and IFR3												
Range of Baseflow	1.5-6.0	2.0-10	2.0-12	2.0-19	4.0-25	8.0-23	3.0-15	2.0-15	1.5-8.0	0.8-6.0	1.0-6.0	0.5-4.0
No. of Events	1	2	2-3	2-3	2	2	1-2	<1	<1	<1	<1	1
Range of Peaks	13-20	25-70	60-220	100-350	70-450	60-200	40-180	9-24	9-16	8-16	7-14	9-3
Main Duration	2 - 3	3 - 4	3 - 5	3 - 5	3 - 5	3 - 5	3 - 5	3 - 4	3 - 4	3 - 5	3 - 4	3 - 4
IFR4												
Range of Baseflow	2.0-8.0	4.0-17	4.0-18	4.0-25	5.0-30	10-40	6.0-25	4.0-22	3.0-12	2.0-12	2.0-8.0	1.0-10
No. of Events	1	2	2-3	2-3	2-3	2-3	1-2	<1	<1	<1	<1	1
Range of Peaks	15-60	30-90	60-240	60-300	90-300	70-210	60-180	15-50	13-40	10-38	9-45	10-40
Main Duration	3 - 4	3 - 6	3 - 6	3 - 6	3 - 6	3 - 6	3 - 6	3 - 4	3 - 6	4	3 - 5	3 - 5

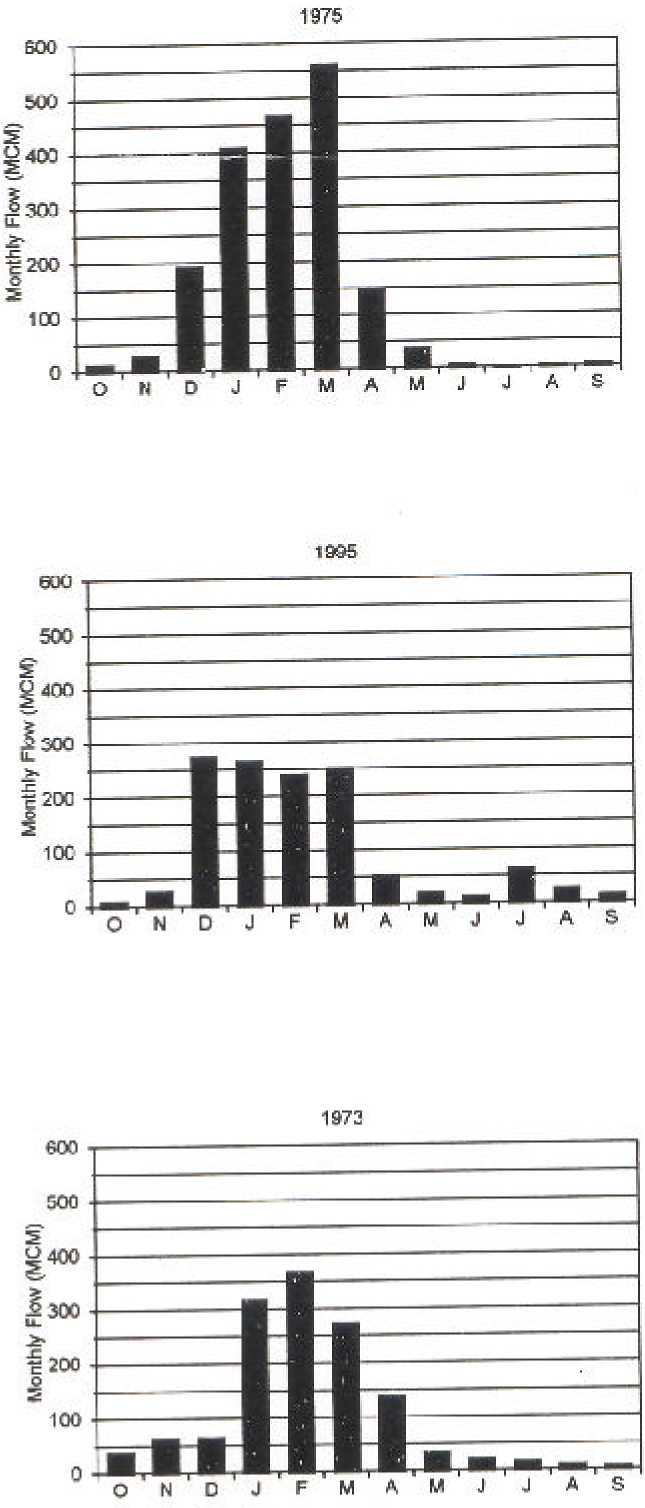


Figure 4. IFR1, Monthly flow volumes for three wet years

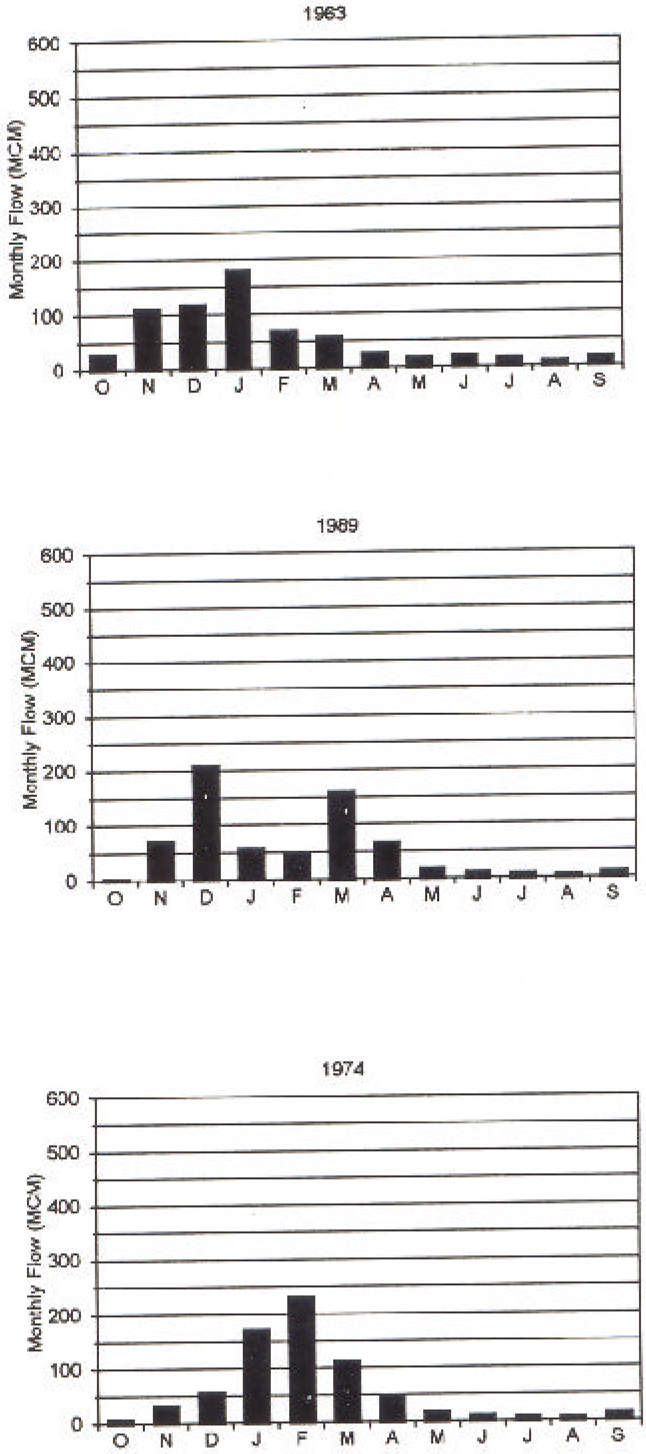


Figure 5. IFR1, Monthly flow volumes for three intermediate years.

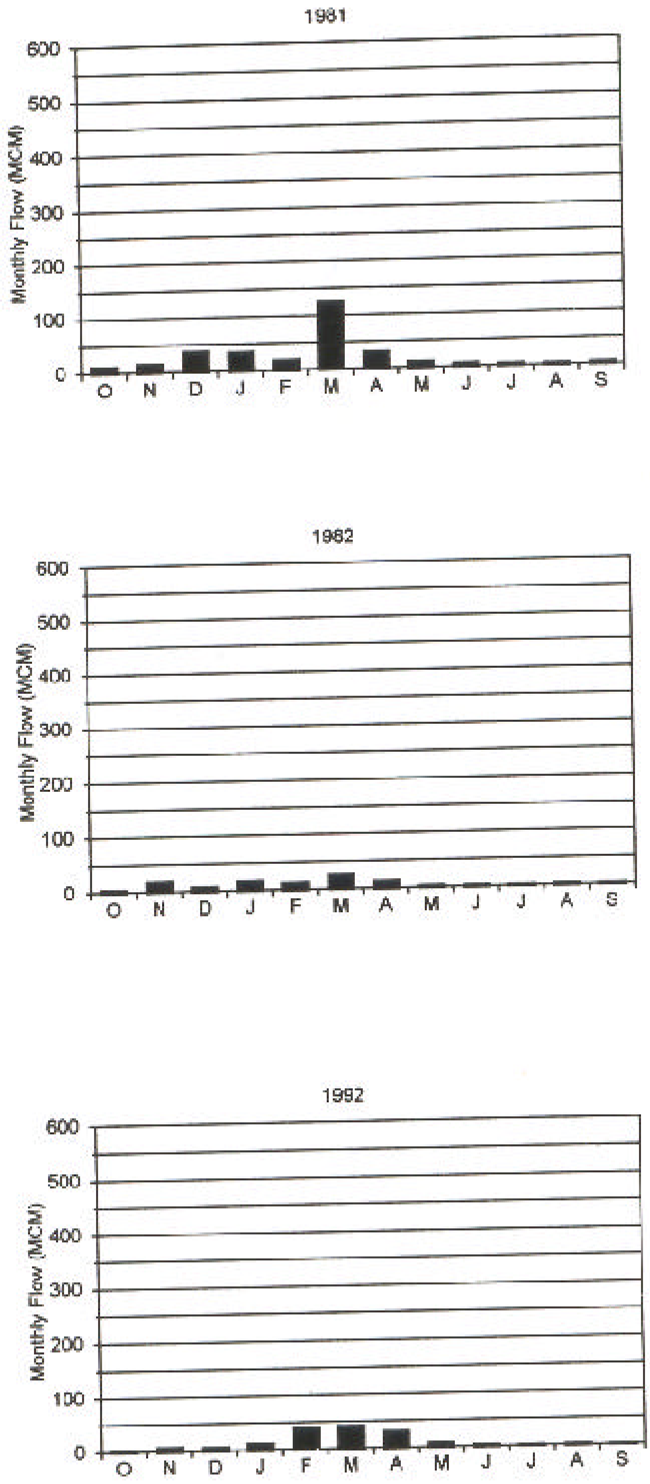


Figure 6 IFR1, Monthly flow volumes for three dry years.

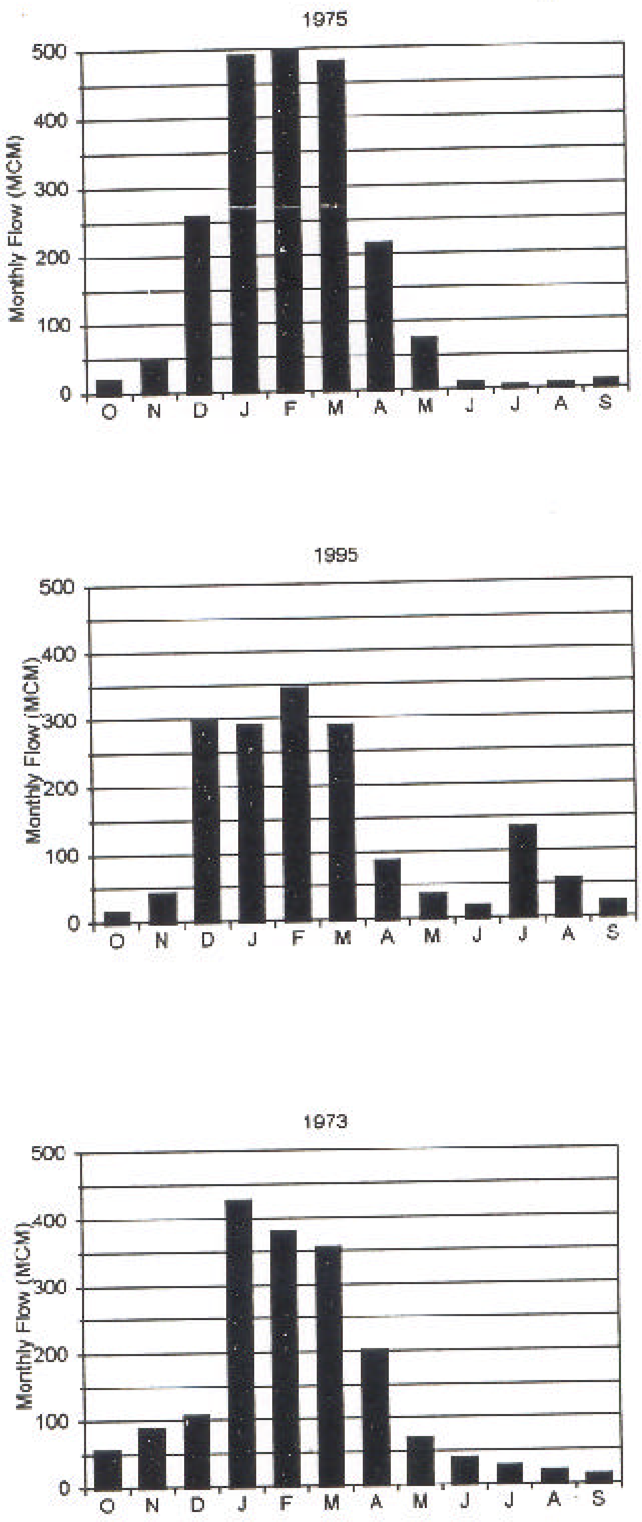


Figure 19 IFR4, Monthly flow volumes for three wet years.

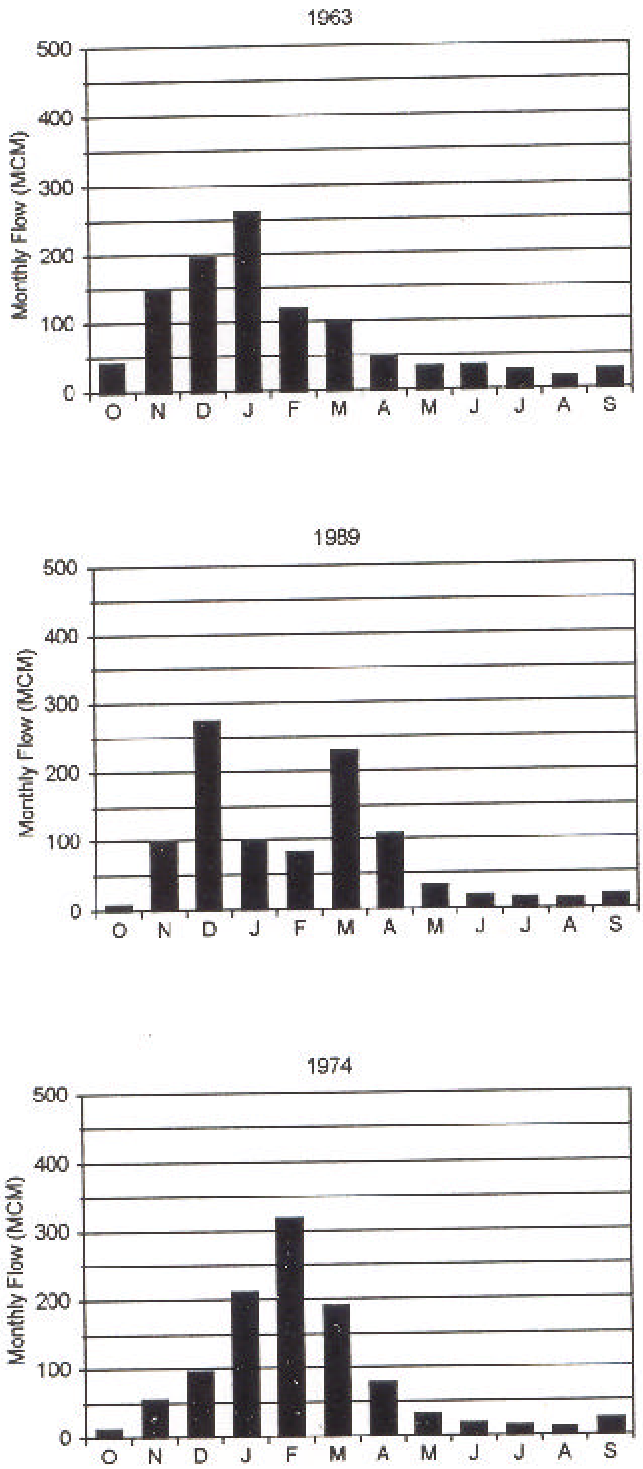


Figure 20 IFR4, Monthly flow volumes for three intermediate years

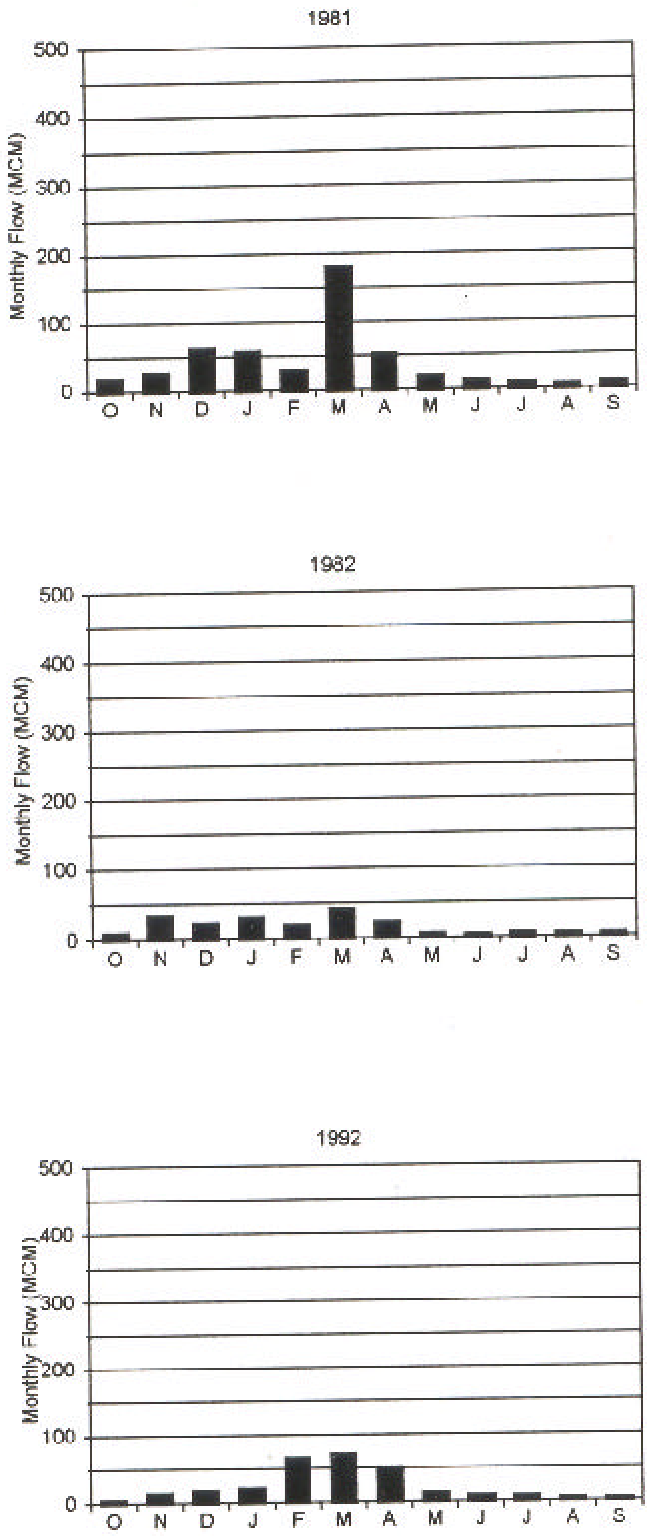


Figure 21 IFR4, Monthly flow volumes for three dry years

APPENDIX O

1. Introduction and Methodology

Instream Flow Assessment (IFA) does not concern itself with secondary (commercial) water demands by various demand sectors or user groups. Consequently, this paper concerns itself with

the non-commercial "social" uses of the Mkomazi River and its riparian vegetation

by

those people living in or near the riverine environment

and who

are to a greater or lesser degree, dependent on the river flow and riparian vegetation for their daily needs or survival.

As the basic social requirements are related to the ecological requirements for maintaining riverine ecosystems, the following discussion is not confined to particular IFR sites (although investigation took cognisance of the sites) but provides an outline of various forms of social dependence on the riverine ecosystem.

The methodology employed for the study incorporated:

- A desktop analysis:
- a review of available literature on social aspects of downstream impacts and water resource usage; and.
- the gathering of available data on the villages to be affected: identification through mapping; obtaining population estimates through the 1986 census.

Central to the investigation was the utilisation of a Participatory Rural Appraisal (PRA) methodology. This involved group discussions with the following groups:

- One group discussion with farmers irrigating lands from the river (drawn form the village of Makhuzeni).
- One group discussion with women who harvest fauna along the river banks for handicrafts (also from Makhuzeni).

- Two group discussions with a cross section of residents who live along the banks of the river (in the vicinity of Makhuzeni and also in the Qiko Tribal Authority).
- Group discussions were held at the river. This helped to stimulate and contextualise discussions. The information generated in the group discussions was supplemented with:
- observations made during the scoping and pre- feasibility studies for the proposed Mkomazi Dams (Impendle and Smithfield).

The objective of the research was to elicit information around the needs that have to be met to maintain the social environment. This involved determining:

- which requirements need to be met and,
- the amount of water required in the system to meet these needs.

At the outset it should be stated that determining which requirements need to be met is complicated by the tendency to adopt a static and ahistorical approach and to assume that current utilisation patterns replicate past patterns and represent a model of future requirements. This assumption becomes increasingly problematic when confronted with the realisation that an analysis of resource patterns concerns a dynamic social situation and not a static one. Problems around this concept became evident during the group discussions and consensus around needs was sometimes difficult to generate. However, the PRA methodology proved to be useful in stimulating discussion and in making people aware of the dynamics of social needs.

2. The Mkomazi River: Overview of the social environment

Seven magisterial districts fall either completely or partly into the Catchment (See Map 1). These are:

Underberg

Impendle

Polela

Richmond

Ixopo

Umzinto

Embumbulu

The seven magisterial districts within the Catchment may be aggregated into three geo- political zones, which, for the purposes of this paper, form the most appropriate unit of analysis. These zones may be classified as; "Hinterland (includes IFR site 1)", "Midlands area of Richmond Ixopo (includes IFR sites 2 and 3) " and, "Coastal (IFR 4 lies in this area) ". The varied development track that these zones have taken reflects the constraints of geography as well as the way in which the national political - economy has shaped the greater catchment area. The areas are:

2.1 Coastal

This area is made is made up of the riverine section that includes portions of the districts of Embumbulu and Umzinto. One of the highest population concentrations within the Catchment occurs in this area. The economy of this portion of the catchment is based on:

- Subsistence agriculture
- Export of labour (largely to Durban as Embumbulu in particular acts as a satellite settlement for the Durban Metro) I
- Limited industrial development evident around the town of Umkomaas itself (Sappi-Saiccor as major player)
- Some commercial farming (mostly sugar cane).

The Mkomazi estuary acts as a resource for the satisfaction of some recreational needs. In the rest of the area the river is used largely for commercial purposes. The town of Umkomaas is the only major formal town and forms a nucleus around which an axis (extending along the N2) of relatively dense peri-urban and closer settlement has developed. A secondary settlement axis linking Umkomaas with Dududu has also developed. Outside of these axes settlement tends to be scattered with local development nodes occurring around smaller service points. In the river valley settlement is particularly scattered as the broken nature of the terrain generally precludes the development of logical access points that follow the line of the valley.

Most of the land that lies within this area falls under tribal tenure. *De jure*, it is held in trust by the Zulu monarch through the Ingonyama Tribal Trust Act. *De facto* land usage and settlement allocations are determined by various Tribal Authorities. In terms of the local government legislation (in the process of being finalised) all areas under tribal tenure are envisaged as being administered at a local level by Tribal Councils. These Councils, along with urban Local Councils and rural District Councils, fall under the auspices of a wider Regional Council that will administer services to non-urban areas.

IFR site four is located in this sub-region.

2.2 Richmond – Ixopo

This area is made up of a freehold commercial farming belt interspersed with areas under tribal trust tenure. Richmond is the most important of the urban areas. Commercial farming is the most important economic activity in the area. Irrigation is of critical importance. Dominant farming types are mixed, dairy, and civiculture. Abstraction from the river for the purposes of irrigation is prevalent in this area.

In terms of the social utilisation of the River, as defined for the purposes of the IFR, recreational canoeing is particularly important. According to representatives of the canoeing fraternity the Mkomazi River is one of the best rivers, for this type of activity, in the county.

2.3 Polela-Impendle-Underberg Hinterland

This area is made up of an "uneasy" mix between freehold commercial farming interspersed with areas under tribal trust tenure and catchment conservation reserve areas. The magisterial districts of Polela and Impendle function in party as labour reserves (tribal trust lands) and in part as commercial farming enclaves. Land tenure is a particularly complex issue in this area and there are four main types of landholders in the Mkomazi Valley area. These are:

- Tribal Authorities
- The Department of Land Affairs holding land scheduled for restitution
- Individual Holders with freehold rights (including the Stoffelton settlement which is one of the largest settlements of "black" freehold farmers in the country).
- Companies with freehold rights.

Most of the area is given over to subsistence agriculture, timber and mixed commercial farming.

The magisterial district of Underberg is largely divided between land held by freehold commercial farmers and land held for the purposes of conservation. The towns of Impendle, Himeville, Underberg and Bulwer are the most important of the formal settlements. *IFR site one is located in this region.*

3. Water usage and the social environment in the Mkomazi River

3.1 Peoples view of "the river" and attitudes to riverine conservation

Socio-economic structures and relations largely determine the outcome of social-environmental relations. Patterns of social relations affect the ways in which natural resources are used; the value ascribed to nature and the importance attached to conservation and rehabilitation. These change as much over time as they do across socio-economic/cultural groups. Furthermore, access to, and use of, resources result from a variety of property regimes (management systems), policies and, tenure arrangements. Forms of social regulation define the boundaries of access.

Under these circumstances it is hardly surprising that different socio-political circumstances and levels of economic development have a significant impact on expectations of, and dependence on, riverine systems.

In the Mkomazi study respondents in the "tribal trust" areas generally did not articulate strong feelings either for or against the need for conservation. For these people the ideal state of the river was one in which water quality was maintained as "clean". People living in the lower reaches of the river particularly articulated this. It was stressed that the quality of the river in winter is usually very good. People who indicated that their primary water sources, (boreholes, springs and smaller tributaries) sometimes dried up in winter emphasised the importance of the water quality in winter. For people in this category the major issue around the state of the river was therefore that it be kept clean and flowing in winter. High summer flows were generally regarded as a nuisance as the water was dangerous when flowing fast and generally too dirty to be used as a potable source.

Respondents for whom recreational canoeing was important did however express strong preferences for the river to be maintained in as pristine a condition as possible. This was regarded as particularly important as the Mkomazi was seen to be less disturbed than almost all other major rivers in KwaZulu-Natal.

Having established people views on the river and the river as environment the dissuasion then turned to the utilisation of resources in and around the river.

3.2 *Resources and the river*

People were asked to list what they considered to be the uses of the river. Rather unsurprisingly, among the residents of the "tribal trust areas", it emerged that people use run of course water for:

- Drinking and domestic cooking
- Livestock watering
- Irrigation (bucket and hand carried variety)
- Building
- Washing (selves, clothes, vehicles)
- Fill the cattle dips
- Recreation (swimming/fishing)
- Religious purposes
- As an ingredient in medicines

People were then asked what the environment alongside the river (banks and floodplains) was used for. People reported that this environment was important in respect of:

- Sand excavations for brick and block making
- Gathering of firewood and building material
- Medicinal plants
- Material for handicrafts

The river is not always the dominant source of domestic water. As intimated above people rely more on springs, boreholes and streams. The river is only used extensively when the springs and streams dry up. This tends to coincide with periods of low river flow and the appearance of algae blooms.

Respondents stated that opportunities for fishing were fast diminishing in some areas and non-existent in other areas. Fishing tends to be of a recreational nature and it did not appear as if fish formed an important part of peoples diets. The overall importance of edible and/or medicinal plants, thatch, clay and building material (for roofing, construction, fencing and household utensils) along the river banks/zone, was emphasised only by most respondents.

From a social perspective it appears that riverine environments commonly have both a utilitarian and a recreational value. The gathering of firewood/building material and the harvesting of edible plants, small animals/reptiles and medicinal plants were regarded by respondents as being of importance. Similarly, activities such as swimming, playing (and even fishing) are undertaken at various points along the river. However, respondents' primary concerns related to domestic water supply; stock watering, firewood and surplus water for agricultural purposes (vegetable gardens and irrigation). The issue of access and flooding was also regarded as a crucial issue with regard to the state of the river.

For the canoeists the river was seen as a recreational resource of critical value. The point was repeatedly made that the river represents some of the last untamed "white water" in the country and that it should remain so. In fact some complaints were made about the amount of afforestation and abstraction that had been allowed and the impact that this had had on the quality of the canoeing.[1]

3.3 The desired state of the river

Having established peoples attitudes towards the river as a resource and established some of the specifics of resource use the discussion focused again on the desired state of the river. In general a system that would regulate the river was regarded, by most respondents from the "tribal areas", as a potentially positive initiative. This was however a position that was taken up only after the effects of building a dam were pointed out to people. The statement that a dam might be a positive development was usually prefaced with cautionary notes.

People said that the regulation of the river would be a positive development if it:

---

[1] This was a minority opinion.

- would prevent the situation whereby there was no water in the river reoccurring (or at least make this a less frequent event) and
- would prevent potentially destructive floods and river flows that impeded access.

However a number of reservations were expressed about regulation. In the main these were that:

- the dam might break and people would be swept away
- that water would be diverted to those already advantaged communities and that they would have no water left in their river
- that people would be prevented from having a say in the management of releases.

In terms of regulation of the river people stated that the flow should be such that:

- people have safe access across the river, at recognised crossing points, at all times
- pools used for swimming remained in a healthy state
- the fish population should be maintained
- there should be sufficient water to be able to run irrigation pumps if so desired
- medicinal, plants along the river course not adversely affected

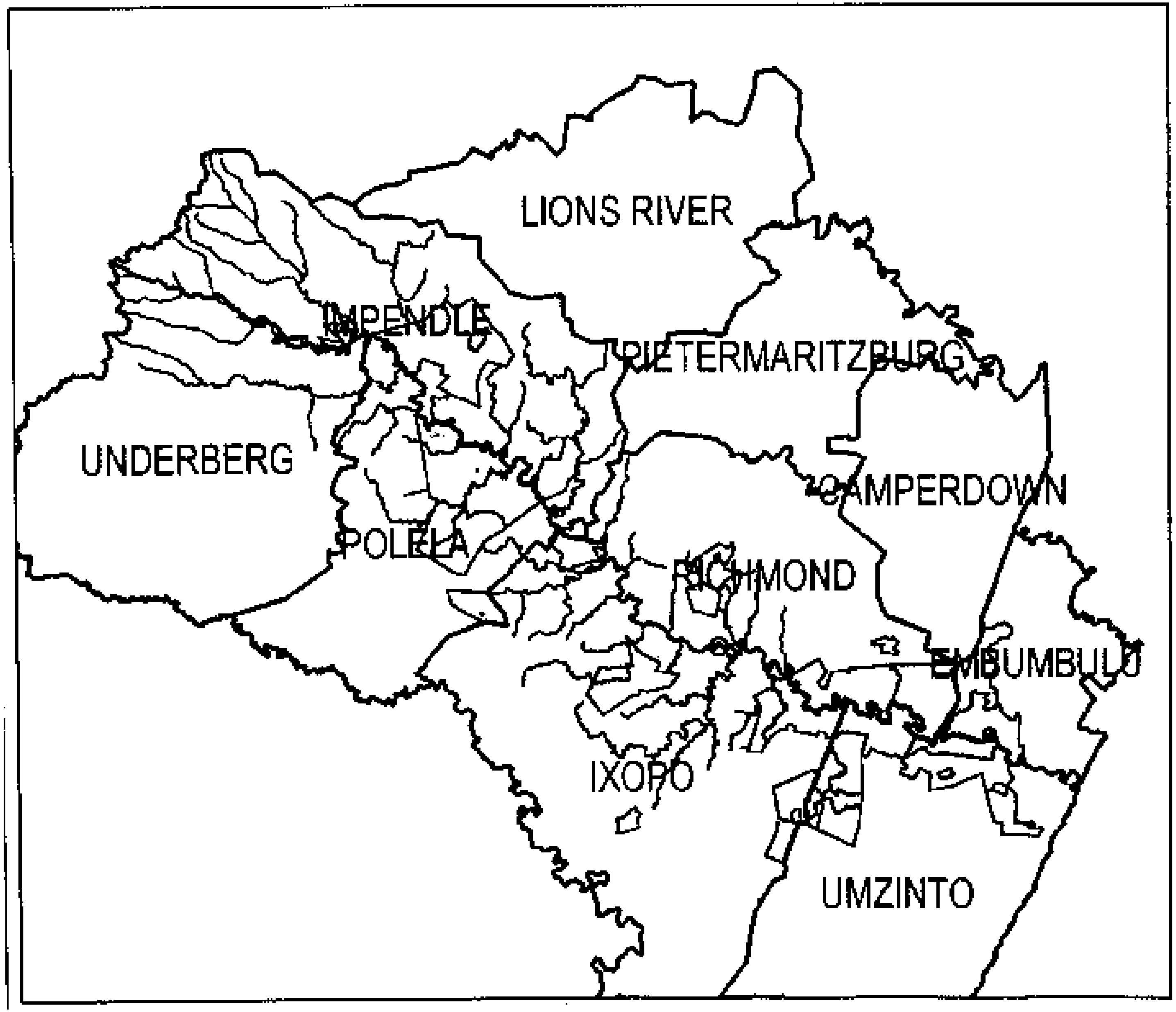
For the canoeists the prospect of damming the river was seen as a threat to their enjoyment of the resource. They emphasised the need to maintain the river as "unmanaged".

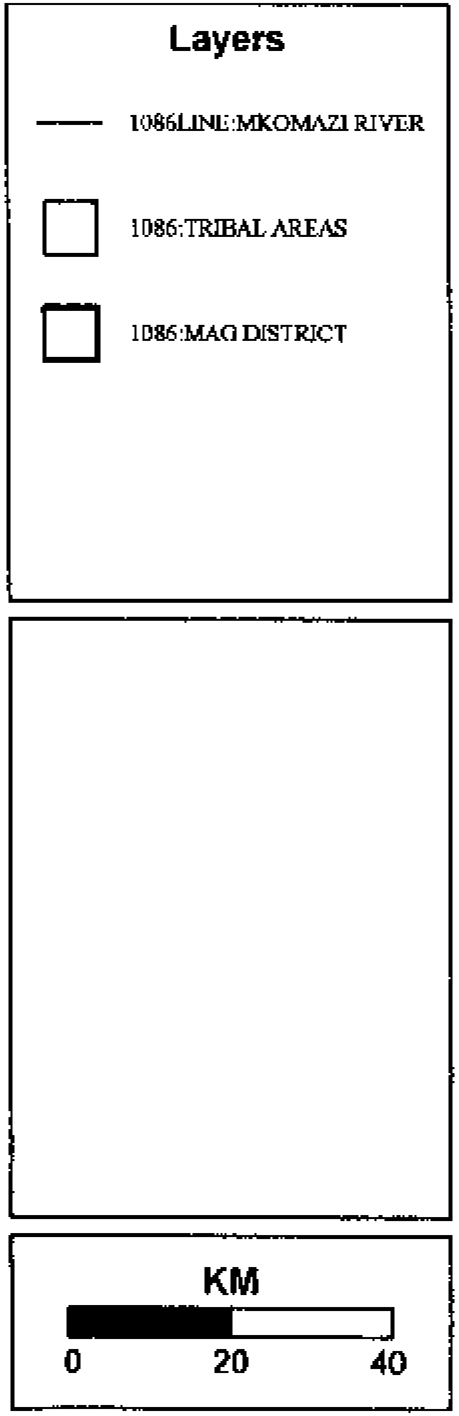
4. Conclusion

Most respondents agreed that all role-players needed to co-operate towards promoting a positive interaction with the regional and local resource base. The introduction of sound water management rules and the establishment of appropriate local water bodies and/or committees to ensure the optimal and sustainable use of available resources were emphasised in this regard. Moreover, it was emphasised that all stakeholders should have a direct say in decisions regarding the seasonal timing of floods or regulated flood releases, and should receive early warning with regard to surplus flows (uncontrolled releases) and related matters.

Mkomazi IFR: Social Aspects (Map 1)

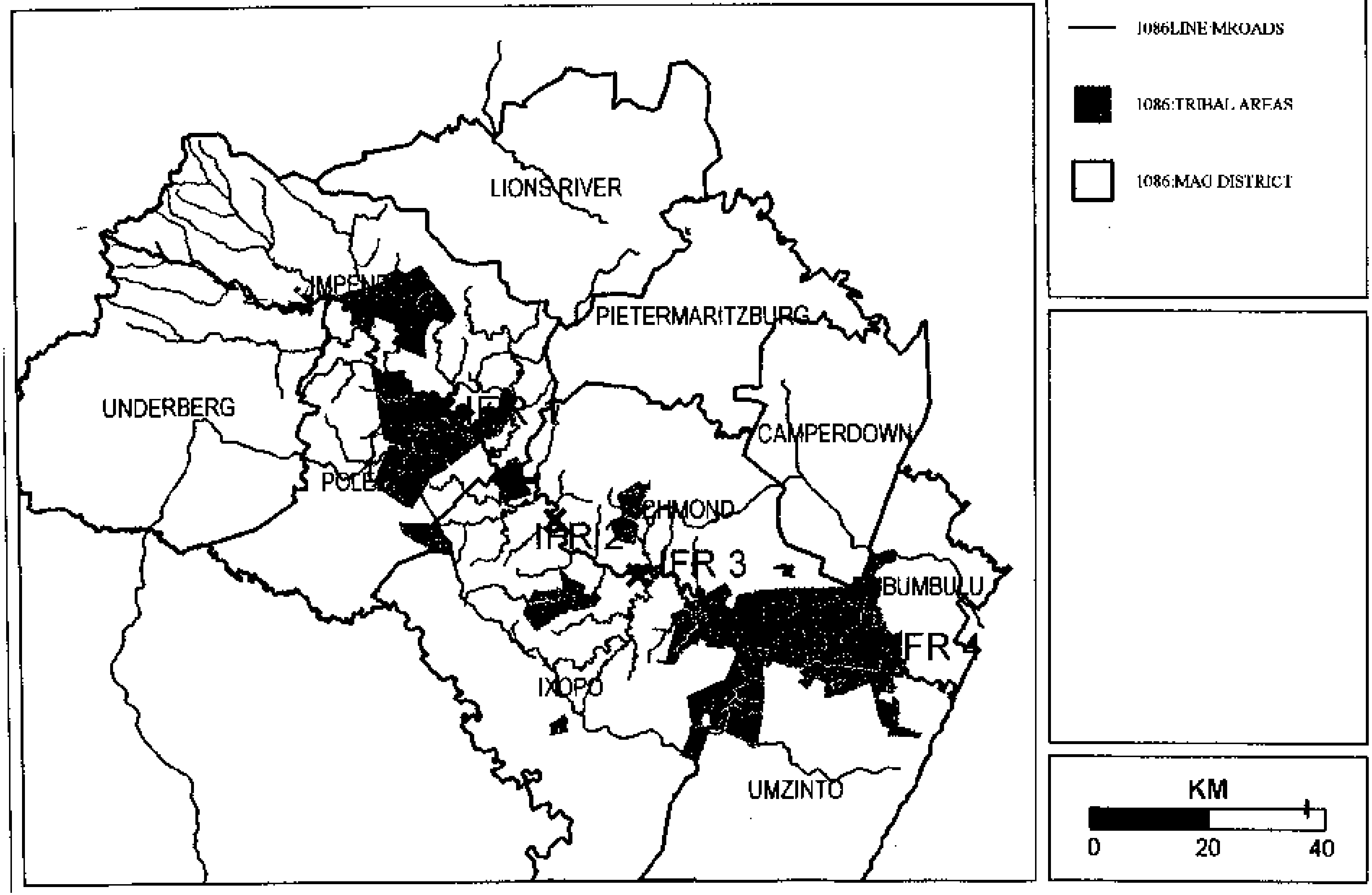
Magisterial Districts





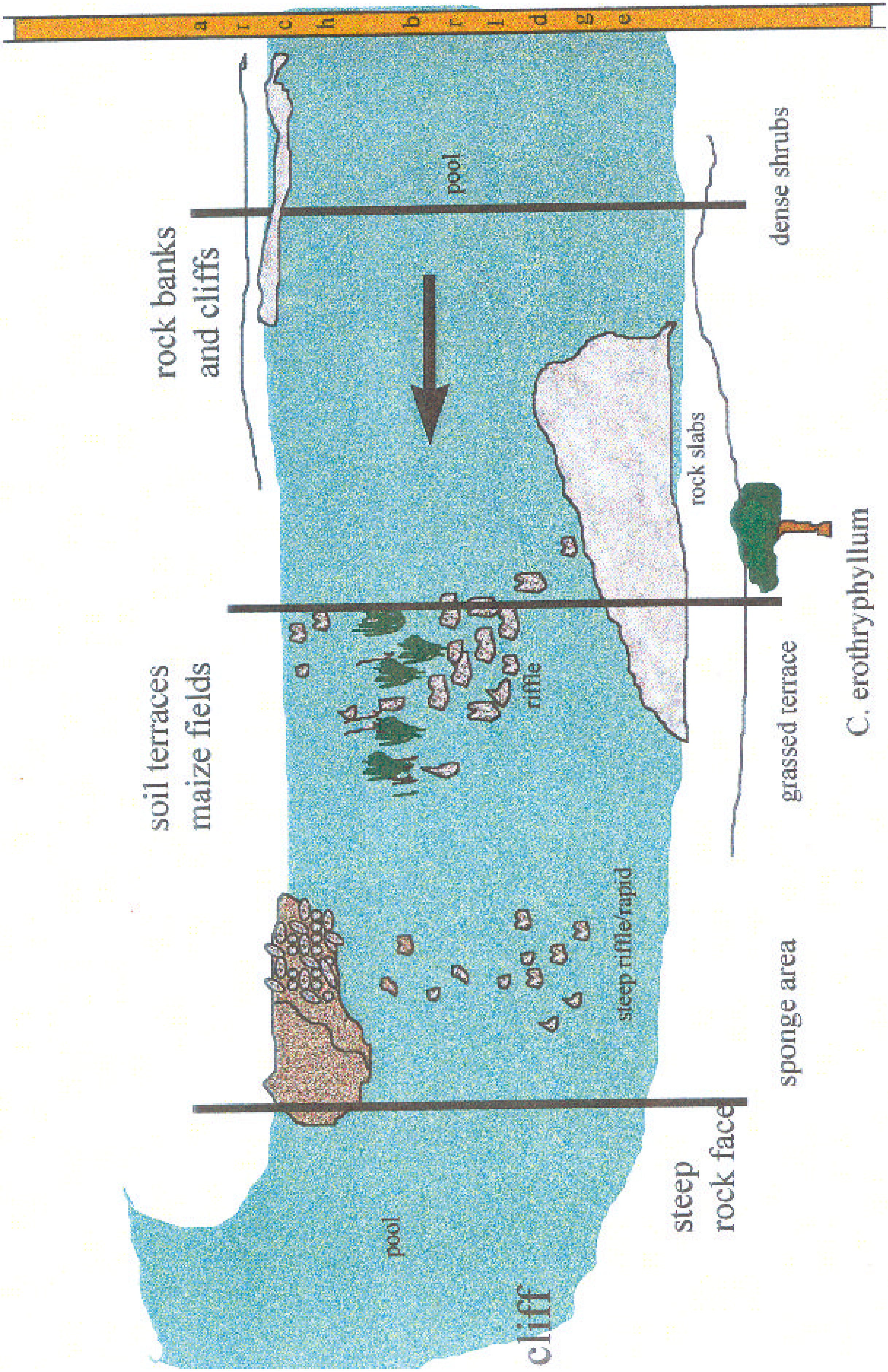
Mkomazi IFR: Social Aspects (Map 2)

IFR SITES

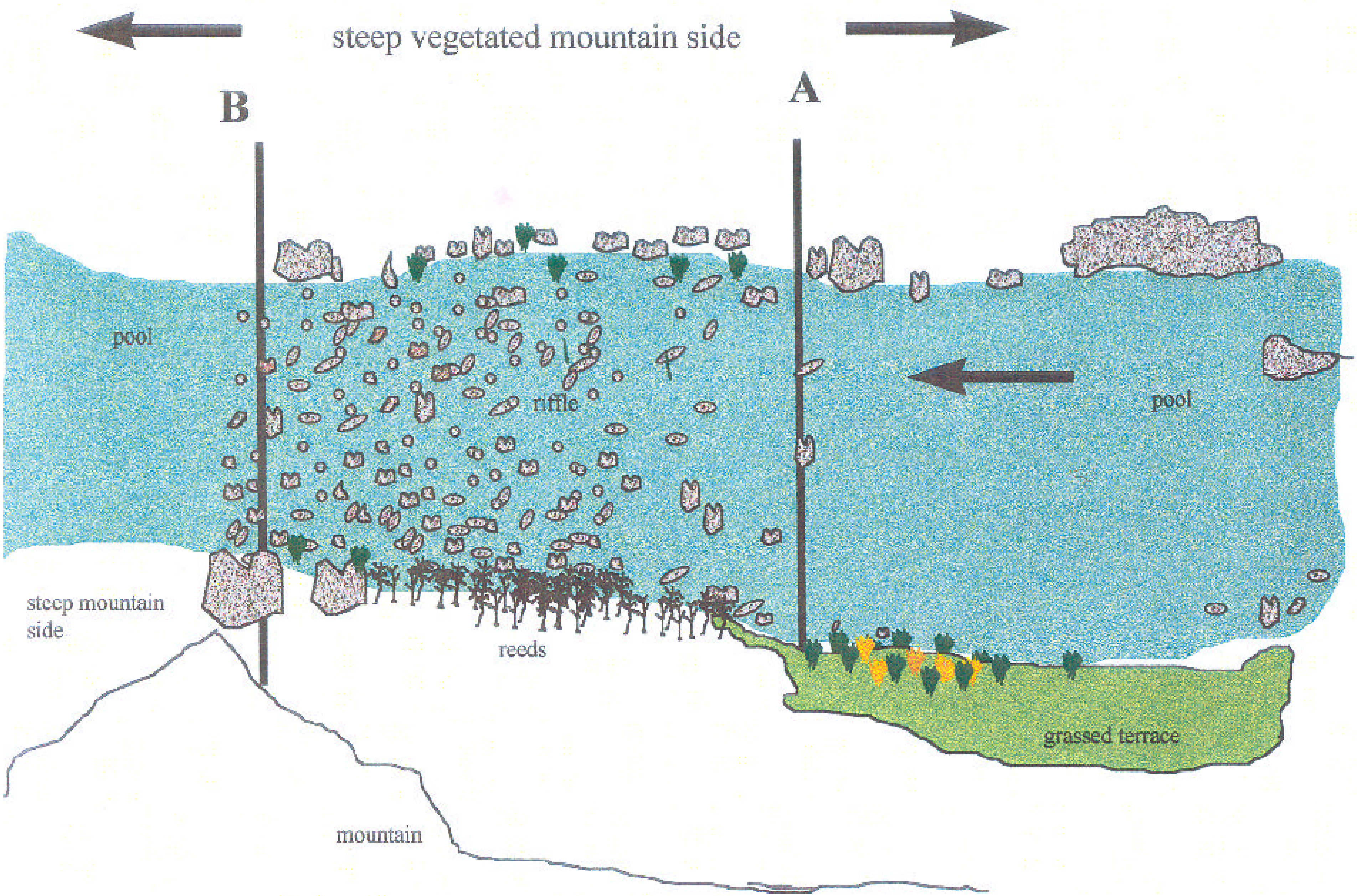


APPENDIX P : PLAN VIEWS

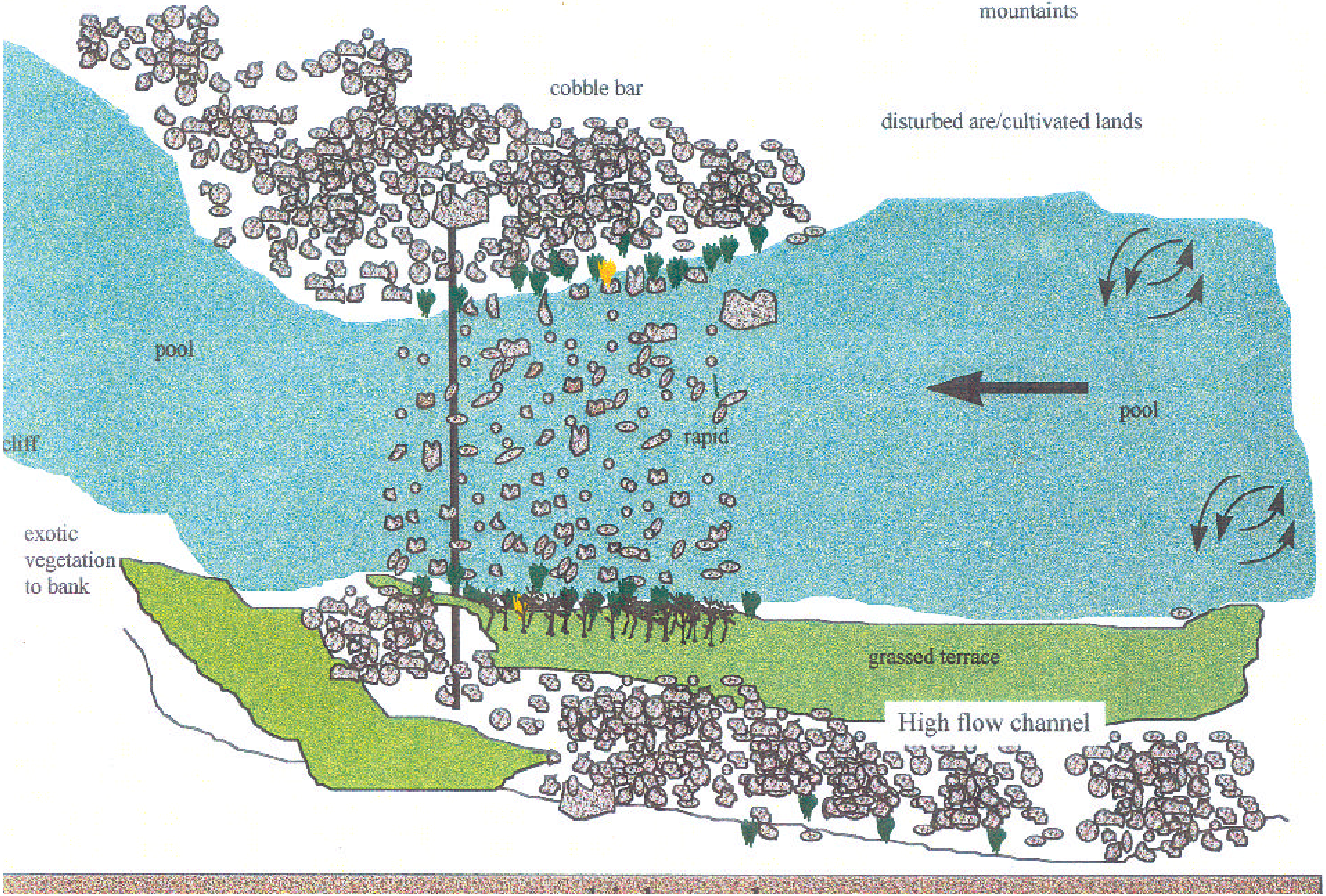
MKOMAZI IFR 1 : LUNDY'S HILL



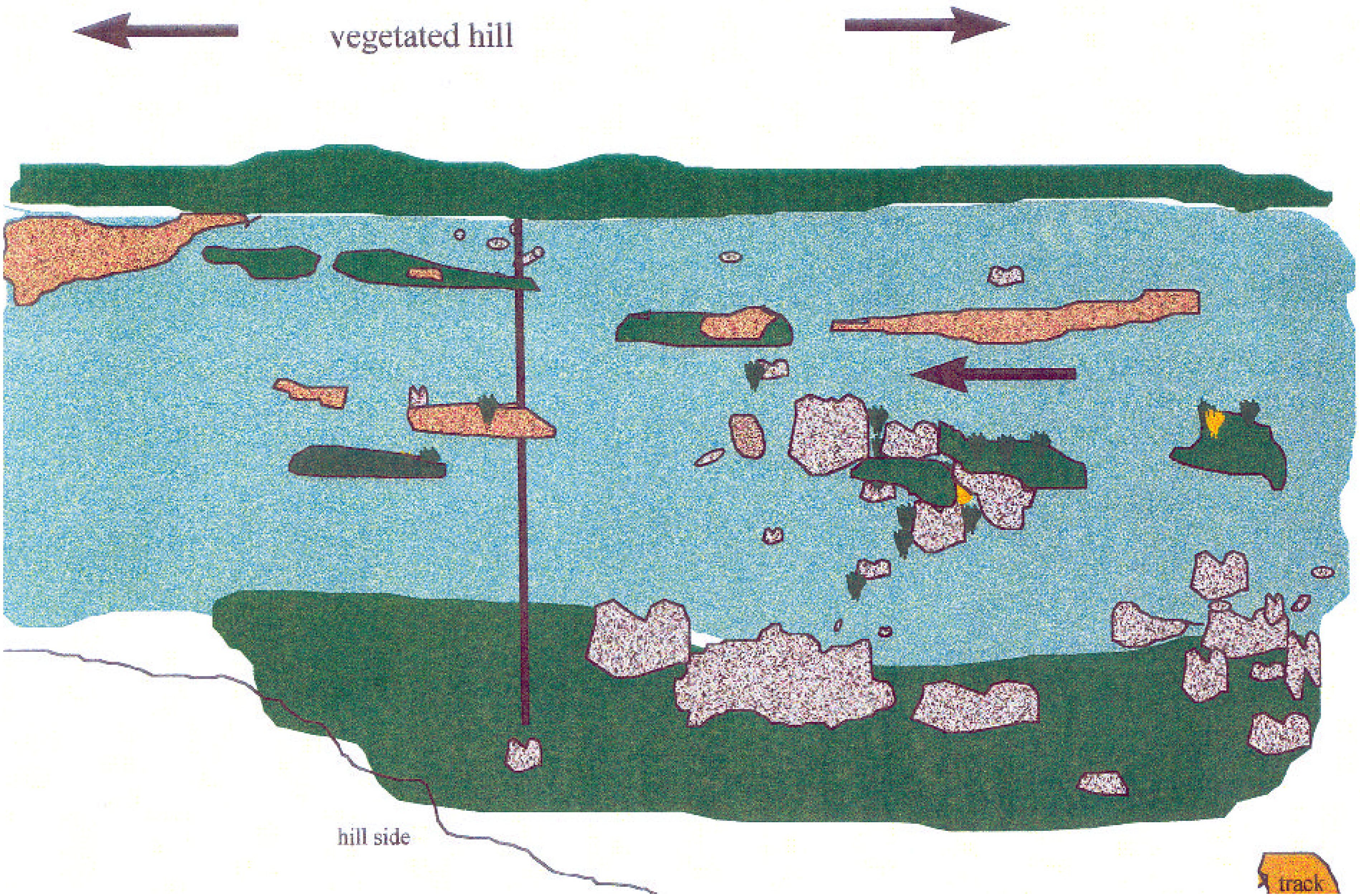
MKOMAZI IFR 2 : HELLA HELLA



MKOMAZI IFR 3 : SNT JOSEPHINE



MKOMAZI IFR 4 : MFUME



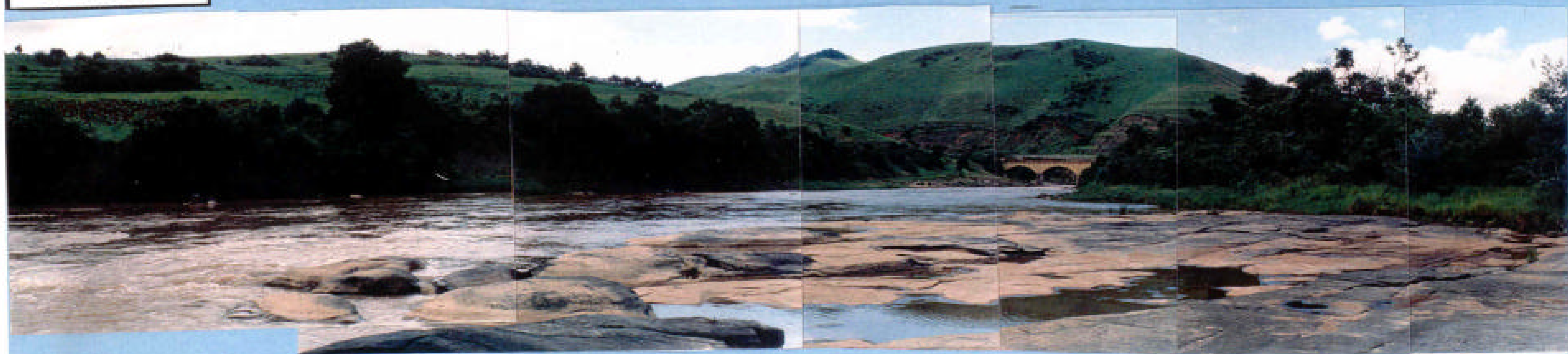
IFR 1 : LUNDY'S HILL

UPSTREAM TO A

5,8 m3/s
14 Oct 97

14 m3/s
12 Dec 97

18,7 m3/s
25 Jan 98



IFR 1 : LUNDY'S HILL

UPSTREAM TO B

5,8 m3/s 14 Oct 97

4,04 m3/s 12 Dec 97

9,6 m3/s 18 Oct 97

19,6 m3/s
18 Oct 97

27,4 m3/s
17 Oct 97

69,7 m3/s
27 Feb 98

27,4 m3/s
17 Oct 97

69,7 m3/s
27 Feb 98

IFR 1 : LUNDY'S HILL

DOWNSTREAM

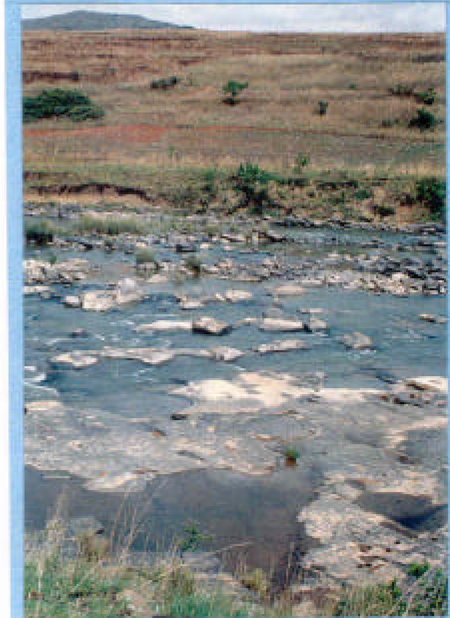
5,8 m3/s
14 Oct 97

5,8 m3/s 14 Oct 97

18,7 m3/s 25 Jan 98

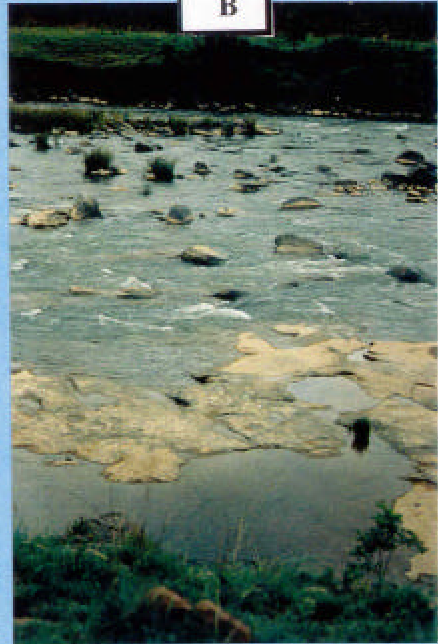
IFR 1 : LUNDY'S HILL

ACROSS



A

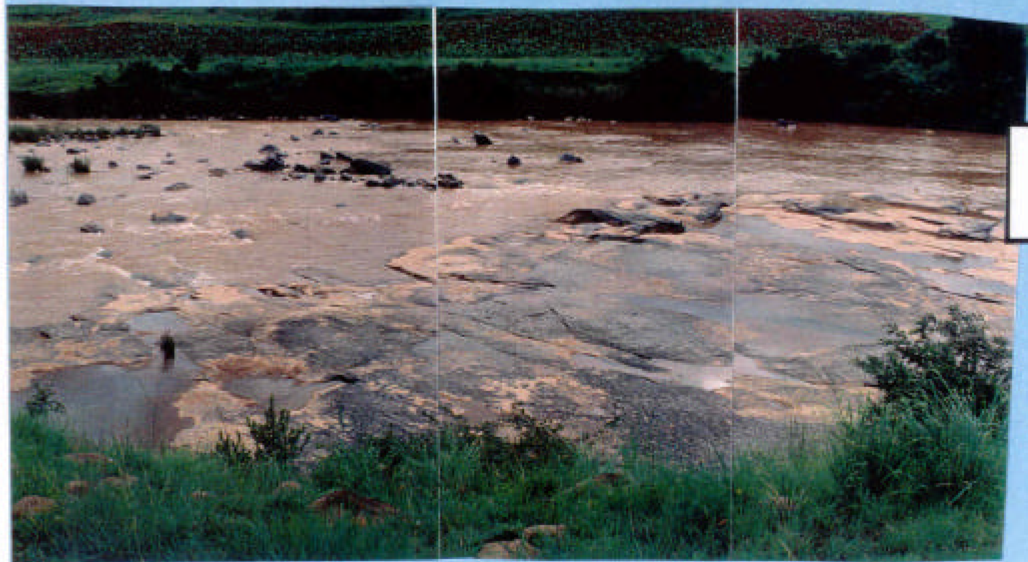
B



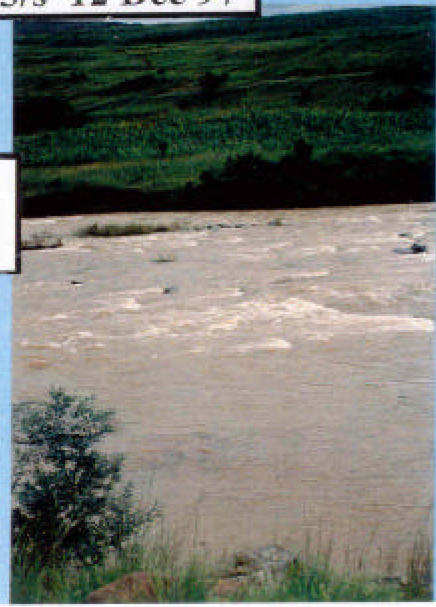
C

5,8 m3/s 14 Oct 97

14,04 m3/s 12 Dec 97



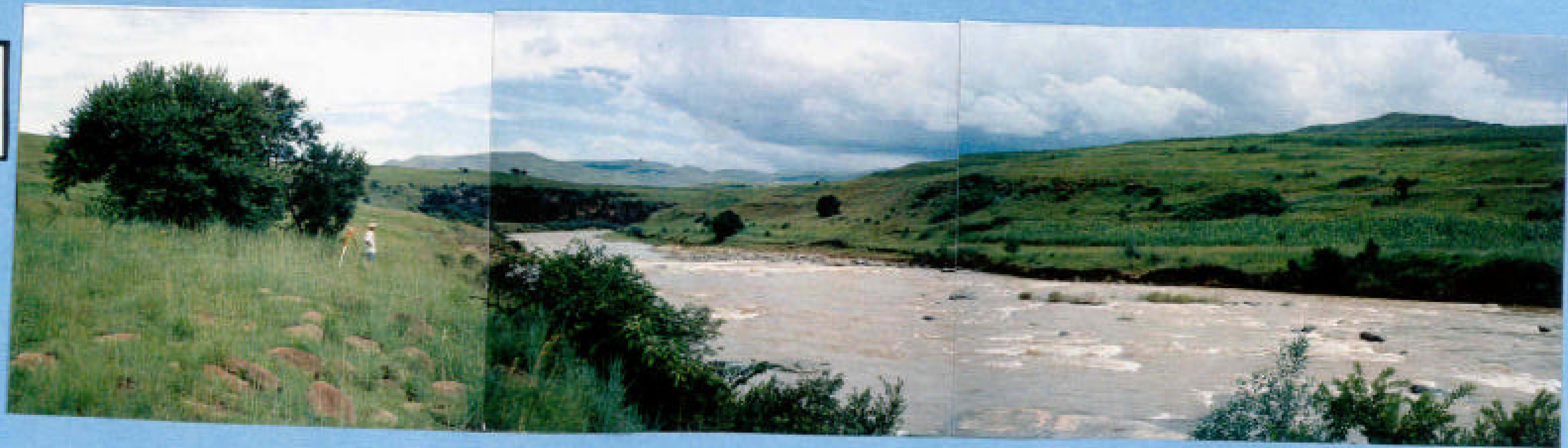
18,7 m3/s
25 Jan 98



69,7 m3/s
27 Feb 98

19,6 m3/s
18 Oct 97

19,6 m3/s
18 Oct 97



C

69,7 m3/s
27 Feb 98

C
18/10/97
19,6 m³/s

LB-MARG VEG

14,04 m3/s 12 Dec 97

A: CROSS-SECTION

LEFT BANK

18,7 m3/s
25 Jan 98

B: CROSS-SECTION

LEFT BANK

IFR 2 : HELLA HELLA

DOWNSTREAM

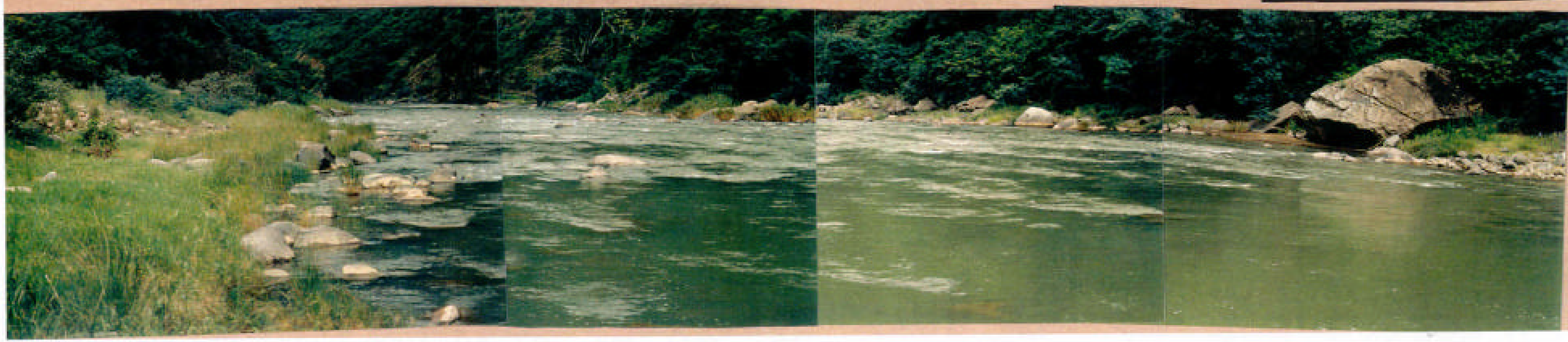
9,6 m3/s
15 Oct 97

18.8 m3/s 19 Oct 97

B

A

19,6 m3/s 12 Dec 97

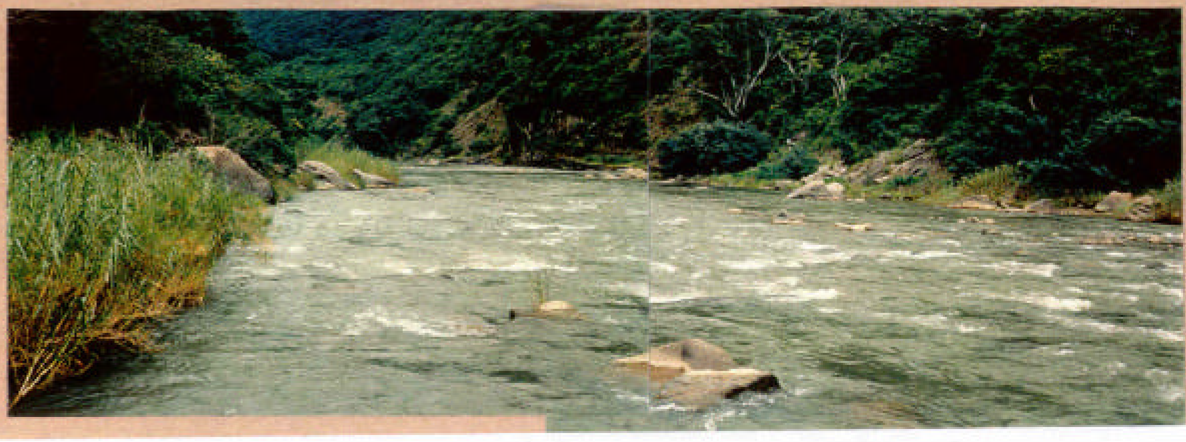


IFR 2 : HELLA HELLA

DOWNSTREAM to B

9,6 m3/s
15 Oct 97

18,8 m3/s
19 Oct 97



19,6 m3/s
12 Dec 97

33,2 m3/s
24 Jan 98

103 m3/s
28 Feb 98

103 m3/s
28 Feb 98

IFR 2 : HELLA HELLA

UPSTREAM to B

18,8 m3/s
19 Oct 97

33,2 m3/s
24 Jan 98

103 m3/s
28 Feb 98

IFR 2 : HELLA HELLA

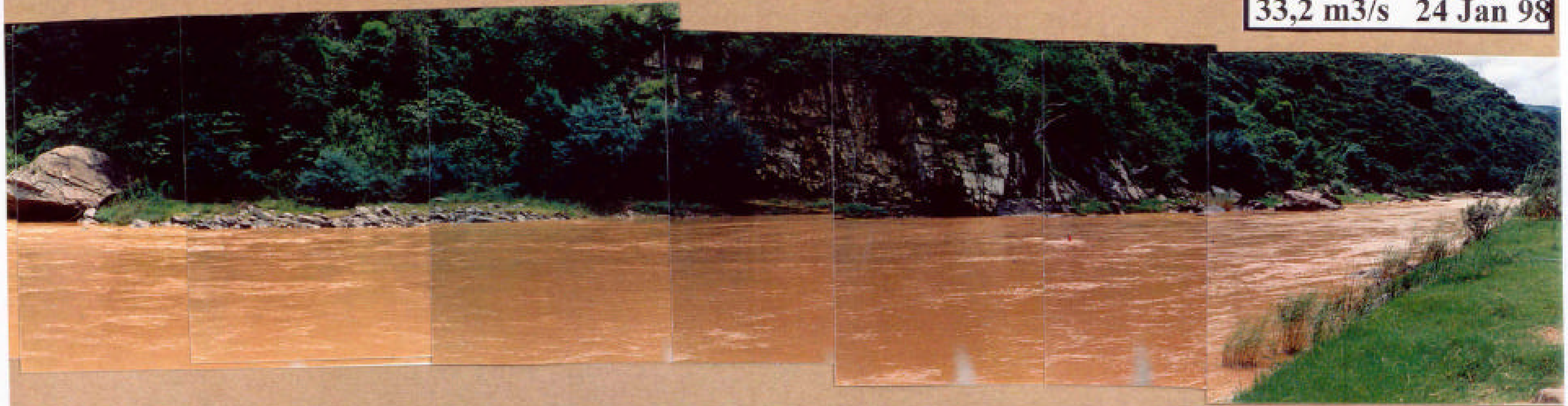
UPSTREAM to B

9,6 m3/s
15 Oct 97

18,8 m3/s
19 Oct 97

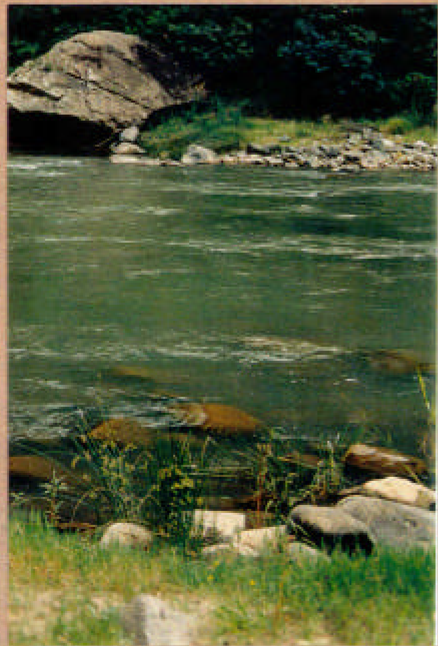
19,6 m3/s
12 Dec 97

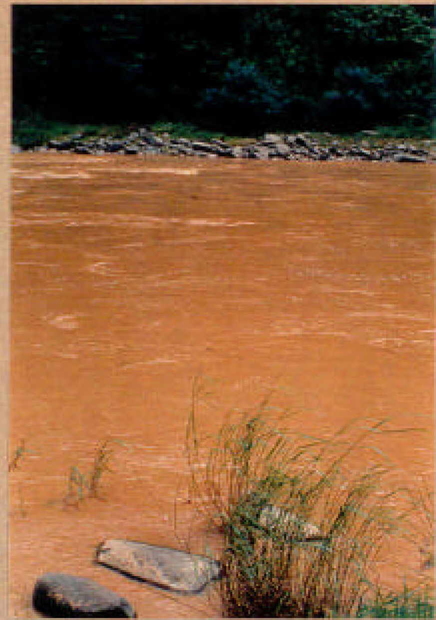
33,2 m3/s   24 Jan 98



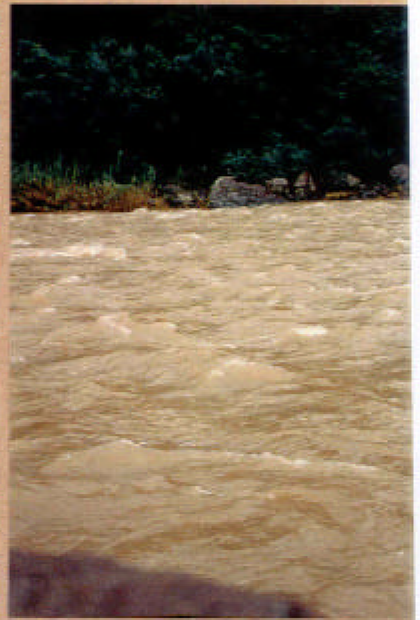
103 m3/s
28 Feb 98

19,6 m3/s 12 Dec 97





33,2 m3/s 24 Jan 98



103 m3/s 28 Feb 98

18,8 m3/s 19 Oct 97

19,6 m3/s 12 Dec 97

33,2 m3/s 24 Jan 98

IFR 3 : SNT JOSEPHINE

UPSTREAM

18 m3/s
20 Oct 97

18,6 m3/s
13 Dec 97

32 m3/s 16 Oct 97

IFR 3 : SNT JOSEPHINE

DOWNSTREAM

18 m3/s
20 Oct 97

18,7 m3/s
13 Dec 97

32 m3/s
16 Oct 97

35 m3/s
24 Jan 98

103 m3/s
28 Feb 98

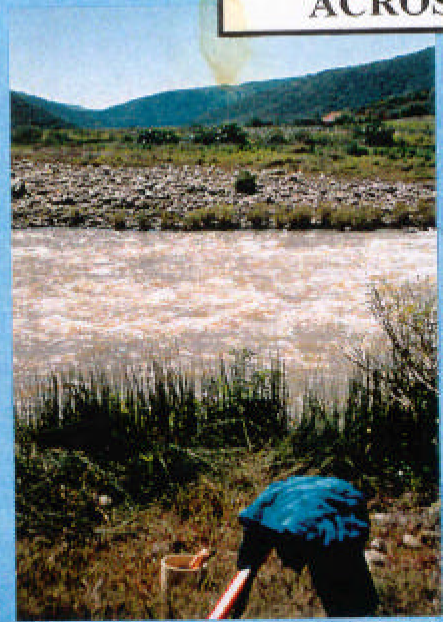
32 m3/s
16 Oct 97

ACROSS

35 m3/s 24 Jan 98

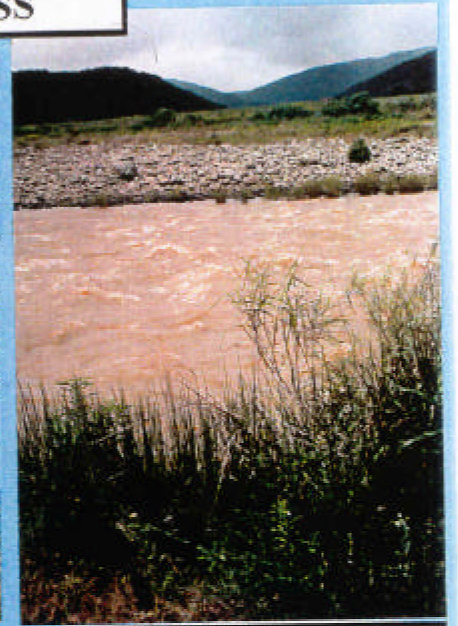
103 m3/s 28 Feb 98

18,7 m3/s
13 Dec 97



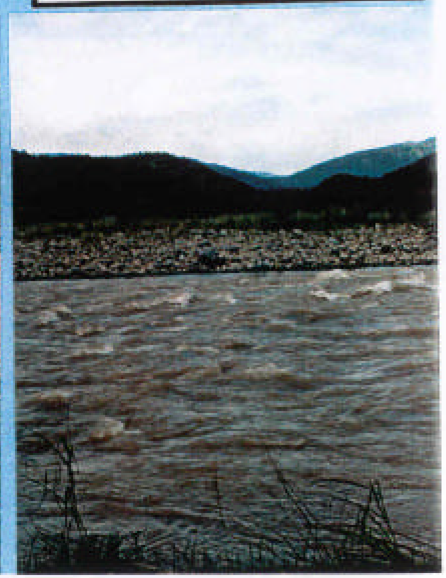
18 m3/s 20 Oct 97

18,6 m3/s 13 Dec 97



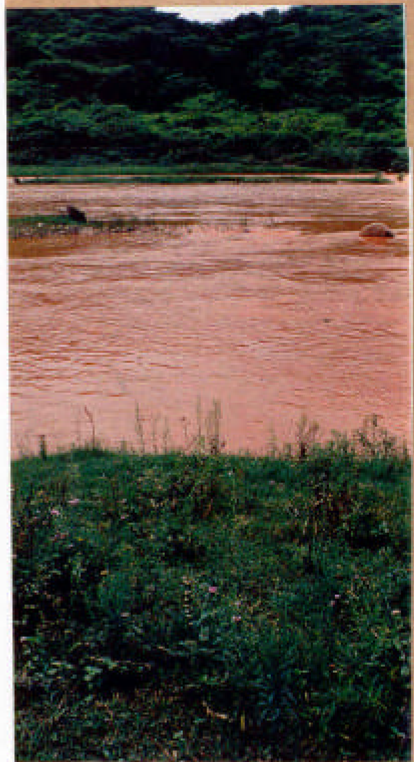
32,1 m3/s 16 Oct 97

103 m3/s 28 Feb 98

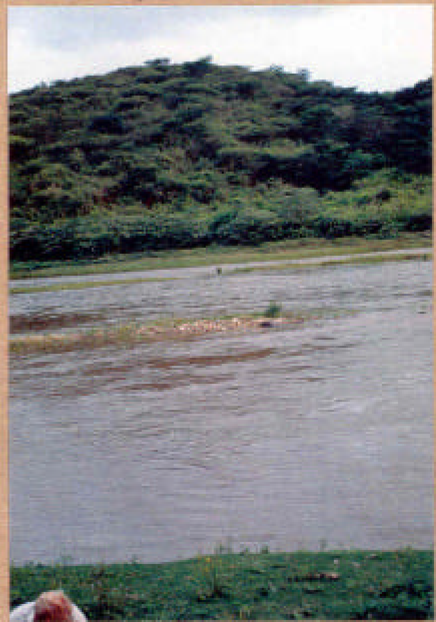


IFR 4 : MFUME

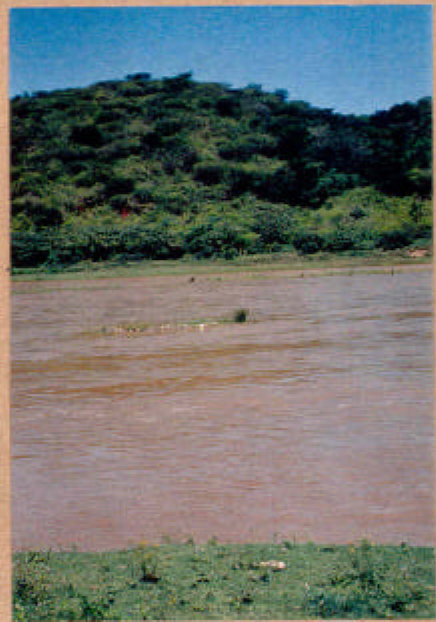
ACROSS



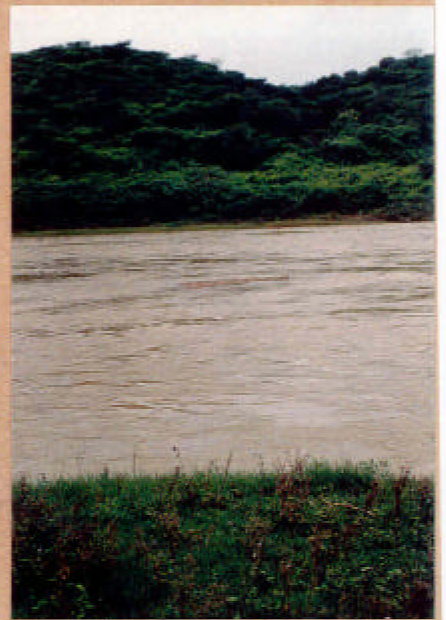
45,1 m3/s
25 Jan 98



55,5 m3/s
17 Oct 97



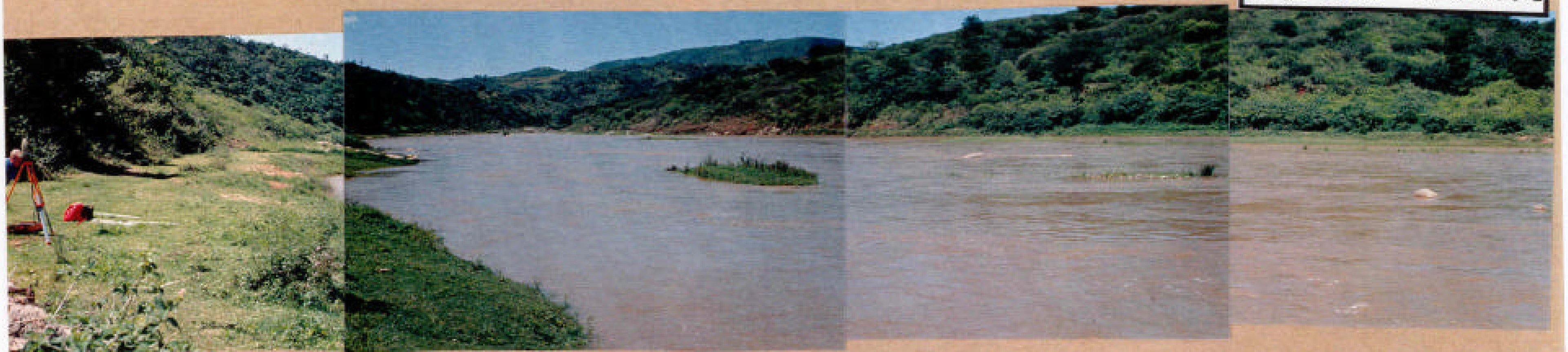
62,5 m3/s
17 Oct 97



117 m3/s
1 Mar 98

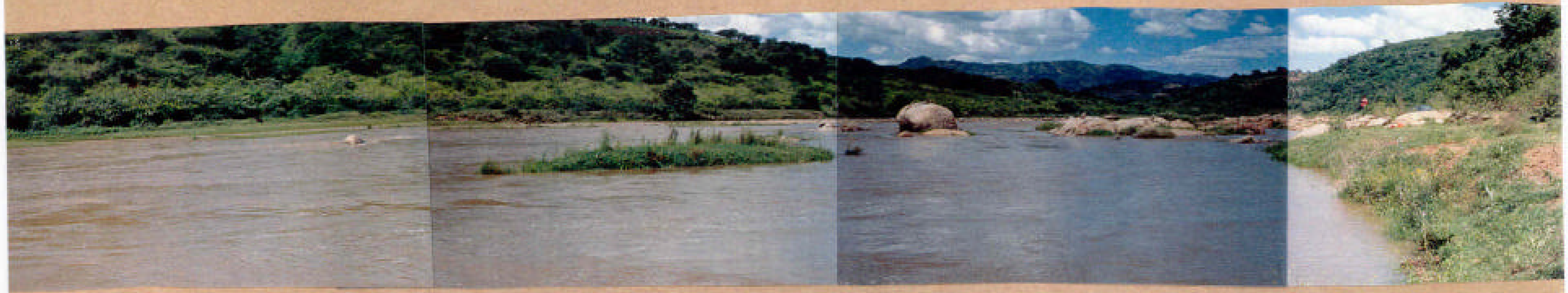
55,5 m3/s 17 Oct 97

62,5 m3/s 17 Oct 98

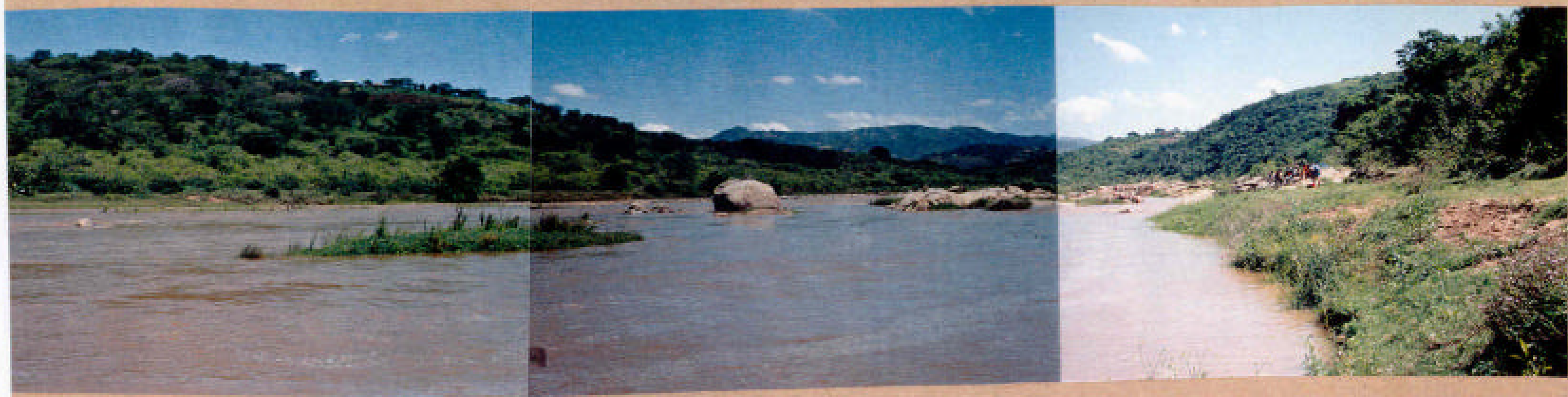


117 m3/s 1 Mar 98

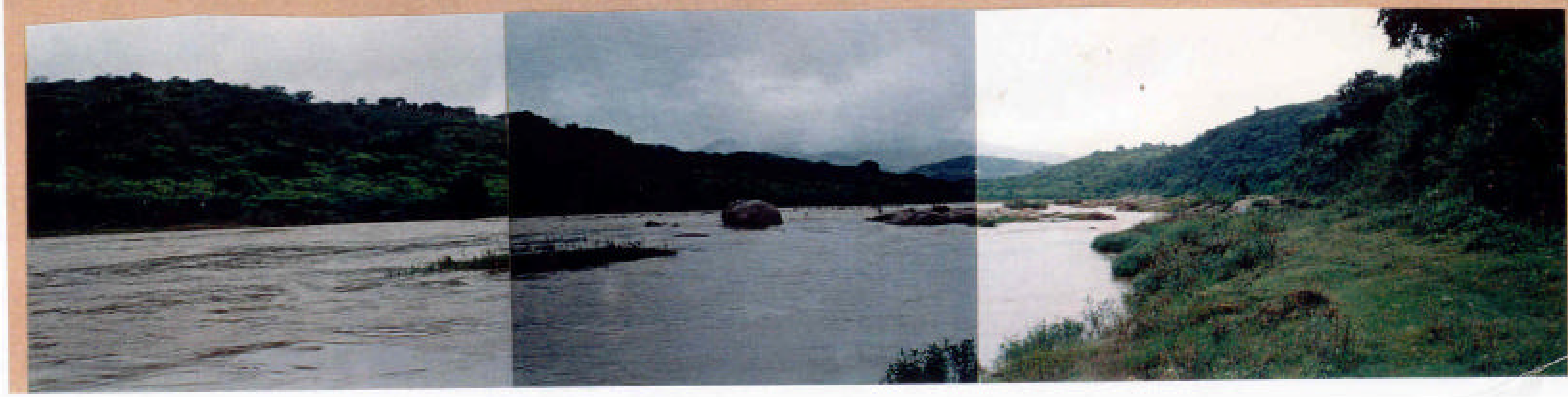
55,5 m3/s 17 Oct 97



62,5 m3/s
17 Oct 97



117 m3/s
1 Mar 98



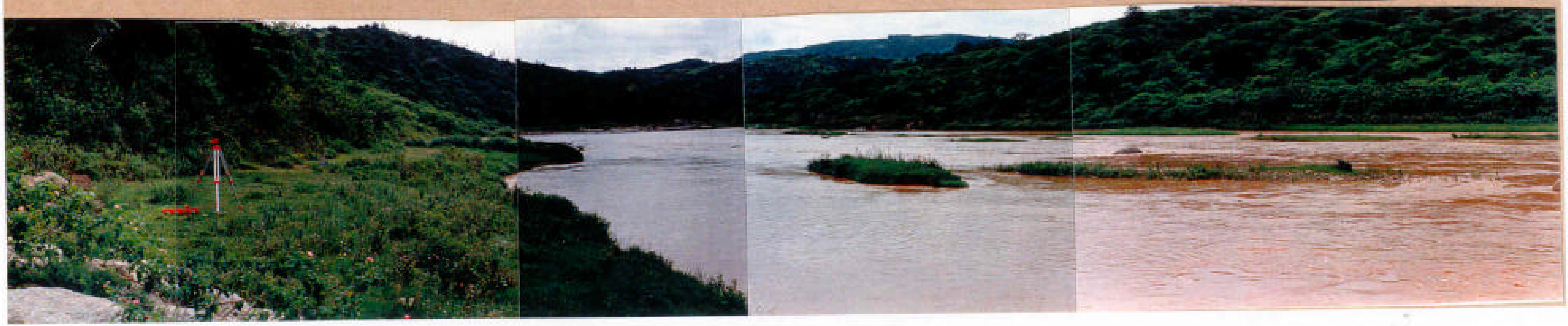
IFR 4 : MFUME

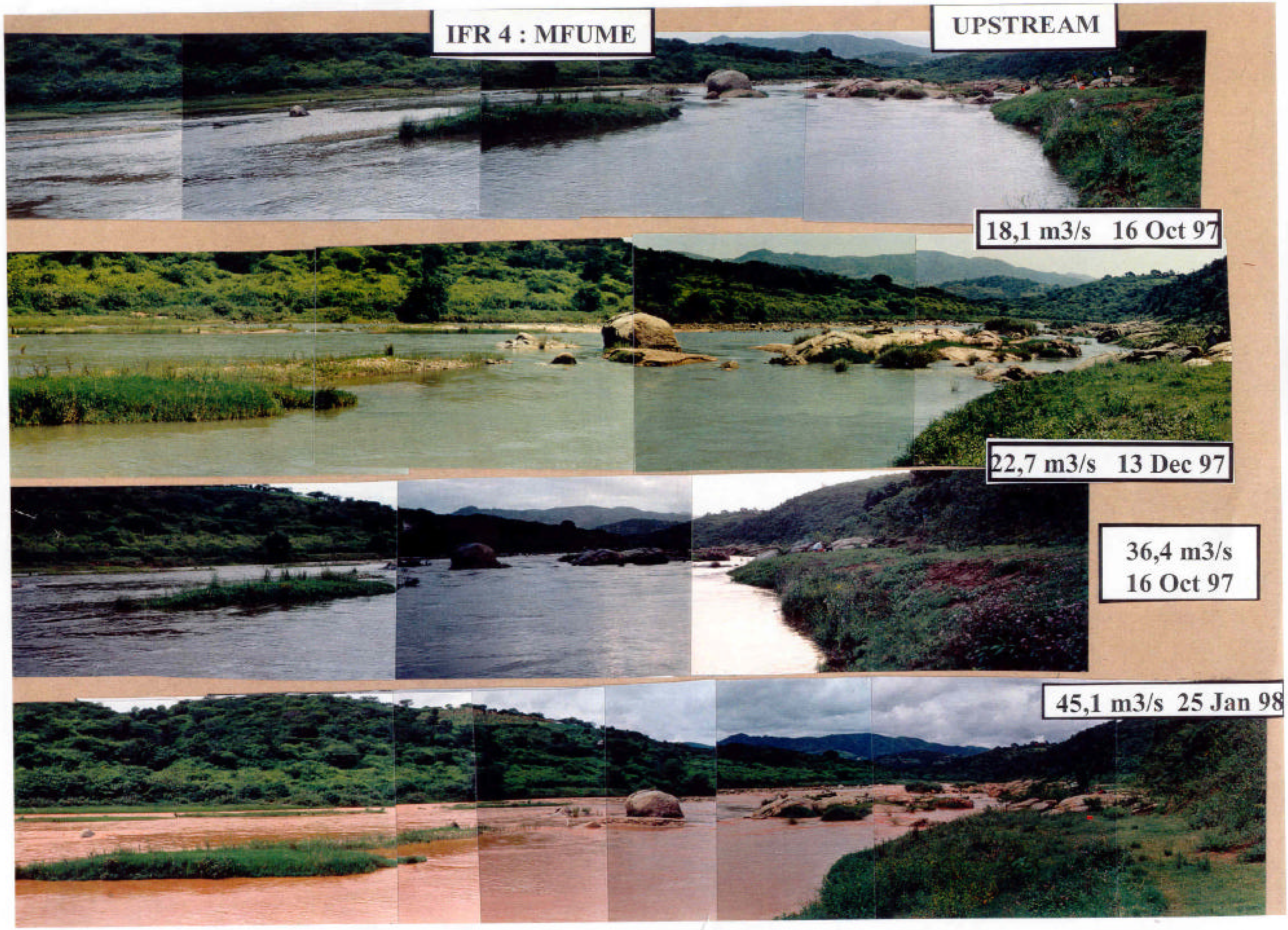
DOWNSTREAM

18,1 m3/s
16 Oct 97

22,7 m3/s
13 Dec 97

45,1 m3/s 25 Jan 98




IFR 4 : MFUME
UPSTREAM
18,1 m3/s 16 Oct 97
22,7 m3/s 13 Dec 97
36,4 m3/s
16 Oct 97
45,1 m3/s 25 Jan 98