National Aquatic Ecosystem
Biomonitoring Programme

National Implementation Assessment

NAEBP Report Series No 8

Published by the

Department of Water Affairs and Forestry

June 1999

All enquiries should be addressed to:

The Director: Institute for Water Quality Studies
Private Bag X313
PRETORIA 0001
Republic of South Africa

Tel: (012) 808-0374

This report should be cited as:

Murray, K.1999. National Aquatic Ecosystem Biomonitoring Programme: National Implementation Assessment. NAEBP Report Series No 8. Institute for Water Quality Studies, Department of Water Affairs and Forestry. Pretoria, South Africa.

Compiled by:

Kevin Murray
Insight Modelling Services CC
Pretoria
South Africa

EXECUTIVE SUMMARY

The progress of the River Health Programme (RHP) overall is generally regarded as having been a success story. However, implementation in some provinces still faces considerable challenges. Insight Modelling Services was approached by the National Coordinating Committee to produce a single concise document which Provincial Champions could use for basic guidance. The document should capture the essence of strategies that have proved successful in other provinces. Accordingly, this document summarises various aspects of the River Health Programme while referring the reader to specific individuals and publications for more details.

SECTION ONE: BACKGROUND

1995 - 1999

The design phase of the National Aquatic Ecosystem Biomonitoring Programme (NAEBP), later simplified to RHP, was commissioned by the Institute for Water Quality Studies (IWQS), DWAF in January 1995. In the following two years workshops and meetings were held resulting in a series of foundation reports. These included a design framework [Hohls, 1995], a classification of South Africa into bioregions [Brown *et al.*, 1996], a protocol for selecting reference and monitoring sites [Eekhout *et al.*, 1996]and a good review of ecological indicators [Uys *et al.*, 1996]. A consultation planning meeting was held in September 1996. Unanimous agreement was reached concerning the applicability and usefulness of the RHP [DWAF, 1996]. Implementation guidelines were also produced [Roux, 1997].

A document currently being prepared that examines the strategies adopted by the RHP over the years is strongly recommended [Roux, 1999]. It gives more detailed insights into the evolution of the RHP.

Of fundamental importance to biomonitoring (and the RHP in particular) is the concept of ecological integrity. All indices should be a measure of this ability of the ecosystem to function in a way comparable to its natural state (that is, without any anthropogenic impacts).

SECTION TWO: THE STATUS QUO

1999

The National Government through the Department of Environment Affairs and Tourism (DEAT) is the custodian of the nation's natural resources. The Department of Water Affairs and Forestry (DWAF) is the public trustee of South Africa's water resources. The National Water Act (No. 36 of 1998) is a radical departure from the previous act. It is now soundly based on good ecological principles (like that of establishing a reserve) and explicitly requires monitoring. The RHP is particularly well suited to this Act and will inevitably play a significant role in its implementation.

Catchment Management Agencies (CMAs) and other water-related organisations (like water user associations and water boards) all have important roles to play in implementation of the RHP. CMAs in particular are currently being closely examined. Initiatives are in place that aim at creating local committees (under the Act) that will have sufficient status to play a significant role in local monitoring.

A number of indices exist in South African biomonitoring circles. Each reflects the ecological integrity (though to differing degrees) of different ecosystem components. The biological components are fish, invertebrates, riparian vegetation. Non-biological components include habitat, hydrology, water quality and geomorphology.

The indices are at greatly varying levels of development. The SASS4 index for invertebrates is by far the most advanced. This involves *in situ* observations of the presence of invertebrate taxa. With due consideration given to weighting their respective tolerances to polluted waters, this results in two indices, namely, SASS4 and ASPT (Average Score Per Taxon). The SASS4 score depends primarily on water quality and habitat availability. An Invertebrate habitat Assessment System (IHAS) is in the early stage of development and testing. It aims at adjusting the SASS4 score in such a way that it becomes independent of habitat availability.

A Fish Assemblage Integrity Index (FAII) is being developed and has been tested. An Index of Habitat Integrity (IHI), involving both instream and riparian habitats, is also available. A Geomorphological Index (GI) has recently been published. However, this requires further testing.

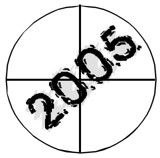
Site selection is an issue of fundamental importance to any monitoring programme. Work is underway to characterise all rivers in a way that takes account of natural variations in climate, geology, geomorphology and so on. Reference conditions for a river type will be defined as those typical of the least impacted sites where that type occurs. Although many indices have built-in reference states, this work will help establish these reference states more objectively. Monitoring sites (as opposed to references sites) should primarily be chosen to satisfy the national objective of State of Environment (SoE) reporting. That is, they should be randomly selected and should represent all river types. However, local objectives, such as assessment of impacts, require that the changes due to the impacts be adequately reflected at the site.

Sampling frequency is typically much less than, for example, chemical monitoring. Frequency needs to be of the order of the life-span of the organisms being measured or that of the natural or anthropogenic changes occurring in the system. Frequencies can therefore vary from 2-3 times per year for invertebrates (SASS4) to every 3-5 years for fish (FAII) and habitat (IHI) indices.

Database management is not at all standardised at present. A “Rivers Database” is being developed which should contribute considerably to this pressing problem.

Training capabilities are widespread throughout South Africa at many institutions. However, it remains somewhat uncoordinated though work is underway to address this.

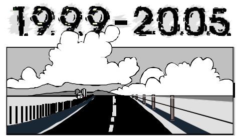
SECTION THREE: VISION 2005



The RHP is primarily a national monitoring initiative. That is, monitoring for State of Environment reporting is the typical level required. However, some indices are suited to local use. A conflict between local, regional and national objectives will necessarily lead to difference in implementation of biomonitoring. (For example, site selection and sampling frequency will be different.) Given limited national funding, local and regional involvement is essential for attainment of national objectives. Accordingly, a model is presented which acknowledges different objectives at national, regional and local levels. However, it stresses the need to find win-win situations in which national objectives are also addressed. For example, by judicious choice of sampling sites and frequency and transferring only selected data from local databases, national objectives could also be met simultaneously with local and regional. Nevertheless, this issue of simultaneously meeting national and local objectives remains ill-defined and should be examined in more detail.

The year 2005 should see biomonitoring in South Africa as a commodity market. There should be suppliers of biomonitoring expertise that can sell their wares anywhere in South Africa. Methods should also be highly standardised. Ultimate users of the information should regard it being a competitive necessity (not a competitive advantage).

SECTION FOUR: THE ROAD AHEAD



A wide variety of problems exist in the various provinces that impede implementation of the RHP. These involve primarily a perceived lack of accountability, resource constraints and a lack of concerned parties perceiving a real need for the RHP. However, it should be emphatically stated that these problems are not pervasive. In a few provinces these problems occur to a much lesser extent that others.

The objectives of the River Health Programme are typically stated as follows [Roux, 1997]:

1. **To measure, assess and report on the ecological state of aquatic ecosystems;**
2. **To detect and report on spatial and temporal trends in the ecological state of aquatic ecosystems; and**
3. **To identify and report on emerging problems regarding the ecological state of aquatic ecosystems in South Africa.**

The implication of these objectives is that the RHP objectives are attained once reports have been produced. However, monitoring programmes should be characterised by producing good information. That is, it must be accurate, complete, economical, reliable, relevant, simple, timely and verifiable [Stair, 1992]. Accordingly, it is proposed that the following fourth objective be included henceforth when stating the objectives of the RHP:

4. **To ensure that all reports provide scientifically and managerially relevant information for national aquatic ecosystem management.**

By “scientifically relevant” is meant that the scientists are confident that the right things have been measured in the right way. By “managerially relevant” is meant that the information provided by the scientists is used in a meaningful and rational way for management of riverine ecosystems.

This new objective now rationalises the existing initiatives to (1) produce ecosystem management models for optimal use of RHP reports and (2) development of grassroots awareness and education in respect of aquatic ecosystems. Both of these provide essential tools for those managers ultimately having to act upon information provided by the RHP.

The way forward will require a compatible combination of both a top-down and a bottom-up strategy. The top-down approach can be enhanced by creating greater statutory legitimacy for the RHP. The bottom-up approach (for which greater emphasis should be given) will involve developing optimum ways of communicating the advantages of the RHP to local and regional players so that their buy-in is created and sustained. Data transfer protocols that ensure a win-win situation for local, regional and national players need to be developed. This aspect will be critical to the ultimate success of the programme.

The national issues facing the National Coordinating Committee (NCC) have been examined briefly and presented in a simplified systems model diagram. It is evident from this that variability is a fundamental issue that drives many of the NCC’s activities. This variability occurs in the ecosystems being monitored, the methods being applied, the people who apply them and in the ultimate user requirements. All vary both spatially and temporally throughout South Africa. (The complexity of this situation is evident when one compares this to the monitoring of a simple chemical variable, say pH, in surface waters which uses a tried and tested standard method.) This variability drives a need for standardisation (and hence quality control) and focussed R&D (and hence huge resource demands). Good communication is a crosscutting issue which remains essential in many contexts.

Although the NCC seems to analyse problems and plan solutions extremely well, a flaw is that the solutions are often not implemented. This is likely to be because the members of the NCC are already significantly overworked and any extra NCC-related workload is not easily accommodated. To address this the appointment of a national coordinator is proposed. This person should be funded for at least six months per annum. The person should be an aquatic ecologist with management experience and good people and communication skills. The primary responsibility will be to execute the tasks identified by the NCC as important. That is, this person is not a delegator. In this way, the national coordinator can reduce the extra load on NCC members to that required to access an individual’s expertise as required for the specific task at hand.

The national coordinator should also chair the NCC and ExCo meetings. The NCC should consist of the following executive portfolios: national coordinator, secretariate, three custodians, provincial champions and R&D officer. *Ad hoc* scientific specialists and special members (for example of other national programmes) can be included in advisory capacities as and when specific needs arise.

ACKNOWLEDGEMENTS

The author wishes to thank the following people
very sincerely for their availability for discussion,
comments on the report and general help in providing information.

Mr Mick Angliss (Dept. of Agriculture, N. Prov.)
Dr Mark Chutter (Afridev Consultants)
Mr Geoff Cowan (DEAT)
Ms Hellen Dallas (Southern Waters)
Mr Pierre de Villiers (DEAT, Free State)
Dr Chris Dickens (Umgeni Water)
Ms Tisha Greyling (Manyaka Greyling Meiring)
Ms Liesl Hill (IQWS, DWAF)
Mr Nigel Kemper (IWR Consultants)
Mr Haroon Karodia (DWAF)
Dr Neels Kleynhans (IWQS, DWAF)
Ms Delana Louw (IWR Consultants)
Mr Solly Manyaka (Manyaka Greyling Meiring)
Mr Peter McMillan (Environmentek, CSIR)
Dr Steve Mitchell (WRC)
Mr Mukhetho Neluvhalani (Dept. Agric., Cons. & Env., Gauteng)
Dr Rob Palmer (Afridev Consultants)
Mr Dirk Roux (Environmentek, CSIR)
Prof Kate Rowntree (Rhodes University)
Mr Bill Rowlston (DWAF)
Mr Nicholas Scarr (Dept. Econ. Affairs, Env. & Tourism, E.Cape)
Dr Patsy Scherman (IWR, Rhodes University)
Mr Maitland Seaman (OFS University)
Mr Huub Schrijver (The Netherlands)
Dr Maritza Uys (Maritza Uys Resources Law Advisor)
Mr Jannie van Staden (DWAF, W. Cape)
Dr Henk van Vliet (DWAF)
Mr Fred van Zyl (DWAF)

CONTENTS

EXECUTIVE SUMMARY i

ACKNOWLEDGEMENTS v

CONTENTS vii

LIST OF ABBREVIATIONS ix

GLOSSARY xi

1. BACKGROUND 1-1
1.1 THE EVOLUTION OF RIVER HEALTH PROGRAMME 1-1
1.2 BIOMONITORING 1-2
1.2.1 Biomonitoring is Response Monitoring 1-2
1.2.2 Meeting Statutory Requirements 1-2
1.2.3 Advantages of Biomonitoring 1-3
1.3 THE STRUCTURE OF THIS DOCUMENT 1-4

2. THE STATUS QUO 2-1
2.1 INTRODUCTION 2-1
2.2 THE RHP AND THE LAW 2-1
2.2.1 Current National Legislation 2-1
2.2.2 The RHP and Provincial Legislation 2-2
2.2.3 Water Management Institutions 2-3
2.2.3.1 Catchment Management Agencies 2-3
2.2.3.2 Water User Associations 2-4
2.2.3.3 Water Boards 2-5
2.3 INDICES FOR BIOMONITORING 2-6
2.3.1 Indicators and Indices 2-6
2.3.1 South African Scoring System Index (SASS) 2-9
2.3.1 Invertebrate Habitat Assessment System (IHAS) 2-12
2.3.1 Fish Assemblage Integrity Index (FAII) 2-13
2.3.1 Index of Habitat Integrity (IHI) 2-15
2.3.1 Geomorphology Index (GI) 2-17
2.4 SITE SELECTION 2-19
2.4.1 Reference Conditions 2-20
2.4.2 Monitoring Sites 2-21
2.5 SAMPLING FREQUENCY 2-21
2.6 DATABASE MANAGEMENT 2-23
2.6.1 Current Mechanisms 2-23
2.6.2 The Proposed “Rivers Database” 2-23
2.7 TRAINING CAPABILITIES 2-24

3. VISION 2005 3-1
3.1 INTRODUCTION 3-1
3.2 AN INFORMATION FLOW MODEL 3-1
3.3 BIOMONITORING: A COMMODITY MARKET 3-5

4. THE ROAD AHEAD 4-1
4.1 THE PROBLEMS 4-1
4.2 RHP OBJECTIVES 4-3
4.3 TOP-DOWN AND BOTTOM-UP 4-4
4.4 STATUTORY LEGITIMACY 4-4
4.4 INCREASING THE RELEVANCE OF RHP INFORMATION 4-5
4.5 DEMONSTRATING SUCCESS 4-6
4.6 GENERAL COMMUNICATION 4-6
4.7 DATABASE MANAGEMENT 4-7
4.8 CREATING SUSTAINABLE REGIONAL CAPACITY 4-8
4.8.1 Committed Provincial Champions 4-8
4.8.2 Demonstrating to Regional Concerned Parties 4-8
4.8.3 Training 4-9
4.8.4 Selecting Indices 4-9
4.9 FINANCIAL CONSIDERATIONS 4-10
4.9.1 Overall Provincial Budgets 4-10
4.9.2 Draft Business Plan 4-11
4.9.3 Potential Donors 4-12
4.10 NATIONAL COORDINATION 4-12
4.10.1 Issues facing the National Coordination Committee 4-12
4.10.2 Roles of National Coordination Committee 4-14
4.10.3 A National Coordinator 4-15
4.10.4 NCC Composition 4-16

5. CONTACT PERSONS 5-1

6. REFERENCES 6-1

LIST OF ABBREVIATIONS

River Health Programme

ASPT	Average Score Per Taxon (Invertebrates)
BP1-5	Biomonitoring Protocol 1 to 5
CCI	Channel Classification Index
DEAT	Department of Environmental Affairs and Tourism
DWAF	Department of Water Affairs and Forestry
EMAP	Environmental Monitoring and Assessment Programme (USA)
EXCO	Executive Committee
FAII	Fish Assemblage Integrity Index
FHAI	Fish Health Assessment Index
FCI	Fish Community Index
GI	Geomorphological Index
HAM	Habitat Assessment Matrix
HBDI	Hydraulic Biotope Diversity Index
HQI	Habitat Quality Index
HI	Hydrological Index
I&AP	Interested and Affected Party
IBI	Index of Biotic Integrity (USA)
IHAS	Invertebrate Habitat Assessment System
IHI	Index of Habitat Integrity
IWQS	Institute for Water Quality Studies
IWR	Institute for Water Research (Rhodes University)
KNPRRP	Kruger National Park Rivers Research Programme
MEC	Member of the Executive Committee
NCC	National Coordinating Committee
NAEBP	National Aquatic Ecosystem Biomonitoring Programme
PIT	Provincial Implementation Team
R&D	Research and Development
RBA	Rapid Biological Assessment
RVI	Riparian Vegetation Index
SASS4	South African Scoring System version 4
SoE	State of the Environment
RIVPACS	River Invertebrate Prediction and Classification System (British biomonitoring procedure)
WQI	Water Quality Index
WRC	Water Research Commission

GLOSSARY

Aquaculture. The production of protein for human consumption in an aquatic environment under controlled or semi-controlled conditions. It includes the production of fish, shell-fish, crustaceans and plants.

Aquatic ecosystems. Ecosystems which provide a medium for habitation by aquatic organisms and sustain aquatic ecological processes.

Anthropogenic. Resulting from the presence or activities of humans.

Assessment Endpoint. An explicit expression of the environmental value that bears directly on the management of ecological resources. An assessment endpoint includes both an ecological component and specific attributes of that entity. For example, fish are a valued ecological component; reproduction and population maintenance of fish form an assessment endpoint.

Backwater. An hydraulically "detached" alcove, of variable depth, where there is no through-flow of water, and water tends to enter and leave using the same route. Velocity tends to be very low and often zero.

Benthic. Living on the bottom of a body substrata (sediments, debris, logs, cobbles, etc.) of aquatic biotopes.

Biological River Segment. A portion of a river in which the fish community remains generally homogenous due to the relatively uniform nature of the physical habitat.

Biomonitoring. The gathering of biological information in both the laboratory and the field for the purpose of making an assessment or decision or in determining whether quality objectives are being met.

Biodiversity. Biodiversity comprises composition, structure, and function. Composition is the identity and variety of elements in a collection, and includes species lists and measures of species diversity and genetic diversity. Structure is the physical organization or pattern of a system, from habitat complexity as measured within communities to the pattern of patches and other elements at a landscape scale. Function involves ecological and evolutionary processes, including gene flow, disturbances, and nutrient cycling.

Bioregions. Geographical regions delineated by South African river scientists as the first level of an hierarchical classification of the rivers of the country. The rivers within each bioregion were considered, on the basis of expert opinion, to be similar in terms of physical and biotic characteristics.

Biota. Animal and plant life characteristic of a given region.

Biotic Integrity. The ability to support and maintain a balanced, integrated, adaptive community of organisms having a full range of elements (genes, species and assemblages) and processes (mutation, demography, biotic interactions, nutrient and energy dynamics and metapopulation processes) expected in the natural habitat of the region.

Biotope. A homogeneous environment that satisfies the habitat requirements of a biotic community (e.g. riffle, pool or sandbank).

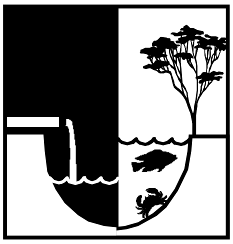
Catchment. The area from which any rainfall will drain into a watercourse through surface flow.

Catchment Management Agency. A statutory body established by the Minister of Water Affairs to delegate water resource management to a local level and to involve local communities. They may be established for specific geographical areas, after public consultation, on the initiative of the community and stakeholders concerned.

Diffuse-source Pollution. Pollution that comes from a wide area, such as fertilisers draining off farmlands or pollutants in the runoff from urban areas.

Ecological Indicator. Measurable attribute of a high-level ecosystem component (biological, chemical or physical). A high-level biological component would typically be either fish, invertebrates or riparian vegetation. (For example, one measurable attribute of fish is frequency of occurrence at a series of sites.) A high-level non-biological component might be either habitat, water quality or geomorphology. (One measurable attribute of geomorphology is bank stability.)

Ecological Index. A single quantitative value that incorporates the information contained in a number of related ecological indicators. It is based on field data that are simple to collect and it provides a meaningful and accurate representation of the river condition for a high-level ecosystem component. The purpose is to simplify the interpretation of the indicators and hence make them more understandable to non-specialists such as resource managers, conservationists and the general public.



Ecological Integrity. The ability of an ecosystem to support and maintain a balanced, integrated composition of physico-chemical habitat characteristics, as well as biotic components, on a temporal and spatial scale, that are comparable to the natural (*i.e.* unimpaired) characteristics of such an ecosystem. (High ecological integrity implies that the structure and functioning of an ecosystem are unimpaired by anthropogenic stresses.)

Ecoregions. Geographic regions grouped together on the basis of shared similar characteristics, such as geology, rainfall, vegetation and altitude.

Ecosystem. Any unit that includes all of the organisms (*i.e.* the community) in a given area interacting with the physical environment so that a flow of energy leads to clearly defined trophic structure, biodiversity and material cycles (*i.e.* exchange of material between living and non-living parts) within the system.

Ecosystem Health. A value judgement of the overall condition (*i.e.* health) of an ecosystem, based on the social well-being, economic development and ecological integrity within that system.

Geomorphology. The study of the origin of secondary topographic features which are carved by erosion in the primary elements and built up of the erosional debris.

Groundwater. Water found underground, typically supplying wells, boreholes, and springs.

Habitat Integrity. The maintenance of a balanced, integrated composition of physico-chemical and habitat characteristics on a temporal and spatial scale that are comparable to the characteristics of natural habitats of the region.

Hydraulics. The branch of science and technology concerned with the mechanics of fluids, especially liquids.

Hydrology. The science that treats the occurrence, circulation, distribution, and properties of the waters of the earth, and their reaction with the environment.

Infrastructure. The basic structure of an organisation, system, etc.

Integrated Environmental Management. A code of practice ensuring that environmental considerations are fully integrated into the management of all activities in order to achieve a desirable balance between conservation and development.

Invertebrate. An animal lacking a backbone and internal skeleton.

Macroinvertebrates. Invertebrates retained by mesh size ≥ 200 µm.

Measurement Endpoint. See ***Ecological Indicator***.

Monitoring Site. For problem-area monitoring, a monitoring site is one identified as important in assessing the condition (*i.e.* available habitat, water quality and biological parameters) of a river or reach, relative to a reference site. For State-of-Environment reporting, monitoring sites are randomly selected impacted or unimpacted sites that will reveal the range of conditions in rivers of a certain kind.

Morphology. The form and structure.

Multivariate Methods. Statistical methods characterised by the fact that they base their comparisons of two or more samples on the extent to which these samples share particular attributes. Either implicitly or explicitly, all multivariate techniques are founded on similarity coefficients calculated between every pair of samples being tested.

Point-source Pollution**.** Pollution that comes from a single source, such as a pipe.

Pool. A feature with slow through-flow of water (low or zero velocity), generally deep relative to river size.

Reference Condition. A benchmark of the best attainable ecological conditions for a specific type of river.

Reference Site. A site that has been exposed to relatively little or no anthropogenic impact that can be used to define the best physical habitat, water quality and biological parameters for a particular kind of river. These sites represent the best condition that can be achieved in a particular kind of river, against which the conditions found at the monitoring sites in the same kind of river can be assessed.

Riffle. A shallow, fast-flowing reach of a river with turbulent flow and broken water.

Riparian. Living or located on the banks of streams or rivers.

Run. An area of transition between a pool/rapid and riffle. Depth is variable and velocity is generally moderate.

Runoff**.** Water that does not filter into soil but flows over the surface and into natural surface waters.

Site-specific**.** Unique or specific to a certain locality.

Stressor. Any physical, chemical or biological entity or process that can induce adverse effects on individuals, populations, communities or ecosystems.

Surface Water**.** Water above the ground surface in lakes, dams, rivers and so on.

Suspended Solids**.** Inorganic or organic matter, such as clay, minerals, decay products and living organisms, that remains in suspension in water. In surface waters it is usually associated with erosion or runoff after rainfall events.

Sustainable Development. Development that meets the needs of the present without compromising the ability of future generations to meet their own needs.

Turbidity**.** A measure of the light-scattering ability of water. It indicates the concentration of suspended solids in the water.

Water Board. An organ of state established or regarded as having been established in terms of the Water Services Act (No 108 of 1997) to perform, as its primary activity, a public function. This includes a "water services provider" who provides water services to consumers or to another water services institution, but does not include a water services intermediary. The National Water Act (No 36 of 1998) provides for the restructuring of water boards as water user associations.

Watercourse**.** A river or spring; a natural channel in which water flows regularly or intermittently; a wetland, lake or dam into which, or from which, water flows.

Water Management Institution. A catchment management agency, a water user association, a body responsible for international water management or any person who fulfils the functions of a water management institution in terms of the National Water Act (No 36 of 1998).

Water Resource. An ecosystem which includes the physical or structural aquatic habitats (both instream and riparian), the water, the aquatic biota, and the physical, chemical and ecological processes which link habitats, water and biota.

Water User Association. Co-operative associations of individual water users who wish to undertake water-related activities for their mutual benefit. They operate at a restricted local level.

2. THE STATUS QUO

1999

2.1 INTRODUCTION

The purpose of this section is to summarise the current state of the River Health Programme. This includes the indices and ongoing related research, current training capabilities, site selection, sampling frequency and database management. It is not within the scope of this document to give details. For more information of the indices and other technical issues, the reader is referred to publications and specific individuals (see section five).

2.2 THE RHP AND THE LAW

2.2.1 Current National Legislation

It is important that the RHP be examined within the context of the law. This has been done in terms of the new National Water Act (No. 36 of 1998). The following includes a number of points made in a recent report.

For more details ...

Uys, 1998

The National Government (acting through the Minister) has the ultimate responsibility as custodian of the nation's water resources. The Minister may delegate some of his powers to government officials or water management institutions.

See National Water Act No 36 of 1998 Chapter 2.

A National Water Resource Strategy (NWRS) must be established by the Minister after public consultation. It is in accordance with this that all water resources will be protected, used, developed, managed, conserved and controlled. It will provide the framework within which water will be managed at regional or catchment level, in defined water management areas. This initiative is underway though is still in its early stages. It will rely on and synthesize inputs from many sources, including the RHP. It will adopt a consensus-seeking approach with the bulk of the strategy likely to become available for comment in September-October 2000 [Rowlston W, DWAF, personal communication]. Importantly, once in place and signed by the Minister, it will be binding on all authorities and institutions exercising powers or performing duties under the National Water Act. It is strongly recommended that the RHP ensures constant input to the NWRS.

A water resource classification system must also be prescribed by the Minister which may establish procedures to determine the Reserve.

The Reserve is defined as the quantity and quality of water required to satisfy basic human needs and to protect aquatic ecosystems in order to secure their sustainable development and use.

All significant water resources will be classified in this way and resource quality objectives (RQOs) will be determined for each, aimed at balancing the need for protection and use of each resource. The RHP is ideally suited to assist in determining and monitoring the achievement of RQOs. However, nothing binds the Minister to consider the RHP [Uys, 1998].

Chapter 14 of the National Water Act states that national monitoring systems must be established. Furthermore, it states that they must provide for the collection of appropriate data and information necessary to assess, among other matters, "the health of aquatic ecosystems".

The National Water Act is a radical departure from the old Act. Involving a classification system, the concepts of the reserve and resource quality objectives, it is now much more soundly based on ecological principles. The RHP addresses these principles extremely well.

It is quite likely that the RHP will find another comfortable home within the new Environment Conservation Act. This is more broadly based than the National Water Act and includes such issues as sustainability and conservation of biodiversity. A project is underway that is examining the RHP within the context of environmental law [Uys, 1999] (as opposed to water law).

2.2.2 The RHP and Provincial Legislation

Although various regional government offices (of various departments) are giving support to biomonitoring programmes, there is little statutory legitimacy for the RHP. However, currently, at a provincial level, the RHP is incorporated in the Mpumalanga Provincial Strategic Planning Document, the Mpumalanga Conservation Bill and the National Parks Act [WRC, 1998].

2.2.3 Water Management Institutions

2.2.3.1 Catchment Management Agencies

See National Water Act No 36 of 1998 Chapter 7 & Schedule 3.

A catchment management agency (CMA) is a statutory body established at the discretion of the Minister to delegate water resource management to a local level and to involve local communities. It may be established for specific geographical areas, after public consultation, on the initiative of the community or stakeholders concerned. The proposal and procedure for its establishment and its powers and duties are detailed in the National Water Act. Its main functions are

- to investigate and advise on the protection, use, development, conservation, management and control of the water resources in its water management area,
- to develop a catchment management strategy, and
- to coordinate the related activities of the water management institutions within its water management area.

No catchment management agencies exist at this time. Before these agencies come into being, DWAF will act as agent in the meantime for the necessary water resource management. The process of establishing them is time-consuming (possibly up to five years [van Vliet H, DWAF, personal communication]). This is partly because a cautious bottom-up approach is being adopted involving public participation and consultation. The aim is to do more than just consult but rather engage interested parties [Karodia H, DWAF, personal communication].

See Government Gazette No 19641, 31 December 1998

A number of "forerunner" regions have been identified as water management areas. These have been proposed in the Government Gazette and comment was invited before 31 March 1999. The following map roughly indicates the location of the areas. For details of individual river catchments included in each area the original Government Gazette should be consulted.

There is currently a perception that these management areas are too large to be practically managed [van Zyl F, DWAF, personal communication]. In particular, involvement of all concerned parties on such a large scale is deemed inappropriate and impractical. This has resulted in a drive to create committees (under the Act) that will consist essentially of local water forums that concern themselves with single rivers or catchments. The aim is to provide these local committees with sufficient status that they are able to play a significant role in monitoring and ultimately pressurising local polluters and authorities. Such local organisations might include schools, bird clubs, tourism agencies, developers, NGO's as well as local government. However, some doubt has been expressed concerning the actual powers such committees will have [van Vliet H, DWAF, personal communication].

Proposed Water Management Areas

Figure 2.1. Water Management Areas proposed for catchment management agencies.

2.2.3.2 Water User Associations

See National Water Act No 36 of 1998 Chapter 8 & Schedule 5.

A water user association (WUA) is a cooperative association of individual water users who wish to undertake water-related activities for their mutual benefit. The purpose of WUA's is to represent specific water users relating to specific water use activities. It is not to undertake overall water resources management aimed at sustainability.

A water user association for a particular purpose would usually be established following a proposal to the Minister by an interested person, but such an association may also be established on the Minister's initiative. The functions of a water user association depend on its approved constitution. The following are a few examples that might typically be associated with a water user association:

1. To protect water resources.
2. To prevent any unlawful act likely to reduce the quality of water in any water resource.
3. To exercise general supervision over water resources.
4. To regulate flow.
5. To provide management services, training and support to rural communities and water services institutions, and to provide catchment management services on behalf of responsible authorities.

2.2.3.3 Water Boards

The primary activity of a water board is to provide water services to other water services institutions within its service area.

See Water Services Act No 108 of 1997 Chapter VI & X.

A water board must achieve a balance between (among other aspects) (i) striving to provide efficient, reliable and sustainable water services, (ii) striving to be financially viable, (iii) taking into account national and provincial policies, objects and developments, (iv) complying with health and environmental policies, and (v) taking reasonable measures to promote water conservation and water demand management, including promoting public awareness of these matters.

The Water Services Act further requires that a national information system of water services be established. One purpose is to record and provide data for the development, implementation and monitoring of national policy on water services. Another is to provide information to water services institutions, consumers and the public.

Therefore, water boards (among others) may well wish to involve themselves in a monitoring programme. It is usually in their interests to ensure that the quality of raw water that they use for purification and distribution is of consistent quality. Any major deterioration in quality may require changes to their process which could be costly for them.

The National Water Act provides for the restructuring of water boards as water user associations.

2.3 INDICES FOR BIOMONITORING

> *"A man would accomplish nothing*
> *if he waited till he could do it so well*
> *that no one could find fault with it"*
> Cardinal John Henry Newman (1801-1890)

2.3.1 Indicators and Indices

The design of a biomonitoring programme should be tailored to the particular type of water-body being assessed. For example, benthic macro-invertebrates and fish are often used as taxonomic groups to assess flowing water. Plants are used in wetlands. Algae and zooplankton can be used in lakes and estuaries.

Ecological Integrity is the cornerstone of measuring and assessing aquatic ecosystems.

Table 2.1. Biological ecosystem components associated with biomonitoring.

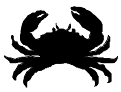
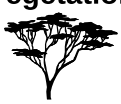
Ecosystem Component	Relevance to biomonitoring
Fish 	Fish comprise one of the main biological components of aquatic ecosystems. Because they are relatively long-lived and mobile they can indicate long-term influences (years) and general habitat conditions in a river reach. They represent a variety of trophic levels and hence integrate effects of environmental changes.
Invertebrates 	Invertebrate communities respond relatively quickly to localised conditions in a river, especially water quality though their existence also depends on habitat diversity. They are common, have a wide range of sensitivities and have a suitable life-cycle duration that indicates short- to medium-term impacts on water quality.
Riparian Vegetation 	Healthy riparian zones maintain channel form and serve as important filters for light, nutrients and sediment. Riparian vegetation regulates river flow, improves water quality, provides habitats for faunal species and corridors for their movement, controls river temperatures, provides nutrients and maintains bank stability. Changes in riparian vegetation structure or function are commonly associated with changes in river flow, exploitation for fire wood or changing use of the riparian zone (for example for grazing or ploughing).

Table 2.2. Non-biological ecosystem components associated with biomonitoring.

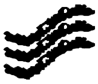
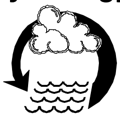
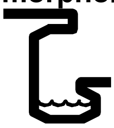
Ecosystem Component	Relevance to biomonitoring
Habitat 	Habitat availability and diversity determine aquatic community structure. Habitat degradation adversely affects biological communities.
Hydrology 	Flow conditions in a river affect the distribution and abundance of biota by creating dynamic habitats characterised by current speed, water depth, and (in the longer term) substratum characteristics.
Water Quality 	Aquatic ecosystems and their biota are affected by turbidity, suspended solids, temperature, pH, salinity, concentrations of dissolved ions, nutrients, oxygen, biocides and trace metals. Changes in these due to pollution, geomorphological or hydrological factors can have detrimental or even lethal effects on aquatic organisms.
Geomorphology 	Geomorphological processes determine river channel morphology which provides the physical environment within which stream biota live. Changes to channel form occurs both naturally and as a result of man-made changes to rivers or their catchments (*e.g.* impoundments, water importation, agriculture and so on).

Table 2.3. Summary of the main indices, associated ecosystem components and typical spatial scale.

Index	Component	Spatial Scale
Biological		
SASS4	Invertebrates	up to 20 m
FAII	Fish	Homogeneous fish segment, typically kms
RVI	Riparian Vegetation	10s of metres
Non-biological		
IHI	Habitat	5 km
IHAS	Habitat (Invertebrates)	up to 20 m
GI	Geomorphology	10s of metres

There are many biomonitoring indices receiving research attention in South Africa. However, they are not only focussed on riverine ecosystems. For example, algae and zooplankton are more appropriate for lakes and estuaries. These will not be discussed further.

A water quality index has been developed for South African conditions. However, it contains indicators not necessarily directly relevant to a biomonitoring programme. It may therefore not be the most appropriate water quality index to aid interpretation of the main biological indicators of the RHP.

For more details ...

Moore, 1990
Uys *et al.*, 1996

There are a number of indices in early stages of development that are likely to be applicable to the RHP. However, these are simply mentioned here and not discussed in any detail.

The Hydraulic Biotope Diversity Index (HBDI) is based on the fact that various geomorphological features have distinct hydraulic characteristics which can be described using numbers like the Froude number and Reynolds number. However, these features are also ecological habitats. An objective way of recognising these habitat features has been developed. It is the intention that this become part of the Geomorphology Index (GI).

For more details ...

Wadeson and Rowntree, 1999
Rowntree and Wadeson, 1996

A site-base Riparian Vegetation Index (RVI) is also being developed. This involves observations from the ground at the relevant site. This has been developed from an approach involving an aerial survey using a helicopter. A description of this can be found below under Index of Habitat Integrity (IHI). Data collected on-site will be on river channel, riparian zone (including invasion), ground and vegetation cover, main species present and disturbances. The formula will reflect the extent to which the natural vegetation is present and its inherent resilience to impacts.

The following figure is a rough (subjective) guide to the relative maturity of the various indices in more common use in the RHP. An index could take more than five years to reach maturity.

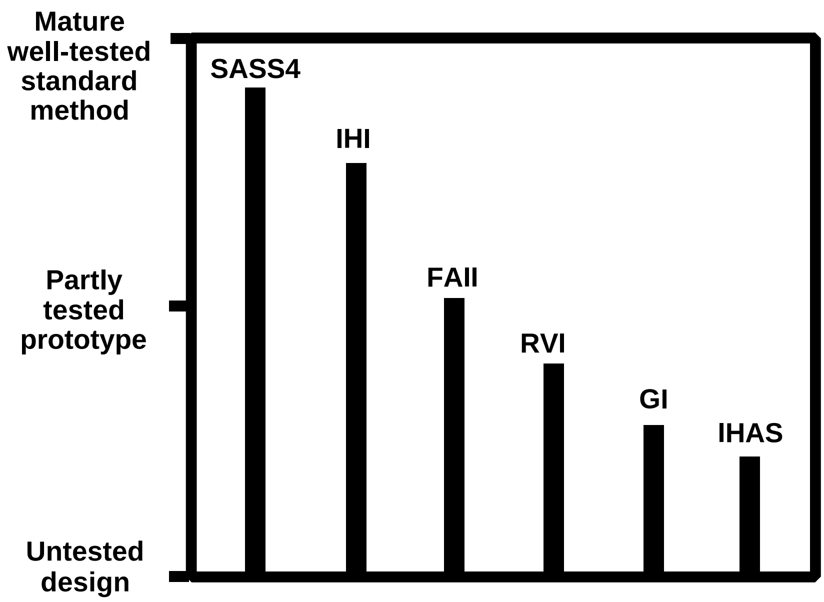


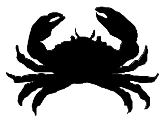
Figure 2.2. Relative maturity of some biomonitoring indices.

It can be noted here that some indices that have been or are being developed in South Africa are not appropriate for a national River Health Programme. The criterion that should be used to assess relevance to the RHP is whether the index permits ecological integrity to be quantified and assessed as a function of time. (Interestingly, SASS4 as presently defined, does not strictly allow this. However, it is so widely used and user friendly that it is accepted as a very valuable index.)

Those indices that are appropriate to the RHP and that have reached a stage at which they can be applied (though more testing and development are required for some), are described briefly in the following sections.

**Definitive methods are outside the scope of this document.
Latest details should be obtained in training courses
or the technical expert responsible for the index.**

2.3.1 South African Scoring System Index (SASS)



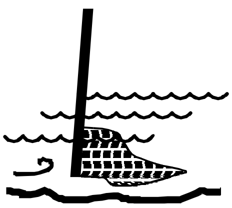
It has long been known that some components of the aquatic flora and fauna of streams and rivers respond in a predictable way to changes in the physical and chemical nature of water. The South African Scoring System version 4 (SASS4) is an index of one such component, namely aquatic invertebrates. This is the backbone of biomonitoring in South Africa [Dickens, 1998]. It has been suggested that the effects of polluted water on invertebrates may last as long as six weeks before noticeable recovery is observed.

***In Situ* observations of the presence of invertebrate taxa ...**

For more details ...

Chutter, 1998
McMillan, 1998
Thirion *et al.*, 1995

In the field, the procedure involves the following. Invertebrates are collected from the watercourse using a standard net by a number of well-defined methods in various habitats (stones in current, stones out of current, sand, gravel, mud, marginal vegetation, aquatic vegetation and bedrock). These collections are placed in a large tray. The types of invertebrates present are recorded on score sheets. Checking for taxa is limited to a maximum of 15 minutes or five minutes since the last taxon was found. The final result is obtained in the field - no laboratory work is required. The invertebrates are typically returned to the water. However, it is noted here that this prevents the assessment from being verified.



... and weighting their respective tolerances to polluted waters ...

Each taxon, typically a family, has been weighted on a scale of 1 to 15 according to its estimated tolerance of polluted conditions. (Formal tolerances have only been measured for a few.) Those least tolerant (*i.e.* most sensitive) are weighted (scored) higher.

... provides two indices, SASS4 and ASPT, ...

The SASS4 index is a function only of the tolerance scores for those taxa found to be present.

$$\textbf{SASS4} = \sum(\text{tolerance scores})$$

where the sum is over all taxa present in the sample.

The Average Score Per Taxon (ASPT) is also calculated:

$$\textbf{ASPT} = \text{SASS4}/(\text{Number of Taxa})$$

... that give a broad assessment of water quality changes.

The interpretation of SASS4 and ASPT has been divided into two classes, depending on the natural acidity of the water. The most widespread class includes waters not naturally acid, having a pH greater than six. The second class includes naturally acid waters (pH<6) typically occurring in parts of the southern and western Cape.

Table 2.4. Guidelines for interpretation of SASS4 and ASPT scores [Chutter, 1998].

Waters not Naturally Acid (pH>6)		**Waters Naturally Acid (pH<6)**		**Interpretation**
SASS4	**ASPT**	**SASS4**	**ASPT**	
>100	>6	>125	>7	Water quality natural, habitat diversity high
<100		<125		Water quality natural, habitat diversity reduced
>100	<6	>125	<7	Borderline between natural water quality and some deterioration in water quality.*
50-100		60-125		Some deterioration in water quality
<50	variable	<60	variable	Major deterioration in water quality

*Interpret on basis of extent by which SASS4 exceeds 100 and ASPT is <6 (or 125 and <7 respectively for naturally acid waters).

ASPT & SASS4 indices are fairly constant over significant sections of a river when in its natural condition.

The method should be used to assess water quality changes in broad terms and is therefore useful in water quality monitoring. It is claimed to be sensitive to all types of water quality change, though less so for changes in Total Dissolved Solids than for others.

Polluted parts of rivers are unambiguously identified as such. Since deteriorating water quality and habitat degradation affect both the SASS4 value and the number of taxa, ASPT (being the quotient of these two) is not greatly affected by the sample size. However, this is obviously less so the fewer the number of taxa. All scores should be used in a final interpretation. The fewer the number of taxa found the less appropriate it is to use the ASPT score.

Furthermore, recording the habitats sampled is also necessary for a more detailed interpretation. In particular, a comparison of SASS4 scores between different locations needs to take account of the respective habitats. A habitat index (IHAS) has been developed specifically for SASS4 and is described elsewhere.

The method has been widely tested in South Africa.

The taxa used in the index have been carefully chosen to include a range of sensitive and hardy taxa. As water quality deteriorates, the number of taxa are selectively decreased. Those most sensitive disappear first. Once the water is significantly polluted, only the most hardy taxa remain. Under these conditions the habitat diversity is no longer an important factor since

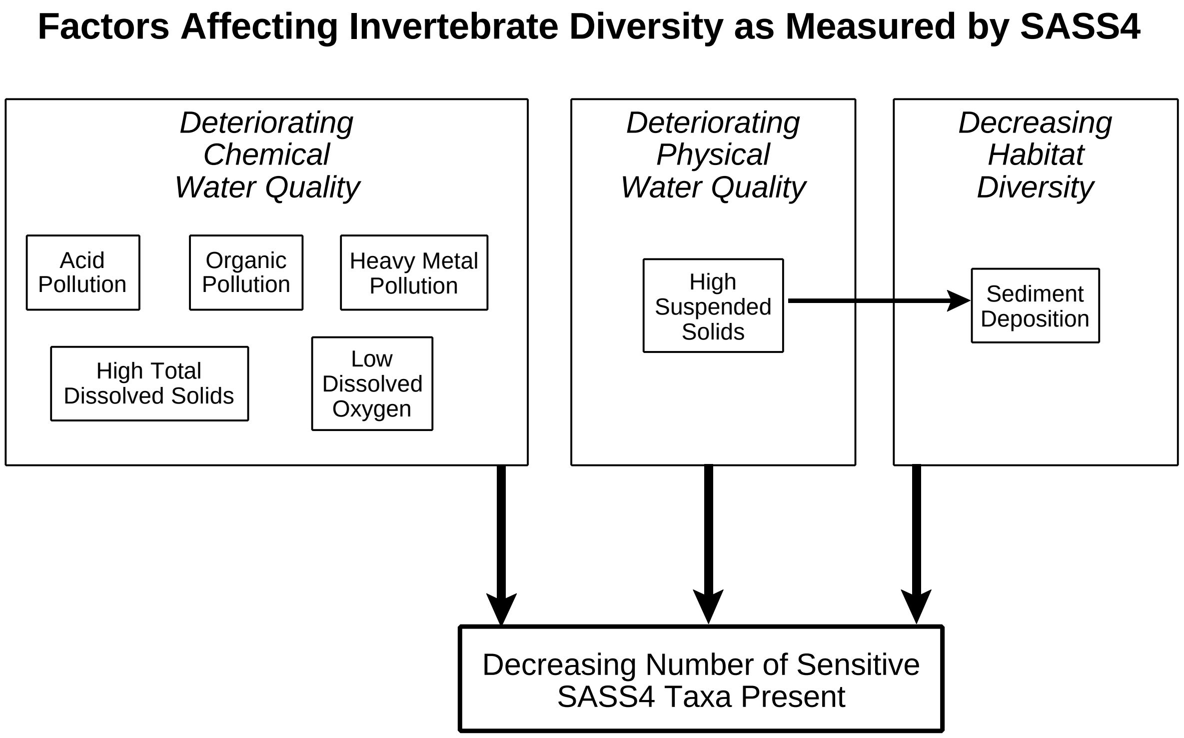


Figure 2.3. Illustration of some factors affecting the invertebrate diversity as measured by the SASS4 index.

the hardy taxa are somewhat evenly distributed among the various habitats. High levels of suspended solids impact on invertebrate communities in two ways. First, the solids clog gills making breathing difficult or impossible. Secondly, if significant quantities of these solids settle on the bottom, habitats become smothered (especially those associated with stones out of the current) and are therefore not available. Some of these relationships between water quality, habitat diversity and the two indices are illustrated in the adjacent figure.

simple and inexpensive resources are required on-site for sampling. These include data sheets, a standard net, and a large
sampling and checking for taxa.

There
invertebrates. A User Manual does exist [Thirion *al.*, 1995] but a more comprehensive
of identification guides is currently being produced [Dickens, 1998]. However, it has been
specific guide should be developed [Palmer, 1999].

Data
project is underway to deal with this problem that is discussed elsewhere in this document.

A
or equivalent, is required. Furthermore, at least seven days training in the field is necessary

It has been noted that a problem that may be encountered is that samplers lose their
skills unless they practice them regularly [Chutter M, Afridev, personal communication].

Invertebrate Habitat Assessment System (IHAS)

For more details ...

This habitat index (IHAS) is specifically associated with the SASS4
originally from the Habitat Assessment Matrix (HAM) through

As noted elsewhere, a SASS4 score depends on two main

IHAS is to provide an overall assessment of habitat at the site at the time of sampling that is
countrywide and easy to determine. Another use of IHAS is to adjust a SASS4 score
dependent on water quality). Therefore, if a SASS4 score is obtained at a site in which there
little habitat diversity, the SASS4 score is adjusted upwards. Equivalently, in a pristine site, the SASS4 score is adjusted (slightly) downwards. This aspect is still being tested.

Table 2.5. Summary of Invertebrate Habitat Assessment Index indicators.

Indicator	**Maximum Allowed Score**
Sampling Habitat	
Stones in Current (SIC)	20
Vegetation	15
Other Habitat / General	20
Stream Condition	
Physical	45

A single page data sheet is available that permits each indicator to be quantified. Each attribute contributing to each indicator is assigned a value on a scale of zero to five. The sum of these for each indicator gives the actual value. If this exceeds the maximum allowed (for the sampled habitats only) then the score is reduced to this maximum. The adjustment required to make it equal to the maximum (either positive or negative) equals the adjustment required to the SASS4 index. An IHAS value of >75% is suggested to indicate good habitat conditions. More than 65% indicates “adequate” habitat conditions.

Application does not require extensive specialist experience. It has only recently been proposed though has been received enthusiastically.

2.3.1 Fish Assemblage Integrity Index (FAII)

An index has been proposed recently for fish based on biological river segments. The Fish Assemblage Integrity Index (FAII) for a particular segment is defined as follows:

For more details ...

Kleynhans, 1999

$$\mathbf{FAII = 100 \times FAII_{Obs} / FAII_{Exp}}$$

where observed index = $\mathbf{FAII_{Obs} = \sum(I_{Exp} \times (F_{Obs} \times H_{Obs})/2)}$

and expected index = $\mathbf{FAII_{Exp} = \sum(I_{Exp} \times (F_{Exp} \times H_{Exp})/2)}$

where each sum extends over all species expected to be present in the segment. I, F and H are defined in the adjacent table. (The above recommended formulae are slightly different from those that occur in the original publication [Kleynhans N, DWAF, personal communication].)

The indicators are summarised in the following table.

Table 2.6. Summary of indicator ratings and criteria used for the Fish Assemblage Integrity Index.

	Indicator		
	I_{Exp}	**F_{Obs} and F_{Exp}**	**H_{Obs} and H_{Exp}**
	Intolerance to changes in conditions	Frequency of occurrence (% of sites at which species occurs)	Health (% of affected fish)
Indicator rating	**Criteria**		
1	Low (least sensitive)	< 34% (infrequent)	> 5%
3	Moderate	34 - 67% (frequent)	2 - 5%
5	High (most sensitive)	> 67% (widespread)	< 2%

Brief descriptions of the final calculated FAII classes are given in the following table.

Table 2.7. Fish Assemblage Integrity Index assessment classes.

FAII Score	**Class**	**Brief description**
90-100	**A**	Unmodified or approximates natural conditions closely
80-89	**B**	Largely natural with few modifications
60-79	**C**	Moderately modified
40-59	**D**	Largely modified
20-39	**E**	Seriously modified
0-19	**F**	Critically modified

The FAII gives a broad description of biological integrity.

This index has been tested on a part of the Crocodile River, Incomati System, Mpumalanga Province. It was found that the index reflected several aspects of the modifications that have occurred in that river. These included water quality and flow changes and the introduction of alien fish.

The following limitations were noted:

6. It was suggested that the index in the above form underestimates the biological integrity. This is because the expected list of species is based on a whole segment not on those expected in the specific habitats that were sampled. Basing the expected indicators on segment as well as habitat will improve the interpretation of the FAII.
7. Fish abundance (as an indicator) is not included in the FAII at present.
8. The FAII is heavily dependent on the intolerance indicator. A more objective approach

to quantifying this needs to be investigated.

9. The FAII is not considered suitable for the assessment of streams with a naturally low fish species richness.
10. The FAII is largely dependent on narrative biological criteria. Numerical criteria will require more research.
11. It is not possible to develop a fish index that can be applied directly without any modification to all South African rivers. Fish indices will need to be developed for specific river types.

It was further suggested that a combination of fish and instream macro-invertebrate indicators be investigated. An index such as FAII should be regarded as part of a system that will lead to more questions being asked in an attempt to solve a particular problem. It should not be regarded as able to determine cause and effect relationships unless considerably more intensive sampling and alternative approaches are used.

Unlike the determination of the SASS index, a considerable amount of work is required before the on-site sampling is done. This involves a calibration exercise that determines the expected occurrence of species. This involves considerable professional judgement and local knowledge of the area.

Resources required to determine an FAII for a river segment depends on the extent of sampling required. However, the simplest involves electroshocking equipment and a small seine net. The type of electroshocking equipment will also dictate the number of people required. The older type ideally requires four people. However, a newer backpack version requires only two. Time on-site for sampling and fish identification may require 2-3 hours.

Considerable expertise is required. Adult fish need to be identified to species level. A local knowledge of the rivers being sampled is also important. Someone with a basic diploma in zoology can probably be trained within a year. This will include considerable work in the field.

2.3.1 Index of Habitat Integrity (IHI)

The habitat integrity of a river provides the template for a certain level of biotic integrity to be realised. Ecological integrity can be regarded as a combination of habitat and biotic integrity.

For more details ...

Kleynhans, 1996

The Index of Habitat Integrity (IHI) assesses the impact of disturbances on a river on the capacity of that river to provide suitable habitats for organisms. Information is collected primarily by continuous video recording taken from a helicopter down the length of the river. Each 5km length of the river is examined for specific indicators, each with a previously assigned weight, and the degree of impact quantified. The indicators, weights and impact classes are summarised in the following tables.

Table 2.8. Habitat Integrity indicators and associated weights.

Instream Indicator	**Weight**	**Riparian Indicator**	**Weight**
Water abstraction	14	Indigenous vegetation removal	13
Flow modification	13	Exotic vegetation encroachment	12
Bed modification	13	Bank erosion	14
Channel modification	13	Channel modification	12
Water quality	14	Water abstraction	13
Inundation	10	Inundation	11
Exotic macrophytes	9	Flow modification	12
Exotic fauna	8	Water Quality	13
Solid waste disposal	6		
TOTAL:	100		100

Table 2.9. Summary of Habitat Integrity impact classes and scores.

Modifications	**Impact on habitat quality, diversity, size and variability**	**Impact Class**	**Score**
Not discernable	None	None	0
Few localities only	Very small	Small	1-5
Small number of localities	Limited	Moderate	6-10
Generally present	Clearly detrimental	Large	11-15
Frequently present	Almost whole of area affected	Serious	16-20
Present overall, high intensity	Almost whole of area detrimentally affected	Critical	21-25

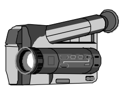
The overall Index is calculated as follows:

$$\mathbf{IHI(instream) = 100 - \sum[(Indicator\ Score/25) \times (Indicator\ Weight)]}$$

where the sum extends over all instream indicators. A similar index, IHI(riparian) is calculated with the sum extending over all riparian indicators.

The final value for each is converted to a narrative description of the overall integrity of the associated river reach.

Preparation includes obtaining a helicopter and a suitably qualified pilot and preparing flight plans. It also includes familiarisation with the area (using maps), identifying the part of the river to be surveyed and dividing this into 5km sectors.



Other resources required include a video camera and GPS. Preferably both the navigator and the videographer should be experienced aquatic ecologists though at least one must be. Comments on observations during flight can be recorded directly using the video's microphone.

Table 2.10. Brief narrative description of Habitat Integrity assessment classes.

IHI as %	Class	Description
100	A	Unmodified, natural
80-99	B	Largely natural with few modifications
60-79	C	Moderately modified
40-59	D	Largely modified
20-39	E	Extensive modification
0-19	F	Critical, almost complete loss of natural habitat and biota

Time on-site should be restricted to a maximum of five hours per day actual recording time to avoid fatigue. A few days on-site may be required. Subsequent analysis of the video and estimation of the final index may require up to ten days.

2.3.1 Geomorphology Index (GI)

Geomorphological processes (like flooding, erosion, silt deposition, etc.) determine the form and structure (the morphology) of river channels. This morphology provides the various physical habitats for stream biota (such as pools, under cobbles and rocks, etc.). Attempts to explain changes in biota may therefore benefit from an examination of changes in geomorphology.

For more details ...

Rowntree and Ziervogel, 1999

The proposed prototype geomorphological index comprises five individual indicators (summarised in **Table 2.11**). (It has also been suggested that an index for degree of channel modification be added in future [Rowntree K, Rhodes Univ., personal communication].)

The overall index is represented as a string of five digits. The index should be interpreted digit by digit and not as a single overall numerical value. For example:

43402 means a **foothills cobble bed**, **alluvial channel** with **extreme bank erosion**, **no bed degradation** and **moderate bed aggradation**.

Full descriptions of each indicator can be found in the original report.

Table 2.11. Summary of indicators contributing to the geomorphological index.

Indicator	Numerical Range	Typical diagnostic features
Zone	1-9	Varies from source through foothills to lowlands; based on gradient and channel features
Channel Type	1-4	Includes bedrock, fixed boulder, alluvial and mixed channels
Bank Stability	0-4	Erosion evidence; degree of vegetation cover; stability of bank toe; root exposure
Bed Degradation	0-4	Absence of fine alluvial material; degree of deepening
Bed Aggradation	0-4	Material accumulation at obstructions; channel blocking by sand and gravel; degree to which cobbles are embedded, degree of silt in pools

The index is based on field work on 14 rivers in the eastern Cape, Western Cape and Kwa-Zulu Natal. Field observations, for which data sheets have been developed, included the following:

1. A photographic record.
2. Condition of local catchment.
3. Sketch of channel morphology (including measured dimensions).
4. Riparian and in-channel vegetation.
5. General site geomorphology (including valley form, channel pattern, perimeter material, morphological units, bar type, channel type, reach type, bed material size distribution and bed packing).

A comprehensive (countrywide) baseline assessment is still required. Routine monitoring, for which data sheets have also been developed, include observations of the following:

1. Sketch of site indicating differences from the reference photographs.
2. A photographic record.
3. Water flow and turbidity.
4. Bank vegetation density in the active channel and impact of alien woody debris.
5. In-channel modifications (weirs, etc.) and bank impacts (*e.g.* by animals, paths, vegetation removal, etc.).
6. Channel condition (bank, bar and bed).
7. A specific rating of bank condition, bed degradation and bed aggradation indicators (providing the final three digits of the overall index).

A short document “Guidelines for Site Assessment” has also been developed which formally defines the many terms used [Rowntree and Ziervogel, 1999]. Some difficulties have been experienced with the terminology by nonspecialists. A project is in the pipeline for producing an illustrated guide to address this problem.

A baseline assessment should be performed when biomonitoring sites (reference or monitoring) sites are chosen. They should also be done after major hydrological events (for example, a 10-year flood) or following any significant upstream disturbance such as a forest fire or major change in land use. This assessment must be carried out by an experienced geomorphologist. Typically one to two hours at the site is required (assuming the help of a field assistant). Resources include data sheets, camera, 50 or 100 m measuring tape and a standard template for particle size measurements.

Routine monitoring should be done by a trained technician on an annual basis during a low flow period to facilitate access to the channel. Each site requires about half an hour to assess. Resources include data sheets and camera. All data sheets are archived. A computer database has still to be developed.

Extensive testing is still required. This is likely to result in changes to the estimation of the overall geomorphological index. Training methods and improved training resources (manuals, videos, CD ROMs, etc.) still need to be developed.

2.4 SITE SELECTION

The issue of "where to monitor" is of fundamental importance to any monitoring programme. This issue has been, and is still being given considerable attention. It is outside the scope of this document to give all relevant detail so further information should be obtained from the original works.

For more details ...

Eekhout *et al.*, 1996

The number of reference and monitoring sites is a function of a number of factors including the distance from the source, natural habitat variability and anthropogenic impacts. This is depicted in the following diagram.

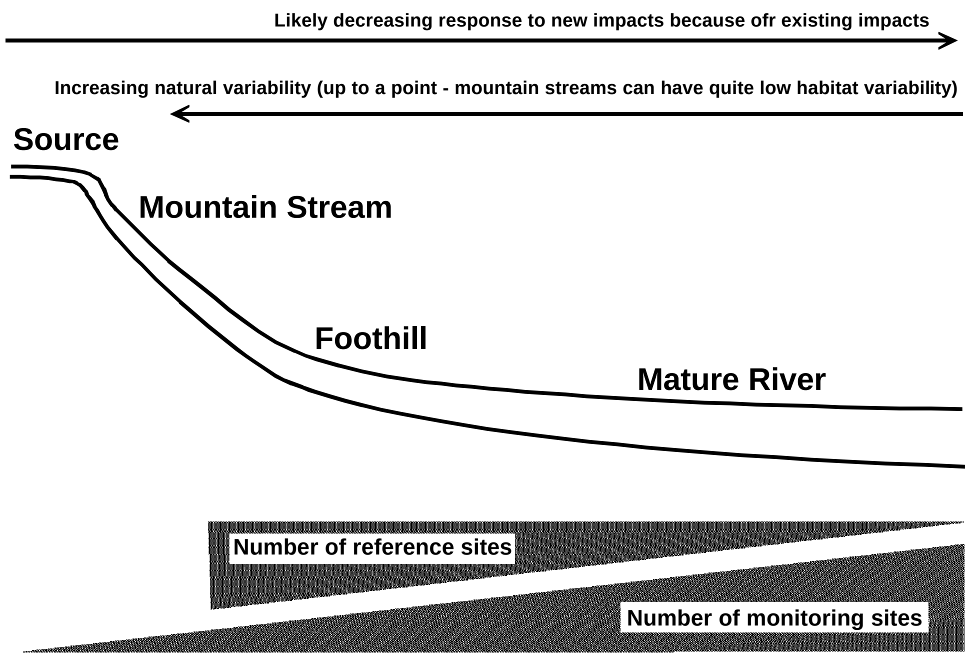


Figure 2.4. Number of reference and monitoring sites as a function of distance from the source [Eekhout, *et al.*, 1996.]

2.4.1 Reference Conditions

Notwithstanding built-in reference states (*i.e.* unimpacted) in the definition of most currently-used indices ...

The basis of biomonitoring in South Africa is ecological integrity. That is, a comparison of current state with natural (unimpacted) state is implied. Many of the indices have built-in reference conditions (defined as the natural state). For example, the Index of Habitat Integrity (IHI) is defined to have a value of 100 (the maximum value) if there is no anthropogenic modification or impact on river segment being assessed. Similarly, the Fish Assemblage Integrity Index (FAII) is defined to have a value of 100 (again a maximum) if the fish segment contains the assemblage of fish expected to exist in such a segment if it was in its natural state. Establishing the "reference condition" under these circumstances is currently largely based on historical records, knowledge of similar sites and expert opinion. Even the SASS4 index has a scale though the maximum is above 100. A SASS4 value greater than 100 with an ASPT value above six is described as having "natural water quality and high habitat diversity". However, the latter have not been based on a formal method for identifying reference conditions.

... work is underway to characterise all rivers to the level of "type" ...

A project is underway to classify all rivers in South Africa in a three-tier system down to the level of "river type" (focussing at present on Mpumalanga). Because of the varied climate, geology and geomorphology in South Africa, classification needs to be established within a spatial framework. Variation in these factors, both between and within rivers, together with natural biogeographic differences in the distribution of riverine biota, may potentially lead to biotic differences.

... that takes account of natural variations in climate, geology and geomorphology.

Having classified all rivers to the level of "type", reference conditions for each type can be defined as those that exist at unimpacted places where a particular type occurs. A number of individual reference sites may be necessary to establish the reference condition.

Reference conditions for a river type will be defined as those typical of the least impacted places where that type occurs.

Because totally unimpacted sites are nonexistent for many river types, an ecological reference condition will be the condition that is representative of a group of "least-impacted" or minimally disturbed habitats. In some instances this reference condition may represent the natural or intrinsic conditions of the water body whilst in others it may represent the "best available", for example in lowland rivers which have been subjected to extensive anthropogenic modification.

(This project will also play an important role in the classifying of South African rivers for the purpose of determining the reserve. The reference condition is likely to be a management class A.)

These will be benchmarks against which monitoring information can be compared. At present this is primarily aimed at the SASS4 index although it will also contribute to the Fish Index (FAII). Defining reference conditions in this way is an objective means of establishing the expected invertebrate and fish assemblages for particular river types.

A report that outlines the development and application of a spatial framework designed to assist with the identification of river types and selection of reference sites has been produced. This report focuses on the rivers of Mpumalanga. A report on the result of ground-truthing of the spatial framework is pending.

For more details ...

Dallas and Fowler, 1999

2.4.2 Monitoring Sites

Characterisation of all rivers into types will also ensure that all types are represented in a random sample for SoE reporting.

Some suggestions have been put forward in respect of choice of monitoring sites for State of Environment (SoE) reporting (the primary national perspective). They should be randomly selected and there should be a sufficient number to cover all river types. There are also pragmatic considerations: They should be suitable for the various monitoring methods; they should be accessible; they should be selected to maximise information content.

For more details ...

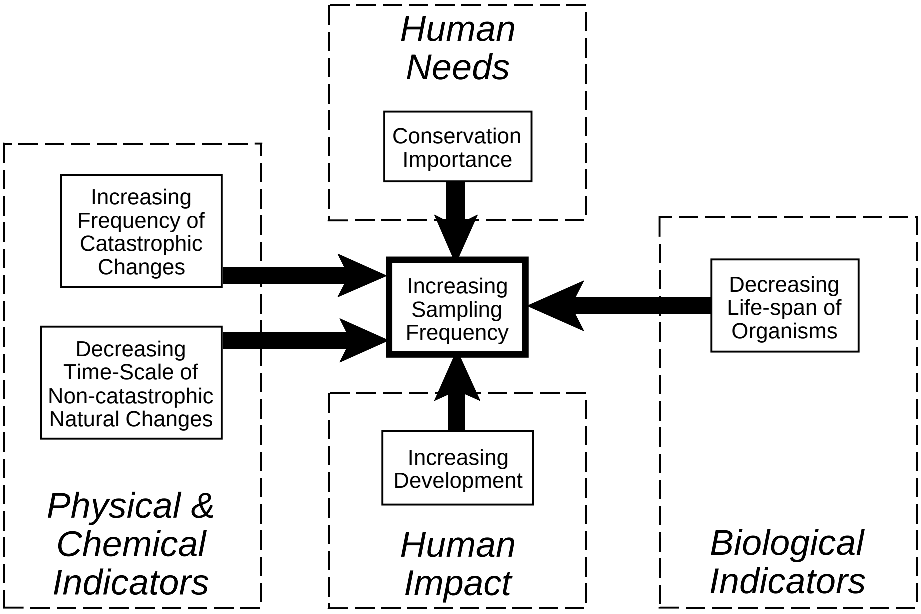
Eekhout *et al.*, 1996

If the purpose of the monitoring is the assessment of impacts (a more regional or local perspective), then sites should be chosen that will adequately reflect changes due to those impacts.

2.5 SAMPLING FREQUENCY

From a purely ecological viewpoint, the frequency of sampling should be related to the time-scales typically associated with change in the ecological component being monitored. This change can be either natural or anthropogenic. However, other factors such as conservation status also play a role. This is illustrated in the following figure.

Generic Factors Determining Sampling Frequency

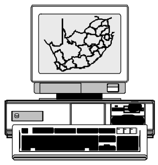


The following table proposes appropriate sampling frequencies.

Table 2.12. Typical sampling frequencies for various biomonitoring indices.

Index	Frequency	Comments
SASS4 & IHAS	2-3 times per year	Preferably during dry season, at end of dry season and at end of wet season
FAII	every 3 years	
RVI	every 3 years	To coincide with fish monitoring
IHI	every 3-5 years	Depending on development rate
GI	Annually during low flow period	Baseline assessment done initially for all rivers; then after major hydrological events or major upstream disturbances such as a forest fire or major change in land use

2.6 DATABASE MANAGEMENT



2.6.1 Current Mechanisms

Current data storage mechanisms are not at all standardised. This is one of the most pressing problems in the RHP.

Umgeni Water stores their biomonitoring data on a Laboratory Information Management System (LIMS). They store the following: All family data contributing to each SASS score, with biotopes sampled and automatic calculation of the SASS score, Taxa, ASPT, number of airbreathers and the final result of HQI and IHAS. Umgeni also collects the data of a number of local organisations doing biomonitoring. However, data storage has become a problem.

Fish data from the Northern Province are currently being stored in spreadsheets [Angliss M, Dept. Agric., personal communication]. Other indices are not yet determined.

BioBase

Southern Waters has developed a database comprising biological (SASS-related) and chemical data from more than 40 studies over a 40 year period [Dallas and Janssens, 1998]. It is available on CD ROM though allows viewing and querying only (not input of data). It uses a three-level hierarchical framework within which the data are accessed and queried. The primary level is the regional or geographic framework (including water quality management regions, bioregions and political regions). The secondary level differentiates longitudinal components or subregions. The tertiary level is the site.

2.6.2 The Proposed "Rivers Database"

A Rivers Database for Mpumalanga was one of the products to be delivered as part of the Ecological Reference Condition project undertaken by Southern Waters in August 1997 for the Institute for Water Quality Studies (IWQS). Initially, the Rivers Database was a comparatively small component of that project. However, during the course of the first year of the project (1998) it became apparent that the potential existed to greatly expand this component to incorporate aspects of general importance to the River Health Programme (RHP) [Dallas H, Southern Waters, personal communication].

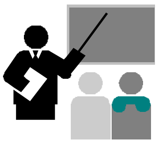
The development of the Rivers Database is divided into three phases. They are focussed only on the rivers of Mpumalanga with expansion to include the whole of DWAF primary drainage regions B and X.

Phase 1 (target date April 1999) involves design, testing and inclusion of site, river and catchment information. The IWQS SASS4 and HAM/HQI data for Sabie, Crocodile, Komati and Olifants River catchments will also be captured and verified.

Phase 2 (November 1999) involves data capture and verification of Fish Assemblage Integrity Index (FAII), Riparian Vegetation Index (RVI) and water chemistry data.

Phase 3 (November 1999) includes development of querying frameworks, a user guide and an import/export facility.

2.7 TRAINING CAPABILITIES



A training protocol is being developed at present by Dr Mitchell (WRC) who holds the training portfolio on the NCC. He is developing an inventory of biomonitoring training throughout South Africa. It is also his task to set up courses and identify institutions and people who can set the necessary standards.

A number of organisations countrywide have biomonitoring training capabilities. The following is a preliminary list: Umgeni Water, Rand Water, University of Cape Town, Rhodes University, Free State University, Potchefstroom University, University of the Witwatersrand, Rand Afrikaans University, Environmentek (CSIR) and Mpumalanga Parks Board.

2. THE STATUS QUO 2-1
2.1 INTRODUCTION 2-1
2.2 THE RHP AND THE LAW 2-1
2.2.1 Current National Legislation 2-1
2.2.2 The RHP and Provincial Legislation 2-2
2.2.3 Water Management Institutions 2-3
2.2.3.1 Catchment Management Agencies 2-3
2.2.3.2 Water User Associations 2-4
2.2.3.3 Water Boards 2-5
2.3 INDICES FOR BIOMONITORING 2-6
2.3.1 Indicators and Indices 2-6
2.3.1 South African Scoring System Index (SASS) 2-9
2.3.1 Invertebrate Habitat Assessment System (IHAS) 2-12
2.3.1 Fish Assemblage Integrity Index (FAII) 2-13
2.3.1 Index of Habitat Integrity (IHI) 2-15
2.3.1 Geomorphology Index (GI) 2-17
2.4 SITE SELECTION 2-19
2.4.1 Reference Conditions 2-20
2.4.2 Monitoring Sites 2-21
2.5 SAMPLING FREQUENCY 2-21
2.6 DATABASE MANAGEMENT 2-23
2.6.1 Current Mechanisms 2-23
2.6.2 The Proposed “Rivers Database” 2-23
2.7 TRAINING CAPABILITIES 2-24

3. VISION 2005

3.1 INTRODUCTION

The previous section presented a summary of the current state of development and implementation of the River Health Programme. Before presenting a fitting future implementation strategy, it is appropriate to establish a common vision. This section aims to do this for the year 2005. It is hoped that this will provide an appropriate direction for the proposed implementation strategy.

3.2 AN INFORMATION FLOW MODEL

Monitoring is about data and information and its effective use. This section suggests a model of how information might flow from biomonitor to the ultimate users. However, to do this it is essential that the national, regional and local roles of biomonitoring are clear.

The RHP is primarily a national monitoring initiative ...

The RHP, being primarily a national programme, is more concerned with “breadth” rather than “depth” [Roux, 1998]. It is not the primary intention that cause and effect relationships are established. It is also evident from the proposed spatial and temporal scales of most of the biomonitoring indices that the emphasis is broad.

... although some indices are also suited to local use.

However, some of the indices are suited to local monitoring. In particular, SASS4 and associated habitat indices are appropriate to particular sites (spatial scale tens of metres), as opposed to river reaches. Therefore, should a local organisation wish to apply biomonitoring (using these indices only) for their own purposes then this is possible.

Naturally, appropriate protocols should be followed for site selection, sampling frequency, reporting formats and so on. It is not within the scope of this document to deal with these in detail at local level. However, it is within the scope to note that this is possible. In addition, if these sites can also provide useful information for national objectives, then a win-win situation is evident. Indeed, if this can be achieved, it is preferable to a situation in which a local organisation is prompted to get involved in a national programme when that organisation does not see obvious benefits for itself.

On this basis, it is deemed appropriate to include local and regional monitoring (with their own independent objectives) in an overall model of national biomonitoring. The proviso is simply that, ideally, national objectives are also met by the local and regional programmes.

There is, nevertheless, an apparent conflict with the national objective of State of Environment (SoE) reporting. Ideally monitoring sites should be chosen randomly for this purpose. Allowing specific local organisations to include their data is not random unless in the unlikely scenario that previously randomly chosen sites just happen to fall within their jurisdiction. Nevertheless, it has been noted that a degree of pragmatism needs to be applied to the choice of monitoring sites. Given the problem of limited resources generally, it is likely to be better to include such data rather than exclude it. (Perhaps efforts should rather be spent on a statistical protocol for an optimum choice of sites for SoE reporting from the set of existing ones.)

Notwithstanding these concerns, a relatively simple generic three-tiered system is proposed. This is illustrated schematically in the adjacent figure.

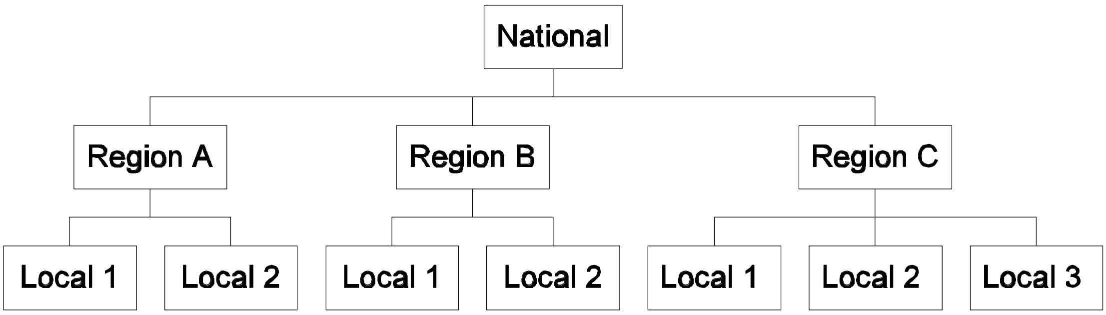
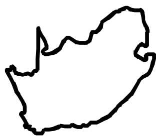
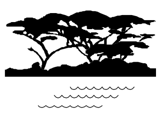


Figure 3.1. Schematic hierarchical structure of biomonitoring programmes.



National refers to the whole of South Africa. A single database would exist that is routinely updated with a selected subset of data from regional databases. As at the regional level, biomonitor(s) may exist that supply information directly to the national database (not via other databases).

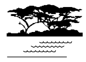
Regional refers to any geographical area that is deemed an appropriate water resource management unit. For example, it may be a "water management area" (defined in the National Water Act as a management unit in the National Water Resource Strategy), a province, a catchment or combination of catchments. A region would typically be covered by a single electronic database which is being routinely updated with a selected subset of data from a number of local areas (i.e. databases). If regional biomonitors exist (*i.e.* those whose data is inserted directly into the regional database, not via a local area database), then their original datasheets and photographs would also be stored at this level.



Local refers to a relatively small area for which a single database exists that contains biomonitoring data for that area. The database may be as simple as a spreadsheet. Original datasheets and photographs (if appropriate) would be stored at this level.

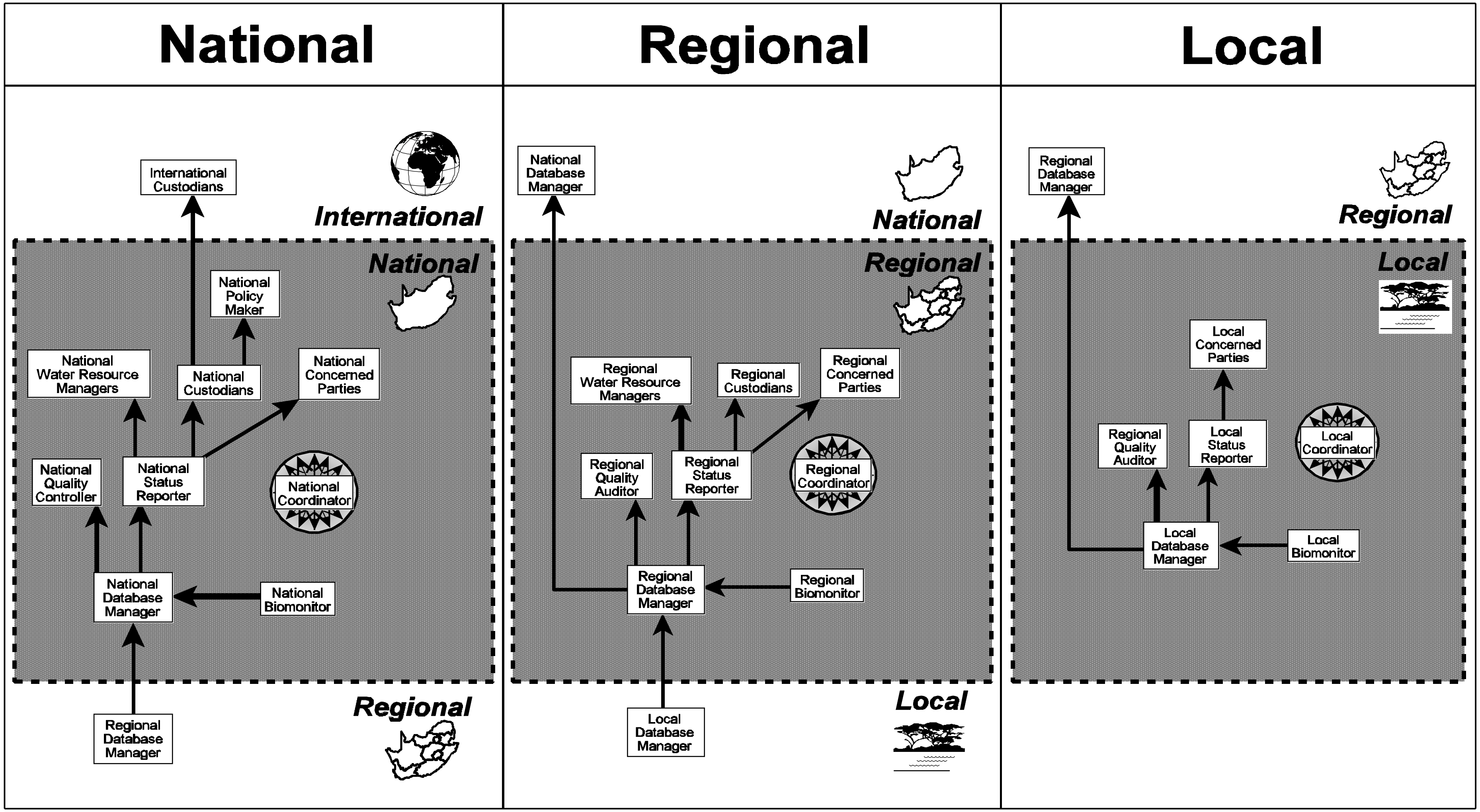
The following table suggests possible role players. Obviously, it is likely in practice that single persons or organisations may play multiple roles.

Table 3.1. Possible role players in a hierarchical RHP execution model.

Role	**Possible Role Players**		
	National 	**Regional** 	**Local** 
Natural Resource Manager	Ministers, DWAF, DEAT	DWAF regional offices, DEAT provincial departments	Industrial Companies, Water forums, Local Authorities, Irrigation Boards
Concerned Parties	Foreign Custodians of International Agreements, WRC	Provincial MECs, Large companies in region, regional water management institutions	Company stakeholders, local water users,
Status Reporter & Coordinator	IWQS or DEAT	DWAF regional offices, DEAT provincial departments, regional water management institutions or local Status Reporters	Company environmental officers (using company Annual Reports), academics (using scientific publications) or consultants (using client reports)
Database Manager	IWQS	DWAF regional offices, DEAT provincial departments, academic institutions or consultants	Environmental officers, academics or consultants
Quality Auditor	Certified specialists from DWAF or DEAT regional offices, academic or consulting institutions		
Biomonitors	Certified IWQS ecologists or consultants	Certified DWAF or DEAT regional office ecologists, academics, students (under supervision) or consultants	Certified environmental officers, academics or consultants

The information flow in this model is depicted in the adjacent figure. It suggests how information might flow from lowest to highest levels. These diagrams refer to data from active monitoring sites.

RHP Flow of Monitoring Information



It is evident from this model that at each level, the structure is basically the same. Each has its own objectives (and hence concerned parties), database manager and status reporter. Each can be regarded as an essentially independent unit. However, it is reiterated that the primary purpose is national, and hence an information flow upwards to national level must be ensured.

The **database manager** receives data in a prescribed format, stores this in the database, maintains the database and makes data available on demand. It is conceivable that because of the increased "broadness" of the requirements at national level that not all data stored on local and regional databases will be transferred upward. However, until an actual system is up and running, it is difficult to assess whether this will indeed be the case. It will also depend on the degree to which national status reporters will need to have ready access to all available data to make their final assessments.

The role of "**coordinator**" is adopted (and not "champion") because it is assumed that in the year 2005 sufficient momentum will have been established to ensure the programme essentially "runs itself". A champion is therefore not appropriate. However, continued coordination of the multitude of ongoing activities will be necessary.

It should be noted that both biomonitors and quality auditors should be certified. That is, they should have attended an appropriate training course and have been given a certificate to confirm this. This will ensure that a suitable minimum standard is maintained. It is important that appropriate quality control be exercised on all parties involved.

3.3 BIOMONITORING: A COMMODITY MARKET

A web site could be used as a South African biomonitoring expertise register and to define latest techniques.

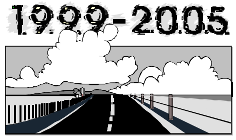
It is envisaged that a web site will be available by this time that provides the definitive source of information on all aspects of the RHP. This should include a comprehensive inventory of certified biomonitors, quality auditors and experts on the South African RHP network. It could also contain the type of information in this document, that is, a summary of the *status quo* (updated six monthly), a clear presentation of the vision and advice on how to attain that vision. It should also contain the latest details on how to determine the various indices.

To achieve optimum cost-effectiveness, by the year 2005 there should be a number of "suppliers" of biomonitoring and an established market for biomonitoring products. (A good example of such a supplier already exists. A company called Environmental Biomonitoring Services exists that specialises in SASS4 biomonitoring.) Biomonitoring should become a "commodity". It should no longer be a competitive advantage to a company but a competitive necessity for effective assessment and management of water resources [Roux, 1999].

3. VISION 2005 3-1
3.1 INTRODUCTION 3-1
3.2 AN INFORMATION FLOW MODEL 3-1
3.3 BIOMONITORING: A COMMODITY MARKET 3-5

Table 3.1. Possible role players in a hierarchical RHP execution model. 3-3

4. THE ROAD AHEAD



4.1 THE PROBLEMS

There are a number of specific problems being experienced by the various provinces. The adjacent figure summarises these. It is not the intention to imply that all the problems are being experienced by all provinces. Furthermore, where they occur, they are problematic to different extents.

It should also be emphasised that in some provinces quite the opposite of some of the issues is evident. There are organisations perceiving a real need for the RHP. There are now some demonstrable results (like the State of the Crocodile River Report). There is considerable support given by certain superiors in government departments. However, **this document is aimed primarily at those regions in which problems are being experienced**.

A number of regions simply lack the resources to do justice to RHP. This is caused by a number of factors. Since the introduction of legislation requiring EIAs to be performed on developments, government departments have been overwhelmed with such reports for reviewing. Since this is a well-defined statutory requirement, this tends to get a higher priority than RHP implementation. This is notwithstanding the fact that DWAF also has a statutory responsibility to establish monitoring programmes, associated information systems and to make this information available. There is a lack of trained personnel generally, but particularly within government departments. That is, even if they had the time, they do not have the necessary expertise. Although consultants can be used, they remain relatively expensive.

In some regions there is an apparent lack of concerned parties with a real need for the RHP. The lack of demonstrable results in some regions has also been mentioned as a deficiency. In terms of the "demonstration-for-resource allocation" model, both of these issues affect each other. Without local demonstrable results, convincing potential concerned parties to get involved is more difficult. However, without concerned parties applying the RHP, it is not easy to produce the demonstrable results.

The remainder of this section specifically addresses issues and actions that deal with these problems.

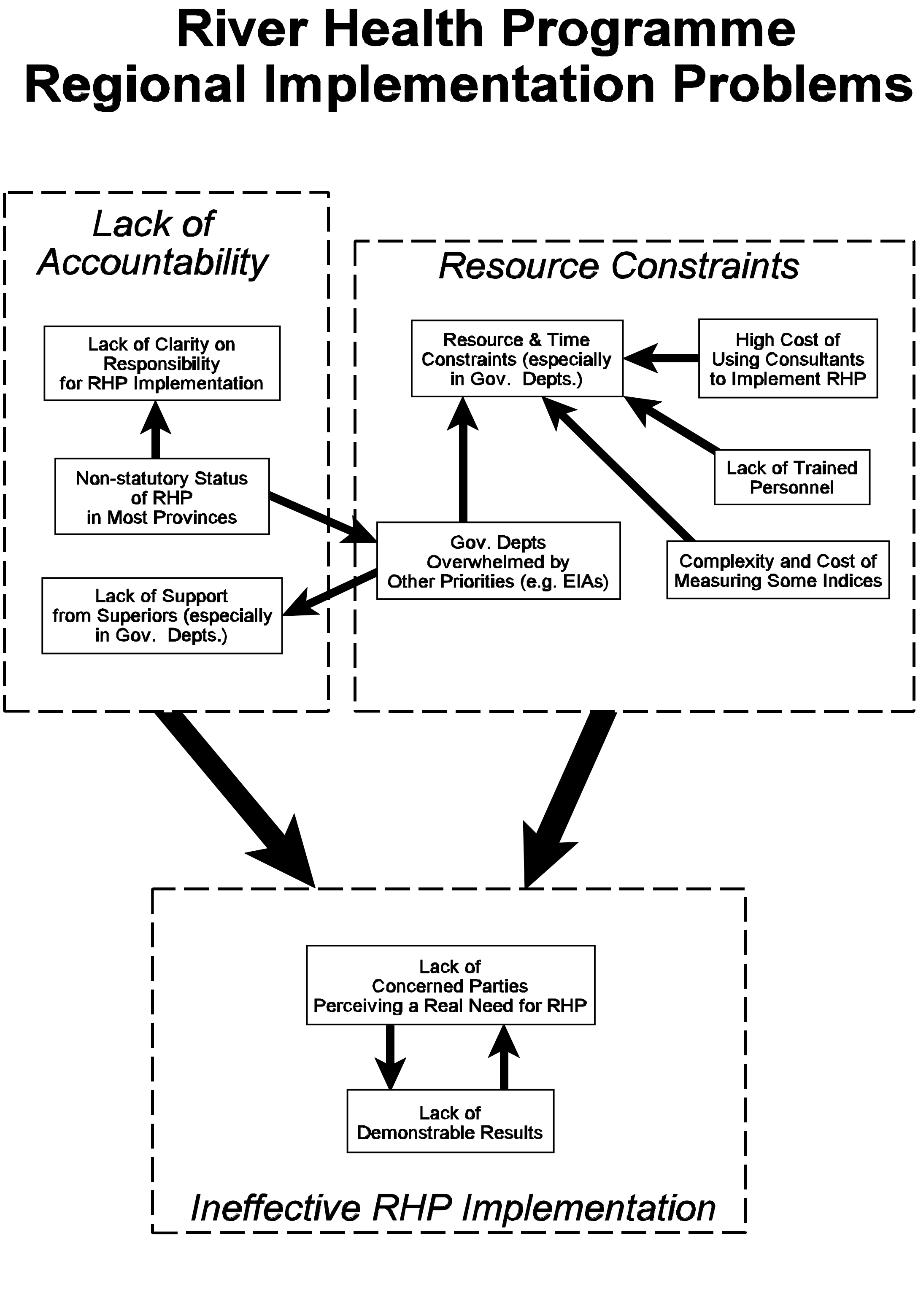


Figure 4.1. Some of the problems impeding regional implementation.

4.2 RHP OBJECTIVES

Objectives are acutely associated with attaining a vision. It is therefore appropriate to examine the current objectives of the RHP.

The objectives of the River Health Programme are typically stated as follows [Roux, 1997]:

1. **To measure, assess and report on the ecological state of aquatic ecosystems;**
2. **To detect and report on spatial and temporal trends in the ecological state of aquatic ecosystems; and**
3. **To identify and report on emerging problems regarding the ecological state of aquatic ecosystems in South Africa.**

One apparent problem with these objectives is that they do not suggest how attainment of each objective (and sub-objective) is best measured.

It is reasonable to assume that it is intended that each task is done with the utmost scientific integrity (though even this could be made explicit). Therefore, it may be possible to measure success from a scientific point of view.

> A common misconception of technology management is that technological advances have intrinsic value. However, the reality is that the customer (the water resource manager), through acceptance and application of the technology, determines value [Steele, 1989].

However, the objectives, as stated, are not explicit about who is requiring the reports and therefore how they might be used. It is stated elsewhere that the RHP is intended as a management information system [Roux, 1997]. In particular, it must support the management of water resources and aquatic ecosystems. Over the years, understanding of the intended capabilities of the RHP has been refined. It is realised that the RHP is primarily a national programme that measures and assesses the general state and annual changes over river reaches [Roux, 1998]. It is not its intention to provide day-to-day operational information or for measuring exact river conditions at specific sites. It has also been proposed that the RHP play an important role in determining the ecological reserve and to assist in the implementation of water quality objectives in a water resource management context [Uys, 1998].

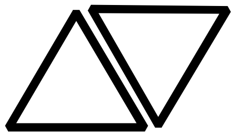
> Good information is accurate, complete, economical, reliable, relevant, simple, timely and verifiable [Stair, 1992].

It is proposed here that these hitherto implicit aspects (the managerial relevance and the sound science) are included in a new objective. It is important to note that it is not the intention here to change in any way the fundamental (and now widely accepted) objectives of the RHP. It is the intention that implicit objectives are simply made explicit. Accordingly the following objective is proposed:

4. **To ensure that all reports provide scientifically and managerially relevant information for national aquatic ecosystem management.**

By "scientifically relevant" is meant that the scientists are confident that the right things have been measured in the right way. By "managerially relevant" is meant that the information provided by the scientists is used in a meaningful and rational way for management of riverine ecosystems.

4.3 TOP-DOWN AND BOTTOM-UP



The successful implementation of the RHP will involve a careful combination of top-down and bottom-up approaches. The top-down approach will have its basis in the current legislation and the creation of an infrastructure to implement and enforce it. The bottom-up approach will be based on identifying those local and regional concerned parties who will themselves benefit from involvement in the RHP. This document deals with both. Particular circumstances will dictate which approach is the most applicable and most likely to produce the desired result at that time.

An appropriate combination of top-down and bottom-up approaches should be adopted with emphasis on bottom-up.

However, **bottom-up should take precedence**. The implementation of a primarily national biomonitoring programme with limited resources requires resource allocation from regional and local parties. It is realistic to assume that such parties will not have national objectives as their top priority (since, simply put, they cannot be paid to do so). Therefore, for them to implement a biomonitoring programme, it must also be in their own interests. This should be the basic principle driving implementation from the bottom up. Furthermore, it is recommended that protocols be developed within the RHP that delineate local implementation (site selection, reporting etc.). That is, the programme is encouraged to “go local” with the specific aim of encouraging local players to find a “win-win” solution in which they see a well-defined return on their investment. That is, provide them with the tools for local implementation in such a way that a contribution to the national objectives is ensured.

4.4 STATUTORY LEGITIMACY

It is proposed that an initiative be undertaken to establish some degree of statutory legitimacy for the RHP in the provinces. The aim could at least be to ensure that the scientific measures developed from it form integral, official, enforceable and binding criteria which will provide some legal certainty as to the scientific basis of the Reserve and the Resource Quality Objectives. This will also remove the possibility of arbitrary and political decision-making during the process of their development.

It is strongly recommended that the RHP ensures constant input to the National Water Resource Strategy. Furthermore, the RHP should align itself as much as possible with the use of legitimate water management institutions (catchment management agencies, water user associations, and so on) in coming years.

4.4 INCREASING THE RELEVANCE OF RHP INFORMATION

The usefulness of RHP information to a water resource manager is very much a function of the capabilities of that manager. Managing aquatic ecosystems is complex. It cannot necessarily be assumed that all water resource managers are familiar with the management of aquatic ecosystems. It is therefore explicitly proposed here that the following activities of the RHP remain active and increase in intensity in coming years:

1. The development and refinement of aquatic ecosystem management models that provide a framework for effective use of RHP information.
2. The development of grassroots awareness and education in respect of aquatic ecosystems.

Both of these activities are aimed at facilitating the achievement of the newly proposed objective (number four), namely producing <u>relevant</u> information. They are essentially providing tools for the intended recipients of the RHP reports and therefore help attain the RHP objectives.

> A misconception commonly associated with the introduction of a new technology is that the power of the new technology determines success. The reality is that the infrastructure required to support the implementation of the technology is often the determining factor [Steele,

Papers have been produced [Roux, 1998; Roux, 1999; Roux *et al.*, 1999] that address the effective use of RHP information. This type of work should be continued.

Furthermore, the Grassroots Communication and Environmental Education (GCEE) programme of the RHP is another mechanism for producing tools for water resource managers (namely, how to involve local communities). Development of this should also continue with the primary objective of ensuring the “relevance” (*i.e.* practical usefulness) of the information supplied by the RHP. This should include using the RHP GCEE programme as a vehicle for environmental education and general upliftment.

It is likely that this focus of the NCC (coordination of the development of processes that better apply RHP products) will increase naturally as biomonitoring methods begin to standardise.

4.5 DEMONSTRATING SUCCESS

The "demonstration-for-resource allocation spiral" model has been successfully implemented in the RHP from its inception [Roux, 1999]. Simply put, show potential resource allocators what can be done and they are more likely to buy in. Biomonitoring and how it might be used are not necessarily simple concepts. Acceptance is only likely when resource allocators are convinced that it is in their own interests to get involved.

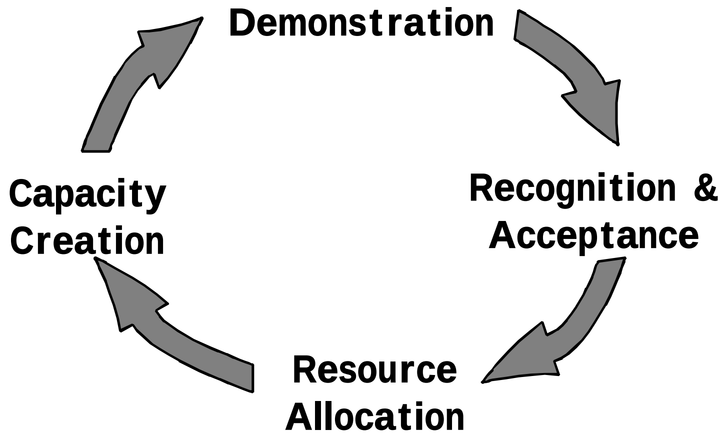


Figure 4.2. The "Demonstration-for-Resource Allocation Spiral" model adopted in the RHP [Roux, 1999].

Results from adjacent areas (even other regions) can be demonstrated to interested parties. Care should be taken to use examples that are appropriate for the type of audience. It is possible that when trying to convey the generic RHP message that individual concerned parties will be unable to "translate" what is being offered into potential solutions for their <u>individual</u> requirements. Therefore, an attempt should be made whenever possible to put yourself in the shoes of each organisation in the audience and to provide that individual organisation with a concrete example of how the RHP will help <u>them only</u>. That is, do the translation for them. Don't assume they can do it.

If good examples are not immediately available, an initial investment in an area may have to be made. This area should be chosen carefully, using criteria that maximise return on investment, such as the following:

3. The greater the local capacity to adopt biomonitoring roles the better.
4. Ideally, local players should reap well-defined benefits from involvement.
5. There should be "real issues" in the chosen area, that is, actual degradation of aquatic ecosystems and many people affected by this.
6. The area should be inherently suitable for demonstration, that is, the results should have a significant impact on those ultimately intended to be brought on board.

4.6 GENERAL COMMUNICATION

A useful document has been produced by Manyaka, Greyling and Meiring on a wide range of issues related to communication [Manyaka Greyling, 1998]. Amongst other aspects, the document deals with the following:

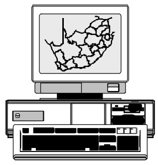
1. Key target audiences.
2. Key and underlying messages to stakeholders.
3. How to arrange workshops, field demonstrations, open days etc.

4. A draft speech for a dignitary.
5. Crisis communication plans.

This document should be consulted and the ideas implemented and tested. Feedback to those authors on lessons learnt and improvements will be to the benefit of all involved.

As mentioned elsewhere, a grassroots communication initiative is also being developed for approaching and involving local communities.

4.7 DATABASE MANAGEMENT



The Vision 2005 hierarchical model allows for considerable flexibility in local and regional programmes. It specifically acknowledges that each local, regional and national agency has its own priorities (which may not coincide significantly with the level above it). Furthermore, it is obvious from this model that for the national level to benefit from these possibly disparate regional and local programmes, an efficient mechanism for data transfer upwards must be available. It should be assumed that the local database manager will not be particularly motivated to go to the trouble of data transfer to a higher level. Therefore, it is suggested that it is of the utmost importance that attention is given to efficient data transfer between databases. It must be ensured that this is as simple as possible so that the local database manager does not regard this task as a major intrusion on his or her time (for little apparent gain).

Ways of rewarding local programmes for supplying their data upwards into the system should be investigated. Obvious ways include (a) supplying them with copies of regional or national reports that use their data and (b) explicit acknowledgement of their contributions in such reports.

The NCC should define the exact degree to which biomonitoring can be applied “locally”. It needs to take account of the apparent conflict between being a “national” programme requiring “local” commitment of resources because of limited national funding. Furthermore, a series of examples should be compiled (that can be used for “demonstration” purposes) of how biomonitoring can benefit local agencies.

Consistency in biomonitoring reports is likely to depend heavily on the capabilities of the database management system. Careful thought should be given to the choice of appropriate icons that communicate the appropriate messages and that can be conveniently incorporated into standard reports (*e.g.* maps) issued directly from the software.

4.8 CREATING SUSTAINABLE REGIONAL CAPACITY

4.8.1 Committed Provincial Champions

The demands of implementing the RHP in a region are significant. A single person who can drive implementation in a region is essential. The ideal person is one who not only has a personal commitment to getting the job done (i.e. personally gets something out of it) but also has superiors who formalise that commitment in a job description.

A survey of the current provincial champions revealed that the percentage of time being spent on RHP implementation varied from 10 to 40%. The average was about 25%. This should perhaps be regarded as a minimum amount of time required for successful implementation.

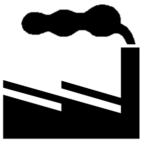
4.8.2 Demonstrating to Regional Concerned Parties

It is the primary responsibility of the Department of Water Affairs and Forestry to implement a national biomonitoring programme. It is also their responsibility to identify other structures with similar responsibilities. The involvement of local and regional concerned parties is likely to be to the advantage of all involved.

Specific water management institutions may already exist in an area. If so, then they may well have interests that overlap with those of the River Health Programme. Alternatively, such organisations could be established so that one of their functions is the implementation of biomonitoring in the area.

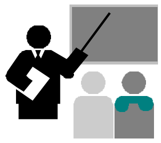
In general, a guiding principle is to identify those local concerned parties that would have an inherent vested interest in a monitoring programme. That is, their involvement in the local programme would be a "win-win" situation. However, whenever possible, results should be demonstrated to any organisation that is approached. For example, actual case studies or reports (like the State of the Crocodile River Report) can be presented.

There are many kinds of organisations that can be considered as regional or local concerned parties. These include catchment management agencies (when these are ultimately created), water user associations, water boards, water forums and conservancies. The functions of many of these have been described generically elsewhere in this document.



A number of major industries in South Africa take a pro-active role in ensuring (and demonstrating) minimal impacts on their local environments. By adopting a biomonitoring programme they demonstrate a social and environmental responsibility. The following are a few examples: ISCOR funds extensive biomonitoring in the Empangeni area, Kwazulu-Natal. Mondi Forests, SAPPI and SAFCOL are jointly funding biomonitoring across forestry areas in South Africa.

4.8.3 Training



Appropriate training (of biomonitors and trainers) is critical for a sustainable capacity. This is not only necessary for continued growth of the RHP but also to ensure that an unexpected loss of a pivotal person does not suddenly leave an expertise vacuum in South Africa that is not easily filled. It must be ensured that the extensive knowledge of those technical experts that have been responsible for the development of the various methods (*e.g.* for determining indices, choosing reference sites and so on) is captured. This can be done by producing instruction manuals. However, it is also critical that on-site word-of-mouth instruction be carried out whenever possible so that the many nuances of biomonitoring, not easily capturable on paper, are passed on.

4.8.4 Selecting Indices

What should be measured in a biomonitoring programme is determined by a number of factors. The primary one should be the specific requirement of the managers of the riverine ecosystem of concern. (One objective of the RHP is to provide relevant information.) It should also be borne in mind that the RHP is a national programme not primarily aimed at identifying local cause and effect relationships (see section on Vision 2005). Available financial resources and expertise of personnel will ultimately determine the degree of biomonitoring performed. SASS4 (and the associated IHAS) is by far the cheapest and easiest to perform (though does require specialised training) and should be the very least that is done.

A series of biomonitoring protocols (combinations of indices) has been suggested [Uys *et al.*, 1996]. However, methods have evolved somewhat since then (and some have not) and the following possibilities can now be considered.

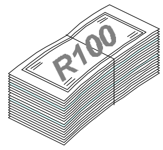
The table acknowledges that SASS4 is generally considered to provide the best return on investment [Uys, *et al.*, 1996]. A determination of SASS should include ASPT and the number of taxa. IHAS has developed from the previously used HAM and HQI and should therefore replace them as the SASS-related habitat index of choice.

Table 4.1. Possible combinations of biomonitoring indices.

Number	Component Indices
1	SASS4, IHAS
2	SASS4, IHAS, FAII
3	SASS4, IHAS, FAII, IHI
4	SASS4, IHAS, FAII, IHI, RVI, GI

It is not being suggested that other indices not be used. However, their inclusion should take account of a need to become as consistent as possible with other initiatives and to move onto new and better indices when these become available. The need for flexibility at local and regional level (while still contributing to the national objectives) is nevertheless acknowledged. This approach of “prototyping” should continue to be applied. Namely, the current version of an index should be applied, accepted and used until such time as an improved version is available [Roux, 1999].

4.9 FINANCIAL CONSIDERATIONS



4.9.1 Overall Provincial Budgets

A concept proposal has been prepared and distributed to potential international donors.

The following presents a provisional budget for RHP implementation in an "average" province. This budget is taken unedited from the concept proposal that has been sent to various potential funding agencies (local and international) [RHP Concept Proposal, 1999].

Table 4.2. Preliminary "average" provincial budgets for RHP implementation.

Task	**Rand per province per annum**	
Programme plan and design	R	20 000
Full initial rating of selected river sites (all indices)	R	50 000
Sampling equipment	R	55 000
Monitoring visits (selected indices only)	R	70 000
Analysis, interpretation and reporting of results	R	40 000
Training and capacity building	R	70 000
Cataloguing and storage of voucher collections	R	10 000
Quality control and quality assurance	R	20 000
Coordination and project management	R	10 000
TOTAL for one year	**R**	**345 000**
TOTAL for 3 years (Including 10% inflation per annum)	**R**	**1 142 000**

These figures are ballpark values of likely costs per activity and can be used in preliminary planning exercises within the provinces, for example, on deciding on likely concerned parties and donors.

Although provincial champions are encouraged to approach both local and international donors directly, it is advisable to approach the NCC first to ensure that this activity is appropriately coordinated [Scherman P, IWR, personal communication].

The following table can also be used as rough guidance on budgetary requirements of a provincial champion (manhours only). The figures are based on a total of 2000 hours available per annum. The Institute for Water Research at Rhodes University recently submitted a proposal to the Eastern Cape DWAF office for funding of a provincial champion at the IWR. This included an estimate of about **R9 000** per annum for disbursements.

Table 4.3. Provincial champion annual manpower budget range.

% of time on RHP	Rands/Hour 150		Rands/Hour 250	
20	R	60 000	R	100 000
40	R	120 000	R	200 000

4.9.2 Draft Business Plan

A business plan has been produced by Chris Dickens of Umgeni Water. This plan also presented approximate monitoring costs per site per annum for 1998. The following table is based on those costs, though increased by about 15% to take account of inflation. Technician rates have also been raised to R100/hr.

Table 4.4. Approximate monitoring costs for reference and monitoring sites.

	Rands per site per annum			
	Recommended Survey[1]		Minimum Survey[2]	
Survey Cost	Reference site	Monitoring site	Reference site	Monitoring site
SASS	330	85	230	58
HAM	44	44	29	29
RVI	115	115	-	-
Average transport cost @ R1.40/km				
5 km local	21	21	14	14
10 km	42	42	28	28
50 km rural	210	210	140	140
100 km rural	420	420	280	280
Travel time (labour cost at technician rate R100/hr)				
local trip 5 km	75	75	50	50
long trip 100 km	300	300	200	200
Total cost/annum for local site (5 km)	**585**	**340**	**323**	**151**
Total cost/annum for distant site (100 km)	**1209**	**964**	**739**	**567**

[1] The recommended survey is based on 3 samples per annum in late summer (March, April), winter (July, August) and late spring (October, November). The difference in SASS costs are that ALL the biotopes are monitored for reference sites but only ONE for monitoring sites.
[2] The minimum survey is based on 2 samples per annum (autumn and spring).

4.9.3 Potential Donors

A funding guide specifically has been prepared for the RHP [Walmsley and Louw, 1997]. It identifies both national and international donors. It contains contact persons, areas of interest of the various funding agencies and proposal protocols. International agencies considered include AUSAID, British Aid, DANCED, Dutch Aid, Finnish Aid, Global Environment Facility (GEF) and Swedish Aid. This document can be used to identify the most appropriate possibilities for funding aspects of either provincial or national implementation initiatives within the RHP.

4.10 NATIONAL COORDINATION

4.10.1 Issues facing the National Coordination Committee

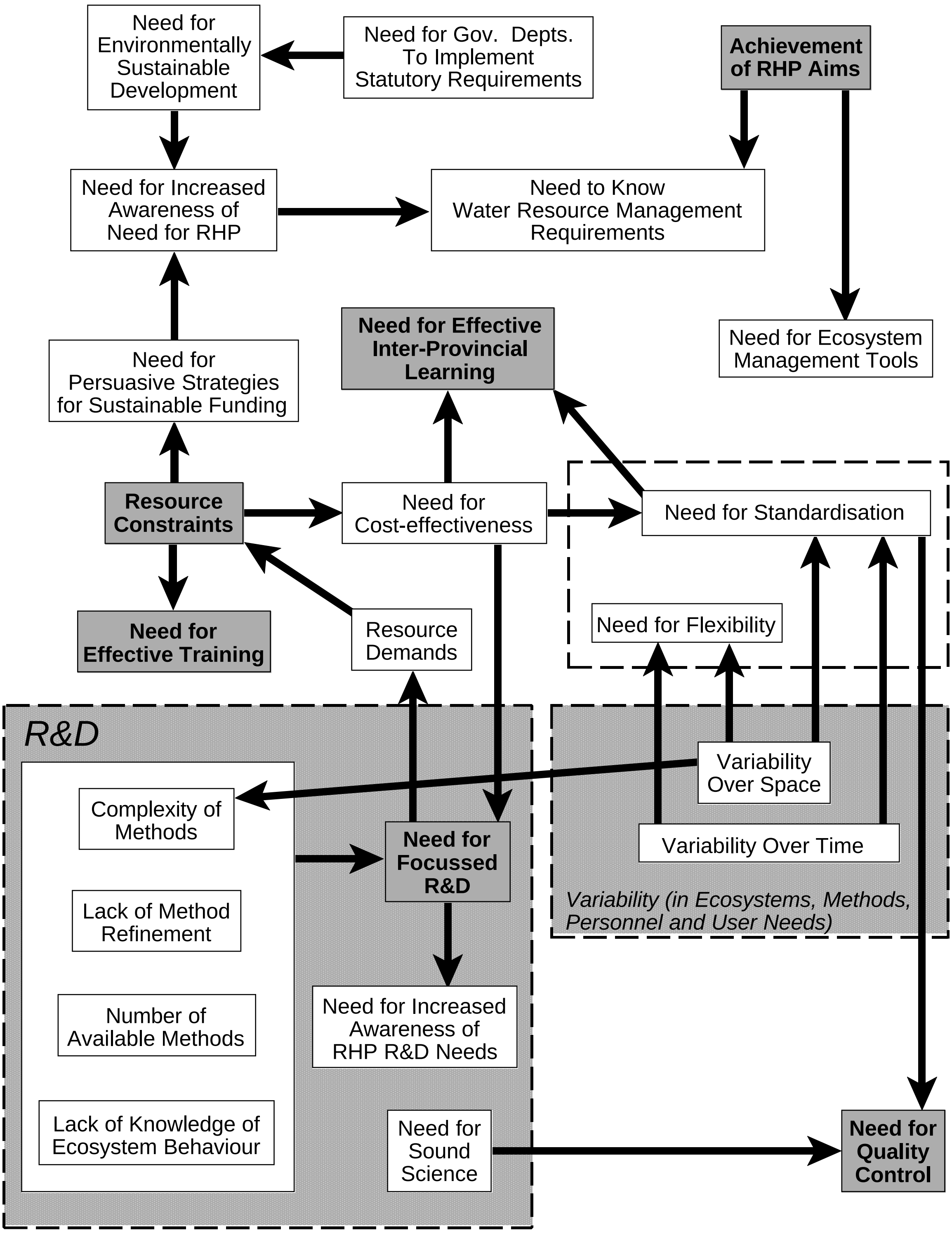
The issues facing the National Coordination Committee (NCC) have been examined briefly in the light of the above vision and proposed road ahead. The analysis has been restricted to an identification of the national issues, a presentation of them in a systems model diagram and a brief discussion.

> *The **systems model** diagram identifies the most important (quantifiable) issues and their interactions though is a considerable simplification. An arrow between issue A and issue B should be interpreted as meaning "issue A drives (or results in) issue B". The issues are <u>not</u> formally defined in the text nor are the interactions described in detail. (A proper analysis would require this.) Nevertheless, the diagram can be used as a basic thinking and discussion tool.*

Variability in space and time (of ecosystem, methods, people and user requirements) is probably the most fundamental issue driving (actually, complicating) most activities in the RHP. The fact that this issue is so pervasive almost suggests that there should be a conscious effort in all activities to counteract this. That is, when given the opportunity to simplify, do so, rather than complicate.

Focussed R&D is essential. It is the object of an index to simplify. The newly proposed aim of the RHP is that scientifically relevant information is provided. The natural inclination of many scientists is to complicate (or at least be comprehensive) to ensure that every nuance is accounted for. The challenge for scientists working within the RHP is to avoid unnecessary complication. However, it is acknowledged that in many cases it is necessary initially to examine all aspects to establish relative importance. Once this is known, then the system can be simplified.

National Issues



A good example of how this process has worked well is the SASS4 index. This started (necessarily) in considerable detail. However, this improved understanding, focussed debate and ultimately resulted in a relatively simple method that can be completed on-site. However, a lesson that can be learnt from the development of the SASS4 index is that it is a time-consuming process.

As always, **resource constraints** drive many issues. They create a need for **standardisation** and a need for general **cost-effectiveness**. This in turn drives a need for **effective inter-provincial learning** so that wheels are not reinvented. Funding models (both local and international) should continue to be developed and investigated. Local models should be based on a sound understanding of the real needs of local organisations.

The need for **standardisation** is obvious. However, there is also a need for a degree of flexibility. At face value, these seem contradictory. However, they need not be. The challenge will be to introduce a degree of standardisation and quality control that is sufficiently flexible to meet the varied needs of all participants.

The need for standardisation and a need for sound science both drive an urgent need for **quality control**. Related to this is ensuring that “fly-by-night” biomonitors are avoided by creating a network of certified biomonitors and quality auditors.

It has been suggested by some current provincial champions that the NCC meetings provide a useful mechanism for **inter-provincial learning**. This is an important issue given the need for cost-effectiveness, standardisation and general complexities of biomonitoring in South Africa at present.

Good **communication** is critical at a number of levels though not appearing explicitly on the systems model diagram. It helps address the need for increased awareness and acceptance of the RHP, facilitate inter-provincial information transfer and learning, maintaining a corporate image and by providing a general secretariate for national coordination.

4.10.2 Roles of National Coordination Committee

It is proposed that the roles of the NCC as a whole remain essentially unchanged for the immediate future. It has been, and should remain, the role of the NCC to coordinate biomonitoring in South Africa on all levels, in a way that takes cognisance of limited financial and human resources. It must act in an advisory capacity, both coordinating and guiding the whole spectrum of interested parties from researchers to ultimate users of the information generated. However, primary responsibility for implementation remains with the provinces.

Research activities are being largely driven by temporal and spatial variability and the fact that indices are not yet standardised. Coordination of continued method development is essential. As methods ultimately become more standardised, the NCC will need to shift its focus from such R&D to improved management techniques for using the information emanating from the RHP [Roux, 1999]. This shift will be essential if biomonitoring is to achieve a “commodity market” status in five years. It has appropriately already begun.

The NCC must continue to match the minimum requirements of the RHP (as a national programme) with local and regional needs and balance this with available resources and capacity.

4.10.3 A National Coordinator

It is proposed that a single person act as a national coordinator. The rationale behind this is as follows.

All the roles of the NCC identified above are important as are those identified for individual portfolios on the NCC (described below). Furthermore, many require specialist expertise. The NCC has over recent years identified a number of tasks that are important to national coordination and regional implementation of the RHP. Often these tasks have been assigned to individual members of the NCC. However, all members of the NCC have full time jobs. Although some have biomonitoring officially on their job descriptions, some do not. Even if they do, capacity and time are often limiting. This has meant that many of these tasks have not been completed. There has also not been any specific mechanism in place that ensures that such tasks are actually completed on time, on brief and on budget.

To address these problems, a national coordinator should be appointed. The exact functions that this person could perform are likely to be determined by that persons' expertise, experience and the available budget. The following ideal job description is proposed which can be tempered by these issues. It is proposed that this person have at least six months per annum full time on this task. Given the considerable rate of change at present, the contract and job description should be reviewed annually by the NCC.

This model assumes that competent people are overworked. It acknowledges that the NCC is comprised of competent people. It proposes that they bring this expertise to annual meetings. However, it attempts to remove as much national coordination responsibility as possible from these people by putting it on the shoulders of a single national coordinator.

The candidate should ideally be an aquatic ecologist with management experience. The candidate should be self-driven, have good people skills, be a strategic thinker and a competent communicator (both verbally and written).

The buck stops here.

This person should be an "executor" (of the various management tasks required for successful implementation of the RHP nationwide) not a "delegator". This person will have the primary responsibility of tasks such as those listed below in consultation with the relevant experts. In this way, the resources required from already overworked NCC experts are minimised to that required to download and capture their critical contributions (typically in one-on-one meetings or telephone conversations). Actually capturing this information (in reports, proposals, and so on), presenting it properly and disseminating it is the job of the national coordinator. The candidate will ultimately be *au fair* with all aspects of the RHP.

The following are typical tasks that should be undertaken by the national coordinator.

1. Analysis of current examples of how biomonitoring is benefiting local organisations. From this should come (a) a series of examples that can be used for demonstration purposes and (b) a better understanding of how other local organisations around South Africa can be approached and convinced that it is their interests to adopt the RHP.
2. Coordination of training countrywide. This should include compiling an expertise register that facilitates the drive towards a biomonitoring commodity market. The national coordinator should also ensure that training courses are executed in a standardised way and that the latest information is presented.
3. Coordination of quality control (closely allied to appropriate training).
4. Development, implementation and coordination of funding models both local and international. The national coordinator should be the primary contact person on international funding proposals.
5. Coordination of continued biomonitoring index development.
6. Chairmanship of the NCC.
7. Active and in-depth involvement with specific provinces experiencing difficult problems to assist in regional implementation.
8. Ensuring a smooth changeover to a new national coordinator (for example, in the case of resignation).

The national coordinator should be appointed by and report to the NCC.

4.10.4 NCC Composition

The NCC should comprise the portfolios in the adjacent table. <u>This assumes that a national coordinator is appointed</u> who has the executive capacity for tasks such as coordination of funding, quality control and training. Until this time these issues may need to be formally executed by people with appropriate expertise. Indeed, it may be preferable that these people remain on the NCC after the appointment of a national coordinator but then only in an advisory (not executive) capacity.

Table 4.5. Proposed composition of the National Coordination Committee.

Portfolio	NCC-related Tasks
Executive Capacity	
National Coordinator	Chairmanship of NCC and ExCo meetings. Coordination of training, quality control, development and implementation of funding models, index development and execution of *ad hoc* tasks deemed important by the NCC. (*The buck stops here.*)
Secretariate	Minute taking, documentation distribution.
Three Custodians	Represent interests of DEAT, DWAF and WRC. The DEAT and DWAF in particular should focus on the top-down implementation perspective.
Provincial Champions	Bring region-specific information to the twice-yearly NCC meetings to facilitate information-sharing. This could include annual reports on regional successes (and less frequent State of Environment reports) that can be used by other provincial champions to demonstrate results to prospective donors.
Communication Officer	Optimise communication-specific perspectives. Produce the annual reports for provincial champions in a format that is appropriate for demonstrating success to donors in other provinces. Produce regular newsletters. Maintain corporate image. Ensure that all provincial champions are aware of what can be offered in respect of communications.
R&D Officer	Ensure focussed R&D. Annually report on R&D gaps, current activities, prioritise research needs.
Advisory Capacity (*ad hoc*)	
Scientific specialists	Provide specialist input and perspectives in particular research fields to facilitate ongoing focussed R&D. Input will primarily be to the R&D Officer and National Coordinator.
Special members	Representatives from other national programmes with whom mutually beneficial relationships could be formed should provide different perspectives, mechanisms for inter-programme learning and ideas on closer collaboration.

4. THE ROAD AHEAD 4-1
4.1 THE PROBLEMS 4-1
4.2 RHP OBJECTIVES 4-3
4.3 TOP-DOWN AND BOTTOM-UP 4-4
4.4 STATUTORY LEGITIMACY 4-4
4.4 INCREASING THE RELEVANCE OF RHP INFORMATION 4-5
4.5 DEMONSTRATING SUCCESS 4-6
4.6 GENERAL COMMUNICATION 4-6
4.7 DATABASE MANAGEMENT 4-7
4.8 CREATING SUSTAINABLE REGIONAL CAPACITY 4-8
4.8.1 Committed Provincial Champions 4-8
4.8.2 Demonstrating to Regional Concerned Parties 4-8
4.8.3 Training 4-9
4.8.4 Selecting Indices 4-9
4.9 FINANCIAL CONSIDERATIONS 4-10
4.9.1 Overall Provincial Budgets 4-10
4.9.2 Draft Business Plan 4-11
4.9.3 Potential Donors 4-12
4.10 NATIONAL COORDINATION 4-12
4.10.1 Issues facing the National Coordination Committee 4-12
4.10.2 Roles of National Coordination Committee 4-14
4.10.3 A National Coordinator 4-15
4.10.4 NCC Composition 4-16

5. CONTACT PERSONS

Information on details of implementation of the many aspects of biomonitoring are relatively widespread. Furthermore, methods are still changing as they are tested and refined. To facilitate obtaining more detailed information (that was outside the scope of this document) the following table has been compiled. It gives primary contact people as well as references to the most relevant publications. Contact Manyaka, Greyling and Meiring (the River Health Programme Communication Officers) in Pretoria for the latest telephone numbers, addresses and affiliations.

Keyword	Contact Person	References
Algae	Prof Braam Pieterse	
Bioaccumulation	Prof Hein du Preez	
BioBase (CD Database)	Ms Hellen Dallas	Dallas and Janssens, 1998.
Biomonitoring, International Programmes	Mr Dirk Roux	Uys *et al.*, 1996
Catchment Management Agency		Gorgens *et al.*, 1998; National Water Act, No 36 of 1998.
Database Management	Ms Hellen Dallas	
Ecotoxicology	Ms Sebastian Jooste	
Fish Assemblage Integrity Index (FAII)	Dr Neels Kleynhans	Kleynhans, 1999.
Fish Health Assessment Index (FHAI)	Ms Valerie Kilian	
Funding models	Dr Patsy Scherman	RHP Concept Proposal, 1999.
Geomorphology Index (GI)	Prof Kate Rowntree	Rowntree and Ziervogel, 1999; Rowntree and Wadeson, 1999.
Habitat Assessment Matrix (HAM)		Roux *et al.*, 1994, Uys *et al.*, 1996
Hydraulic Biotope Diversity Index (HBDI)	Dr Roy Wadeson	Wadeson RA and KM Rowntree, 1999; Rowntree KM and RA Wadeson, 1996.
Index of Habitat Integrity (IHI)	Dr Neels Kleynhans	Kleynhans, 1996; Uys *et al.*, 1996
Invertebrates	See South African Scoring System (SASS4)	
Reference Sites	Ms Hellan Dallas	Dallas and Fowler, 1999.
Riparian Vegetation Index (RVI)	Mr Nigel Kemper	
River Health Programme	Mr Dirk Roux	Hohls, 1996; Brown *et al.*, 1996; Eekhout *et al.*, 1996; Uys *et al.*, 1996; DWAF, 1996; Roux, 1997; Rowntree and Ziervogel, 1999.
South African Scoring System (SASS4)	Dr Mark Chutter	Chutter, 1998; McMillan, 1998; Dallas, 1997; Dickens, 1998b; Thirion et al., 1995;

Training (Overview)	Dr Steve Mitchell	
Water Quality Index (WQI)		Moore, 1990; Uys *et al.*, 1996
Zooplankton	Ms Christa Thirion	

5. CONTACT PERSONS 5-1

6. REFERENCES

Brown CA, S Eekhout and JM King, 1996. *National Biomonitoring Programme for Riverine Ecosystems: Proceedings of Spatial Framework Workshop.* NBP Report Series No. 2. Institute for Water Quality Studies, Department of Water Affairs and Forestry, Pretoria, South Africa.

Dallas H, 1997. *A Preliminary Evaluation of Aspects of SASS (South African Scoring System) for the Rapid Bioassessment of Water Quality in Rivers, with Particular Reference to the Incorporation of SASS in a National Biomonitoring Programme.* Sth. Afr. J. Aquat. Sci., 23(1), 79-94.

Dallas H and J Fowler, 1999. *Delineation of River Types of Mpumalanga, South Africa: Establishing a spatial Framework for Selection of Reference Sites.* Working Document. Southern Waters Ecological Research and Consulting CC, Cape Town.

Dallas HF and MP Janssens, 1998. *The Biological and Chemical Database: A User's Manual.* Water Research Commission Report TT 100/98.

Dallas HF, MP Janssens and JA Day, 1999. *An Aquatic Macroinvertebrate and Chemical Database for Riverine Ecosystems.* Water SA, 25(1), 1-8.

Dickens C, 1998a. *River Health Programme - Business Plan.*

Dickens C, 1998b. *Macro-invertebrate Identification Guides.* WRC project. In progress.

DEAT, 1998. *White Paper on Environmental Management for South Africa.* Government Gazette, Vol. 395, No. 18894.

DWAF, 1996. *National Biomonitoring Programme for Riverine Ecosystems: Proceedings of Consultation Planning Meeting.* NBP Report Series No. 5. Institute for Water Quality Studies, Department of Water Affairs and Forestry, Pretoria, South Africa.

Eekhout S, CA Brown and JM King, 1996. *National Biomonitoring Programme for Riverine Ecosystems: Technical Considerations and Protocol for the Selection of reference and Monitoring Sites.* NBP Report Series No. 3. Institute for Water Quality Studies, Department of Water Affairs and Forestry, Pretoria, South Africa.

Gorgens A, G Pegram, M Uys, A Grobicki, L Loots, A Tanner, Bengu, 1998. *Guidelines for catchment management to achieve integrated water resources management in South Africa.* Water Research Commission Report No. KV 108/98.

Hohls DR, 1996. *National Biomonitoring Programme for Riverine Ecosystems: Framework document for the programme.* NBP Report Series No. 1. Institute for Water Quality Studies, Department of Water Affairs and Forestry, Pretoria, South Africa.

Karr, JR, 1996. *Ecological Integrity and Ecological Health are not the same.* In: C Schulze (ed.) Engineering within ecological constraints. National Academy Press, Washington DC.

Karr JR and Chu W, 1997. *Biological Monitoring and Assessment: Using Multimetric Indexes Effectively.* EPA 235-P97-001. University of Washington, Seattle.

Kleynhans CJ, 1996. *A Qualitative Procedure for the Assessment of the Habitat Integrity Status of the Luvuvhu River (Limpopo system, South Africa).* J. Aquat. Ecosystem Health, 5, 1-14

Kleynhans CJ, 1999. *The Development of a Fish Index to Assess the Biological Integrity of South African Rivers.* Water SA (in press).

ManyakaGreyling JV, 1998. *River Health Programme. National Aquatic Ecosystem Biomonitoring Programme. Communication Manual.* First Draft.

McMillan PH, 1998. *An Integrated Habitat Assessment System (IHAS v2), for the Rapid Biological Assessment of Rivers and Streams.* A CSIR research project, number ENV-P-I 98132 for the Water Resources Management Programme, CSIR. Ii + 44pp.

Moore CA, 1990. *Classification Systems and Indices for Reporting and Determining the Effect of Management on Water Quality in South African Waterbodies.* Summary Report. CSIR Division of Water Technology, 21pp.

Palmer RW, 1999. *Discussion Document: Procedures to Ensure Quality Control and Assurance in the River Health Programme.* AfriDev Consultants.

Ramm, AE, 1988. *The Community Degradation Index: A New Method for Assessing the Deterioration of Aquatic Habitats.* Water Research 22: 293-301.

RHP Concept Proposal, 1999. *The South African River Health Programme: Biomonitoring of South African rivers into the 21st century ... with your assistance.*

Roux D, 1997. *National Aquatic Ecosystem Biomonitoring Programme: Overview of the Design Process and Guidelines for Implementation.* NAEBP Report Series No. 6. Institute for Water Quality Studies, Department of Water Affairs and Forestry, Pretoria, South Africa.

Roux D, 1998. *The National River health Programme as a Tool in Effective Water Resource Management.* Annual conference of the South African Affiliate of the International Association for Impact Assessment - Innovative Tools and Methods. Sep 30 to Oct 2, 1998.

Roux D, 1999. *Strategies use to Guide the Design, Growth and Anchoring of a National River Monitoring Programme in South Africa.* (In preparation).

Roux D, CJ Kleynhans, C Thirion, L Hill, JS Engelbrecht, AR Deacon and NP Kemper, 1999. *A Procedure for the Adaptive Assessment and Management of the Ecological State of Riverine Ecosystems, with an Example of the Crocodile and Elands Rivers, Mpumalanga, South Africa.*

Manuscript in preparation.

Roux D, C Thirion, M Smidt and MJ Everett, 1994. *A Procedure for Assessing Biotic Integrity in Rivers - Application to Three River Systems Flowing Through the Kruger National Park, South Africa*. Report Number N 0000/00/REQ/0894, IWQS, DWAF.

Rowntree, KM and RA Wadeson, 1999. *A Hierarchical Framework for Categorising the Geomorphology of Selected River Systems.* Water Research Commission Report.

Rowntree KM and RA Wadeson, 1996. *Translating channel morphology into hydraulic habitat: application of the hydraulic biotope concept to an assessment of discharge related habitat changes*. Proceedings 2nd IAHR International Symposium on Hydraulic and Habitats, Quebec City, June 11 - 14, 1996.

Rowntree, KM and G Ziervogel, 1999. *National Aquatic Ecosystem Biomonitoring Programme: Development of an Index of Stream Geomorphology for the Assessment of River Health.* NAEBP Report Series No 7. Institute for Water Quality Studies, Department of Water Affairs and Forestry, Pretoria, South Africa.

Stair RM, 1992. *Principles of Information Systems: A Managerial Approach.* Boyd & Fraser Publishing Company, Boston.

Steele LW, 1989. *Managing Technology - The Strategic View.* McGraw-Hill Book Company, New York.

Uys M, 1998. *Biomonitoring and Assessment of Rivers as a Basis for Water Management. Legal and Institutional Aspects. Report II: Institutional Restructuring of Water Resources Management Mechanisms towards Integrated and Sustainable Resources Management. Part I: Institutional Water Law Mechanisms and River Health.*

Uys M, 1999. *Biomonitoring and Assessment of Rivers as a Basis for Water Management. Legal and Institutional Aspects. Report II: Institutional Restructuring of Water Resources Management Mechanisms towards Integrated and Sustainable Resources Management. Part I: Institutional Environmental Law Mechanisms and River Health.* (In preparation.)

Uys MC, P-A Goetsch and JH O'Keeffe, 1996. *National Biomonitoring Programme for Riverine Ecosystems: Ecological indicators, a review and recommendations.* NBP Report Series No. 4. Institute for Water Quality Studies, Department of Water Affairs and Forestry, Pretoria, South Africa.

Walmsley J and D Louw, 1997. *National Aquatic Ecosystems Biomonitoring Programme. Funding Guide.*

WRC, 1998. *Second Progress Report on Development of Procedures for Regional Implementation and Maintenance of the National RHP - the Mpumalanga State of The Rivers Project.* K5/850. Overview Document.

6. REFERENCES 6-1