STATUS REPORT ON THE KRUGER NATIONAL PARK RIVERS RESEARCH PROGRAMME:

A SYNTHESIS OF RESULTS AND ASSESSMENT OF PROGRESS TO JANUARY 1996

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Report to the Water Research Commission on behalf of

the Kruger National Park River Research Programme

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EXECUTIVE SUMMARY

In August 1995, the Programme Development and Management Committee of the Kruger National Park Rivers Research Programme (KNPRRP) recommended to the Water Research Commission (WRC) that an information synthesis and status report of the Programme be undertaken. The main purpose of the report is to inform all the interested parties (including researchers, managers, and funding agencies) of the achievements and capabilities of the Programme; to assess these in relation to the stated goals and tasks of the "Second Phase: Programme description"; and to identify gaps and priorities for further work.

The structure of the Programme is based on a decision support system which is summarised in figure 1. From this it can be seen that the research and information gathering has been carefully targeted to provide essential information to assist in management decision making.

The aims of this report are as follows:

A. To examine and summarise the information collected within the Programme to date.
B. To relate the resulting synthesis to the objectives of the KNPRRP.
C. To draw conclusions as to how far the objectives of the first phase have been met.
D. To make recommendations of outstanding priority objectives that need to be addressed in the future.
E. To assess how far the information collected within the Programme can contribute to the setting of interim instream flow requirements at the Instream Flow Requirements workshop on the Sabie River, planned for 1996.

The synthesis is primarily based on the KNPRRP Data Catalogue (Biggs *et al*, 1995), which is the most comprehensive reference work for the rivers of the Kruger National Park. The data catalogue includes references for all the projects that have contributed to the knowledge, information and methods required to achieve the goals of the KNPRRP, including those which were begun before the Programme started, or those which were developed outside the Programme. We acknowledge the very important contributions which projects outside the Programme have made to an understanding of the rivers of the KNPRRP, and this synthesis is in no way an attempt to take credit for work that has not been done within the Programme.

The purpose of the synthesis is to allow members of the programme and stake-holders to see clearly what work has been done and how it relates to the aims of the programme. The synthesis does not aim to summarise in detail the information that has been gathered on the rivers of the KNP, but indicates what work has been done, at what level of detail, and how far the aims of the programme have been achieved.

The main part of the report (sections 2.2.1 to 2.2.30) is organised as short reviews of each component of the Programme (headings are listed on the contents page), each one organised under the following sub-headings: Purpose; Tasks; Progress; Evaluation; List of main products; Other relevant documents and datasets.

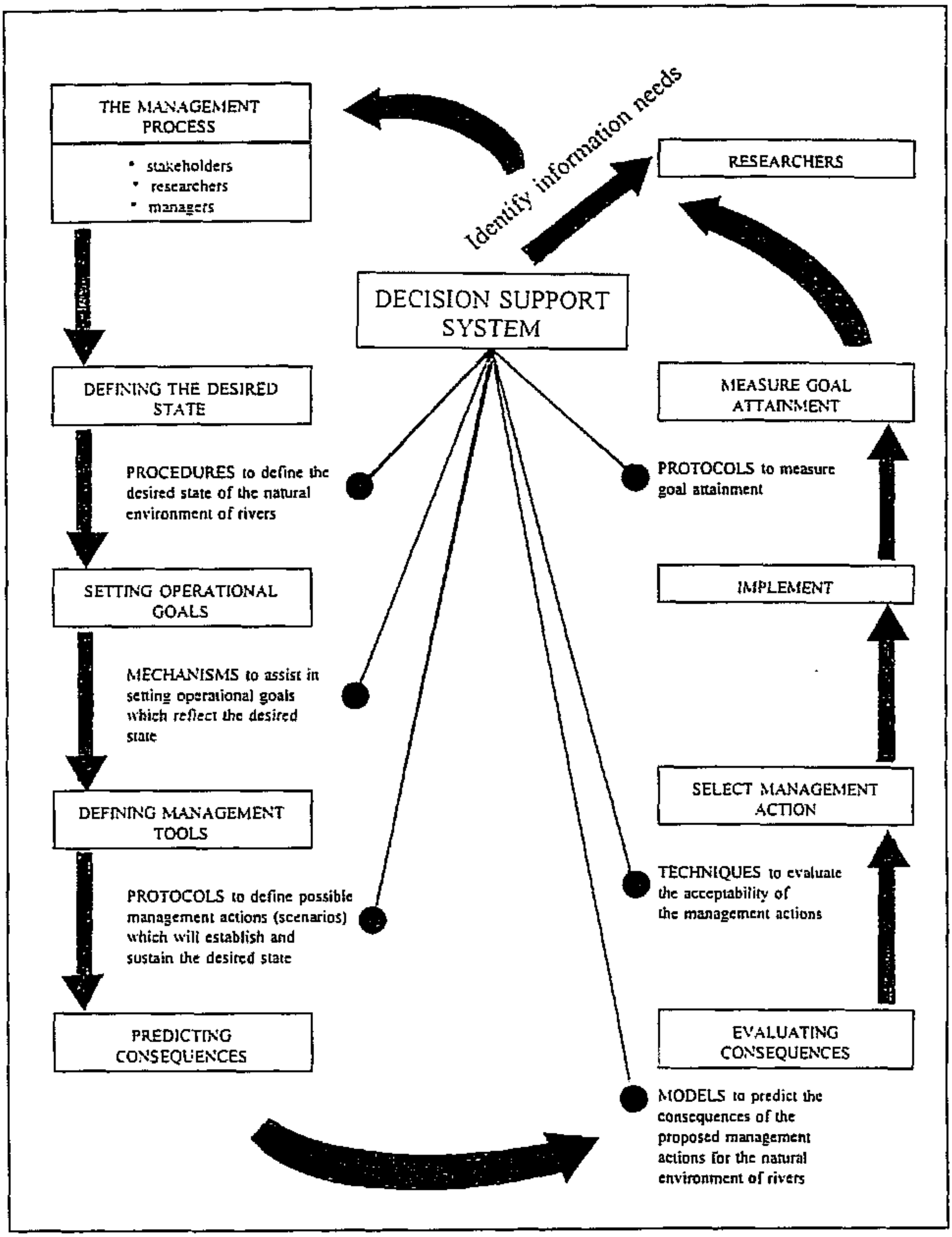

Figure 1. Elements of the Decision Support System and their relationship to the management process. (From the Second Phase Programme Description).

CONCLUSIONS AND RECOMMENDATIONS

The final section of the report summarises the achievements of the programme in relation to its goals and tasks, lists the main products and expertise that has emerged, and identifies the remaining gaps and priorities for further work.

3.1 ACHIEVEMENTS IN RELATION TO THE SUBSIDIARY GOALS OF THE PROGRAMME

Each of the subsidiary goals is quoted below, and a brief summary of the Programme's achievements is appended:

a. To develop, refine and maintain Decision Support systems (DSS) for responding to information needs.
   The DSS has been developed, and is a dynamic process which continues to guide and refine the activities of the Programme. Modelling components are still being developed.

b. To establish an interdisciplinary team with common principles, goals and commitment to design, guide and evaluate the programme thereby ensuring it achieves its primary goals.
   The Programme team has become a close-knit and effective unit, and has developed considerable inter-disciplinary skills.

c. To develop the understanding of the functioning of the natural environment of rivers required for predicting their responses to changing conditions.
   The current project to link abiotic and biotic models of the river functioning will be a major contribution to our understanding and predictive ability.

d. Develop methods for assessing the asset value of the natural environment of rivers and for evaluating the acceptability of predicted changes in asset value.
   This is an area in which the Programme has not yet made significant progress, and should be a focus of further effort.

e. Implement and manage a cost-effective research programme.
   By linking with other research outside the Programme's direct funding, a great deal of knowledge and information has been gained from a relatively modest research budget. This has sometimes meant that the research sequence and focus have not exactly followed the Programme plan.

f. Adapt the methodologies developed for management of the natural environment of rivers for application to rivers elsewhere.
   There has yet to be a concerted effort to extrapolate from the Kruger national Park (KNP) rivers (and the Sabie River in particular) to other rivers in the country, but the partnership between the Instream Flow Requirements (IFR) process and the Programme, which will culminate later in 1996 in the Sabie River IFR workshop, will be a major contribution to this goal.

Figure 2, based on the design of the DSS in the second phase Programme description (Breen *et al*, 1994) summarises the progress that has so far been made towards achieving the main tasks of the Programme.

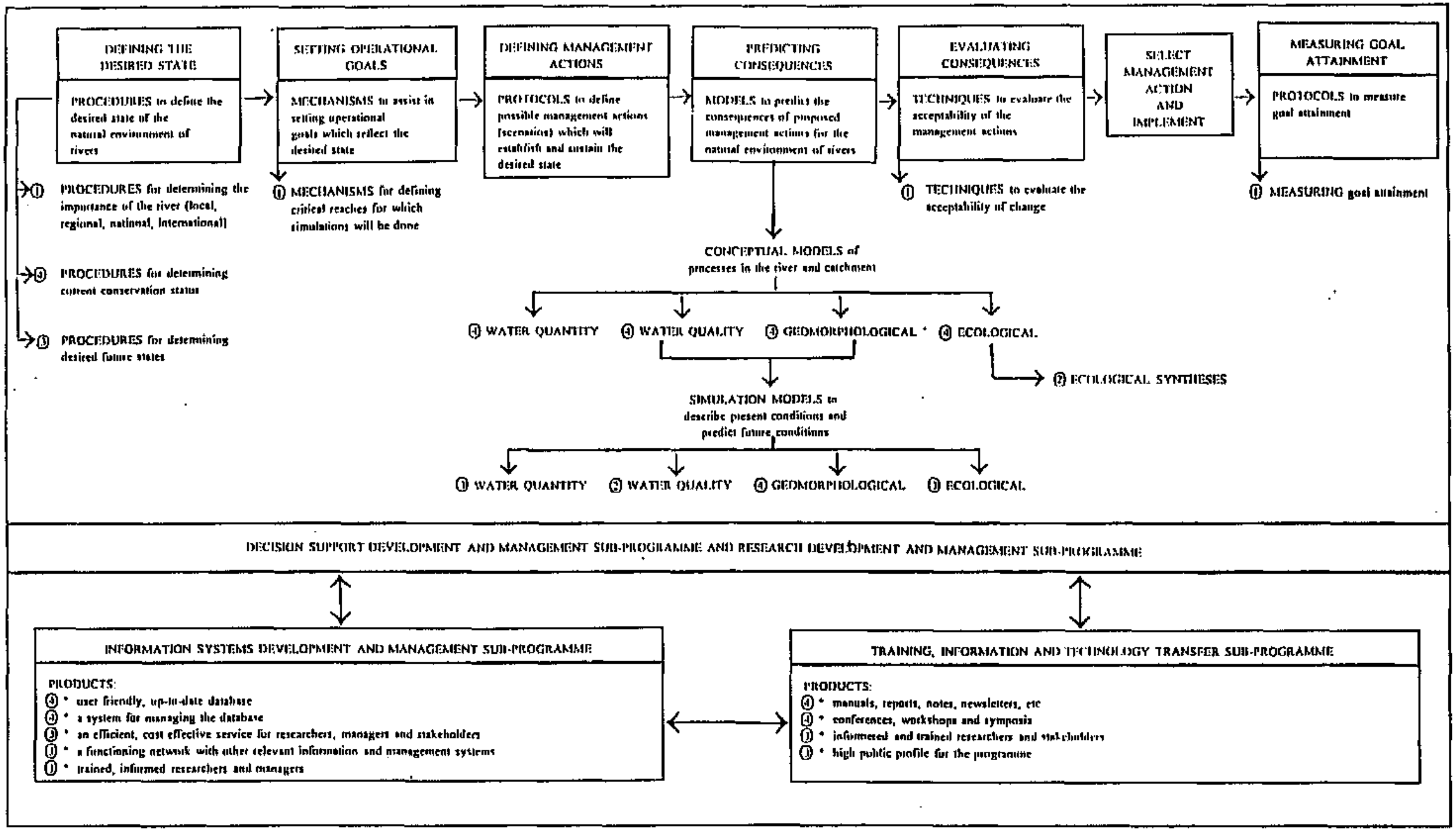

Figure 2: Planned elements of the decision support system (from the second phase: Programme Description), summarising the progress that has been made to date. Numbers beside each element indicate the following:
1 = not done; 2 = some work done; 3 = work in progress; 4 = substantial work completed

3.3 CAPABILITIES OF THE PROGRAMME BY THE END OF PHASE 2 (DECEMBER 1996)

This section summarises the products and expertise that has been, or will have been developed by the end of the current phase. These achievements are once again expressed in relation to the specific goals and tasks of the Programme, but should also be seen in the context of the main holistic achievement of the Programme: The development of a multi-disciplinary, multi-institutional research management team which has made a substantial contribution to the understanding of fundamental environmental processes in rivers.

- Existing information on the rivers of the KNP has been collated and can now be accessed by all potential users.
- A decision support system has been developed which can provide users with an information pathway to assist in management decisions, or in explaining and motivating environmental water use.
- The desired state, or goals, for KNP rivers will be clearly defined in terms that can be implemented.
- Catchment studies have been completed for all the main rivers, describing land-use, present development of water use, probable future demand, and possible scenarios for supply.
- Detailed inventories and the status of the following components of the Sabie River are available:
  - Riparian vegetation
  - Fish
  - Invertebrates
  - Large aquatic animals
  - Geomorphological units/sediment transport
  - Water quality
  - Hydrology
  - Hydraulics
- A predictive capability will be available to link the effects of changing flows on all of the above, at differing levels of resolution.
- First estimates of environmental water requirements for all the major rivers are available.
- There will be a refined assessment of the environmental flow requirements of the Sabie River, with motivations, following the Sabie IFR workshop in September 1996.

3.4 PRIORITIES FOR FURTHER WORK

Because of the inevitable constraints of finances and resources, the Programme has concentrated on a small number of key projects, the synthesis of existing information, and the development of a coherent research management framework, rather than attempting all the tasks that are necessary for the comprehensive achievement of the goals. There has also been a reliance on research and monitoring activities funded and motivated outside the Programme, to augment the internal activities. For these reasons, there are still considerable gaps in the structure of the DSS, which need to be filled to maximise its potential as a toolbox for river managers. These are summarised briefly below:

- Although the information base and understanding of the Sabie River is probably the most comprehensive for any South african river, no structured research programme has yet been applied to the other KNP rivers. Valuable research has been done on other rivers (eg water quality in the Olifants River), but is mostly individual projects carried out for specific purposes. One of the results is that it is difficult to assess how far the information and knowledge on the Sabie can be extrapolated to other rivers.

- Even the research on the Sabie has mostly been confined to reaches within the KNP. This has been to avoid, as far as possible, the confounding variables of anthropogenic disturbance, but means that there is much less environmental information available for the upper and middle reaches of the river, than for the lower reaches in the Park.
- No work has yet been done on the macro links between the riverine systems and the adjacent terrestrial ecosystems. The dependence of most of the larger animals on the rivers is obvious, but needs to be quantified and made explicit, as part of the motivation for the maintenance of the rivers as major resources for the Park as a whole.
- Most of the work of the Programme has concentrated on the natural environments of the KNP rivers, since this was the original terms of reference. However, it has become increasingly important to assess the direct use of the rivers by the local people, and to direct research and management to the long-term maintenance of the natural resource values of the rivers. (Direct use includes all activities involving contact with the river and riparian zone, including fishing, water collection, laundry, recreation, reed-cutting etc; but excluding pumped extraction or storage for domestic, industrial or irrigation use)
- The Programme has concentrated more on water quantity requirements than on water quality. This has largely been a consequence of the Sabie focus of the Programme, where reduced flows are presently a greater threat than impacts on water quality. However, there are major water quality problems in the Olifants and Crocodile Rivers in particular. At present only rudimentary methods for the assessment of environmental water quality requirements are available, and methods similar to those for IFR assessment are necessary.
- Very little work has been done to quantify the value of maintaining the rivers in a good environmental state. This resource economics approach will become a vital part of the motivation for the conservation of rivers, and the obvious value of the KNP rivers in sustaining the Kruger National Park as the country's leading tourist destination has yet to be assessed.
- The implementation of the findings and products of the Programme is perhaps the major priority for further work. The main project for 1996 is the integration of biotic and abiotic knowledge of the Programme into models that will predict the effects of changing flow regimes. Once this has been completed, the Programme will have a suite of powerful management tools for assessing environmental impacts on rivers, and for recommending future management. The implementation of these tools will require that they be understood and supported by a variety of water users, researchers, and managers.

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1. INTRODUCTION AND TERMS OF REFERENCE

The Kruger National Park Rivers Research Programme (KNPRRP) grew out of initiatives taken during 1987 to start to define the environmental water requirements of the rivers which run through the KNP. The first phase of the programme had broad goals relating to environmental water requirements, but was unstructured in detail. It was not until 1994 that the second phase was initiated. This second phase entailed a much more structured framework than the first, with a formal decision support system providing a framework, defining specific aims, goals and tasks. The plan for the second phase is detailed in "A description of the Kruger National Park Rivers Research Programme (Second Phase)" by Breen, Quinn, and Deacon (1994). The second phase of the Programme is due to end at the end of 1996.

1.1 STRUCTURE OF THE KNPRRP

The second phase description of the Programme describes it as: A cooperative, interdisciplinary endeavour. It is directed at contributing to the conservation of the natural environment of rivers through developing skills and methodologies required to predict the response of the systems to natural and anthropogenic factors affecting water supply (quantity and quality); skills and methodologies required to establish the social acceptability of predicted changes; and through directed research, to develop the understanding of the ecological functioning of these systems required to improve the quality of prediction and advice to resource-use managers, researchers and stakeholders. Figure 1 portrays the elements of a decision support system (DSS) which is at the centre of the Programme. The DSS provides a framework for the identification of research priorities, and directs the activities of the Programme towards its goals (listed in Appendix 1).

1.2 AIMS OF THIS REPORT

The main purpose of this synthesis report is to inform all parties involved (members of the programme, stake-holders and other interested parties) about the products of the programme and how far these have met the aims of the programme. It indicates the work that has been done and relates the resulting synthesis to the objectives/aims of the programme. The synthesis largely ignores the distinction between the first and second phases of the programme, and relates all the work that has been done to the goals and aims of the second phase.

The aims of this report are as follows:

A. To examine and summarise the information collected within the Programme to date.

B. To relate the resulting synthesis to the objectives of the KNPRRP.

C. To draw conclusions as to how far the objectives of the first phase have been met.

D. To make recommendations of outstanding priority objectives that need to be addressed in the future.

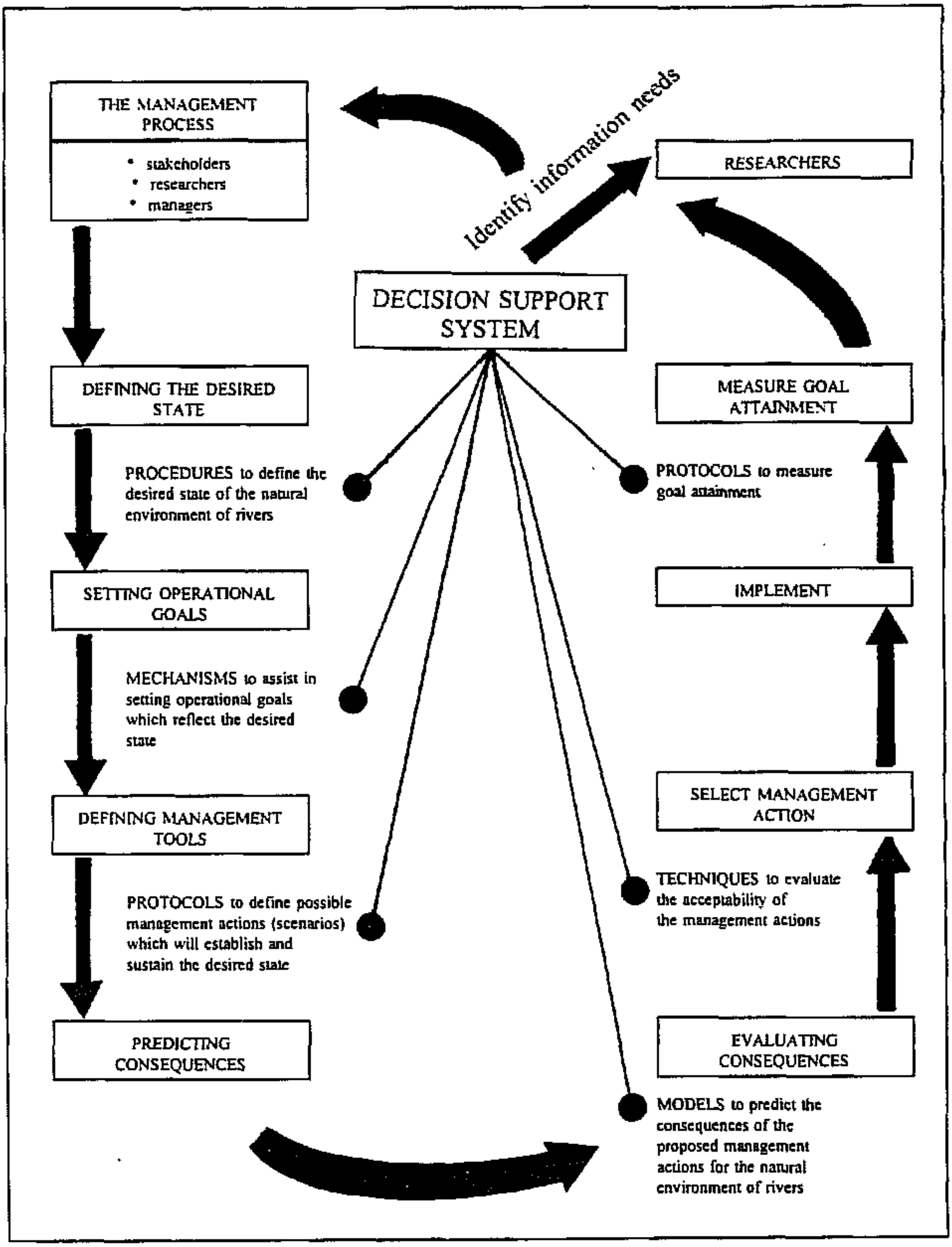

Figure 1. Elements of the Decision Support System and their relationship to the management process. (From the Second Phase Programme Description).

E. To assess how far the information collected within the Programme can contribute to the setting of interim instream flow requirements at the IFR workshop on the Sabie River, planned for 1996.

The KNPRRP was designed at a time when a great deal of river research was already in progress, both on the rivers of the KNP and on rivers in other parts of the country. The Programme has initiated and promoted many projects, has provided a framework for others, has integrated many outside projects into its objectives, and has used the results and advances of others to strengthen and direct its own activities. This synthesis includes all the projects that have contributed to the knowledge, information and methods required to achieve the goals of the KNPRRP, including those which were begun before the Programme started, or those which were developed outside the Programme. We acknowledge the very important contributions which projects outside the Programme have made to an understanding of the rivers of the KNPRRP, and this synthesis is in no way an attempt to take credit for work that has not been done within the Programme. For example, the development of methods for assessing conservation status; some of the water quality data; much of the early ecological data; and the Instream Flow Requirement workshops were all developed/collected outside the Programme. The catchment studies were completed before the Programme was devised. However, all of these databases and methods have been used to augment the efforts of the Programme, and it would not be meaningful to assess our progress towards an understanding of the KNP rivers without reference to them.

The synthesis is not intended to be a justification or a critique of the Programme, but is intended to assess how far the goals and aims of the Programme have been and are being achieved, by advances in knowledge and increases in information from all sources.

2. SYNTHESIS

2.1 PURPOSE AND LEVEL OF DETAIL.

The purpose of the synthesis is to allow members of the programme and stake-holders to see clearly what work has been done and how it relates to the aims of the programme. The synthesis does not aim to summarise in detail the information that has been gathered on the rivers of the KNP, but will indicate what work has been done, at what level of detail, and how far the aims of the programme have been achieved. For example, the report does not list all the fish species in the Sabie River, but does point out that there is adequate information on their present distribution, and where this information is to be found.

2.2 STRUCTURE OF THE SYNTHESIS.

In planning the report, we have tried to organise the information under headings which would make most sense to users and provide a logical progression through the different elements of the programme. We have used mainly figure 1B on page 63 of the KNPRRP second phase programme description (Breen *et al*, 1994) to identify the different sections of the synthesis, since this figure is probably the most concise listing of the elements of the Decision Support System and therefore of the framework of the programme as a whole.

The sub-sections of the report are as follows:

Desired state
Conservation status
Conservation importance
Representative reaches
Models/methods/results for:
    Environmental water quantity) assessments
    Environmental water quality) of
    Geomorphology and sediment transport
    Riparian vegetation and changes
    Habitat changes
    Temperature changes
    Water quality
    Hydraulics
    Hydrology
    Bank Storage Dynamics (Groundwater)
    Ecology
    Fish
    Invertebrates
    Aquatic plants
    Large aquatic vertebrates
Classification
Social use and dependence
Resource economics
Information syntheses

Decision support system
Catchment studies
Technology transfer
Environmental management
Measuring goal attainment (acceptability)
Monitoring
Legislation

For each of these sections, the structure of the report is as follows:

Purpose:
What is it ?
What is it for ?

Tasks:
What tasks were defined by the programme plan ?

These tasks have generally been taken from the KNPRRP Second Phase: Programme Description (Breen *et al*, 1994), but in some cases the tasks have been modified by the Programme managers since the publication of Breen *et al* (1994).

Progress:
What has been done ?

Evaluation:
How far have the aims been achieved ?
What still needs to be done ?

List of main products:
Author, date and title of all main documents/datasets associated with the section. Reference numbers given at the end of each product (eg MAN-DOC-053) are the keys to the KNPRRP Data Catalogue which is available as a hard copy or computer disc.

Other relevant documents and datasets:
A list of reference numbers of all other associated documents/datasets in the KNPRRP Data Catalogue (Biggs *et al*, 1995) is also given.

2.2.1 Desired state

Purpose:

The "desired state" of a river defines the management objectives and goals for that river/stretch of river, in terms of its user requirements. This should ideally be defined with reference to all the different users of the river, and may range from the maintenance of a completely unmodified natural river, to the maintenance of its present modified state, or even in extreme cases to the rehabilitation of a canalised river in order to reconstitute some of its natural processes and biota.

In the case of the reaches of river within the KNP the need to maintain natural biodiversity will of course be paramount. The need to set goals for the conservation of the rivers in terms that are definable and achievable in management terms is a basic requirement of the programme. Without such a desired state it is impossible to know whether the rivers are in an acceptable state, and what management actions are necessary to achieve an acceptable state. The objectives and goals for river conservation collectively define the "desired state".

Tasks:

To develop protocols for developing acceptable, achievable and auditable goals for river conservation.

Progress:

Although there have been attempts to set desired states for most of the rivers of the KNP, both by Parks Board officials (see refs. below) and in IFR workshops, the protocol has not yet been fully developed. A project is presently under way to develop a method for defining the desired state of river reaches within the KNP, in terms that can be measured and achieved by managers.

The project leader is Prof. Kevin Rogers at the Centre for Water in the Environment, University of the Witwatersrand.

Evaluation:

At present the desired state for any river is being set by small groups of experts who may not be fully representative. There is a need to develop a method which will include the wishes and goals of all the stake-holders. The current project is in its early stages, but will provide a method for the rivers within the KNP. Because of the more extensive requirements, further development will be necessary before the method can be applied outside the KNP. The project will also make recommendations on how the methods can be applied to river systems in general.

This component has therefore only partly been achieved, but further work is in progress, and it will be substantially achieved by the end of phase two.

List of main products:

The Letaba River in the KNP: Management objectives of the NPB and general overview of impacts on the river. (1994) Venter F J and Deacon A R : MAN-DOC-053

The Luvuvhu River in the KNP: Management objectives of the NPB and general overview of impacts on the river. (1994) Venter F J and Deacon A R : MAN-DOC-055

Management objectives of the NPB regarding water quality requirements of rivers in the KNP. (1990) Venter F J and Deacon A R : MAN-DOC-054

Other relevant documents and datasets:
MAN-DOC-007; CON-DOC-016; BIORIP-DOC-012; WQ -DOC-039; WQ-DOC-050; HDR-DOC-013; HDR-DOC-018; HDR-DOC-022; HDR-DOC-102

2.2.2 Conservation status

Purpose:

The conservation status (equivalent to the biological or ecological integrity) describes the present state of a river or part of a river, in relation to its natural state. It is therefore a measure of the extent to which the river has been modified from its natural state. There are various indices which can be used to describe the conservation status, and these serve as a baseline assessment of present state, against which to judge what needs to be done to achieve the desired state (see section 2.2.1)

Tasks:

To inform the integrated environmental management (IEM) process and relevant environmental impact process (Afrikaans acronym: ROIP) through developing protocols for determining the conservation importance and status of rivers.

Progress:

There are a number of existing methods which can be used for the assessment of conservation status. These include methods developed by Dr Neels Kleynhans of the Institute for Water Quality Studies and Nigel Kemper of Ninham Shand (for riparian vegetation), as well as a more detailed expert system-based method (the River Conservation System RCS) developed by Prof Jay O'Keeffe of Rhodes University. The former two methods were developed for use in IFR assessments, and have been used to evaluate the Luvuvhu, Letaba, and Olifants Rivers.

Evaluation:

The existing methods, developed outside the KNPRRP, are suitable for the assessment of any river in the KNP, at different levels of detail. They have yet to be applied to the Sabie and Crocodile Rivers, or to any of the minor rivers of the KNP. It will always be possible to improve the existing methods, but they are adequate to provide consistent usable measures at present.

This component has there been achieved in terms of method development, but requires further implementation.

List of main products:

Letaba Instream Flow Requirements: An assessment of the conservation status of the Great Letaba River and selected tributaries. (1994) Kleynhans C J and Engelbrecht J S : CON-DOC-002

Other relevant documents and datasets:
INF-DOC-022; INF-DOC-025; INF-DOC-016; BIORIP-DOC-012; CON-DOC-001; CON-DOC-005; CON-DOC-006; CON-DOC-007; CON-DOC-008; CON-DOC-009; CON-DOC-010; CON-DOC-011; CON-DOC-012; CON-DOC-014; CON-DOC-015; MAN-DOC-008; WQ -DOC-039

2.2.3 Conservation importance

Purpose:

The conservation importance of a river/part of a river expresses its priority relative to other rivers. Because resources are always limited, decisions have to be taken as to where the greatest investment of conservation resources should be made. All the KNP rivers have a high conservation importance, but there may be a necessity to prioritise one or more over the others for management purposes. An assessment of conservation importance should provide the basis for deciding how much of the available resources should be allocated to transforming a river from its present state (defined by its conservation status) to its desired state (see sections 2.2.1 and 2.2.2) and to maintaining it there. Aspects that should be included in an assessment of conservation importance: Nature conservation (rarity, diversity, endemism, representativeness etc.); socio-economic importance; cultural and historic importance.

Tasks:

To inform IEM and ROIP processes through developing protocols for determining the conservation importance and status of rivers.

Progress:

There have been implicit attempts (eg for the Letaba River) to assess the conservation importance of the KNP rivers, but there has been no formal development of a protocol for the assessment of conservation importance within the programme. Jake Alletson, of Natal Parks Board, has developed a method for use in IFR workshops, but this is at present confined to aspects of nature conservation.

Evaluation:

This component of the programme has yet to be achieved. To date the sequence of the programme has not been disrupted by the lack of a formal protocol, although it would have been useful for IFR evaluations. In the near future, our ability to implement the recommendations of the programme may be prejudiced if we cannot make a convincing case for the relative importance of individual rivers.

List of main products:

Conservation and management of the rivers of the Kruger National Park: suggested methods for calculating instream flow needs. (1991) O'Keeffe J H and Davies B R : CON-DOC-013

Other relevant documents and datasets:
MAN-DOC-006; MAN-DOC-017; CON-DOC-004; CON-DOC-010; CON-DOC-011; BIOTHER-DOC-004; BIOTHER-DOC-005; INF-DOC-041; WQ -DOC-005

2.2.4 Representative reaches

Purpose:

Whole river studies to evaluate water quantity and quality requirements are impractical due to the high demands placed on finances and manpower. River systems display high physical variability, both temporally and spatially as a result of the high variability in catchment control variables (flow magnitude and variability, sediment input and transport). It is therefore necessary to subdivide study rivers into smaller more manageable units termed representative reaches which may be regarded as representative of other similar units which recur throughout the length of the river or may be unique. Studies of physical and biological processes may then be concentrated on these reaches in order to assess water quantity and quality requirements. This project adopts an evaluation method based on fluvial geomorphology and the identification of local geomorphological units.

Tasks:

To develop a methodology for defining representative reaches on the Sabie River where physical; chemical and biological processes can be monitored and modelled which can be extended to similar reaches along the river to generate an overall picture of the entire system.

Progress:

Initially a qualitative procedure for representative reach identification was developed. This methodology was refined and tested using Geographical Information System (GIS) spatial analysis and clustering procedures. This allowed five reaches to be selected on the Sabie River for detailed hydrodynamic monitoring to develop local physical change models. Vegetative links have been established at the level of morphological unit for each of the representative reaches. Ongoing modelling of geomorphological change in the representative reaches is being used in collaboration with other studies to assess the response of vegetation and fish communities to a variety of flow scenarios.

Evaluation:

A geomorphological approach has proved extremely useful for understanding the spatial complexity of the Sabie River and this methodology may be easily applied to other river systems. Links between the geomorphology and vegetation have been established and current research indicates that it will be possible to establish links between the geomorphology and fish communities. Through this approach it should finally be possible to establish biological responses to geomorphological changes which are in turn influenced by changes in flow regime and sediment input. Predictions of geomorphological change on the Sabie River at the representative reach scale is possible through the findings of the study on "Geomorphological Change in the Sabie and Letaba River Systems in Response to Changing Flow Regime" (eg GEO-DOC-009). The representative reach study provides the potential for linking change in flow and sediment regime to ecological changes through predictions of geomorphological change.

A separate, but equally important concept of "critical reaches", has not yet been addressed. Critical reaches are normally defined in terms of the biota, and are those reaches which act as essential refuges for biota, particularly in stressful times such as droughts, or those reaches which provide specialised habitat for rare or endemic species. The maintenance of suitable conditions in critical reaches is therefore essential for conserving the biodiversity of any river.

List of main products:

River Classification for Management: The geomorphology of the Sabie River in the eastern Transvaal. South African Geographical Journal, 1995, 77(2), 68-76 Van Niekerk A W, Heritage G L and Moon B P : MAN-DOC-024

Letaba Instream Flow Requirements: Geomorphological characteristics of the Letaba River and the effects of decreased flow on these characteristics. (1994) Heritage G L : GEO-DOC-002

Luvuvhu Instream Flow Requirements: The geomorphology of the Luvuvhu River. (1994) Heritage G L : GEO-DOC-003

Geomorphology of the Sabie River: overview and classification. (1993) Van Niekerk A W and Heritage G L : GEO-DOC-015

Fisiese kenmerke van bereike van die standhoudende riviere in die Nasionale Kruger wildtuin. [Eng.: Physical characteristics of the perennial river reaches in the KNP.] (1991) Venter F J : GEO-DOC-018

Other relevant documents and datasets:
HDR-DOC-148

2.2.5 Assessments of environmental water quantity

Purpose:

This is perhaps the central component of the whole programme, since the main effect of the increasing exploitation of the KNP rivers outside the Park has been and will continue to be a reduction in the flows into the Park. The main information requirement for the KNP is therefore to know how much water is necessary to maintain or achieve the stated conservation goals ("desired state", see section 2.2.2) of their rivers. One of the main goals of the programme is "To develop, test and refine methods for predicting the responses of the natural environments of rivers flowing through the KNP and in southern Africa to changing water quality and patterns of supply". Much of the work of the programme has therefore been aimed directly at the achievement of this goal, or at providing the data, information, and knowledge which will allow such predictions to be made. Once they can be made, we shall be in a position to recommend a flow regime which would maintain the dynamics of the natural environment and biota in the desired state, as long as the management options are available to implement the recommendations. The difficulty of this task is not so much in making the recommendations, but in providing the detailed motivation and confidence limits which will facilitate the implementation of these recommendations in the face of competing demands.

Tasks:

To evaluate the consequences for the natural environment of changes in water quality and quantity.

To predict the responses of the natural environment to changes in water quality and quantity.

Progress:

A number of methods and models have been proposed for the assessment of environmental water quantity requirements (instream flow requirements), and these have been applied to all the main rivers of the Park. The methods that have been tried are the following:

1. The "Skukuza method" (consumptive/non-consumptive water use), which was developed and applied in various forms at the 1987 Skukuza workshop. Assessments were made for all the major rivers of the Park in Bruwer (1991)

2. The Physical Habitat Simulation (PHABSIM) hydraulic model developed in the USA. This model was used to produce a preliminary assessment for the Sabie River by Gore *et al* (1992)

3. The conservation assessment of hydrological scenarios developed by O'Keeffe and Davies in association with Chunnett, Fourie and Partners. Used to assess the requirements of the Sabie River (O'Keeffe and Davies, 1991)

4. The "Building block methodology" of King *et al* (1994), developed as the backbone of the IFR workshops. Workshops have been held for the Luvuvhu, Letaba and Olifants Rivers to date.

All these methods have provided interim assessments of instream flow requirements which can be used to calculate the storage necessary to provide adequate flows. The three methods used for the Sabie River have all provided roughly the same recommended flows, and therefore are likely to prove to be adequate to maintain the conservation goals for the river.

Evaluation:

All these methods are felt to lack the detailed understanding of processes necessary for the confident prediction of the effects of reduced flows in the long term, so that, although they can be used for management purposes in the interim, the results of the more detailed studies of the KNPRRP second phase will provide a better idea of whether they are adequate or need to be revised.

The planned Sabie IFR will provide the opportunity to assess how useful the detailed research on the hydrology, geomorphology, biota, riparian zones etc. of the Sabie has been in improving our predictive capacity for environmental water requirements. In addition, the major programme activity planned for 1996 is to link the detailed studies of physical processes in the Sabie with the results of biological studies, to develop a suite of predictive models which will considerably improve our ability to assess the ecological consequences of changing flows for the Sabie River. The models should be operational by the end of 1996.

List of main products:

Relationships between low flows and the river fauna in the Letaba River. (1993) Chutter F M and Heath R G M : HDR-DOC-007

Water requirements of the Luvuvhu River. (1991) O'Keeffe J H : HDR-DOC-014

Chapter 8. Determination of flow requirements and impact of proposed water resources development on the Crocodile River within the KNP. In: Flow Requirements of KNP rivers. (1991) Bruwer C : INF-DOC-014

Olifants-Sand Instream Flow Requirements. Bruwer C (Custodian) (1993) : INF-DOC-004

Chapter 5. Water requirements of the Letaba and Shingwedzi Rivers. In: Flow Requirements of KNP rivers. (ed Bruwer C). (1991) Chutter M, Ashton P, Walmsley D and Van Schalkwyk A : INF-DOC-005

Chapter 7. Water requirements of the Sabie-Sand River system. In: Flow Requirements of KNP rivers. (ed Bruwer C). (1991) Davies B R : INF-DOC-007

Chapter 4. Water requirements of the Luvuvhu River. In: Flow Requirements of KNP rivers. (ed Bruwer C). (1991) O'Keeffe J H : INF-DOC-009

Chapter 6. Water requirements of the Olifants River. In: Flow Requirements of KNP rivers. (ed Bruwer C). (1991) Rooseboom A : INF-DOC-011

Flow requirements of the KNP rivers. (1991) Bruwer C (Ed) : INF-DOC-014

Managing rivers and their water resources as sustainable ecosystems. The South African Experience. (1995) O'Keeffe J H : MAN-DOC-028

Management of water releases from proposed impoundments on the Sabie and Sand Rivers: ecological consequences for the rivers within the KNP. (1990) O'Keeffe J H and Davies B R : MAN-DOC-029

The allocation of water rights for ecobiotic requirements. Uys M : MAN-DOC-041

Management objectives of the NPB regarding water quality requirements of rivers in the KNP. (1990) Venter F J and Deacon A R : MAN-DOC-054

Other relevant documents and datasets:
HDR-DOC-004; HDR-DOC-018; HDR-DOC-038; HDR-DOC-039; HDR-DOC-055; HDR-DOC-064; HDR-DOC-065; HDR-DOC-143; HDR-DOC-144; HDR-DOC-145; INF-DOC-002; INF-DOC-003; INF-DOC-012; INF-DOC-015; INF-DOC-017; INF-DOC-021; INF-DOC-026; INF-DOC-027; INF-DOC-038; INF-DOC-039; INF-DOC-040; INF-DOC-041; INF-DOC-042; MAN-DOC-043

2.2.6 Assessments of environmental water quality

Purpose:

One of the main goals of the programme is "To develop, test and refine methods for predicting the responses of the natural environments of rivers flowing through the KNP and in southern Africa to changing water quality and patterns of supply". In other words the programme is charged with predicting the consequences of water development projects (such as dams) on water quality and quantity, and with setting standards for different aspects of water quality which will allow the natural communities to survive in the long term.

Tasks:

To evaluate the consequences for the natural environment of changes in water quality and quantity.

To predict the responses of the natural environment to changes in water quality and quantity.

Progress:

Preliminary water quality guidelines have been set for all the main rivers of the KNP (see Moore *et al*, 1991). Environmental requirements have also been suggested at IFR workshops for the Luvuvhu and Letaba Rivers. All the guidelines to date have been based on the Department of Water affairs and Forestry's (DWAF) historical water chemistry database. Experiments on the tolerances of selected invertebrates from the Sabie River to salinity are being analyzed by Dr Carolyn Palmer and colleagues at the Institute for Water Research (IWR), Rhodes University. National environmental guidelines are also in draft stage at DWAF.

Evaluation:

Although there are environmental guidelines for the KNP rivers, all of them have been based on the DWAF water chemistry database, rather than on known tolerances of the biota, and are therefore extremely tentative. They only include the chemical variables regularly monitored by DWAF, and therefore important variables such as temperature and turbidity are missing. A great deal of additional work on the tolerances of the biota needs to be done before these guidelines can be refined with confidence. In the meantime, a combination of the standards suggested by Moore *et al* (1991), and those in the national guidelines, will have to be used.

List of main products:

Water quality management of the Crocodile River catchment, Eastern Tvl. Vol. 9: Management guide (Annex 26-30: water quality guidelines, assimilative capacity, water quality management problems, information requirements and research needs, water quality management plan). (1994) Ashton P J : WQ-DOC-010

Water quality assessment of the major rivers of the KNP. (1991) Van Veelen M and Moore C A : WQ-DOC-044

Preliminary water quality guidelines for the KNP. (1991) Moore C A, Van Veelen M, Ashton P J and Walmsley R D : WQ-DOC-011

Water quality requirements of the biota of the KNP rivers. (1990) Moore C A : WQ-DOC-033

Letaba Instream Flow Requirements: water quality in the Great Letaba River, and methods of predicting the effects of flow modification. (1994) O'Keeffe J H, Palmer C and Hughes D : WQ-DOC-013

Luvuvhu Instream Flow Requirements: water quality in the Luvuvhu River, and methods of predicting the effects of flow modification. (1994) O'Keeffe J H, Palmer C and Hughes D : WQ-DOC-014

Other relevant documents and datasets:
MAN-DOC-009; MAN-DOC-028; MAN-DOC-041; MAN-DOC-043; WQ -DOC-001; WQ -DOC-008; WQ -DOC-035; WQ -DOC-041; WQ -DOC-043; WQ -DOC-052; HDR-DOC-018; HDR-DOC-063; INF-DOC-010

2.2.7 Geomorphology and sediment transport

Purpose:

Fluvial Geomorphology is the logical integrating discipline to link river response to ecological functioning as it is the geomorphology that forms the physical template for habitats to develop. Also river response may be predicted at a geomorphological scale that may be directly related to habitat units. The form of river channels is primarily determined by the influence of water and sediment, and any alteration of this balance results in geomorphological change. If the geomorphological template is altered this directly affects the habitat availability, also geomorphological change is likely to be longer term and less reversible than changing hydraulic conditions in response to the flow regime. The aim of geomorphological research within the programme is to develop the capability to predict the geomorphological response to changing flow regimes in the KNP river systems with a view to providing information and protocols for environmentally sound management of the water resources of these catchments.

Tasks:

To develop conceptual models of geomorphological processes in the river and catchment.

To develop simulation models to describe present conditions and to predict future conditions.

To develop conceptual models of sediment transport processes in the river and catchment.

Progress:

Geomorphological studies have been a central theme of the programme, with particularly intensive investigations of the Sabie River within the KNP by the Centre for Water in the Environment at the University of the Witwatersrand. A comprehensive classification of reaches and morphological units, and a predictive model relating flow patterns to erosion/deposition processes has been built for the section of the Sabie in the Park. Vogt (1992) has described short-term changes in the Sabie and Letaba Rivers. Venter (1991) has provided descriptions of the different reaches of all the major rivers of the KNP. The Sabie and Letaba Rivers behave differently from alluvial temperate river systems and must be investigated outside the framework that exists for these rivers. A number of useful concepts and products have emerged as a result of the study on these two rivers which will prove invaluable in gaining a more detailed understanding of rivers in Southern Africa:

1. A methodology for the geomorphological classification and spatial categorisation of rivers influenced by both bedrock and alluvium. Such a classification is easily applicable to any river system and allows a direct standardised comparison between

different rivers.

2. A research rationale that relates the geomorphological structure of a river to the principal catchment control variables in order to conceptualise pathways of possible channel change.

3. An integrative field research framework that quantifies the importance of the catchment control factors and provides information on regional (whole river) and local (representative channel type) scales.

4. Qualitative models of short (annual) and long term (decades and centuries) channel change.

5. A semi-quantitative model of channel response that routes sediment through a series of channel types as defined by the hierarchical classification and river structuring. The model operates using daily average flows and generates annual changes in the sediment balance at the scale of channel type.

6. A research methodology for investigating bedrock influenced semi-arid river systems.

Evaluation:

Knowledge of fluvial geomorphological processes and predictive capabilities have increased enormously as a result of the programme. The defined tasks have been achieved, and the researchers at the Centre for Water in the Environment (CWE) are ready to implement their findings in terms of predictions of the short- and long-term state of the Sabie River within the KNP under modified flow regimes. The main aim of the research sub-programme for 1996 is to link the geomorphological and biological information into a suite of models which will predict the consequences of changing flow regimes on erosion/deposition processes, habitat availability, and therefore the riverine biota and riparian vegetation.

Further work is required to verify the Sabie model, and to examine how far the Sabie results can be extrapolated to the other rivers of the KNP.

List of main products:

River Classification for Management: The geomorphology of the Sabie River in the eastern Transvaal. South African Geographical Journal, 1995, 77(2), 68-76 Van Niekerk A W, Heritage G L and Moon B P : MAN-DOC-024

Letaba Instream Flow Requirements: Geomorphological characteristics of the Letaba River and the effects of decreased flow on these characteristics. (1994) Heritage G L : GEO-DOC-002

Luvuvhu Instream Flow Requirements: The geomorphology of the Luvuvhu River. (1994) Heritage G L : GEO-DOC-003

Short-term geomorphological changes in the Sabie and Letaba Rivers in the KNP. (1992) Vogt, I : GEO-DOC-006

Morphological response of the Sabie River to changing flow and sediment regimes. (1994) Heritage G L and Van Niekerk A W : GEO-DOC-009

Geomorphology of the Sabie River: overview and classification. (1993) Heritage G L and Van Niekerk A W : GEO-DOC-015
Fisiese kenmerke van bereike van die standhoudende riviere in die Nasionale Kruger wildtuin. [Eng.: Physical characteristics of the perennial river reaches in the KNP.] (1991) Venter F J : GEO-DOC-018

Drought conditions and sediment transport in the Sabie River. (1994) Van Niekerk A W and Heritage G L : HDR-DOC-008

Silt concentrations of the Olifants River in the KNP and the survival of Tilapia rendalli exposed to silt from the Phalaborwa barrage. (1994) Büermann Yvette : WQ-DOC-015

Letaba Instream Flow Requirements: Changes in present sedimentation due to development in the Letaba catchment. (1994) Heritage G L : INF-DOC-019

Other relevant documents and datasets:
MAN-DOC-020; MAN-DOC-021; MAN-DOC-022; MAN-DOC-023; INF-DOC-010; WQ -DOC-004; GEO-DOC-007; GEO-DOC-011; GEO-DOC-012; GEO-DOC-013; GEO-DOC-016; GEO-DOC-017; HDR-DOC-026; HDR-DOC-029; HDR-DOC-128; GEO-DOC-017; WQ -DOC-032; WQ -DOC-047; WQ -DOC-048; WQ -DOC-051; INF-DOC-010

2.2.8 Riparian vegetation and changes

Purpose:

The riparian vegetation forms an integral part of the functional riparian ecosystem. Dynamics and distribution patterns of the vegetation within the riparian zone are determined to a large degree by hydrogeomorphic processes of the river. Changes in the flow regime and sediment load as a result of upstream development are therefore likely to have an impact on future vegetation composition and distribution patterns along the rivers within the Kruger National Park (KNP). A conceptual model linking local hydraulics, channel morphology and riparian biota has been developed and used as the framework for investigating the riparian vegetation, and a number of studies were identified that would address the problem of providing a basis for determining non-consumptive and consumptive water requirements of the riparian vegetation along the rivers within the KNP, and for predicting the consequences of change.

Tasks:

Inform simulation modelling and habitat characterisations by determining roughness coefficients for riparian vegetation.

In order to understand distribution patterns and the dynamics of the riparian vegetation, and so provide a basis for determining the non-consumptive requirements of the vegetation, a number of tasks were undertaken. They were:

To describe the vegetation composition of the different rivers;

To relate the vegetation distribution patterns to hydrological, hydraulic and geomorphological characteristics of the physical environment;

To develop abiotic and biotic links, and rules of regeneration for riparian trees;

To establish landscape state changes along the rivers from aerial photographs;

To establish changes in the vegetation composition as a result of a prolonged low flow event.

In order to provide a basis for determining the consumptive requirements of the vegetation, the task was undertaken to establish transpiration at near potential rates for riparian trees and reeds.

Progress:

Composition, distribution patterns, dynamics, and non-consumptive requirements:

Descriptions of the riparian vegetation exist for the Crocodile, Sabie, Olifants, Letaba and Luvuvhu Rivers. Further studies on the vegetation have concentrated mainly on the Sabie River. Vegetation distribution patterns have been related to characteristics of the physical environment along the Sabie River, showing a good relationship to exist with height above the main channel. Relationships were also found to exist with the fluvial geomorphology along the macro-channel floor, where the degree of bedrock control is seen to be an important factor. These relationships confirm that hydrogeomorphic processes are important in determining vegetation distribution patterns. Further links between vegetation distribution, flooding and fluvial geomorphology are being investigated. Closely related to this work is an investigation into the dynamics of regeneration of riparian trees in relation to abiotic factors such as the geomorphology.

Temporal changes at the landscape level (water, sand, rocks, reeds, herbaceous vegetation, woody vegetation) have been described from aerial photographs at four dates between 1939-1988 for the five major rivers of the park. Markovian models have been used to test the proposed sequence of successional changes from rocks to sand to reeds to herbaceous vegetation to reeds to woody vegetation. Other studies on temporal changes include a census of dead trees following an extreme prolonged low flow event along the Luvuvhu and the Sabie River. Trees growing along secondary channels in mixed and bedrock anastomosing reaches were found to be most impacted.

Consumptive requirements:

Transpiration levels at near potential rates were established for riparian trees and reeds. A significant difference in transpiration was found between reeds and trees. Climatic variability accounted for the majority of the variation in the observed transpiration.

Evaluation:

Composition, distribution patterns, dynamics, and non-consumptive requirements:

A good understanding of the processes involved in the distribution patterns and the dynamics of the riparian vegetation now exists for the Sabie River within the KNP. This is not the case however for the other major rivers of the KNP. An understanding of the dynamics of regeneration of trees along the Sabie River has also contributed greatly to the understanding of vegetation distribution patterns and dynamics. The level of understanding is at a point where predictions can be made as to what changes in vegetation composition and distribution are likely to take place in response to certain flow events and changes in the fluvial geomorphology. The results of the studies however do not attempt in any way to prescribe what flow regime is suitable to maintain the functioning of the riparian vegetation. The potential has been developed to predict changes in the riparian vegetation in response to certain changes in the flow and fluvial geomorphology. The adequacy of this predictive potential has still to be tested against clearly stated conservation goals which will be developed in 1996. It can be expected that there will still be many gaps that need to filled, and links between the vegetation, hydrology, and geomorphology that need to be more explicitly established.

Consumptive requirements:

While the project has been completed and consumptive requirements of trees and reeds can be estimated, they require further validation.

List of main products:

A survey of the riparian vegetation of the Crocodile River in the KNP. (1993) Bredenkamp G J and Van Rooyen N : BIORIP-DOC-002

A survey of the riparian vegetation of the Luvuvhu River in the KNP. (1993) Bredenkamp G J and Van Rooyen N : BIORIP-DOC-003

A survey of the riparian vegetation of the Letaba River in the KNP. (1993) Bredenkamp G J and Van Rooyen N : BIORIP-DOC-004

A survey of the riparian vegetation of the Olifants River in the KNP. (1993) Bredenkamp G J and Van Rooyen N : BIORIP-DOC-005

The vegetation of the Sabie River, KNP. (1991) Bredenkamp G J, Van Rooyen N and Theron G K : BIORIP-DOC-006

Letaba Instream Flow Requirements: The status of riparian vegetation of the Letaba River and its major tributaries. (1994) Kemper N P : BIORIP-DOC-007
Riparian vegetation of the Sabie River: relating spatial distribution patterns to the physical environment. (1993) Van Coller A L : BIORIP-DOC-010

Modelling and monitoring the riparian water balance of a river system for environmental studies (1993) Birkhead A and James C S : HDR-DOC-002

Other relevant documents and datasets:
GEO-DOC-001; BIORIP-DOC-010; HDR-DOC-001; GEO-DOC-011; WQ -DOC-004; INF-DOC-016; BIORIP-DOC-001; BIORIP-DOC-008; BIORIP-DOC-009; BIORIP-DOC-011; BIORIP-DOC-012; CON-DOC-001; MAN-DOC-005

2.2.9 Habitat changes

Purpose:

Habitats can be changed in three ways by the modification of the flow regime: Reductions (or increases) in the flow rate will affect the depth of water, current speeds, and area of aquatic habitat available for the instream biota; erosion/deposition processes will change, altering channel morphology and therefore the structure and diversity of instream and riparian habitats; water quality will change, affecting the chemistry, turbidity and temperature of the aquatic environment.
One of the assumptions which underlies much of the research done in the programme is that the availability and diversity of habitats is the major factor governing the distribution and abundance of the biota, and that the decrease or increase of habitat can be measured as a surrogate for changes in the biota.

Tasks:

To develop, test and refine methods for predicting the responses of the natural environments of rivers to changing water quantity and quality.

Progress:

Habitat changes in response to changing flows have been measured and modelled at a number of different scales in the Sabie River. Geomorphological research at the Centre for Water in the Environment, University of the Witwatersrand, has resulted in a model to predict changes in channel morphology of the Sabie River in response to changed flows. Evidence from historical aerial photos of all the permanent rivers of the Park has been used to assess changes in reedbeds over time. Fish habitat preferences and changing availability at different flows have been assessed for the Sabie River by Weeks *et al* (1996), and for all the permanent rivers by Russell and Rogers (1991). Assessments of habitat integrity have been carried out for the Luvuvhu, Letaba and Olifants Rivers as preparation for IFR workshops.

Evaluation:

Considerable ability to measure and predict habitat changes and availability has been developed by the programme. Although no specific tasks were identified for this component, it has been implicit as a major aim of much of the ecological research in the programme. The 1996 programme plan to develop models linking flow changes with habitat changes in order to predict biotic changes, will use the skills developed in this component to achieve one of the main goals of the programme (see tasks above) for the Sabie River.

The remaining priority task for this component is to assess how far the knowledge developed for the Sabie River in the KNP can be extrapolated to the other rivers of the KNP, however, this is unlikely to be achieved during the remainder of Phase 2.

List of main products:

A pre-impoundment study of the Sabie River Eastern Tvl. with special reference to predicted impacts on the KNP. (1990-1993) O'Keeffe J H : HDR-DOC-017

Other relevant documents and datasets:
BIOFISH-DOC-020; MAN-DOC-020; MAN-DOC-021; MAN-DOC-022; MAN-DOC-024; GEO-DOC-002; GEO-DOC-003; GEO-DOC-009; GEO-DOC-015; GEO-DOC-016; GEO-DOC-017; HDR-DOC-008

2.2.10 Temperature changes

Purpose:

Water temperature is a major determinant of the distribution of instream biota in rivers. The Sabie River, flowing steeply from the western escarpment, has been described as a cold finger of water flowing into the lowveld, and this temperature anomaly has been suggested as one of the reasons for the high biodiversity of the system. Impoundment of the Sabie, or any of the other rivers, will considerably change the temperature regime, due to the thermal inertia of large water bodies, and processes such as thermal stratification. At the least the effect will be to delay seasonal changes, since the water in a large impoundment will stay warmer in autumn, but having cooled down during winter, will stay colder in spring. Such effects attenuate downstream and would eventually be undetectable, but the recovery distance would depend on factors such as the size of the dam, the rate of flow and the type of outlet.

Apart from anthropomorphic effects, the lowveld rivers experience sudden temperature reductions after hail storms in the catchment. These often cause fish kills, but are natural events, and presumably the biota is adapted to withstand such disturbances.

Tasks:

To develop conceptual models of temperature processes in the river and catchment.

To develop simulation models to describe present conditions and
to predict future conditions.

Progress:

Except for one operated by DWAF at Paul Kruger Gate on the Sabie, there are no continuous temperature recorders on any of the KNP rivers, and therefore the water temperature database is restricted to sporadic readings taken during individual projects. Models are available to predict the effects of impoundments on water temperature, and the Hydrological simulation Program in FORTRAN (HSPF) model being developed within the TTIT sub-programme will provide such predictions. To date there has been no formal research into the effects of temperature changes on the riverine biota, but the studies of Weeks *et al* (1996) on the fauna of the Sabie River have shown that the fish assemblages can be zoned along the river according to altitude, and that various transitional species extend their ranges according to seasonal changes. The main variable governing these distributions is likely to be temperature, but a number of other variables also change with altitude and season, and may also be influential.

Evaluation:

Linking the results of Weeks *et al* with predictions from HSPF, we could predict the consequences of temperature changes on the fish fauna of the Sabie River. As with much of the detailed research on the Sabie, it is difficult to know how far such predictions can be extrapolated to the other rivers. The present database is unsatisfactory, because of the absence of any continuous historical records.

List of main products:

None

Other relevant documents and datasets:
WQ -DOC-018

2.2.11 Water quality

Purpose:

Apart from water quantity, or flow rates, water quality is the major physical factor affecting the ecological condition of a river that can be managed directly. Water quality and quantity are intimately linked, by such processes as dilution, as well as the effects of effluent inputs, impoundment and inter basin transfers. For these reasons, one of the main goals of the programme is "To develop, test and refine methods for predicting the responses of the natural environments of rivers flowing through the KNP and in southern Africa to changing water quality and patterns of supply".

Tasks:

To develop conceptual models of water quality processes in the river and catchment.

To develop simulation models to describe present water quality conditions and to predict future conditions.

To evaluate the consequences for the natural environment of changes in water quality and quantity.

To predict the responses of the natural environment to changes in water quality and quantity.

Progress:

Considerable research and monitoring of many aspects of water quality have been achieved through the programme. These range from the analysis of the growing DWAF water chemistry database (e.g. van Veelen 1990), to detailed water quality management plans for the Crocodile and Olifants Rivers (e.g. Ashton, 1994), and numerous studies on the effects of metals on selected fish species in the Olifants River by the Research Unit for Aquatic and Terrestrial Ecosystems at Rand Afrikaans University. The great majority of the work has concentrated on chemical aspects of water quality, with no work on the effects of temperature, and very little on turbidity and the effects of suspended sediment, with the exception of Looser (1993) and Büermann (1994).

A workshop in 1991 used the accumulated expertise of many of the water scientists in South Africa to develop preliminary water quality guidelines for the major rivers of the KNP (Moore *et al*, 1991). Because of the dearth of information on the tolerances of aquatic organisms, the guidelines were mostly based on the historical ranges of concentrations measured at the DWAF gauging weirs. The workshop identified the need to establish the water quality tolerances of key aquatic organisms, and an environmental ecotoxicological programme was initiated by the Institute for Water Research at Rhodes University, a main aim of which is to experimentally determine these tolerances for selected invertebrates in the Sabie River.

Evaluation:

There has been an enormous increase in the amount of information now available on water quality in the KNP rivers since the start of the programme. The DWAF database on water chemistry provides an invaluable record of conditions in all the major rivers. Other work has been extensive, but has been largely uncoordinated, and major gaps remain. The DWAF database is confined to water chemistry, and lacks information on important variables such as water temperature, dissolved oxygen, and suspended sediment concentrations.

There is at present little predictive potential to assess the likely effects of water resource developments in any of the rivers, and therefore the main water quality goal of the programme has only partially been met. The links between changing water quantity and quality have yet to be made.

List of main products:

Water quality management of the Crocodile River catchment, Eastern Tvl. Vol. 1: Executive summary. (1994) Ashton P J : WQ-DOC-002

Preliminary water quality guidelines for the KNP rivers. (1991) Moore C A, Van Veelen M, Ashton P J and Walmsley R D : WQ-DOC-011

Letaba Instream Flow Requirements: Water quality in the Great Letaba River, and methods of predicting the effects of flow modification. (1994) O'Keeffe J H, Palmer C and Hughes D : WQ-DOC-013

Luvuvhu Instream Flow Requirements: Water quality in the Luvuvhu River, and methods of predicting the effects of flow modification. (1994) O'Keeffe J H, Palmer C and Hughes D : WQ-DOC-014

Water quality in the six main rivers of the KNP during the drought of 1991/1992. (1993) Deacon A R, Strydom F G and Goetsch P : WQ-DOC-019

Water quality situation assessment of the Crocodile River, Eastern Tvl. (1995) Ashton P J and Heath R G : WQ-DOC-024
KNP: Water quality inventory of the six main river systems for the hydrological years 1983-1992. (1993) Kilian V and Du Plessis B J : WQ-DOC-026

Water quality requirements of the biota of the KNP rivers. (1990) Moore C A : WQ-DOC-033

A water quality management plan for the lower Olifants River, Eastern Tvl. (1993) CSIR : WQ-DOC-041

Water quality assessment of the major rivers of the KNP. (1991) Van Veelen M and Moore

C A : WQ-DOC-044

Other relevant documents and datasets:
HDR-DOC-005; HDR-DOC-028; HDR-DOC-110; WQ -DOC-001; WQ -DOC-003; WQ -DOC-004; WQ -DOC-005; WQ -DOC-006; WQ -DOC-007; WQ -DOC-008; WQ -DOC-009; WQ -DOC-010; WQ -DOC-040; WQ -DOC-012; WQ -DOC-015; WQ -DOC-016; WQ -DOC-017; WQ -DOC-018; WQ -DOC-020; WQ -DOC-021; WQ -DOC-022; WQ -DOC-023; WQ -DOC-025; WQ -DOC-027; WQ -DOC-028; WQ -DOC-029; WQ -DOC-030; WQ -DOC-031; WQ -DOC-032; WQ -DOC-035; WQ -DOC-036; WQ -DOC-037; WQ -DOC-038; WQ -DOC-039; WQ -DOC-042; WQ -DOC-043; WQ -DOC-045; WQ -DOC-046; WQ -DOC-047; WQ -DOC-048; WQ -DOC-049; WQ -DOC-050; WQ -DOC-051; WQ -DOC-052; WQ -DOC-053; WQ -DOC-054; WQ -DOC-055; WQ -DOC-056; BIOINV-DOC-010; BIOFISH-DOC-002; BIOFISH-DOC-005; BIOFISH-DOC-011; BIOFISH-DOC-012; BIOFISH-DOC-013; BIOFISH-DOC-014; BIOFISH-DOC-028; BIOFISH-DOC-029; BIOFISH-DOC-030; BIOTHER-DOC-001; MAN-DOC-012

2.2.12 Hydraulics

Purpose:

Local hydraulic conditions define instream habitats directly in terms of current velocity and flow depth. Local hydraulic conditions also determine sediment dynamics which act as one of the controls on local channel morphology, in turn influencing biotic response. It is therefore necessary to determine local channel hydraulic parameters in order to understand the existing geomorphology, to predict future geomorphological change, and hence understand biotic response to modified hydraulic conditions and potential geomorphological change. Information generated also feeds into the IFR workshop process which uses hydraulic information generated from a series of transects to convert ecological information on habitat preferences of riparian biota into estimates of required discharge.

Tasks:

To develop simulation models to describe present hydraulic conditions and to predict future conditions.

To establish generalised channel flow resistance parameters for different channel types, incorporating the effects of riparian vegetation. These will be used in hydraulic simulation models, assuming that the same channel type will display similar changes in hydraulic parameters with discharge, regardless of its location.

Progress:

Hydraulic transects have been established on all of the major rivers in the KNP except the Crocodile. There are in excess of 60 rated transects at representative points on the Sabie River, established as data gathering points for hydraulic, flow resistance and geomorphological studies, and during field data collection for PHABSIM. On the other rivers there are far fewer transects, usually three to nine established for IFR workshops. A further twenty have been established on the Letaba River for data collection for geomorphological studies. Detailed studies on local channel hydraulics and flow resistance have been conducted by the CWE at the University of the Witwatersrand in the project: "Translating Hydrological

Modelling into Local Hydraulic Conditions". These have used the representative channel types defined through the "Geomorphological Change to the Sabie and Letaba River Systems in Response to Changing Flow Regime" and the "Representative Reach" studies. Channel roughness which has an important influence on channel hydraulics has been assessed as a function of discharge for the five different channel types, and the influence of vegetation and morphology on this parameter has been determined. Hydraulic and sediment transport characteristics have been defined for all transects in the KNP. A multiple channel overspill model has been developed at the CWE to model hydraulic characteristics of channels with multiple bedrock controlled distributaries which are common in a number of Lowveld rivers (particularly the Sabie).

Evaluation:

Extensive field data is available on hydraulic conditions at representative sites. Major effort has been focused on the Sabie River and stage/discharge data are available for all flows from drought conditions through to extreme floods. Channel flow resistance parameters have been quantified for the five channel types on the Sabie River and this information can be used to estimate flow resistance for similar unmeasured channel types in other rivers. Changes in hydraulic conditions in response to changing flow can be predicted using the stage/discharge and channel overspill models developed by CWE as well as models used for the IFR workshops. The channel overspill model has only been verified for a limited range of discharges and requires further testing to improve confidence. The 1996 Programme project to link abiotic and biotic knowledge into a suite of predictive models will assess a combination of hydraulic changes and geomorphological changes to predict habitat availability at different flows.

List of main products:

None published, but the following products have been developed:
Geomorphological classification system
Flow resistance parameters for all channel types
Methodology to predict hydraulics as function of discharge for unmeasured sites
Bulk sediment routing model to predict channel change
Channel Overspill Model

Other relevant documents and datasets:
GEO-DOC-004; GEO-DOC-005; GEO-DOC-010; BIORIP-DIG-006; GEO-DIG-003

2.2.13 Hydrology

Purpose:

The hydrological responses of the upstream catchments govern the flow in the rivers of the KNP. Changing flow impacts on the ecological and geomorphological functioning of these rivers. Thus, it is important to quantify the hydrological responses of the catchment.

Tasks:

To configure hydrological simulation models in order to describe present hydrological conditions and to simulate potential future conditions.

Progress:

It is necessary that the hydrological model selected operates at a daily time step, offers spatial resolution suitable for the simulation of catchment runoff and sediment yield and requires limited calibration. The Department of Agricultural Engineering at UNP were contracted to produce simulations of flow and sediment yield in the Sabie. catchment. The Sabie catchment has been sub-divided into 56 sub-catchments, and the Agricultural Catchments Research Unit (ACRU) model has been set up to use this configuration. The sub-catchments retain the 35 subcatchments defined in a previous consultants report (Chunnet, Fourie and Partners, 1991), with some further breakdown of those catchments to account for the finer spatial resolution required for simulation of sediment production. The runoff and sediment yield simulated by the ACRU model at each subcatchment is in the process of being linked to the modules of the HSPF model that deal with processes occurring in the river channel.

Evaluation:

The lack of information regarding abstractions from the river channel is a major problem. Verification of the hydrological simulations cannot be completed satisfactorily until information regarding the industrial, domestic and agricultural use of water is obtained.

List of main products:

Sabie River catchment study: Volume 7: Appendix 18; Hydrology-runoff simulations : HDR-DOC-028

Kruger National Park Rivers Research Programme. Water for Nature. Hydrology: Luvuvhu River. (1990) Hill Kaplan Scott Inc. Consulting Engineers : HDR-DOC-054

Kruger National Park Rivers Research Programme. Water for Nature. Hydrology: Letaba River. (1990) Steffen Robertson and Kirsten : HDR-DOC-085

Kruger National Park Rivers Research Programme. Water for Nature. Hydrology: Olifants River. (1990) Theron Prinsloo Grimsehl and Pullen : HDR-DOC-120

Other relevant documents and datasets:
HDR-DOC-002; HDR-DOC-003; HDR-DOC-006; HDR-DOC-009; HDR-DOC-010; HDR-DOC-021 HDR-DOC-025; HDR-DOC-040; HDR-DOC-041; HDR-DOC-042; HDR-DOC-043; HDR-DOC-044; HDR-DOC-066; HDR-DOC-067; HDR-DOC-091; HDR-DOC-104; HDR-DOC-105; HDR-DOC-106; HDR-DOC-107; HDR-DOC-137; HDR-DOC-138; GEO-DOC-008; WQ-DOC-006; INF-DOC-008; INF-DOC-033; MAN-DOC-033

2.2.14 Bank storage dynamics (groundwater)

Purpose:

Bank storage dynamics describes the response of alluvial water in the riparian zone to fluctuations of river stage and extractions to support evapotranspiration. Water availability in the riparian zone is the major determinant regulating plant growth and species distribution, and bank storage dynamics is the interface between surface flow and water losses by riparian vegetation.

Tasks:

The development of integrated models for (i) river hydraulics, (ii) bank storage dynamics, and (iii) transpiration losses, to quantitatively describe the riparian water balance in the Sabie River, Kruger National Park (KNP).

Progress:

A quasi-three dimensional finite-difference model describing the response of alluvial water in the saturated and unsaturated zones has been developed. This model has been validated using analytical solutions, and verified for a study site on the Sabie River using morphological, hydraulic and hydrological data collected over the period 1992 to 1995. Semi-empirical models for transpiration have been developed using climatic, sap flow, leaf area and groundwater data from the site. The project has been undertaken by the Centre for Water in the Environment, University of the Witwatersrand, with the transpiration component developed by the Division of Forest Science and Technology, CSIR.

Evaluation:

The overall project is in the final stages of completion, and meets the objectives set for the project by providing the following major products: (i) hydraulic models and data for different geomorphological types occurring along the Sabie River in the KNP; (ii) a model of the bank storage dynamics, which has been tested at a site on the Sabie River; and (iii) the development of transpiration models for (a) common woody riparian species and (b) the abundant reed species Phragmites mauritianus.

List of main products:

Modelling and monitoring the riparian water balance of a river system for environmental studies. (1993) Birkhead A and James C S : HDR-DOC-002
Water resource planning of the Letaba River Basin: (Annexure 13: groundwater resources). (1990) Steffen Robertson and Kirsten : HDR-DOC-108

Olifants River Catchment: (Annexure 11: groundwater resources). (1990) Steffen Robertson and Kirsten : HDR-DOC-134

Other relevant documents and datasets:
HDR-DOC-113; GEO-DOC-001

2.2.15 Ecology

Purpose:

The ecology of a river is a catchall phrase which includes the biota, interactions between them, and between them and the physical and chemical variables which govern their distribution and abundance. The ultimate aim of the Programme is to ensure that ecological components and processes of the KNP rivers are understood at a level of resolution which will allow informed management decisions to maintain them in their desired states. Many of the ecological aspects of the rivers have been described under their component headings, e.g. fish, riparian vegetation, water quality, geomorphology etc.

There remain the tasks of integrating our understanding of the separate components of the system, since the management of natural ecosystems is ultimately a holistic exercise. Individual components cannot be managed without a web of secondary effects.

Tasks:

To develop conceptual models of ecological processes in the river and catchment.

To develop simulation models to describe present conditions and to predict future conditions.

Progress:

Linked conceptual models have been developed for the following aspects of the rivers: internal relationships of the physical fluvial system; hydrology; factors affecting the morphology of river reaches; relationships between riparian biota, local hydraulics and channel morphology; and biotic and abiotic processes and variables determining instream biodiversity. These are described in the KNPRRP second phase Programme description by Breen *et al* (1994).

Simulation models are available, or in development, for the hydrology, sediment transport and geomorphology of the Sabie River. A semi-quantitative model predicting the changes in fish communities under different flow regimes has also been developed for the Sabie and Sand Rivers. Predictive links between hydrology, geomorphology and riparian vegetation are also being developed.

The proposal for the final year of phase two of the Programme is that the research effort should be devoted to modelling the major links between the biotic abiotic components of the Sabie River. This will include the processes in the sequence: flow modifications - changes in channel morphology - changes in the diversity and availability of habitats - changes in the abundance and diversity of the fish fauna.

Evaluation:

The initial stages of the Programme have inevitably concentrated on detailed studies of individual components of the system, but these focused advances have been paralleled by the development of holistic conceptual models within the DSS, which have concentrated on the contributions of the individual studies to the overall understanding of the ecology of the rivers. The Programme is now in a position to develop predictive links between the different biotic and physical aspects of the rivers. From such links, the Programme will be able to provide managers with predictions of the effects of changing flow regimes (as a result of water resource development) on the structure and biota of the rivers.

Major gaps remain in the Programme: Much of the research has deliberately concentrated on the Sabie River, and the extent to which the detailed knowledge of the Sabie can be extrapolated to other rivers is uncertain. Inevitably, because of the complexity of ecosystems, not all the aspects have been covered. Research into water quality processes has generally received a low priority because there are few water quality problems in the Sabie river (but see results in section 2.2.13 Water Quality), and our ability to predict water quality requirements lags behind that for quantity requirements. The 1996 Programme project to link biotic and abiotic information will provide the ability to predict the effects of changing flows on the fish and riparian vegetation in the Sabie river within the KNP, but is unlikely to address other components of the biota (such as invertebrates), and cannot address other rivers, or the Sabie upstream of the Park.

List of main products:

(See also the following sections: 2.2.8 Geomorphology; 2.2.9 Riparian changes; 2.2.10 Habitat changes; 2.2.13 water quality; 2.2.15 Hydrology; 2.2.18 Fish; 2.2.19 Invertebrates)

An ecological evaluation of the Upper Sabie River catchment, Eastern Tvl. (1993) Everard D A, Van Wyk G F and Viljoen P J : HDR-DOC-006

A pre-impoundment study of the Sabie River Eastern Tvl. with special reference to predicted impacts on the KNP. (1990-1993) O'Keeffe J H : HDR-DOC-017

Other relevant documents and datasets:
OTH-DOC-006; CON-DOC-003; CON-DOC-009; CON-DOC-011; BIOTHER-DOC-008; BIOFISH-DOC-009; BIOFISH-DOC-023; BIORIP-DOC-010; INF-DOC-002; INF-DOC-038; WQ -DOC-017; HDR-DOC-011; HDR-DOC-012; HDR-DOC-013; HDR-DOC-015; HDR-DOC-016; HDR-DOC-022; HDR-DOC-102; HDR-DOC-145

2.2.16 Biota: Fish

Purpose:

The fish fauna of any river has perhaps the highest profile of the truly aquatic communities. In the KNP rivers, and the Sabie River in particular, there is a diversity of fish species unsurpassed anywhere in South Africa. The maintenance of this diversity is a major aim of the Programme, both because of its contribution to the biodiversity of the Kruger National Park, and as an indication of the ecosystem health of the rivers

Tasks:

Synthesis of life history processes and habitat requirements of selected animals as determined by the development of protocols for determining the conservation importance and status of rivers as well as the protocols for defining the desired state of a river.

Progress:

There was already a considerable database on the fish fauna of the rivers of the KNP before the Programme began, largely as a result of the research of Pienaar (1978), Gaigher (1969) and others, as well as the surveys by Transvaal provincial nature conservation. This served as a benchmark to describe the historical changes in distribution of fish species over time. Russell and Rogers (1991) provided some clues about the changes in the KNP since the fish surveys of Pienaar in the 1960's, and following the droughts of the early 1980's, but it is difficult to know if these changes are cyclical or unidirectional. Intensive sampling since 1991 by river research staff of the National Parks Board will do much to clarify the long-term community trends.

The pre-impoundment study of the Sabie-Sand by the Institute for Water Research has provided further detailed information on the distribution of fish communities throughout the system, and has concentrated on describing the habitat requirements of selected species, particularly in terms of hydraulic variables such as current velocity, depth and substrate type. From this information it has been possible to construct semi-quantitative predictions about the likely changes in fish communities following flow modifications.

Evaluation:

The presence/absence and distributions of fish in all the major rivers is now well documented. Knowledge of their habitat requirements, and sensitivity to changing flow conditions is also developed, at least at a qualitative level. Much of the available data still requires synthesis, especially in the terms of the defined task. The habitat requirements and sensitivity to changing flow conditions, defined for the fish in the Sabie River, requires confirmation for the other KNP rivers.

Perhaps most important, information is required on the breeding and early life history requirements of key species. This information is almost entirely lacking at present, and is crucial for confident predictions of the water quantity requirements. Providing suitable conditions for the survival of the adults is meaningless if breeding fails or the juvenile stages are unable to survive.

List of main products:

Relationships between low flows and the river fauna in the Letaba River. (1993) Chutter F M and Heath R G M : HDR-DOC-007

Letaba Instream Flow Requirements: Summarised assessment of the status of the fish community of the Great Letaba (Limpopo system) and selected tributaries from the Fanie Botha Dam to Black Heron Dam in the KNP. (1994) Engelbrecht J S and Hoffman A H : BIOFISH-DOC-003
Luvuvhu Instream Flow Requirements: An assessment of the status of the fish community in the Luvuvhu River (Limpopo system) from Albasini Dam to the Limpopo River confluence in the KNP. (1994) Engelbrecht J S, Roux F and Hoffman A H : BIOFISH-DOC-004

The freshwater fishes of the Kruger National Park. (1978) Pienaar U de V : BIOFISH-DOC-015
Surveillance of fish communities and habitats: Past changes, present status and future

projections. (1991) Russell I A and Rogers K H : BIOFISH-DOC-020

A pre-impoundment study of the Sabie-Sand River system, eastern Transvaal, with special reference to the predicted impacts on the KNP (1990-1993) O'Keeffe J H : HDR-DOC-017

Other relevant documents and datasets:
HDR-DOC-005; HDR-DOC-037; WQ -DOC-015; WQ -DOC-018; WQ -DOC-021; WQ -DOC-033; BIOFISH-DOC-001; BIOFISH-DOC-002; BIOFISH-DOC-005; BIOFISH-DOC-006; BIOFISH-DOC-007; BIOFISH-DOC-008; BIOFISH-DOC-009; BIOFISH-DOC-010; BIOFISH-DOC-011; BIOFISH-DOC-012; BIOFISH-DOC-013; BIOFISH-DOC-014; BIOFISH-DOC-017; BIOFISH-DOC-018; BIOFISH-DOC-019; BIOFISH-DOC-021; BIOFISH-DOC-022; BIOFISH-DOC-023; BIOFISH-DOC-024; BIOFISH-DOC-025; BIOFISH-DOC-026; BIOFISH-DOC-027; BIOFISH-DOC-028; BIOFISH-DOC-029; BIOFISH-DOC-030; BIOTHER-DOC-002

2.2.17 Biota: Invertebrates

Purpose:

The benthic macro-invertebrates are the most diverse communities in any river. They have traditionally been used as indicators of the ecological health of rivers, and particularly for water quality assessments. A number of such indices exist world-wide, and in South Africa the South African Scoring System (SASS4) index has recently been developed. A survey of invertebrates provides a time-integrated picture of conditions in the river throughout the lifetime of the community, which may be in the order of a few weeks to a few months. This is more informative than the instantaneous information provided by water chemical analysis. Benthic macro-invertebrates are more sedentary than fish, and therefore less able to escape to refugia as local conditions deteriorate.

Invertebrate communities are important as major energy and nutrient processors in rivers, as essential elements of the biodiversity, and as the most effective bioindicators of ecosystem health.

Tasks:

Synthesis of life history processes and habitat requirements of selected animals as determined by the development of protocols for determining the conservation importance and status of rivers as well as the protocols for defining the desired state of a river.

Progress:

A number of invertebrate surveys have been carried out in the rivers of the KNP both before and during the Programme. Moore and Chutter (1988) surveyed all the major rivers. Chutter and Heath (1993) sampled the Letaba over all seasons, and the Sabie has recently been the subject of a major three year project. There is therefore a reasonable benchmark database of the communities in the rivers within the KNP, but only the Sabie has been comprehensively sampled throughout its length.
The Sabie project has provided information on the hydraulic
habitat requirements of some of the major groups of invertebrates, and since it covered the period of the major drought in 1991/92, the effects of very low and no-flows on the

invertebrates are documented.

Evaluation:

The Programme has generated the capacity to predict, at a coarse level, the effects of reduced flows and the habitat requirements of the invertebrate communities. There is a reasonable knowledge of the existing diversity, against which to measure future changes. There is also a capability to use the invertebrates as indicators of the condition of the rivers, and this is being done in a pilot project by the Department of Water Affairs and Forestry (DWAF) in several of the rivers.

Very little functional knowledge of the invertebrates has been gained to date, and there is a dearth of information on the invertebrate communities outside the KNP.

List of main products:

Relationships between low flows and the river fauna in the Letaba River. (1993) Chutter F M and Heath R G M : HDR-DOC-007

A pre-impoundment study of the Sabie River Eastern Tvl. with special reference to predicted impacts on the KNP. (1990-1993) O'Keeffe J H : HDR-DOC-017

Water quality requirements of the biota of the KNP rivers. (1990) Moore C A : WQ-DOC-033

Letaba Instream Flow Requirements: The aquatic invertebrates of the Great Letaba River and their habitat requirements. (1994) Bruwer C (Custodian) : BIOINV-DOC-018

Luvuvhu Instream Flow Requirements: Aquatic invertebrates of the Luvuvhu River and their habitat requirements. (1994) Palmer C and O'Keeffe J H : BIOINV-DOC-019

A survey of the conservation status and benthic biota of the major rivers of the KNP. (1988) Moore C A and Chutter F M : CON-DOC-008

Other relevant documents and datasets:
WQ-DOC-038; BIOINV-DOC-005; BIOINV-DOC-006; BIOINV-DOC-007; BIOINV-DOC-017; BIOINV-DOC-020; BIOINV-DOC-022; BIOTHER-DOC-001; BIOTHER-DOC-002; BIOTHER-DOC-003

2.2.18 Biota: Aquatic plants

Purpose:

For the purposes of the Programme, aquatic plants can be described in three subsets: indigenous macrophytes which contribute to the natural biodiversity of the rivers; introduced and invasive macrophytes (usually floating) which can choke the river channel, impede flow, and alter the riverine habitats; and filamentous and planktonic algae which may be natural to the river, but may increase to nuisance proportions if waters become nutrient-enriched.

Indigenous aquatic macrophytes are rare in the perennial rivers of the KNP, since the fluctuations in flow and the scouring effects of large floods prevent their establishment.

Emergent plants such as reeds are very common and have a fundamental influence on the channel morphology, habitats and organic inputs to the rivers, but these have been studied (and are reviewed) under the riparian vegetation section (2.2.8).

Invasive plants include Eicchornia crassipes in the Crocodile River, and Pistia stratiotes in the Lower Sabie River, both of which cause disruptions to the riverine ecosystems. Except locally in pools, algae has not so far been reported as a problem in the KNP rivers.

Tasks:

Synthesis of life history processes and habitat requirements of selected plants as determined by the development of protocols for determining the conservation importance and status of rivers as well as the protocols for defining the desired state of a river.

Progress:

Although research has been undertaken by the Agricultural Research Council's (ARC) Plant Protection Research Institute to find suitable insects to control Pistia and Eicchornia, this research has not been carried out under the auspices of the Programme. The Programme has yet to initiate any work to investigate the abundance or distribution of macrophytes or algae in the rivers.

Evaluation:

The task identified has not been carried out. This is primarily because there are few macrophytes in the Sabie River, and no algal problems have been encountered to date. The ARC's Plant Protection Research Institute has released a species of weevil into the Pistia in the Sabie in an attempt to control it.

Aquatic plant research has not been a priority for the limited resources in the Programme, for the reasons outlined above. A priority for future research will be the study of periphytic algae, which has important effects on water quality, and may be the most responsive section of the biota to water quality changes.

List of main products:

None.

Other relevant documents and datasets:
BIORIP-DOC-014

2.2.19 Biota: Large aquatic vertebrates

Purpose:

Hippopotami in the Kruger National Park (KNP) are confined mainly to the larger river complexes. The quality and quantity of these river complexes is steadily declining. Each hippopotamus sub-population is therefore faced with problems relating to its particular river and needs to be monitored and managed accordingly. This monitoring project is funded entirely by the National Parks Board.

Tasks:

To monitor population trends by means of annual aerial surveys of major river complexes and to submit management recommendations regarding the various hippopotamus sub-populations. (This was not explicitly defined as a task of the KNPRRP, but is a National Parks Board task).

Progress:

Annual censuses of hippopotami have been conducted in all the major rivers in the KNP since 1984. Most of the census data have been analyzed with particular reference to spatial trend and the possible effect of river flow rates and the grazing potential in areas surrounding some of the rivers.

Evaluation:

The overall population trends, both in space and time, of hippopotami have been adequately addressed by this project. However, the effect of fluctuations in river flow rates on localised changes in density needs to be further investigated. A mathematical model under development between Prof. Rollie Lamberson (Humbolt State University) and the KNP will address some aspects regarding the interaction between river flow rates and trends in localised hippopotamus distribution. Furthermore, the role of hippopotami in nutrient flow from the surrounding terrestrial areas into the river systems needs to be investigated.

List of main products:

None

Other relevant documents and datasets:
BIOTHER-DOC-006

2.2.20 River classification

Purpose:

Classification requires the ordering of sets of observations or characteristics into meaningful groups based on their similarities or differences and provides a means for extrapolating data and knowledge from one locality to others. The decision to concentrate research on the Sabie River has meant that there is now a great deal more information and knowledge on the Sabie than on any of the other rivers. There is a need to classify the similarities and differences between the rivers and between different parts of the same rivers in order to judge how far methods can generalise for a particular river or extrapolate from one to another, since there are not the resources to study all the rivers in the same detail. Geomorphological extrapolation will be possible at the scale of channel type. Classification also facilitates the linking of riparian biota to the fluvial geomorphology at a range of scales through habitat requirements and hence, through an assessment of geomorphological response to flow regime, linking of biotic response to flow regime.

Tasks:

Transferring knowledge [from the Sabie River] to other rivers

Development of classification systems for use in describing rivers at a chosen scale or range of scales in order to provide a basis for establishing biotic/abiotic links

Progress:

No overall classification system for the KNP rivers has yet been developed. There are several geomorphological classifications at different scales, including that of Venter (1991) for the major rivers of the KNP based an overview of different reaches. Wadeson and Rowntree (1993) have developed a divisive classification system which can be used to identify different sections of river in the context of a catchment. Van Niekerk and Heritage (1995) have developed an agglomerative hierarchical classification system based on a description of geomorphological units which can be used to distinguish channel types at ecologically relevant scales. Both the divisive and agglomerative approaches to river classification provide information related to ecological change. The divisive approach defines the larger scale elements of the geomorphological hierarchy and hence enables broad scale influences on controls on channel form such as sediment production zones to be identified. Using the agglomerative approach allows smaller scale units in the hierarchy to be accurately defined in terms of the processes which form them. It is these scales that provide the direct link between ecological habitat and geomorphology. Thus the agglomerative approach defines the fine structure of the river and the divisive approach provides information on the spatial variation in catchment control factors that act to influence the smaller scale features. The agglomerative and divisive approaches have different origins and are useful for different purposes.

Evaluation:

All the main KNP rivers appear to have important physical, chemical and biological differences from one another, and these differences preclude the extrapolation of knowledge in detail between them, although many generalities are common to all of them. The geomorphological classifications are useful because channel form and sediment transport characteristics are a major link between flow changes, consequent habitat changes, and the resulting biotic shifts. They are also the basis for defining different zones in the same rivers, an essential preliminary to understanding natural downstream changes in biota.

The hierarchical divisive and agglomerative classification systems can be used to describe any river at a chosen scale or range of scales. The divisive classification has been used to characterise the Sabie River at catchment scale and the agglomerative classification has used geomorphological units to describe the Sabie and Letaba Rivers in the Kruger National Park and to identify and map individual channel types along the length of the rivers. Channel type is the smallest scale at which prediction of geomorphological change is possible. Finer scale changes are inferred from conceptual models of channel type change. In the KNPRRP, the channel types provide the basis for investigating geomorphological change in response to changing flow regime and thus providing a link to the riverine biota through their habitat (substrate) requirements.

List of Main Products:

Fisiese kenmerke van bereike van die standhoudende riviere in die NKW. [Eng. Physical characteristics of the perennial river reaches in the KNP.] (1991) Venter F J : GEO-DOC-018

In addition, the following unpublished products and capabilities have been developed:
Complementary agglomerative and divisive classification systems
Classification of the Sabie and Letaba Rivers down to the level of channel type
Conceptual models for channel type change
Geomorphological methodology for defining representative reaches

Other relevant documents and datasets:
GEO-DOC-012; GEO-DOC-013; GEO-DOC-015; MAN-DOC-022; MAN-DOC-024

2.2.21 Social use and dependence

Purpose:

Social use and dependence refers to direct human use of the natural riverine ecosystem, for uses such as washing, laundry, subsistence fishing, cultural rituals, harvesting riparian plants for thatch or medicines, as well as recreation such as sport fishing, tourism or white-water rafting. The success of any of these enterprises relies on a healthy river and the maintenance of the natural processes which ensure good water quality, the production of fish and riparian vegetation etc.

Specifically excluded from this definition are the bulk water uses of rivers, such as domestic, industrial and agricultural water supply, which imply an exploitation rather than a conservation of the water resources of a river.

Tasks:

No specific tasks have been identified and described for Social use and dependence.

Progress:

The evaluation of quantity and quality needs for social use of the river have become a central part of the IFR process. Social needs are assessed during the preparation for IFR workshops and are taken into account in the recommendations for environmental flow allocations. IFR workshops on the Luvuvhu, Letaba and Olifants all included a component for social use of the river. However, none of these analyses achieved more than an overview of the social uses of rivers in general. The most comprehensive attempt to evaluate social needs for the KNP rivers was aimed at the tourist perceptions of water bodies in the Park (Fiedelday, 1994).

Evaluation:

Although attempts have been made to include social aspects in the Programme, there has been no development of a method for the assessment of the social uses of and dependence on rivers. There remains no data on the relative importance of different uses, the numbers of people involved, their priorities for the river, or their aspirations for the future state of the rivers. This is serious gap in the Programme's ability to quantify environmental water requirements upstream of the KNP, where there are large populations who depend on the maintenance of healthy rivers for many of their basic needs.

List of main products:

Luvuvhu Instream Flow Requirements: Social dependence on the natural flow regime of the Luvuvhu River and the riparian vegetation. (1994) Bester A : MAN-DOC-005

Water in the natural environment: landscape preference and the perception of water in the KNP. (1994) Fiedelday A C : MAN-DOC-013

Olifants-Sand Instream Flow Requirements: social dependence on natural flow regime of river. (1993) Bruwer C A (Custodian) : INF-DOC-012

Other relevant documents and datasets:
MAN-DOC-006; MAN-DOC-014; MAN-DOC-015; MAN-DOC-016; MAN-DOC-048; WQ -DOC-050

2.2.22 Resource economics

Purpose:

Resource economics is the art or science of evaluating natural resources and their uses. This evaluation need not necessarily be in financial terms, but must be in a currency that will allow a comparison of the advantages and disadvantages of different uses of the resource. The value of a resource economics approach in assessing the KNP rivers is that it should provide objective advice for managers allocating scarce water resources from the rivers.

Tasks:

Develop methods for assessing the asset value of the natural environment of rivers and for evaluating the acceptability of predicted changes in asset value

Techniques to evaluate the acceptability of management actions

Progress:

A project to develop a multiple choice model for the KNP rivers is in progress at the University of Cape Town.

Evaluation:

This remains one of the important gaps in the Programme's ability to motivate the KNP's need for water allocations. Much of the ecological justification of the need for specified flows in the rivers has been provided, but there is at present no quantified motivation for water allocations for the Park in the face of priority demands for primary water supply, forestry and agricultural requirements upstream. Unless the priority of the Park is to rely purely on moral arguments, the development of resource economic methods and analyses will be essential.

List of main products:

None

Other relevant documents and datasets:
MAN-DOC-027, MAN-DOC-037, MAN-DOC-039

2.2.23 Information synthesis

Purpose:

The purpose of the Information System Development and Management Programme is to "Provide an information management system enabling efficient capture, storage, retrieval and dissemination of information to serve the needs of researchers, decision makers and stakeholders".

Tasks:

Collation of historic and current information and data.

Determine criteria for information management system.

Review existing data management systems and design and implement a system to manage specialist ecological information.

Develop guidelines for efficient storage, capture and retrieval of information.

Focus projects on data capture and storage requirements.

Develop guidelines for ownership and custodianship.

Representative review of data available and identification of strategic data requirements.

Progress:

A project directory has been completed and is maintained by the secretariat. An up-to-date data catalogue has been developed and both hardcopy and digital versions are available, the latter also on the World Wide Web. The catalogue describes the information management system for the metadata. Furthermore, a status report on the programme is in preparation (Prof. J O'Keeffe). Criteria for the information management systems have been determined and are defined in the catalogue as well as guidelines for use of the information.

Evaluation:

Formal feedback received on the catalogue has been mostly positive and appears to be useful to researchers whose field of work has been included in the catalogue. Certain key areas of activity in the program, e.g. the status report, have been able to function far better since the catalogue became available.

The catalogue will be expanded to include image capture and maintenance, abstracts and model metadata during 1996.Experimental systems for managing access to actual data, rather than the metadata provided thus far, are being developed. Guideline advice for the efficient storage, capture and retrieval of actual data has still to be formalised, but is firmly in place for metadata. At present much of the time series data are managed by the Watershed Data Management System (WDM) but other systems will also be investigated. A critical review of data available and identification of strategic data requirements is in preparation and will be published early in 1996. Updating the metadata and ensuring continuity of availability thereof via robust automated means will be major issues in 1996.

List of main products:

The 1991\1992 drought in the KNP: some notes on its intensity and effects. (1994) Venter F J, De Vos V, Mills M G L and Viljoen A J : OTH-DOC-006

A description of the Kruger National Park Rivers Research Programme (Second phase). (1994) Breen C, Quinn N and Deacon A : MAN-DOC-003

Kruger National Park Rivers Research Programme: Situation statement and management assessment. (1992) Görgens A and Lee J : MAN-DOC-019

An integrated programme for research on the KNP rivers. (1992) Rogers K H, Pullen R A, O'Keeffe J H and Moon B P : MAN-DOC-031

Preliminary water quality guidelines for the KNP rivers. (1991) Moore C A, Van Veelen M, Ashton P J and Walmsley R D : WQ-DOC-011

Other relevant documents and datasets:
OTH-DOC-002; MAN-DOC-030; MAN-DOC-032; BIOINV-DOC-021; WQ -DOC-017; WQ -DOC-042; WQ -DOC-056; WQ -DOC-021

2.2.24 Decision support systems

Purpose:

Ensuring adequate riverflow to sustain in-stream and riparian ecosystems, while simultaneously meeting the water demands related to human activities in catchments, is a complex task. It requires planning and management decisions that occur in a multi-disciplinary environment and that need to be based on a wide variety of data and information. Most importantly, it requires understanding of natural processes related to the generation of runoff and riverflow in catchments, and of how ecosystems might respond if riverflow patterns are changed through land-use and development of water supply schemes, such as dams. Decision support systems (DSS) are "tools" that water planners and managers use in the complex task of linking data, information and understanding in an efficient manner. Such "tools" are usually computer-based and assist users to predict the consequences of physical changes in catchments in terms of riverflow quantity and/or quality and/or ecosystem responses.

The rivers of the KNP are all downstream of rapidly developing catchments for which a very active process of water scheme planning and development is in progress. DSS, such as the "tools" described above, are therefore acutely needed to maintain a management focus on the ecological water requirements of the KNP rivers.

Tasks:

To provide methodologies for integrating information and expert opinion into structured DSS aimed at achieving the best possible answer at the time and at informing researchers of the information needs required to improve answers in the future.

Progress:

i. On the "abiotic" side: a predictive simulation model of catchment hydrology and water quality has been configured for the Sabie River. This model has been linked to a graphical user interface (GUI) that is easy to use and that provides smooth access to a comprehensive physiographic, meteorological, streamflow, water quality and geomorphological data base on the Sabie catchment.

ii. On the "biotic" side: A series of mini-workshops have been held to link a rule-based model of geomorphological responses to streamflow changes to a rudimentary rule-based model of fish responses to habitat changes. The focus is being broadened to include riparian vegetation.

Evaluation:

The DSS development is approximately on track. The deliverable prototype is expected to be focused on the linkage of the biotic response predictive sub-models (referred to in (ii) above) to the abiotic catchment simulation models mentioned in (i). The first rudimentary linkages have been promising. A particularly severe drawback is the lack of information on upstream water use in the Sabie catchment during the past decade.

List of main products:

A description of the Kruger National Park Rivers Research Programme. (1994) Breen C, Quinn N and Deacon A : MAN-DOC-003

Nasionale Krugerwildtuin Riviere Navorsings Program. Bestuursdoelstellings en uitsetbehoeftes. [Eng.: KNPRRP. Management objectives and expansion needs. (1992) DWAF : MAN-DOC-011
Kruger National Park Rivers Research Programme: Situation statement and management assessment. (1992) Görgens A and Lee J : MAN-DOC-019

A prototype decision support system for the KNPRRP. (1994) MacKay H M (Ed) : MAN-DOC-025

An integrated programme for research on the KNP rivers. (1992) Rogers K H, Pullen R A, O'Keeffe J H and Moon B P : MAN-DOC-031

Other relevant documents and datasets:
MAN-DOC-032; MAN-DOC-052; BIORIP-DOC-008; HDR-DOC-010

2.2.25 Catchment studies

Purpose:

The catchment study for the Sabie River describes its scope and purpose as follows:

To establish and develop the following:

- Catchment characteristics
- Expected future developments
- Present and expected future water requirements
- Present and potential utilisable water
- Present water shortages
- Proposals to supply the short-, medium-, and long-term water requirements
- Hydro-power potential
- Costs of water resources development proposals
- Proposals for the joint development, management and control of the water resources by the various states and territories that occupy the Sabie River catchment.

Catchment studies are carried out at the reconnaissance or pre-feasibility stage of water development programmes, and aim to provide the background information essential for planning water resource allocation.

Tasks:

Collation of historic and current information and data

Critical review of data available and identification of strategic data requirements

Progress:

Catchment studies were undertaken and completed for all the major rivers of the KNP: the Luvuvhu, the Letaba, the Olifants, the Sabie and the Crocodile. The studies contain information, at a reconnaissance level, on climate, soils, environmental aspects, water quality, sedimentation, population trends, agriculture, forestry, mining, industry, and fisheries. They also describe existing water rights, water requirements, hydrology, existing and planned impoundments and water transfers. They conclude with recommendations for planning and development of the water resources of the catchment.

Evaluation:

The completed catchment studies have formed the background datasets and motivation for the KNPRRP, and are therefore an invaluable basis for the Programme. They help to identify the available information on each catchment, and provide a framework within which to plan research priorities, by describing the likely development options and by pinpointing data deficiencies.

Because the catchment studies were undertaken at a reconnaissance level, the information is not detailed, and serves more as an overview than as a comprehensive database. The environmental sections, for example, serve to identify potential problems and lack of knowledge rather than to answer questions.

List of main products:

Water Resources Planning Luvuvhu River catchment study report: Vol. 1 (Executive summary) (Nov 1990) Hill, Kaplan and Scott : HDR-DOC-055

Water Resources Planning Luvuvhu River catchment study report: Vol. 2 (Main report) (Nov 1990) Hill, Kaplan and Scott : HDR-DOC-056

Letaba River catchment: executive summary. (1990) Steffen, Robertson and Kirsten : HDR-DOC-086

Letaba water resource development pre-feasibility study: main report. (1990) Steffen, Robertson and Kirsten : HDR-DOC-088

Letaba water resource development pre-feasibility study: development and management proposals . (1990) Steffen, Robertson and Kirsten : HDR-DOC-092

Water Resource Planning of Letaba River Basin: executive summary. (1990) Steffen, Robertson and Kirsten : HDR-DOC-119

Letaba River Catchment: Executive summary. (1990) Steffen, Robertson and Kirsten : HDR-DOC-121

Olifants River Catchment: Executive summary. (April 1991) Theron, Prinsloo, Grimsehl and Pullen : HDR-DOC-122

Olifants River Catchment: Main report. (April 1991) Theron, Prinsloo, Grimsehl and Pullen : HDR-DOC-124

Sabie River catchment study: executive summary of catchment study report.(March 1990) Chunnett, Fourie and Partners : HDR-DOC-050

Summary report on reconnaissance study for the development and management of water resources of the Sabie River catchment: main report. (March 1991) Chunnett, Fourie and Partners : MAN-DOC-045

GIS and IEM in planning and management of water resources. Task 4: Environmental atlas for the Sabie River catchment. (1994) Van Riet W F, Van Rensburg J D J, Dreyer D and Slabbert S : MAN-DOC-037

Water quality management of the Crocodile River catchment, Eastern Tvl. Vol. 1: Executive summary. (1994) Ashton P J : WQ-DOC-002

Water quality situation assessment of the Crocodile River, Eastern Tvl. (1995) Ashton P J and Heath R G : WQ-DOC-024

Other relevant documents and datasets:
MAN-DOC-002; MAN-DOC-026; MAN-DOC-034; MAN-DOC-036; MAN-DOC-038; MAN-DOC-047; MAN-DOC-048; MAN-DOC-049; MAN-DOC-050; MAN-DOC-051; MAN-DOC-053; MAN-DOC-055; BIORIP-DOC-006; BIORIP-DOC-013; WQ -DOC-003; WQ -DOC-004; WQ -DOC-005; WQ -DOC-006; WQ -DOC-007; WQ -DOC-008; WQ -DOC-009; WQ -DOC-010; WQ -DOC-046; WQ -DOC-049; HDR-DOC-006; HDR-DOC-025; HDR-DOC-026; HDR-DOC-027; HDR-DOC-028; HDR-DOC-029; HDR-DOC-030; HDR-DOC-031; HDR-DOC-032; HDR-DOC-033; HDR-DOC-034; HDR-DOC-035; HDR-DOC-036; HDR-DOC-037; HDR-DOC-038; HDR-DOC-039; HDR-DOC-040; HDR-DOC-041; HDR-DOC-042; HDR-DOC-043; HDR-DOC-044; HDR-DOC-045; HDR-DOC-046; HDR-DOC-047; HDR-DOC-048; HDR-DOC-049; HDR-DOC-051; HDR-DOC-057; HDR-DOC-058; HDR-DOC-059; HDR-DOC-060; HDR-DOC-061; HDR-DOC-062; HDR-DOC-063; HDR-DOC-064; HDR-DOC-065; HDR-DOC-066; HDR-DOC-067; HDR-DOC-068; HDR-DOC-069; HDR-DOC-070; HDR-DOC-071; HDR-DOC-072; HDR-DOC-073; HDR-DOC-074; HDR-DOC-075; HDR-DOC-076; HDR-DOC-077; HDR-DOC-078; HDR-DOC-079; HDR-DOC-080; HDR-DOC-081; HDR-DOC-082; HDR-DOC-083; HDR-DOC-084; HDR-DOC-085; HDR-DOC-087; HDR-DOC-089; HDR-DOC-090; HDR-DOC-091; HDR-DOC-093; HDR-DOC-094; HDR-DOC-095; HDR-DOC-096; HDR-DOC-097; HDR-DOC-098; HDR-DOC-099; HDR-DOC-100; HDR-DOC-101; HDR-DOC-102; HDR-DOC-103; HDR-DOC-104; HDR-DOC-105; HDR-DOC-106; HDR-DOC-107; HDR-DOC-108; HDR-DOC-109; HDR-DOC-110; HDR-DOC-111; HDR-DOC-112; HDR-DOC-113; HDR-DOC-114; HDR-DOC-115; HDR-DOC-116; HDR-DOC-117; HDR-DOC-118; HDR-DOC-120; HDR-DOC-123; HDR-DOC-125; HDR-DOC-126; HDR-DOC-127; HDR-DOC-128; HDR-DOC-129; HDR-DOC-130; HDR-DOC-131; HDR-DOC-132; HDR-DOC-133; HDR-DOC-134; HDR-DOC-135; HDR-DOC-136; HDR-DOC-137; HDR-DOC-138; HDR-DOC-139; HDR-DOC-140; HDR-DOC-141; HDR-DOC-142; HDR-DOC-143; HDR-DOC-144; HDR-DOC-145; HDR-DOC-146; HDR-DOC-147; HDR-DOC-148

2.2.26 Technology transfer

Purpose:

To provide participants in the programme with the training, information and technology required to secure the success of the project, and to provide primary clients and stakeholders with appropriate and desired programme products and thereby to promote the image of the programme nationally and internationally.

It was recognised at the outset that a primary objective of the Training, Information and Technology Transfer (TITT) subprogramme would be to foster integration, and the basis for successful integration is good communication founded on faith and trust. Furthermore the TITT Sub-programme took the view that good internal communication forms the basis for good outward communication. Good internal communication is therefore a primary objective.

Tasks:

Conceptualise the processes of training, information and technology transfer.

Produce tangible technological mechanisms whereby programme participants, sponsors and stakeholders can interact with the complex mass of interconnecting information.

Use the wide area computer networks to overcome the impediments to regular communication caused by the geographic separation of researchers and thereby maintain momentum in the programme.

Train programme participants, sponsors and stakeholders in the use of these technologies.

Stimulate networking between researchers, stakeholders and institutions which could assist the programme.

Organise conferences and workshops and the publication of newsletters, radio and TV material.

Progress:

Computer software incorporating simulation models, information bases, geographical information systems (GIS) and other graphical user interfaces (GUI's), have been developed. This system is accessible through the Internet and incorporates software which runs both on the Computing Centre for Water Research's computers and on the user's personal computer. The system has become an integral part of the ongoing and developing training and information and technology transfer initiative.

A wider base of researchers who are participating in the programme will be trained to use the system in 1996. The system is a major focus in the process of integration within the programme.

Evaluation:

The modelling, graphical display, data management and Internet communication systems which have been developed in 1995 are addressing both the internal and external communication and providing a common currency for communication on major aspects of the programme. In addition to an increasingly vibrant internal communication within the KNPRRP, there is evidence of growing international interaction with the KNPRRP through the common ground which these technologies have established.

The Programme has organised a number of workshops and annual conferences, as well as special presentations to senior representatives of the funding and client organisations. These have been aimed at informing the market of the activities of the Programme. This report is a further step to inform people both within and outside the Programme, of its progress and products.

Internal communication and understanding within the Programme has progressed rapidly in the last year, but there is undoubtedly more that needs to be done to promote the products of the Programme to potential users at all levels outside the Programme.

List of main products:

None published

Other relevant documents and datasets:
None published

2.2.27 Environmental management

Purpose:

The main aims of the Programme are to gather information and develop methods for use by managers. However, it has become increasingly obvious that the Programme has a responsibility to help in the implementation of its results. There is little point in continuing to collect data on the KNP rivers unless the increasing knowledge is used to help solve the pressing problems which beset the rivers. Nor will it be acceptable simply to hand over reports to managers and consider the job done.

Although no specific environmental management tasks were identified in the Programme plan, the Programme managers have accepted the need to initiate an implementation phase, to begin in 1996. In this phase, the researchers will co-operate with the managers (primarily the National Parks Board and the Department of Water Affairs and Forestry), to make sure that the information generated from the Programme's research is produced and promoted in forms that are usable by managers, and the researchers will be available to help with the implementation of the Programme's recommendations.

Tasks:

None specified

Progress:

Members of the National Parks Board (NPB) have developed a river forum for each of the major rivers, in which water users from different sectors can meet to discuss and resolve problems related to the allocation of water and its quality. The Sabie forum, in particular, has achieved local successes in voluntary water restrictions during droughts.

Evaluation:

The Programme has yet to initiate any implementation of environmental management, because information gathering is still ongoing, and method development is still at an early stage. Plans are being prepared for an implementation phase to begin in 1996. This phase will mainly be driven by client needs, and in particular those of the NPB. Major aims of the implementation will be to educate and convince water users and decision makers at all levels, of the importance of environmental management and sustainable utilisation of rivers.

List of main products:

Nasionale Kruger wildtuin Riviere Navorsings Program. Bestuursdoelstellings en uitsetbehoeftes. [Eng.: KNPRRP. Management objectives and expansion needs. (1992) DWAF : MAN-DOC-011
Letaba River in the KNP: Management objectives of the NPB and general overview of impacts on the river. (1994) Venter F J and Deacon A R : MAN-DOC-053

Management objectives of the NPB regarding water quality requirements of rivers in the KNP. (1990) Venter F J and Deacon A R : MAN-DOC-054

The Luvuvhu River in the KNP: Management objectives of the NPB and general overview of impacts on the river. (1994) Venter F J and Deacon A R : MAN-DOC-055

Conservation and management of the rivers of the KNP: suggested methods for calculating instream flow needs. (1991) O'Keeffe J H and Davies B R : CON-DOC-013

Other relevant documents and datasets:
MAN-DOC-004; MAN-DOC-007; MAN-DOC-008; MAN-DOC-010; MAN-DOC-018; MAN-DOC-023; MAN-DOC-026; MAN-DOC-028; MAN-DOC-039; MAN-DOC-042; MAN-DOC-056; CON-DOC-009; INF-DOC-024; INF-DOC-031; INF-DOC-041; WQ-DOC-009; WQ-DOC-050; HDR-DOC-027; HDR-DOC-109

2.2.28 Measuring goal attainment (acceptability)

Purpose:

There are two aspects to goal attainment: The achievement of the goals set by the Programme, which are expressed in terms of information gathering and the development of methods; and the attainment of goals for the rivers, or the achievement of the desired state. Strictly speaking, the latter is a management issue and therefore outside the terms of reference of the research programme, but the ultimate goal must be the achievement of the desired state. The design of monitoring activities to assess whether goals have been attained is the responsibility of the programme, and is reviewed in section 2.2.29.

Having a yardstick against which to measure whether goals have been attained is obviously important. For the research programme, the main goals, subsidiary goals, sub-programme aims, and specific tasks set out in the Second Phase: Programme Description (Breen *et al*, 1994) provide a hierarchy against which to measure the progress of the Programme. For the rivers, the desired state must be expressed in enough detail, and in measurable goals. The difference between the conservation status, a measure of the present state of a river, and the desired state, is a measure of goal attainment (or lack of it).

Although acceptability is not quite the same thing as measuring goal attainment, the two are closely linked in terms of the desired state. By definition, the desired state will define acceptable goals, and their achievement will be the criteria for deciding whether or not the river is in an acceptable state.

Tasks:

Techniques to evaluate the acceptability of management actions

Protocols to measure goal attainment

Develop protocols for defining the desired state of a river and for measuring achievement of this state

Progress:

Two projects are in progress which will contribute to the measurement of goal attainment, and the acceptability of management actions: The multiple criteria assessment method being developed at the University of Cape Town; and the development of methods for defining desired state, at the University of the Witwatersrand. Both projects are unfinished, but are due to be completed in 1996.

The multiple criteria assessment method aims to produce an objective protocol for evaluating the acceptability of change to the natural environment of rivers. It will derive methods for: the selection of and agreement on criteria by which change is evaluated; assigning weights to criteria; and achieving consensus among groups or individuals as to the acceptability of change.

Evaluation:

Since both projects in this field are still under way, it is difficult to assess how far the tasks will be completed at this stage. Assuming that both will be successfully completed, the Programme will have provided the essential tools for measuring goal attainment and acceptability. However, these tasks have strong links with resource economics, for which we still have no accepted methods of evaluation. Without quantitative methods for comparing the value of different management options, it will always be difficult to decide on the acceptability of any river state.

List of main products:

None published

Other relevant documents and datasets:
None published

2.2.29 Monitoring

Purpose:

Monitoring implies a long-term programme of data-collection, usually by means of repetitive sampling. There may be a number of reasons for monitoring: to build up long-term information on a system; to make sure that pre-defined conditions are met; or to recognise indicators of change in a system. Monitoring systems are not usually designed to discover the causes of change, but simply to raise "red flags" if indicators change beyond acceptable limits, after which more complex actions may be initiated to discover causes or redress changes. For the KNPRRP, monitoring will be a vital check on the accuracy of the predictions which the Programme aims to make about the future changes in the rivers.

In most cases, a monitoring programme is designed at the simplest possible level, so that minimal skills and resources are required for the data-collection, and that continuity and comparability are maintained between different sites and different operators. The challenge is therefore to design a monitoring system which is robust and cheap, but collects the required information as comprehensively as possible.

For the KNP rivers, a monitoring programme should use biological and physico-chemical indicators to measure the health or biological integrity of the rivers. The benchmarks should be the present state of the rivers (as measured by their conservation status), and their desired state. Any deterioration in conservation status should raise a red flag, and achievement of the desired state would indicate achievement of the goals.

Tasks:

No specific tasks described for Monitoring.

Progress:

Hydrological gauging weirs have provided continuous monitoring of flows in the major rivers of the KNP for many years. Additional weirs have been built in the 1980's (e.g. in the Sabie and Mutale tributary of the Luvuvhu). Water chemical samples are collected (generally every two weeks) at all the gauging weirs and at a number of additional sites within the KNP since 1983. Fixed point photographs of the rivers, and an aerial census of hippos, are taken annually.

No long-term biomonitoring has yet been initiated, but regular fish surveys are now being conducted by NPB researchers, and the DWAF has initiated a pilot monitoring scheme using benthic invertebrates (SASS4 system) and habitat assessment as indicators of the biological integrity of a number of lowveld rivers.

Evaluation:

Useful monitoring data-bases take many years to build up, if they are to reflect the full range of conditions over time, and identify trends as well as cyclical changes. The hydrological database is generally of sufficient length and detail to allow conclusions on flow changes over time. Shortcomings are that floods are generally larger than the weirs' measurement capacity, and that there are still insufficient weirs to provide confident estimates of flow in all the rivers.
The water chemistry database is also invaluable for defining baseline water quality ranges, but lacks some important variables, such as suspended sediment concentrations (an indirect measure of erosion in the catchment), dissolved oxygen concentration, and water temperature.

As a result of surveys since the 1960's and research projects carried out under the auspices of the Programme, there is now reasonable baseline data on the major biological communities of the rivers. There is a need for a structured biomonitoring programme to begin to define seasonal, drought/wet cycle, and long-term unidirectional changes in the riverine communities. Following the important geomorphological research initiated within the Programme, there is also a need to initiate monitoring of erosion/deposition patterns, and channel form changes, since these govern the eventual distribution and diversity of riverine habitats.

List of main products:

None published

Other relevant documents and datasets:
WQ-DOC-039; WQ-DOC-038; WQ-DOC-012; WQ-DOC-056; WQ-DOC-026; BIOTHER-DOC-006; MAN-DOC-047; BIOFISH-DOC-020; GEO-DOC-001; HDR-DOC-022; HDR-DOC-117; HDR-DOC-002

2.2.30 Legislation

Purpose:

In order to allocate water for environmental purposes, it is necessary that natural ecosystems have lawful right to water in terms of the Water Act of 1956. Unless such a right exists, there is little value in determining the water requirements of such systems. Moreover, the river system can hardly be conserved in terms of quantity and quality, unless this is enforced in terms of the legal system. It is therefore necessary to investigate the provisions of the South African water law as far as water rights for the environment are concerned.

Tasks:

To investigate the current water allocation system in order to determine what legal protection exists for the water requirements of ecosystems, and to investigate the historical development of the water law, in order to determine the origin of the allocation system as far as environmental water rights are concerned.

Progress:

The research has been completed and submitted to the WRC.

Evaluation:

It was discovered that the South African water allocation system granted no protection for environmental water needs. One of the most important reasons for this lack of legal protection, was vested in the origin of water allocation rules: although the Roman water law made provision for water rights for each and all in need of it, the Roman-Dutch lawyers placed political and geographical restrictions on water rights, which was, in South African law, further restricted to riparian ownership, under the influence of foreign law.

It was recommended that the original Roman principles be reconsidered as the basis of a water allocation system where water belongs to each and all in need of it, irrespective of purposes of use, land ownership, the legal status of the water or the river segment where it is utilised. Water should be managed in a catchment oriented way for the benefit of each and all dependent on it, for whatever reason. Moreover, the environment should not only be regarded as a competitive water user, but as the source of water which should per se be conserved for sustainable utilisation.

List of main products:

The allocation of water rights for ecobiotic requirements. Uys M : MAN-DOC-090
Statutory protection for the water requirements of natural ecosystems. (1992) Uys M : MAN-DOC-092
A structural analysis of the water apportionment mechanisms in the Water Act 54/1956, in

view of the requirements of competing user sectors. Uys M. Water Research Commission Report.

Other relevant documents and datasets:
MAN-DOC-089; MAN-DOC-091; MAN-DOC-093

3. CONCLUSIONS AND RECOMMENDATIONS

The main goals of the Programme (see Appendix 1) are to provide information about water quality and quantity requirements to sustain the natural environments of the KNP rivers, and to develop methods for predicting the responses of rivers to changing flow regimes and water quality. The KNPRRP has undoubtedly contributed to these goals, both directly through Programme-funded research, and indirectly by providing a focus for associated research projects. The process of achieving the goals of the Programme, and the management of the rivers to achieve acceptable conditions or the "desired state", are intimately linked, and will be an iterative procedure, since rivers are not static systems, and the definition of acceptable conditions will change in response both to natural and anthropogenic effects in the catchments. As long as the rivers are being managed, there will always be a need for improved and updated information.

The aims of the Programme were extremely ambitious, many of the tasks have yet to be completed, and some have not been started. However, there is no doubt that our knowledge about the rivers of the Kruger National Park is now far more extensive, that we have a more fundamental understanding of the processes that occur in the rivers and that govern their condition and biota, and that we have a far greater confidence in predicting the consequences of changing flow conditions.

This section summarises the achievements of the Programme in relation to the goals and priority actions that were set at the beginning of Phase 2, and identifies those tasks which are suggested as priorities for further work. Because the main goals of the Programme, and each of the sub-programmes, are worded as general statements of intent, it is difficult to assess precisely how far they have been achieved. They are worth summarising here, and it can be seen from section 2 that an enormous amount of work has been directed at these main goals.

This synthesis of information has included many projects and information sources which have not been generated within the Programme. Many of the projects, such as the catchment studies, were begun before the KNPRRP was devised, and others have developed independently of the Programme and subsequently been used to augment the information and methods of the Programme. We acknowledge that the Programme has had limited resources, and that the contributions of activities outside the Programme have been fundamental to achieving many of the goals described below. Nowhere has this been more true than in the development of IFR workshops and the Building Block Methodology, which have mainly been the responsibility of Dr Jackie King of the Freshwater Research Unit at the University of Cape Town, Delana Louw of the Environmental Studies Unit at DWAF, and their colleagues. Although a number of the key participants have also been part of the KNPRRP, the development of the IFR process has been quite separate from the Programme, but has been applied to a number of KNP rivers. The strength of these parallel research and development efforts has been that they can, and are being used to augment and strengthen the achievements of the Programme. The planned IFR workshop on the Sabie River is an excellent example of cooperation between Programme personnel and those from other projects.

Main Goals of the KNPRRP and each sub-programme:

1. To inform researchers, system managers and stakeholders about the water quality and quantity requirements to sustain the natural environments of rivers which flow through the KNP.

2. To develop, test and refine methods for predicting the responses of the natural environments of rivers flowing through the KNP an in Southern Africa to changing water quality and patterns of supply.

Sub-programme 1: Information Systems Development and Management

* To provide an information management system enabling efficient capture, storage, retrieval and dissemination of information to serve the needs of researchers, decision makers and stakeholders.

Sub-programme 2: Decision Support System Development and Management

* To provide methodologies for integrating information and expert opinion into structured DSS directed at achieving the best possible answer at the time and at informing researchers of the information needs for future improvement

Sub-programme 3: Research Development and Management

* To provide in an efficient and cost effective manner, the information and expert opinion required to improve the quality and usefulness of response to enquiries from researchers, resource managers and stakeholders.

Sub-programme 4: Training, Information and Technology Transfer

* To ensure effective transferral of information and technology developed within the programme to the appropriate users

To the extent that the Programme has a structured DSS, and has collected information, and organised it in a way that can be used to inform managers and to provide answers to them, these goals have been and are being achieved. The integration of the available information, and its transfer to users, is under way now, and should be a major focus of further effort by the Programme.

To assess the achievements of the Programme as precisely as possible it is necessary to compare its products with the subsidiary goals, detailed priority actions and tasks that were set out at the beginning of the second phase, and it is these that are the focus of the remainder of this section.

3.1 ACHIEVEMENTS IN RELATION TO THE SUBSIDIARY GOALS

Each of the subsidiary goals is quoted below, and a brief summary of the Programme's achievements is appended:

a. To develop, refine and maintain DSS for responding to information needs.

The DSS has been developed, and is a dynamic process which continues to influence and refine the activities of the Programme. Modelling components are still being developed.

b. To establish an interdisciplinary team with common principles, goals and commitment to design, guide and evaluate the programme thereby ensuring it achieves its primary goals.

The Programme team has become a close-knit and effective unit, and has developed considerable multi-disciplinary skills.

c. To develop the understanding of the functioning of the natural environment of rivers required for predicting their responses to changing conditions.

The current project to link abiotic and biotic models of the river functioning will be a major contribution to our understanding and predictive ability.

d. Develop methods for assessing the asset value of the natural environment of rivers and for evaluating the acceptability of predicted changes in asset value.

This is an area in which the Programme has not yet made significant progress, and should be a focus of further effort.

e. Implement and manage a cost-effective research programme.

By linking with other research outside the Programme's direct funding, a great deal of knowledge and information has been gained from a relatively modest research budget. This has sometimes meant that the research sequence and focus has not exactly followed the Programme plan.

f. Adapt the methodologies developed for management of the natural environment of rivers for application to rivers elsewhere.

There has yet to be a concerted effort to extrapolate from the KNP rivers (and the Sabie River in particular) to other rivers in the country, but the partnership between the IFR process and the Programme, which will culminate later in 1996 in the Sabie River IFR workshop, will be a major contribution to this goal. In addition, the Sabie IFR workshop will test how well IFR methods, developed separately from the Programme, are able to accommodate the wealth of information that is now available for the Sabie.

3.2 GOALS AND TASKS OF EACH SUB-PROGRAMME

Sub-programme 1: Information Systems Development and Management

* Collation of historic and current information and data
* Determine criteria for info management system
* Review existing data management systems and design and implement a system to manage specialist ecological info
* Develop guidelines for efficient storage, capture and retrieval of info
* Focus projects on data capture and storage requirements
* Develop guidelines for ownership and custodianship

* Critical review of data available and identification of strategic data requirements

The production of the data catalogue, both in hard copy and electronic form, has provided a summary of the available information for the KNP rivers, and made this information available to any potential users. The catalogue has been the basis for the compilation of this status report, which also acts as a summary of information from the programme. The priority actions defined above have all been addressed in the achievement of these tasks.

Sub-programme 2: Decision Support System Development and Management

* Establish philosophical basis for predictive modelling
* Review available models and select modelling system
* Identify model input data requirements
* Prepare input data sets, identifying hydrodynamic reaches including selected scenarios for changing water quality and quantity
* Run model and evaluate consequences for the natural environment of changes in water quality and quantity
* Review validity of the approach and recommend
* Predicting the responses of the natural environment to changes in water quality and quantity
* Evaluating the acceptability of predicted changes
* Transferring the systems to other rivers, particularly of the KNP

The first four of these priority actions have been accomplished, and models are now available for the hydrology and water quality of the Sabie River. The linking of these models to geomorphological and biological consequences will at least partly be the focus of the current year's development of the Programme. A refined predictive capability is the aim for the end of phase 2 in December 1996. Prediction in relation to water quantity changes is likely to be further advanced than for water quality.
The final two priority actions have not yet been addressed, and it is unlikely that they will be during the current phase.

Sub-programme 3: Research Development and Management

* Inform IEM and ROIP processes through developing protocols for determining the conservation importance and status of rivers
* Develop protocols for defining the desired state of a river and for measuring achievement of this state
* Synthesis of life history processes and habitat requirements of selected plants and animals as determined by the above two statements
* Inform simulation modelling and habitat characterisations by determining roughness coefficients for riparian vegetation

The first of these priority actions has only partially been addressed to date. There are methods for determining the conservation status (or ecological integrity) of rivers, developed separately from the Programme, and these can be adequately applied to the KNP rivers, but at present there is no developed methodology for the assessment of conservation importance. A protocol for defining the desired state of the KNP rivers is currently being developed, and should be operational by the end of 1996. The third action has partially been addressed for the Sabie

River by the detailed studies of riverine plant communities, fish and benthic invertebrates, to a level at which they can be used to assess the effects of flow changes in the river. The last priority may seems somewhat specialised, but was specifically targeted as a weakness in our ability to predict flows necessary for the maintenance of riparian vegetation (see section 2.2.12.)

Sub-programme 4: Training, Information and Technology Transfer

* Define targets and needs
* Distributing information i.e. guidelines, protocols, research updates
* Training i.e. information management system, technology, methods (ROIP, IFIM), modelling
* Networking via inter-institutional links
* Public relations i.e. newsletter, radio, TV, press
* Conference/ Symposia i.e. local, international

The TITT sub-programme has essentially had to wait for the products of the other sub-programmes before disseminating information to users and other interested parties, and its major external role will emerge during the implementation phase of the Programme. Planning for this has begun, and will commence with the series of "road shows", presenting the Programme to users and other interested parties later in 1996. To date actions have concentrated on networking and information within the Programme, an essential procedure for an organisation which spans a large number of institutions in different parts of the country. The Programme has maintained a high profile in conferences and symposia, including the organisation of annual Programme conferences, specialist workshops, and contributions to local and international scientific meetings.

Figure 2 provides an overview of the achievements of the Programme so far, in relation to the tasks defined in the second phase Programme description. Progress with the defined tasks has been classified into 4 classes: 1 = No significant progress has been made; 2 = Some progress; 3 = The task is presently being undertaken (and significant progress may or may not have been achieved); and 4 = Substantial progress has been made, to the point where information and/or methods are adequate for management purposes (but in many cases could still be improved). This classification is of necessity fairly rough, but is intended to provide a graphical overview of the status of the Programme "at a glance".

3.3 CAPABILITIES OF THE PROGRAMME BY THE END OF PHASE 2 (DECEMBER 1996)

This section summarises the products and expertise that has been, or will have been developed by the end of the current phase. These achievements are once again expressed in relation to the specific goals and tasks of the Programme, but should also be seen in the context of the main holistic achievement of the Programme: The development of a multi-disciplinary, multi-institutional research management team which has made a substantial contribution to the understanding of fundamental environmental processes in rivers.

- Existing information on the rivers of the KNP has been synthesized and can now be accessed by all potential users.

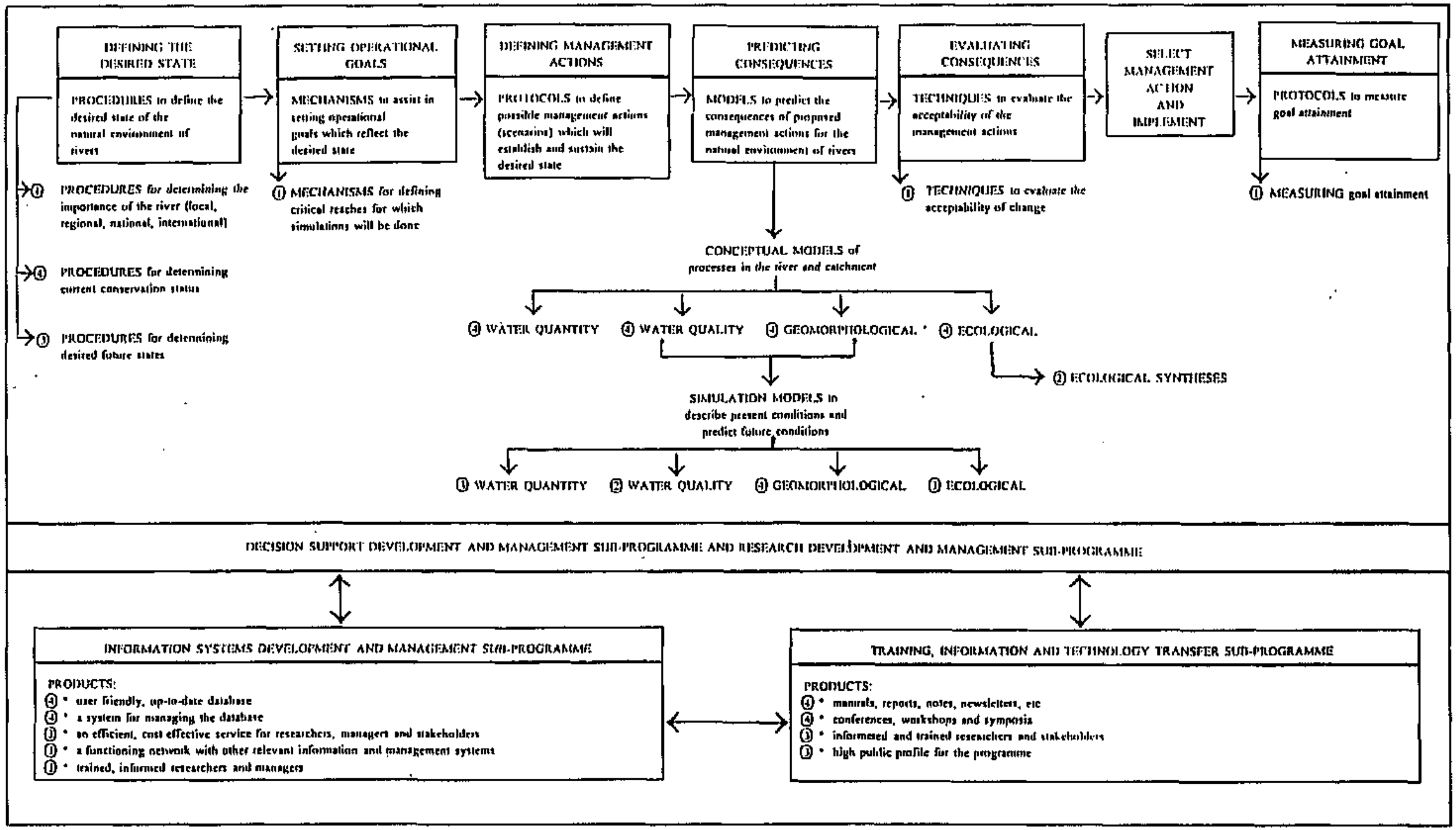

Figure 2: Planned elements of the decision support system (from the second phase: Programme Description), summarising the progress that has been made to date. Numbers beside each element indicate the following:
1 = not done; 2 = some work done; 3 = work in progress; 4 = substantial work completed

- A decision support system has been developed which can provide users with an information pathway to assist in management decisions, or in explaining and motivating environmental water use.
- The desired state, or goals, for KNP rivers will be clearly defined in terms that can be implemented.
- Catchment studies have been completed for all the main rivers, describing land-use, present development of water use, probable future demand, and possible scenarios for supply.
- Detailed inventories and the status of the following components of the Sabie River are available:

  Riparian vegetation (within the KNP only)
  Fish
  Invertebrates
  Large aquatic animals
  Geomorphological units/sediment transport (within the KNP only)
  Water quality
  Hydrology
  Hydraulics of channel types (within the KNP only)
- A predictive capability will be available to link the effects of changing flows on all of the above, at differing levels of resolution.
- First estimates of environmental water requirements for all the major rivers are available. For the Luvuvhu, Letaba and Olifants Rivers second estimates are also available, and for the Sabie, three separate estimates have been produced
- There will be a refined assessment of the environmental flow requirements of the Sabie River, with motivations, following the Sabie IFR workshop in September.

3.4 PRIORITIES FOR FURTHER WORK

Because of the inevitable constraints of finances and resources, the Programme has concentrated on a small number of key projects, the synthesis of existing information, and the development of a coherent research management framework, rather than attempting all the tasks that are necessary for the comprehensive achievement of the goals. There has also been a reliance on research and monitoring activities funded and motivated outside the Programme, to augment the internal activities. For these reasons, there are still considerable gaps in the structure of the DSS, which need to be filled to maximise its potential as a toolbox for river managers. These are summarised briefly below:

- Although the information base and understanding of the Sabie River is probably the most comprehensive for any South african river, no structured research programme has yet been applied to the other KNP rivers. Valuable research has been done on other rivers (eg water quality in the Olifants River and the geomorphology of the Letaba), but is mostly individual projects carried out for specific purposes. One of the results is that it is difficult to assess how far the information and knowledge on the Sabie can be extrapolated to other rivers.
- Even the research on the Sabie has mostly been confined to reaches within the Kruger National Park. This has been to avoid, as far as possible, the confounding variables of anthropogenic disturbance, but means that there is much less environmental information available for the upper and middle reaches of the river, than for the lower reaches in the Park.

- No work has yet been done on the macro links between the riverine systems and the adjacent terrestrial ecosystems. The dependence of most of the larger animals on the rivers is obvious, but needs to be quantified and made explicit, as part of the motivation for the maintenance of the rivers as major resources for the Park as a whole.
- Most of the work of the Programme has concentrated on the natural environments of the KNP rivers, since this was the original terms of reference. However, it has become increasingly important to assess the direct use of the rivers by the local people, and to direct research and management to the long-term maintenance of the natural resource values of the rivers. (Direct use includes all activities involving contact with the river and riparian zone, including fishing, water collection, laundry, recreation, reed-cutting etc; but excluding pumped extraction or storage for domestic, industrial or irrigation use)
- The Programme has concentrated more on water quantity requirements than on water quality. This has largely been a consequence of the Sabie focus of the Programme, where reduced flows are presently a greater threat than impacts on water quality. However, there are major water quality problems in the Olifants and Crocodile Rivers in particular. At present only rudimentary methods for the assessment of environmental water quality requirements are available, and methods similar to those for IFR assessment are necessary.
- Very little work has been done to quantify the value of maintaining the rivers in a good environmental state. This resource economics approach will become a vital part of the motivation for the conservation of rivers, and the obvious value of the KNP rivers in sustaining the Kruger National Park as the country's leading tourist destination has yet to be assessed.
- The implementation of the findings and products of the Programme is perhaps the major priority for further work. The main project for 1996 is the integration of biotic and abiotic knowledge of the Programme into models that will predict the effects of changing flow regimes. Once this has been completed, the Programme will have a suite of powerful management tools for assessing environmental impacts on rivers, and for recommending future management. The implementation of these tools will require that they be understood and supported by a variety of water users, researchers, and managers.

APPENDIX 1: MAIN GOALS, SUBSIDIARY GOALS, SUB-PROGRAMME AIMS AND TASKS OF THE KNPRRP, AS DEFINED IN THE SECOND PHASE: PROGRAMME DESCRIPTION (BREEN ET AL, 1994)

A. Main Goals of the KNPRRP:

1. To inform researchers, system managers and stakeholders about the water quality and quantity requirements to sustain the natural environments of rivers which flow through the KNP.

2. To develop, test and refine methods for predicting the responses of the natural environments of rivers flowing through the KNP an in Southern Africa to changing water quality and patterns of supply.

Subsidiary goals:

a. To develop, refine and maintain DSS for responding to information needs.
b. To establish an interdisciplinary team with common principles, goals and commitment to design, guide and evaluate the programme thereby ensuring it achieves its primary goals.
c. To develop the understanding of the functioning of the natural environment of rivers required for predicting their responses to changing conditions.
d. Develop methods for assessing the asset value of the natural environment of rivers and for evaluating the acceptability of predicted changes in asset value.
e. Implement and manage a cost-effective research programme.
f. Adapt the methodologies developed for management of the natural environment of rivers for application to rivers elsewhere.

Sub-programme aims

Sub-programme 1: Information Systems Development and Management

* Provide an information management system enabling efficient capture, storage, retrieval and dissemination of information to serve the needs of researchers, decision makers and stakeholders.

Priority actions:

* Collation of historic and current information and data
* Determine criteria for info management system
* Review existing data management systems and design and implement a system to manage specialist ecological info
* Develop guidelines for efficient storage, capture and retrieval of info
* Focus projects on data capture and storage requirements
* Develop guidelines for ownership and custodianship
* Critical review of data available and identification of strategic data requirements

Sub-programme 2: Decision Support System Development and Management

- Provide methodologies for integrating information and expert opinion into structured DSS directed at achieving the best possible answer at the time and at informing researchers of the information needs for future improvement

Priority actions:

- Establish philosophical basis for predictive modelling
- Review available models and select modelling system
- Identify model input data requirements
- Prepare input data sets, identifying hydrodynamic reaches including selected scenarios for changing water quality and quantity
- Run model and evaluate consequences for the natural environment of changes in water quality and quantity
- Review validity of the approach and recommend
- Predicting the responses of the natural environment to changes in water quality and quantity
- Evaluating the acceptability of predicted changes
- Transferring the systems to other rivers, particularly of the KNP

Sub-programme 3: Research Development and Management

- To provide in an efficient and cost effective manner, the information and expert opinion required to improve the quality and usefulness of response to enquiries from researchers, resource managers and stakeholders.

Priority actions:

- Inform IEM and ROIP processes through developing protocols for determining the conservation importance and status of rivers
- Develop protocols for defining the desired state of a river and for measuring achievement of this state
- Synthesis of life history processes and habitat requirements of selected plants and animals as determined by the above two statements
- Inform simulation modelling and habitat characterisations by determining roughness coefficients for riparian vegetation

Sub-programme 4: Training, Information and Technology Transfer

- Ensure effective transferral of information and technology developed within the programme to the appropriate users

Priority action:

- Define targets and needs
- Distributing information i.e. guidelines, protocols, research updates
- Training i.e. information management system, technology, methods (ROIP, IFIM), modelling
- Networking via inter-institutional links
- Public relations i.e. newsletter, radio, TV, press
- Conference/ Symposia i.e. local, international

APPENDIX 2: LIST OF ACRONYMS USED IN THE TEXT

ACRU	-	Agricultural Catchments Research Unit model, an agro-hydrology simulation model
CWE	-	Centre for Water in the Environment, University of the Witwatersrand.
DSS	-	Decision support system.
DWAF	-	Department of Water Affairs and Forestry.
GIS	-	Geographical information system.
GUI	-	Graphical User Interface, user-friendly front ends for computer programs.
HSPF	-	Hydrological Simulation Program in FORTRAN.
IEM	-	Integrated Environmental Management, a management system adopted by DWAF to minimise environmental impacts resulting from development projects.
IFR	-	Instream Flow Requirements. IFR workshops using the Building Block Methodology, are a method of assessing the flows needed to maintain riverine environments in an acceptable state
IWR	-	Institute for Water Research, Rhodes University.
KNP	-	Kruger National Park.
KNPRRP	-	Kruger National Park Rivers Research Programme
NPB	-	National Parks Board.
PHABSIM	-	Physical Habitat Simulation Model, an American method of determining habitat availability at different flows.
RCS	-	River Conservation System, an expert system-based method of assessing the conservation status of a river.
ROIP	-	Afrikaans acronym for Relevant Environmental Impact Prognosis, a method for evaluating the impacts of a proposed project on the environment.
TITT	-	Training, Information and Technology Transfer sub-programme of the KNPRRP.
SASS4	-	South African Scoring System (version 4). A biomonitoring index based on riverine invertebrates
WRC	-	Water Research Commission.

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